Battelle
The Business of Innovation

FINAL REPORT



GROWING NORTHERN ARIZONA'S BIOSCIENCE SECTOR:

A REGIONAL ROADMAP

PREPARED FOR:
Northern Arizona Bioscience Steering Committee
with financial support provided by the Flinn Foundation

PREPARED BY:
Battelle
Technology Partnership Practice

October 2007

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Executive Summary

INTRODUCTION

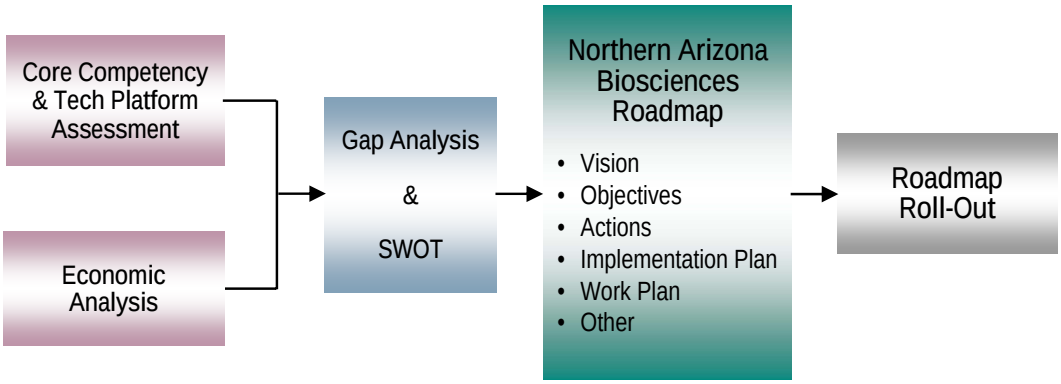
In 2002, public and private leaders in Arizona committed to making the investments necessary to position Arizona as a leading center for the biosciences. *Arizona's Bioscience Roadmap*[1] called for building the state's infrastructure around selected technology platforms, growing a critical mass of bioscience firms, and offering a business climate and environment to support bioscience enterprises. Significant progress has been made in building an environment in Arizona that is supportive of the biosciences.

Northern Arizona is an important contributor to Arizona's bioscience sector. The region is highly specialized in medical devices and Northern Arizona University (NAU) has strengths in key bioscience areas. The region is home to a number of established bioscience firms, including W.L. Gore and to a small base of start-up and emerging companies. Northern Arizona, under the leadership of the Greater Flagstaff Economic Council, NAU, and the City of Flagstaff, and with support provided by the Flinn Foundation, has developed this regional bioscience roadmap to complement the statewide effort and to focus on specific challenges and opportunities facing Northern Arizona. This Roadmap, developed with the assistance of Battelle, lays out a pathway to accomplish the following Vision:

> ***The biosciences is a key driver of Northern Arizona's economy providing high wage jobs, high quality health care, and career opportunities for its citizens. The region is home to a vibrant cluster of bioscience companies and a global leader in medical devices.***

This Roadmap was developed with guidance and input from the region's educational and research institutions, economic development organizations, bioscience companies, and other public and private leaders. The Battelle project team collected and analyzed data on Northern Arizona's bioscience industry and research bases and interviewed academic, research, business, and civic leaders to develop an understanding of the region's existing bioscience research strengths and capabilities and to gather input on the types of investments needed to enable Northern Arizona to become a well-recognized regional bioscience center. Figure 1 displays the project methodology. Key findings from these analyses are presented below.

Figure ES-1: Project Methodology

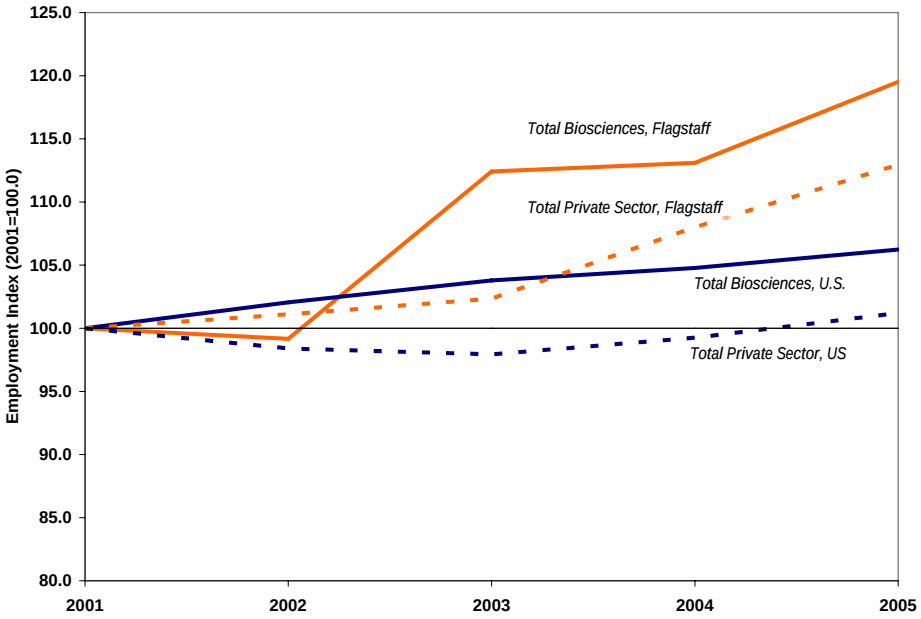


[1] *Platform for Progress: Arizona's Bioscience Roadmap*. Prepared for the Flinn Foundation by Battelle Technology Partnership Practice. December 2002.

NORTHERN ARIZONA'S BIOSCIENCE INDUSTRY

Bioscience employment in the Flagstaff metropolitan area grew three times faster than that of the nation between 2001 and 2005. See Figure ES-2. The biosciences employed more than 5,500 in Coconino and Yavapai Counties in 2005, spanning 37 business establishments. In Flagstaff, the biosciences employed 4,199 in 2005 across 12 business establishments. Local bioscience firms have increased payrolls in the metropolitan area by nearly 700 jobs or 19.5 percent since 2001, outpacing a national bioscience industry that added 6.2 percent to its employment base during this period.

Figure ES-2. Flagstaff MSA and U.S. Job Growth in the Biosciences and Total Private Sector, 2001-2005 (Index, 2001=100.0)



Source: Battelle calculations based on Bureau of Labor Statistics, QCEW/ES202 program data and Minnesota IMPLAN Group, Inc.

Similar to Flagstaff, the Prescott MSA has experienced strong job growth in the biosciences in recent years. Though modest in size, Prescott's bioscience sector boosted employment by 12 percent since 2001 and in 2005 stands at more than 1,300 jobs in total. At the same time, the region increased its number of bioscience business establishments from 18 to 25.

The Flagstaff metro area accounts for 5.4 percent of Arizona's bioscience jobs, although the region accounts for only 2.9 percent of total statewide employment. The location quotient for the Flagstaff MSA reached 1.98 in 2005, meaning the region is almost twice as concentrated in the biosciences as its counterparts nationally. The relative concentration of total bioscience jobs in the region is considered to be "specialized."

Medical devices and equipment is the fastest growing bioscience subsector and the most specialized, due to the presence of W.L. Gore. Flagstaff's large medical device sector relative to its total private employment yields a very high location quotient—7.80 in 2005. The LQ highlights a specialized local industry that is nearly eight times more concentrated than at the national level. ***In Battelle's 2006 national report for the Biotechnology Industry Organization (BIO), the Flagstaff metropolitan area***

ranked third among all small metro areas (166 total) for its LQ in the medical devices and equipment subsector in 2004.[2]

Hospitals are the largest employer in the region's bioscience sector. In 2005, the hospital sector in Flagstaff accounted for 70 percent of the total sector and in Prescott, the share was 86 percent. The hospital subsector employed 2,944 in 2005 across 3 establishments in Flagstaff. Reflecting the metropolitan area's strong population growth in recent years, local hospital jobs have increased by 13 percent since 2001. Job growth in the Flagstaff subsector has outpaced a robust national sector by nearly 2 to 1 since 2001 as the national sector added 7 percent to its employment base. In 2005, two hospital establishments employed 1,132 in Yavapai County The subsector LQ for 2005 was 0.60. Local hospitals added 135 jobs in the Prescott MSA from 2001 to 2005, a 13.6 percent increase in its employment base.

Compared with their counterparts in the total private sector, Northern Arizona bioscience workers are earning nearly $20,000 more per year. In addition, the major regional bioscience subsectors—hospitals and medical device manufacturing—are at or near the top in both regions. In both Flagstaff and Prescott, bioscience workers earn more than $45,000 on average compared to only $27,000 - $28,000 for their counterparts in the overall private sector.

Table ES-1. Average Annual Wages in N. Arizona MSAs for the Biosciences and other major industries, 2005

Northern Arizona: Average Annual Wages by Industry, 2005		
Industry	**Flagstaff MSA**	**Prescott MSA**
Medical Devices & Equipment	**$46,466**	**$44,806**
Total Non-Hospital Biosciences	**$46,041**	**$36,405**
Total Biosciences	**$45,363**	**$45,279**
Hospitals	**$45,074**	**$46,774**
Management of Companies & Enterprises	$44,920	$69,120
Wholesale Trade	$44,733	$40,090
Manufacturing	$43,958	$33,850
Health Care & Social Assistance	$40,641	$32,965
Finance & Insurance	$40,472	$42,707
Information	$38,432	$43,751
Research, Testing, & Medical Labs	**$35,651**	**$35,713**
Prof., Scientific & Technical Services	$35,273	$35,233
Transportation & Warehousing	$34,062	$30,137
Real Estate & Rental & Leasing	$32,449	$29,434
Construction	$28,258	$30,052
Total Private Sector	**$27,194**	**$28,026**
Retail Trade	$22,180	$23,978
Accommodation & Food Services	$14,564	$14,546

Source: Battelle calculations based on Bureau of Labor Statistics, QCEW program data from IMPLAN.

In summary, Northern Arizona is an important contributor to the state's bioscience industry sector. The region's bioscience sector exhibited strong growth from 2001 to 2005. This is particularly impressive as Northern Arizona's non-hospital bioscience employment is found primarily in the medical device subsector, which experienced employment losses nationally while growing rapidly in Northern Arizona.

[2] See "*Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006*," by Battelle Technology Partnership Practice and SSTI, April 2006. The full report can be accessed online at http://www.bio.org/local/battelle2006/.

At the same time, bioscience employment in Northern Arizona is highly concentrated in one company, W.L. Gore, which accounted for most of the employment growth. Total employment and the number of bioscience establishments are small. Northern Arizona needs to build on its medical device and hospital sectors while at the same time diversifying its bioscience industry base in other areas.

NORTHERN ARIZONA'S BIOSCIENCE RESEARCH STRENGTHS

Northern Arizona's bioscience R&D base is growing rapidly but remains small. Northern Arizona's bioscience R&D base grew from approximately $6 million in FY 1997 to more than $16 million in FY 2005. This growth was driven primarily by growth in the biological sciences. The total bioscience R&D base, however, remains small. In comparison, the bioscience R&D base in Southern Arizona was $255 million in FY 2004.

The quality of the bioscience research being conducted at NAU is high as demonstrated by NIH awards. NIH funding, generally considered the "gold standard" of funding for biomedical research and basic biological sciences, increased from $1.4 million to $2.6 million at NAU between 2001 and 2005. The average increase in NIH funding awarded to NAU researchers of 20 percent annually greatly exceeded the 10.2 percent increase in NIH funding at the national level.

In addition to biomedical research, Northern Arizona has a research base in environmental biology. Between 2000 and 2006, Northern Arizona received $8.1 million in NSF funding from the Division of Environmental Biology. Publication and citation data show a high rate of publications and citations in the Environment/Ecology field, as well. Other areas in which Northern Arizona has a strong publication record include plant sciences, earth sciences, and animal sciences.

Targets of Opportunity for Northern Arizona

The biosciences present so many opportunities for the future that it is extremely important for a state or region to have a strong basis of understanding of where its opportunities will lie within a very broad universe of bioscience disciplines, opportunity areas, and possibilities. The areas of greatest opportunity for developing technology platforms are those in which a region has:

- Existing research strengths
- Bases of commercial activity emerging or established within the region with genuine opportunity to create a base in the near future
- Distinct opportunities to leverage the region's comparative advantages to create competitive marketplace advantages
- Significant product market potential
- Links to, or reinforcements of, other bioscience strengths and core research competencies, thereby helping to enhance other fields as a platform expands.

Previous work conducted by Battelle for the Flinn Foundation has identified Arizona statewide bioscience technology platforms and much progress has been made in advancing development in the state along these platform pathways. Analysis of the bioscience R&D core competencies in Northern Arizona shows that the region plays an important contributory role in most of the ten statewide technology platforms. The four platforms in which Northern Arizona is a very important contributor are: cancer, bioengineering, bioagriculture, and infectious diseases.

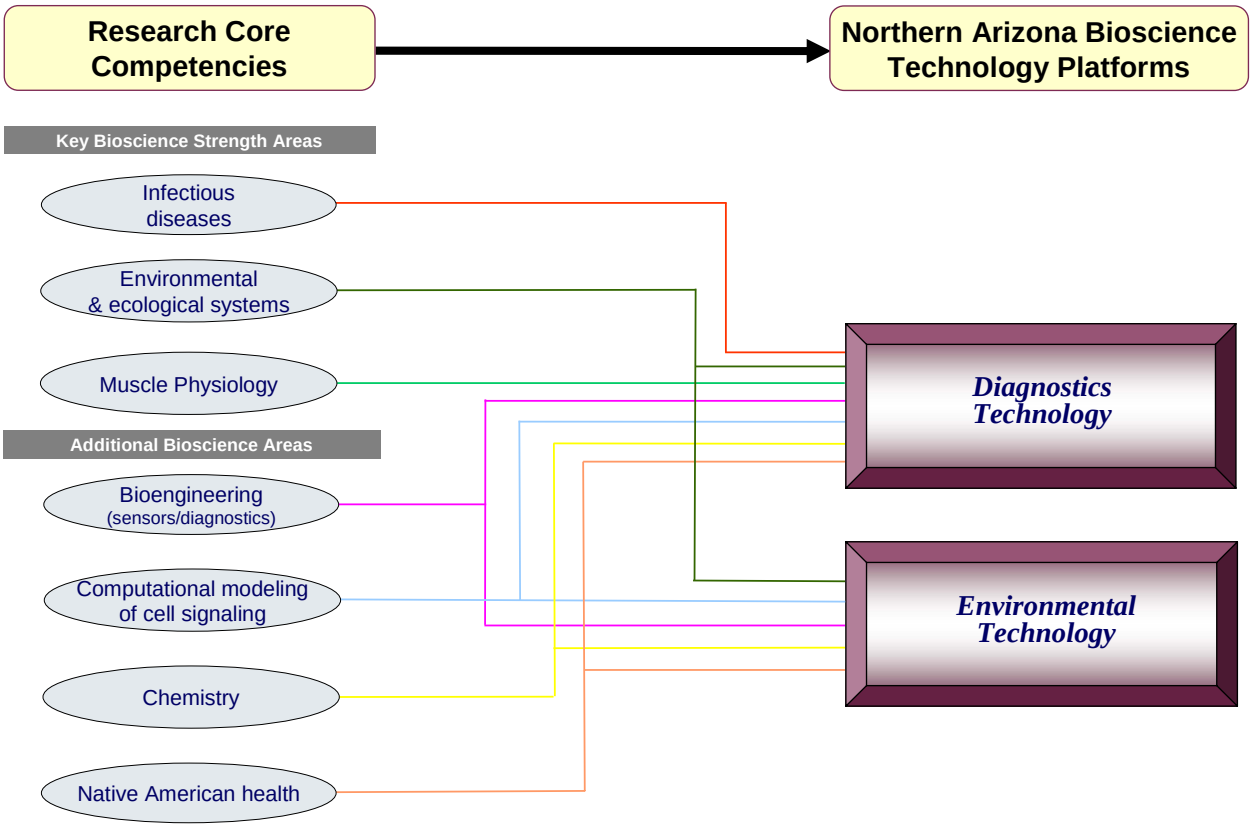
To identify the specialized niches for Northern Arizona, Battelle employed a methodology that uses the "marketplace" of academe, including peer-driven recognition systems, e.g., publications, citations, and federal fund awards, along with extensive number of interviews with research leaders, to identify targets of opportunity. Based on this analysis, Battelle documented Northern Arizona's research core competencies and recommended associated technology platforms, which can form the basis for the future growth of Northern Arizona's bioscience sector.

The Battelle team identified two unique technology platforms that build upon Northern Arizona's core research competencies and can be sources of innovative technologies and products for its economy. They are:

- Diagnostics Technology
- Environmental Technology.

Figure ES-4 shows the relationship between Northern Arizona's core competencies and these two platforms.

Figure ES-4: Relationship Between Northern Arizona's Research Strengths and Northern Arizona Technology Platforms



LEVERAGING THE REGION'S UNIQUE ASSETS

Northern Arizona has a number of unique assets on which to build its bioscience base. These include:

- **A growing base of medical device companies and health care institutions and a nascent research, testing, and medical laboratory sector.** Overall, Flagstaff is almost twice as specialized in the biosciences as the nation and within medical devices and equipment is nearly eight times more specialized than the nation and ranks third among all smaller metropolitan areas in the country in medical devices and equipment employment specialization. Flagstaff ranks only second to Glenn Falls, NY, among such competitor regions as Minneapolis, Bloomington, Indiana, and Kalamazoo, Michigan, in medical device employment per establishment. Its medical device firms have nearly seven times the employment per establishment as the U.S. as a whole. **The region should build on the presence of W.L. Gore and seek to develop a stronger supplier chain of medical device firms in the region.**
- **NAU, USGS, and TGen North.** Northern Arizona has a small but excellent bioscience research base with expertise in specific areas of the biosciences. These institutions have the capacity to develop new, innovative technologies that could form the basis for new, start-up bioscience companies that could complement the region's existing base in medical devices and hospitals. NAU also offers strength in science education to help address workforce issues over the long term as well as offering courses and degrees responsive to the growing bioscience employer base.
- **Coconino Community College and Yavapai College**. The region's community colleges are expanding their offerings in the biosciences and working to meet the workforce needs of existing employers. The colleges are in a position to ensure that the region is able to develop a skilled bioscience workforce to meet the future needs of the region's expanding bioscience sector.

Competitive Advantages

- Quality of life that appeals to many talented individuals
- Emerging base of bioscience companies that offer high-wage jobs
- Northern Arizona University
  - Tech Platform Strengths
  - Students and Graduates
- Strong talent pool
  - CCC and Yavapai College
- Developing technology infrastructure
  - Science and Tech Park
  - Incubator
  - USGS campus
  - Tech Park at Embry Riddle
  - TGen North

Challenges

- High cost of housing and worker shortages
- Lack of diversified bioscience employment base
- Inability to retain more of the graduates of the region's colleges and universities
- NAU has a small research base and limited interaction with industry
- K-12 schools are not graduating students with sufficient STEM skills and the schools have limited funding to address these needs
- Lack of entrepreneurial support infrastructure
  - Lack of risk capital
- Transportation improvements needed
- Business climate with City perceived as challenging in spite of City's innovative and creative approaches, e.g., USGS, S & T park, etc.

- **Proximity to Phoenix**. To date, much of the growth in the biosciences in Arizona has occurred in Tucson, and, to a lesser extent, the Greater Phoenix area. Northern Arizona is well positioned to partner with bioscience institutions in Phoenix and to provide a location for expansions as Phoenix's bioscience business community expands. The growth of the bioscience sector in Phoenix also means that bioscience companies in Northern Arizona will have more opportunities for partnering with firms in the Phoenix area and accessing specialized bioscience services.
- **Image as both a tourism destination and a region with a very attractive quality of life.** Northern Arizona's quality of life can be used to attract bioscience talent to the region, which will in turn make it a good location for bioscience companies. In addition, the region has a long history of attracting international travelers because of its location near the Grand Canyon and other outdoor attractions. Northern Arizona can take greater advantage of the fact that it is a destination site for global travelers to build its bioscience image and brand.

STRATEGIES AND ACTIONS

The strategies proposed for Northern Arizona focus on leveraging the region's assets—its colleges and universities, the presence of a global biomedical company, its proximity to Greater Phoenix, a growing health service sector and a very attractive quality of life—to grow its bioscience sector. Specific strategies proposed to accomplish this include:

Strategy One: ***Improve the business climate in Arizona for bioscience industry development and growth.*** Three actions are proposed to accomplish this objective: 1) Northern Arizona must continue to invest in technology infrastructure, such as incubators, technology parks, and transportation improvements; 2) creative ways must be found to overcome the region's high cost of housing, which is making it difficult to attract and retain workers; and 3) the region must seek to diversity its bioscience industry sector by growing its existing base in medical devices through an enhanced supplier chain, attracting biomanufacturing operations, and building a research, testing and medical labs industry base.

Strategy Two: ***Build the region's research base in the identified platforms and facilitate commercialization of research findings***. NAU has an excellent but small bioscience research base. The university should 1) seek to grow this research base around the two Northern Arizona specific platforms by adding research faculty positions, making investments in facilities and equipment, and placing greater focus on undergraduate and selective graduate science programs; 2) seek to promote greater commercialization of research findings by establishing a senior level capacity to steer, catalyze, and cement its relationship with industry and to coordinate intellectual property management with Arizona State University and build greater institutional capacity directly over time; and 3) establish a commercialization function and providing funding for early-stage commercialization activities.

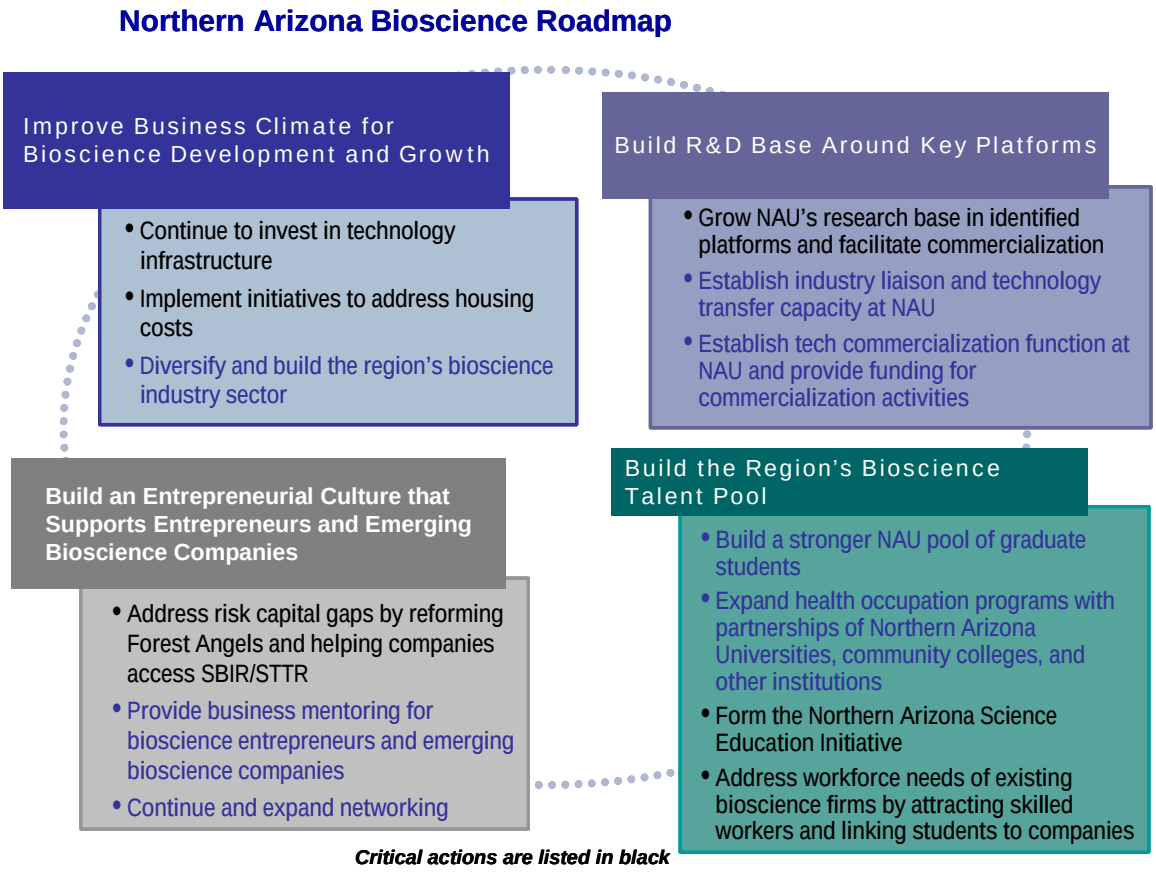
Strategy Three: ***Build the region's bioscience talent pool.*** To address existing worker shortages, employers need to tap the region's current student population developing new career paths for non-experienced entry level workers and providing opportunities for them to gain work experience while they are still in school. To meet future workforce needs, the region needs to encourage more students to consider careers in the biosciences and to take the courses that will prepare them for such careers. In addition, because of rapid changes in technology, it is essential for the bioscience workforce to constantly be educated on a lifelong basis—which necessitates the building of career ladders whereby a student from high school on can enter and exit with various skill levels, moving from a technician level to a post doc or scientist if he or she should desire at some point in his or her career. To meet existing and future

workforce needs, the following is proposed: 1) build a stronger pool of NAU graduate students; 2) expand health science programs in Northern Arizona and throughout the state; 3) form a Northern Arizona Science Education Initiative to create a science talent pipeline; and 4) undertake activities to attract skilled workers to the region and to better link students to companies by offering internships and part-time employment.

Strategy Four: ***Build an entrepreneurial culture that supports bioscience entrepreneurs and emerging bioscience companies.*** To grow a critical mass of bioscience companies, Northern Arizona must encourage entrepreneurs, provide in-depth support to new bioscience companies, and create a climate that is supportive of bioscience companies. Northern Arizona can foster the growth of start-up bioscience companies by 1) addressing risk capital gaps by encouraging the re-formation of the Forest Angels group and helping companies to access the SBIR/STTR program; 2) providing business mentoring for bioscience entrepreneurs and emerging bioscience companies; and 3) continuing and expanding researcher, bioscience company, and service provider networking.

These four strategies and the thirteen actions proposed to achieve them are outlined in Figure ES-5 It is anticipated that a majority of these actions would be implemented over a five-year time period by the private and public sectors in Northern Arizona.

Figure ES-5: Overview of Strategies and Actions



Immediate Work Plan Priorities

Immediate work plan priorities are those steps the private and public sectors in Northern Arizona should undertake within the first 12 months of implementation. Several critical priorities need to be implemented right away, while others will need to be planned and resources secured before they can move forward.

The following actions should be undertaken in the first year of implementation of the strategy:

- City of Flagstaff, NAU, Flag 40, and other groups need to reach a consensus on near-, mid-, and long-term approaches to address the housing situation—it is unlikely there is a magic bullet option which will meet all needs and requirements;
- Convene angel investors to determine interest in re-constituting the Forest Angels group and what support or assistance, if any, they need;
- Convene public and charter schools, community colleges, and NAU to develop pathways for bioscience careers addressing curriculum, articulation, resources, and other impediments to making Northern Arizona a science education center of excellence that will be able to build and retain its own talent pool over the long-term;
- Continue to implement the Science and Technology Park, including incubator build-out and planning for an accelerator/multi-tenant space;
- Work with the Arizona Department of Commerce and the U.S. EDA to get funding for the development of the technology park at Embry Riddle in Prescott; and
- Work with Science Foundation Arizona to which actions if any they will invest dollars in to move the Northern Arizona Bioscience Roadmap forward.
- Work with the Arizona Board of Regents and Department of Commerce officials as well as Science Foundation Arizona and private sponsors to secure resources for 1) enhancing technology transfer and commercialization capabilities at NAU; 2) creating a technology commercialization fund at NAU; and 3) increasing support for NAU graduate students.
- Work with Arizona's Bioscience Roadmap Steering Committee to address the need for a BioSeed Fund and other risk capital.

Resources

Because so many of the actions will require further discussion it is not possible to estimate the total cost of these actions. However, it should be noted that a number of these items are already underway, e.g., incubator, science and technology park, etc., thus the public investment that will be required to implement the actions in the Roadmap will be primarily in the areas of research, technology and its commercialization, and education and training. The private investments required will include risk capital. Because of the progress already being made, Northern Arizona is not likely to have a huge resource requirement to move forward with this Regional Roadmap. More important are the issues of stewarding the Roadmap and its implementation.

Organization and Structure

The Steering Committee formed to provide guidance and oversight in the formulation of the Northern Arizona Bioscience Roadmap should continue to meet to steer and steward this effort in its

implementation. Membership of the Committee should be broadened to include representation from Prescott and Payson. Additional industry representatives from these areas should be given strong consideration.

Measures of Success and Accountability

Specific measures to guide progress in Roadmap implementation include:

1. Assessing Flagstaff's and Prescott's cost of living relative to other communities in Arizona and the West, including housing affordability (Indexes);
2. Maintaining Flagstaff's specialization in medical devices and broadening Northern Arizona's bioscience specialization to at least one other industry area (measured by LQ levels);
3. Tracking graduates in bio-related areas by level—Associate, Bachelor's, Graduate and Northern Arizona's retention rate of such graduates; and
4. Tracking statistics on success in commercialization of research: disclosures, patents, licenses, equity, and spin-offs

CONCLUSION

Flagstaff is making considerable progress on items important to the region's future in the biosciences. The region, due to the strong presence of W.L. Gore, is a recognized global player already in the biosciences. The growth of NAU research base; increased faculty interest in entrepreneurship; world class research around strengths in infectious diseases, environmental and ecological systems, and plant sciences; and the opportunity to build on its science education reputation to address regional needs, such as biomedical engineering, place Northern Arizona in a favorable position to grow its bioscience sector.

But there are challenges to address led by the interrelated issues of cost of living/housing costs and shortages of workers with most major employers in the community having a significant number of job openings. Some of this shortage is due to limitations in what is produced from the education system at the high school, community college, and university levels. But, some of it is also due to national shortages of skilled and experienced bioscience workers.

Two fundamental issues will determine whether Northern Arizona succeeds in the biosciences. Novel and creative solutions will be needed to address the issues of affordable housing and worker shortages. While there has been much discussion and debate over the housing issue, and it is not the purpose of this Roadmap to solve that problem, suffice it to say that if this problem is not solved it will be increasingly difficult for employers—biosciences or others—to stay, let alone expand. And it will limit efforts to recruit and attract suppliers to existing medical device firms to come to Flagstaff. Building a private-public consensus on solutions is critical, as Prescott has found in its efforts, and it will require creative and flexible responses by business, university, and city government leaders.

Addressing, if not totally solving, the housing issue will directly and indirectly help address the worker shortages. But, ultimately, the worker shortage suggests the region rethink how it builds its talent pool in the long term. This is hardly a short-term solution but providing more opportunities for part-time employment for college and high school students and increasing the scale of internships and co-op programs will increase the ability of the region's employers to attract these students upon graduation. In turn, this requires building career ladders and requires employers to adjust deployment of personnel as

they build their workforce from within the community. Education institutions have to more rapidly respond to such a strategy by considering advanced biomedical engineering programs at NAU; health occupation programs at Coconino Community College (CCC), Yavapai College, and NAU; and entrepreneurship programs emerging from the College of Business at NAU and elsewhere.

Introduction

> *Arizona is the leading southwestern state in selective bioscience sectors, built around world-class research, clinical excellence, and a growing base of cutting-edge enterprises and supporting firms and organizations.*
>
> *Platform for Progress: Arizona's Bioscience Roadmap*, 2002[3]

In 2002, the State of Arizona adopted the above vision for Arizona's future. The state's public and private sectors joined together and committed to making the investments necessary to become a leading center for the biosciences. *Arizona's Bioscience Roadmap* called for building the state's infrastructure around selected technology platforms, growing a critical mass of bioscience firms, and offering a business climate and environment to support bioscience enterprises.

Much has been accomplished in building such an environment in Arizona since 2002. Arizona's public and private sectors have invested to build the state's bioscience infrastructure. The State of Arizona allocated $440 million for new bioscience research buildings and equipment. At least $35 million have been invested annually in biomedical research through the Arizona Biomedical Research Commission (ABRC) and funding made available through Proposition 301. Just this past year, the Greater Phoenix Leadership, Northern Arizona Leadership Council (SALC) and Flagstaff 40 created Science Foundation Arizona, a nonprofit organization that will award funds for science, medicine and technological research projects. The Arizona Legislature appropriated $35 million to create a 21st Century Fund to spur medical, scientific, and engineering research that was used to provide Science Foundation Arizona's funding support in its first year of operation.

Two key technology anchors, the Translational Genomics Research Center (TGen) and the Critical Path Institute (C-Path), have become fully operational and are attracting staff and dollars. TGen has relocated to its new six-story, $46 million building as the cornerstone of the Phoenix Biomedical Center, a bioscience and medical research campus under development in downtown Phoenix. Most recently, TGen North opened in Flagstaff to work with NAU and its Keim Lab. C-Path, which was formed by the U.S. Food and Drug Administration (FDA), the University of Arizona (UA), the drug industry and others is an independent, publicly funded, nonprofit organization located in Tucson that is dedicated to speeding up the process of bringing new drugs and therapies to the market. C-Path fosters research and educational programs to enable the pharmaceutical industry to safely accelerate the development of new medications.

Efforts also have been initiated to spur the creation and growth of new bioscience companies by creating initiatives aimed at commercializing technology developed at Arizona's universities and research institutions and providing support to start-up and emerging bioscience companies. The Legislature created the Small Business Capital Investment Tax Incentive Program, also known as the Angel Investment Program, to expand the pool of capital available to bioscience and other qualified small businesses. Individuals who invest in qualified bioscience companies may receive a tax credit of up to 35 percent of

[3] *Platform for Progress: Arizona's Bioscience Roadmap*. Prepared for the Flinn Foundation by Battelle Technology Partnership Practice. December 2002.

the investment over a 3-year period. Such initiatives will result in the creation of new bioscience firms and the growth of emerging bioscience companies.

Significant progress has been made in building around the near-term bioscience platforms identified in the Roadmap, which include bioengineering, cancer therapeutics, and neurosciences. Strategies for further developing these platforms have been adopted and are being implemented. Progress has also been made in addressing the need to develop cross-cutting areas, such as bioimaging, tissue, and translational research. Work is nearing completion on scientific plans to address mid-term platforms including agricultural biotechnology and asthma.

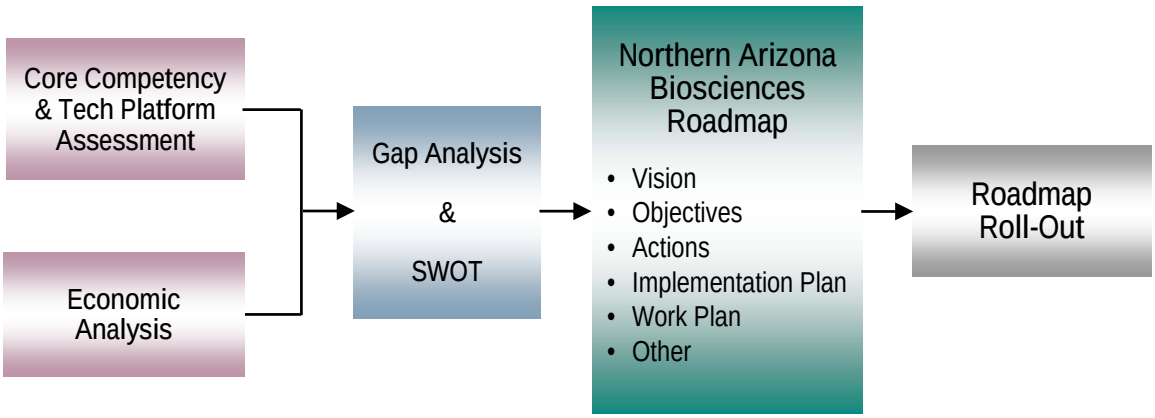
To continue this progress, the Flinn Foundation in 2006 engaged the various regions of Arizona in discussions as to their desires and interests in the biosciences and Flinn was asked to provide financial assistance to Battelle's Technology Partnership Practice (TPP) to assist in preparing regional bioscience competitiveness roadmaps for both Northern and Southern Arizona. The regional roadmaps will complement the statewide Bioscience Roadmap, but will focus on the specific challenges and opportunities that exist at the regional level. The regional roadmaps will lay out a bioscience vision for Northern and Southern Arizona and identify the tactics, strategies, and actions required to achieve that vision. The Southern Arizona Bioscience Roadmap was completed and released in November, 2006, and is now in the process of being implemented through the offices of the Southern Arizona Leadership Council and a Steering Committee formed for its implementation.

In Northern Arizona, the Greater Flagstaff Economic Council in partnership with Northern Arizona University and the City of Flagstaff assembled the Northern Arizona Bioscience Steering Committee to oversee development of a bioscience roadmap for the region. (Appendix A contains a list of the members of the project steering committee.) The Battelle team assisted the Steering Committee in developing this Roadmap.

METHODOLOGY

This Roadmap was developed with guidance and input from the region's educational and research institutions, economic development organizations, bioscience companies, and other public and private leaders. The Battelle project team collected and analyzed data on Northern Arizona's bioscience industry and research bases and interviewed academic, research, business, and civic leaders to develop an understanding of the region's existing bioscience research strengths and capabilities and to gather input on the types of investments needed to enable Northern Arizona to become a well-recognized regional bioscience center. Figure 1 displays the project methodology.

Figure 1: Project Methodology



This report

- Examines Northern Arizona's existing bioscience industry base.
- Proposes bioscience technology platforms that hold the greatest potential for development of the region's bioscience economy.
- Identifies gaps in private and public investments, policies, programs, and activities that need to be addressed if the region is to accelerate the growth of its bioscience economy.
- Sets forth a vision for the region's bioscience future.
- Presents a set of strategies and actions for achieving that vision.
- Outlines an implementation plan for moving forward.

Northern Arizona's Bioscience Industry Base

A critical component of any strategic regional plan is an economic assessment that examines the current state of the industry and investigates strengths and emerging opportunities for economic growth. Battelle examined employment and establishment data to assess the size and composition of Northern Arizona's bioscience sector and to identify emerging and existing subsector strengths that provide unique opportunities to grow the bioscience industry base in this region of the state.

THE BIOSCIENCE SECTOR

The biosciences represent a knowledge-based industry cluster driven by innovation in the life sciences. The industry combines cutting-edge laboratory research with the latest technologies to develop a range of products that boost productivity, advance health care, reduce environmental impacts, and potentially save lives.

Bioscience activity spans multiple markets and includes manufacturing, services, and research sectors. The sectors engaged in bioscience research and commercialization include **producers of agriculture-based goods** from feedstocks to fertilizers and bio-fuels such as ethanol; **pharmaceutical manufacturers that develop medicines and diagnostics; manufacturers of medical devices** ranging from magnetic resonance and other imaging equipment to surgical and laboratory appliances; the critical **research, testing**, **and medical laboratories sector** engaged in life sciences research and development (R&D); and the contributions of research hospitals and other research-driven institutions. Though each bioscience subsector has its own supply chains, research drivers, and other unique characteristics, nations and regions are building viable economic bases in the biosciences by promoting partnerships and shared resources with existing university, hospital, and industry anchors within and across these industry segments.

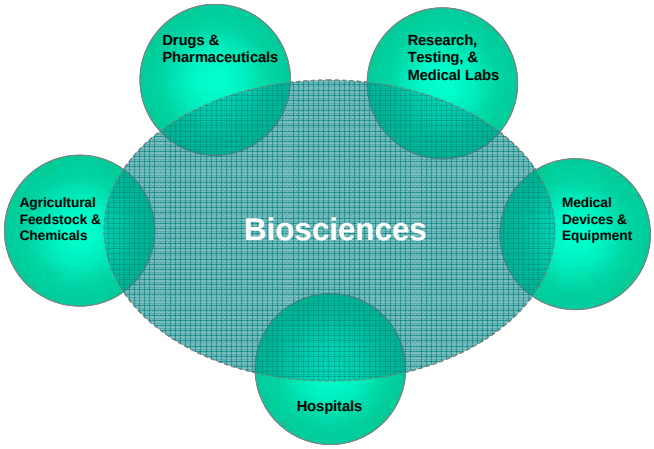
Key Findings

- Bioscience employment in the Flagstaff metropolitan area grew three times faster than that of the nation between 2001 and 2005
- The Flagstaff metro area accounts for 5.4 percent of Arizona's bioscience jobs, although the region accounts for only 2.9 percent of total statewide employment
- Medical devices and equipment is the fastest growing bioscience subsector and the most specialized, due to the presence of W.L. Gore
- Hospitals are the largest employer in the region's bioscience sector
- The Prescott MSA has experienced strong job growth in the biosciences, with employment growing 12 percent between 2001 and 2005
- Payson has a health science center and at least one start-up enterprise on which to develop its bioscience base.

The changing and diverse nature of the biosciences makes it difficult to define. The federal statistical system does not identify one complete bioscience industry classification. To encompass the range of bioscience activity in the United States, many detailed industries must be combined. Battelle has assisted many states and local areas throughout the United States in identifying and developing their bioscience industry bases. After years of research and field work, Battelle has identified five major subsectors that engage in key bioscience activity. The five major subsectors, shown in Figure 2, include the following:

- **Agricultural Feedstock and Chemicals**. This subsector applies life science knowledge and biotechnologies to the processing of agricultural goods and production of organic and agricultural chemicals. Product examples include ethanol, fertilizers, pesticides, sustainable lubricants and oils, and food and feed additives.
- **Drugs and Pharmaceuticals**. The subsector produces commercially available medicinal and diagnostic substances. Firms are generally large and multinational and are heavily engaged in R&D activities to bring drugs to market. Product examples include vaccines; oncology, neurology, and cardiology treatments; tissue and cell culture media; herbal supplements; and diagnostic substances.
- **Hospitals**.[4] The subsector covers a wide range of health care services in addition to significant life science research. The sector includes general medical and surgical, psychiatric and substance abuse, and other specialty hospitals. Research hospitals, academic health centers, and other research-driven medical institutions are major contributors to life science R&D.
- **Medical Devices and Equipment**. Firms in this subsector produce biomedical instruments and other health care products and supplies for diagnostics, surgery, patient care, and laboratories. Product examples include bioimaging equipment, orthopedic and prosthetic implants and devices, dental instruments and orthodontics, laser eye surgery equipment, defibrillators (automated external defibrillators), and stents and other implantable devices.
- **Research, Testing, and Medical Laboratories**. This subsector includes a range of activities, from highly research-oriented companies developing and commercializing new drug discovery/delivery systems, to more service-oriented medical or other testing firms. Product examples include functional genomics and drug discovery techniques, diagnostic testing, preclinical drug therapeutics, protein receptors, and research models and laboratory support services.

Figure 2: Bioscience Subsectors



The North American Industry Classification System (NAICS) is the official federal government system for classifying establishments and their activities into the appropriate sectors. The NAICS is based on the production processes of firms and categorizes them in groups with other establishments engaged in the same or similar activities. NAICS industries at the most detailed (six-digit) level were selected for this analysis and together make up the major sectors and subsectors. Using this system, 30 industries at the six-digit level of detail were chosen. These detailed industries were aggregated to five major subsectors of the bioscience industry. A full list of bioscience NAICS codes is shown in Table 1.

[4] The inclusion of hospitals as a major bioscience subsector in the data analysis in this report differs from what Battelle used in its 2006 report for the Biotechnology Industry Organization (BIO), *Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006*. For this reason, total bioscience industry estimates will differ from those presented in the BIO report because employment in three detailed hospital codes from NAICS are included here. This analysis will, however, distinguish between these total bioscience data and the "nonhospital" bioscience totals that use the same four-subsector data from the BIO report.

Table 1: Bioscience Subsector Industries and NAICS Codes

Agricultural Feedstock & Chemicals	
311221	Wet corn milling
311222	Soybean processing
311223	Other oilseed processing
325193	Ethyl alcohol manufacturing
325199	All other basic organic chemical manufacturing
325221	Cellulosic organic fiber manufacturing
325311	Nitrogenous fertilizer manufacturing
325312	Phosphatic fertilizer manufacturing
325314	Fertilizer (mixing only) manufacturing
325320	Pesticide and other agricultural chemical manufacturing
Drugs & Pharmaceuticals	
325411	Medicinal and botanical manufacturing
325412	Pharmaceutical preparation manufacturing
325413	In-vitro diagnostic substance manufacturing
325414	Other biological product manufacturing
Hospitals	
622110	General medical and surgical hospitals
622210	Psychiatric and substance abuse hospitals
622310	Specialty hospitals
Medical Devices & Equipment	
334510	Electromedical apparatus manufacturing
334516	Analytical laboratory instrument manufacturing
334517	Irradiation apparatus manufacturing
339111	Laboratory apparatus and furniture manufacturing
339112	Surgical and medical instrument manufacturing
339113	Surgical appliance and supplies manufacturing
339114	Dental equipment and supplies manufacturing
339115	Ophthalmic goods manufacturing
339116	Dental laboratories
Research, Testing, & Medical Laboratories	
541380**	Testing laboratories
541710**	Physical, engineering, and biological research
621511	Medical laboratories
621512	Diagnostic imaging centers

**Includes only the portion of these industries engaged in relevant biological or other life science activities.

Two of the six-digit NAICS industries in Table 1—testing laboratories (NAICS 541380) and physical, engineering, and biological research (NAICS 541710)—were adjusted in this analysis to include only the share of these industries directly engaged in biological or other life science activities. To isolate these relevant life science components, Battelle used information and data from the U.S. Census Bureau's Economic Census.

Relevant bioscience activity in the hospitals subsector cannot be isolated. Ideally, one would segregate research hospitals, academic health centers, and other research-driven institutions to identify only the life science R&D that occurred in those settings. Unfortunately, there are no reliable ways in which to isolate

these components from the three existing detailed hospital NAICS industries. The overall hospitals sector is included here because it is important and relevant, but this data issue and data limitations must be acknowledged and recognized.

Given the dynamic nature of the biosciences, one must also acknowledge the possibility that certain economic activities are not captured in this definition according to NAICS codes. Aggregating production activities on a broad scale will inevitably result in some data gaps; however, characterizing this industry according to the most detailed NAICS data available is the best approach to analyze the vast majority of key bioscience economic activity in Northern Arizona and the United States. Finally, the database used, which relies on employers' self-classifications for purposes of each state's unemployment compensation program, is dependent on both employer and state quality control measures; at times, employers may inappropriately classify themselves.

DATA AND METHODOLOGY

The following economic analysis examines data and corresponding trends in the Flagstaff and Prescott Metropolitan Statistical Areas (MSAs)[5] and the U.S. as a whole in the biosciences from 2001 to 2005. The Flagstaff MSA includes only Coconino County and the Prescott MSA includes only Yavapai County. For employment analysis, Battelle has selected the Bureau of Labor Statistics' (BLS) Quarterly Census of Employment and Wages (QCEW) data. The QCEW data (formerly known as the ES-202 program) are the most current, detailed state- and county-level industry employment, establishment, and wage figures available.[6] Battelle receives an "enhanced" version of these state and county data from a private vendor, the Minnesota IMPLAN Group, Inc.

The QCEW Program is a cooperative program involving BLS and the State Employment Security Agencies (SESAs). The QCEW program produces a comprehensive tabulation of employment and wage information for workers covered by State unemployment insurance (UI) laws and Federal workers covered by the Unemployment Compensation for Federal Employees (UCFE) program. Publicly available files include data on the number of establishments, monthly employment, and quarterly wages, by NAICS industry, by county, by ownership sector, for the entire United States. These data are aggregated to annual levels, to higher industry levels (NAICS industry groups, sectors, and supersectors), and to higher geographic levels (national, State, and Metropolitan Statistical Area).

[5] The U.S. Census Bureau defines a Metropolitan Statistical Area as a core area containing a substantial population nucleus, together with adjacent communities having a high degree of social and economic integration with that core. Metropolitan and micropolitan statistical areas comprise one or more entire counties.

[6] In general, QCEW monthly *employment* data represent the number of covered workers who worked during, or received pay for, the pay period that included the 12th day of the month. Virtually all workers are reported in the State in which their jobs are located. Covered private-industry employment includes most corporate officials, executives, supervisory personnel, professionals, clerical workers, wage earners, piece workers, and part-time workers. It excludes proprietors, the unincorporated self-employed, unpaid family members, and certain farm and domestic workers. An *establishment* is an economic unit such as a farm, mine, factory, or store that produces goods or provides services. It is typically at a single physical location and engaged in one, or predominantly one, type of economic activity for which a single industrial classification may be applied. *Total wages*: Covered employers in most States report total compensation paid during the calendar quarter, regardless of when the services were performed. Under most State laws or regulations, wages include bonuses, stock options, severance pay, the cash value of meals and lodging, tips and other gratuities, and--in some States--employer contributions to certain deferred compensation plans such as 401(k) plans. Major exclusions from UI coverage, and thus from the QCEW data, include self-employed workers (both Farmers and Nonag), some wage and salary agricultural workers, unpaid family workers, railroad workers, and some State and Local government workers.

Since 2001, the QCEW has been producing and publishing data according to the NAICS system. Federal statistical agencies have a mandate to publish industry data according to this improved classification system. Compared with the prior classification system—the 1987 Standard Industrial Classification (SIC) system, NAICS better incorporates new and emerging industries.

Employment, establishment, and wage estimates produced by the QCEW program for 2001 to present are not comparable with SIC-based industry estimates from prior years. This limits the ability to construct a longer time series for data analysis; however, five years of NAICS-based data are available for analysis.

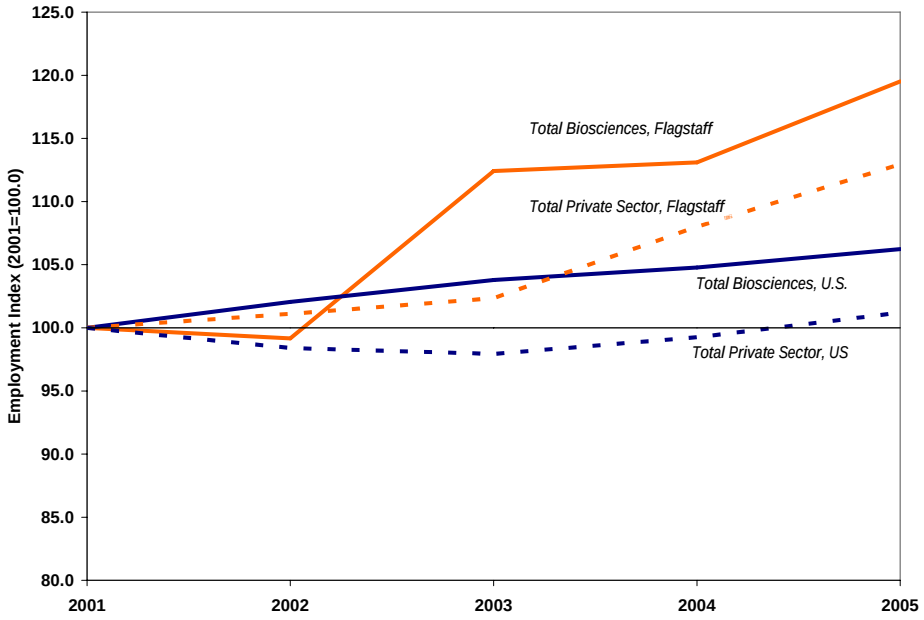
The following analysis will focus on the current state of the bioscience industry in the Northern Arizona metropolitan areas from an employment, establishment, and wage perspective. In some cases, more analytical space will be devoted to the Flagstaff MSA given its larger employment presence and specialized bioscience industries.

THE BIOSCIENCE SECTOR IN NORTHERN ARIZONA

The biosciences employed more than 5,500 in two Northern Arizona counties in 2005, spanning 37 business establishments. This combines the total bioscience sectors of the two metropolitan statistical areas (MSAs)—Flagstaff and Prescott. Three-quarters of this employment resides in the Flagstaff MSA.

In Flagstaff, the biosciences employed 4,199 in 2005 across 12 business establishments (Table 2). Local bioscience firms have increased payrolls in the metropolitan area by nearly 700 jobs or 19.5 percent since 2001, outpacing a national bioscience industry that added 6.2 percent to its employment base during this period (Figure 2). ***This rapid rate of bioscience job growth for the Flagstaff region during the early to mid 2000's was over three times faster than that for the nation***.

Figure 2. Flagstaff MSA and U.S. Job Growth in the Biosciences and Total Private Sector, 2001-2005 (Index, 2001=100.0)



Source: Battelle calculations based on Bureau of Labor Statistics, QCEW/ES202 program data and Minnesota IMPLAN Group, Inc.

The private sector in Flagstaff has seen rapid job growth since 2001, boosting employment by about 13 percent overall. Flagstaff's labor market proved robust during the early 2000's despite a national private sector that experienced overall employment declines in 2002 and 2003 following the recession of 2001.[7] Flagstaff had modest, yet steady employment gains during those years of about 1 percent and in 2004 and 2005, saw its rate of job growth hover around 5 percent. Despite this solid regional performance, at both the local and national levels, job growth in the biosciences was much greater than for the entire private sector.

Table 2. Northern Arizona MSAs and National Bioscience Industry Comparison, 2001-2005

Metric	*Flagstaff MSA*		*Prescott MSA*		*United States*	
	Biosciences	Total Private Sector	Biosciences	Total Private Sector	Biosciences	Total Private Sector
Establishments						
2001	27	3,108	18	4,485	43,455	7,733,520
2005	12	3,548	25	5,683	48,417	8,308,128
2001-05 % change	-56.5%	26.7%	38.9%	26.7%	11.4%	7.4%
Employment						
2001	3,513	37,683	1,178	40,582	5,200,957	109,321,800
2005	4,199	42,559	1,323	48,827	5,525,594	110,634,500
2001-05 % change	19.5%	12.9%	12.3%	20.3%	6.2%	1.2%
Average Annual Wages						
2001	$36,424	$22,968	$33,712	$23,392	$41,120	$36,159
2005	$45,363	$27,194	$45,279	$28,117	$49,523	$40,499
2001-05 % change	24.5%	18.4%	34.3%	20.2%	20.4%	12.0%
Location Quotient						
2001	**1.96**	NA	0.61	NA	1.00	NA
2005	**1.98**	NA	0.54	NA	1.00	NA
Share of Private Sector Employment (Percent)						
2001	9.3%	100%	2.9%	100%	4.8%	100%
2005	9.9%	100%	2.7%	100%	5.0%	100%

Source: Battelle calculations based on Bureau of Labor Statistics, QCEW/ES202 program data and Minnesota IMPLAN Group, Inc. Specialized subsector location quotients are highlighted in red.

The bioscience sector in Flagstaff represents a significant 10 percent share of the region's overall economy, and the local industry continues to grow. This share of bioscience employment is almost exactly twice that of the national average for 2005 (5.0 percent). Location quotients (LQ) quantify this relative degree of employment concentration.[8] A location quotient of 1.0 indicates a similar degree of

[7] The National Bureau of Economic Research (NBER) Business Cycle Dating Committee is the official arbiter of U.S. Business Cycles. The Committee determined that a peak in the business cycle occurred in March 2001, marking the end of an expansion and the beginning of a recession. The peak ended a record-long expansion (10 years). The business cycle trough occurred in November 2001, ending a recession of relatively short duration. For more information, visit http://www.nber.org/cycles.html/.

[8] Location quotients are a standard measure of the concentration of a particular industry in a region relative to the nation (reference area). The LQ is the share of total regional employment in the particular industry divided by the share of total industry employment in the nation (reference area). A LQ greater than 1.0 for a particular industry indicates that the region is relatively concentrated, whereas an LQ less than 1.0 signifies a relative under-representation. A location quotient greater than 1.20 denotes employment concentration significantly above the national average. Throughout this report, LQs are used to report regional industry concentrations relative to the U.S. as a whole. The minimum concentration threshold for declaring a regional specialization is a matter of judgment and varies somewhat in the relevant literature. In this analysis, regional specializations are defined by LQs of 1.20 or greater.

concentration as for the nation. When the region has significantly above-average employment—a location quotient greater than 1.20—the area is said to possess a specialization in that industry. Figure 3 shows the formula for calculating a location quotient.

The location quotient for the Flagstaff MSA reached 1.98 in 2005, meaning the region is almost twice as concentrated in the biosciences as its counterparts nationally. The relative concentration of total bioscience jobs in the region is considered to be "specialized."

Figure 3. Calculating a Location Quotient

$$LQ_{it} = (E_i / E_t) / (US_i / US_t)$$

Where:
- E_i = Industry *i* regional employment
- E_t = Total regional employment
- US_i = Industry *i* national employment
- US_t = Total national employment

Wages in the biosciences reflect a strong demand for highly-skilled, well-educated workers. The industry pays average wages that significantly exceed those for the overall private sector. This wage premium exists at both the local and national levels. In Flagstaff, bioscience workers earn $45,363, on average, compared with $27,194 for their counterparts in the private sector. Nationally, bioscience workers earn $9,000 more than the private sector average in 2005--$49,523 vs. $40,499.

While annual wages for bioscience workers in Flagstaff remain slightly below the national average, strong regional demand has pushed wages up for these workers. Regional bioscience workers have seen their average wages rise by about 25 percent (in nominal terms) since 2001, compared with 20 percent for workers at the national level.

The high concentration of bioscience jobs in Flagstaff extends to the state level as well. ***The Flagstaff MSA accounts for a disproportionately large share of the state's bioscience jobs***. The region accounts for just 2.0 percent of all private sector jobs, but 5.4 percent of all jobs in the state bioscience sector. The region thus has a greater influence on Arizona's overall bioscience industry than might be expected given its overall size.

Similar to Flagstaff, the Prescott MSA has experienced strong job growth in the biosciences in recent years. Though modest in size, Prescott's bioscience sector boosted employment by 12 percent since 2001 and in 2005 stands at more than 1,300 jobs in total. At the same time, the region increased its number of business establishments from 18 to 25.

In Prescott, the biosciences account for 2.7 percent of all jobs. The metropolitan area has seen its overall private sector employment rise by 20 percent in just 4 years, a noteworthy accomplishment given the relatively sluggish condition of the U.S. labor market during the early 2000's. This rapidly growing labor market has kept the concentration of bioscience jobs low relative to the U.S. average. The location quotient for the Prescott MSA measured 0.54 in 2005, or about one-half the national average concentration.

Average bioscience wages in Prescott are essentially the same as those in Flagstaff, $45,279 in 2005. Wage growth in Prescott has exceeded that of both the U.S. and its neighboring county, growing 34 percent since 2001.

The Non-Hospital Biosciences

Hospitals account for the majority of bioscience employment in both the Flagstaff and Prescott metropolitan areas. In 2005, the hospital sector in Flagstaff accounted for 70 percent of the total sector

and in Prescott, the share was 86 percent. It is therefore useful to examine the structure of the non-hospital sector subtotals and current labor market trends before moving on to dissect the detailed subsectors of the bioscience industry.

The non-hospital biosciences in Flagstaff employ 1,255 individuals across 9 establishments in 2005 (Table 3). These firms in the metropolitan area are exclusively involved in two of the four major non-hospital sectors—medical devices and equipment, and research, testing, and medical laboratories. ***Regional jobs in the non-hospital sector have grown significantly since 2001, up 37 percent; proving Flagstaff's bioscience sector is driven not only by its large employment base in hospitals, but also by a thriving non-hospital component***. Job growth in the non-hospital sector has far outpaced that at the national level which grew just 2.8 percent during the same period. Almost all of this employment is associated with one firm—WL Gore—and compared to other regions with strong biomedical device concentrations (as is the case with Flagstaff)—Flagstaff is much less diversified across bioscience segments than most of these comparable communities.

Limiting the analysis to the non-hospital sector reveals a relative employment concentration in Flagstaff that is even greater than that for the total biosciences. ***In 2005, the non-hospital bioscience location quotient in Flagstaff reached 2.66, or more than 2.5 times the national average job concentration***. Flagstaff owes this high degree of employment specialization to its large medical device subsector which will be analyzed in detail in the following section of the report.

Table 3. Northern Arizona MSAs and National Non-Hospital Bioscience Industry Comparison, 2001-2005

Metric	*Flagstaff MSA*		*Prescott MSA*		*United States*	
	Non-Hospital Biosciences	Total Private Sector	Non-Hospital Biosciences	Total Private Sector	Non-Hospital Biosciences	Total Private Sector
Establishments						
2001	23	3,108	17	4,485	36,346	7,733,520
2005	9	3,548	23	5,683	40,901	8,308,128
2001-05 % change	-63.0%	26.7%	38.3%	26.7%	12.5%	7.4%
Employment						
2001	914	37,683	181	40,582	1,191,619	109,321,800
2005	1,255	42,559	191	48,827	1,224,831	110,634,500
2001-05 % change	37.3%	12.9%	5.5%	20.3%	2.8%	1.2%
Average Annual Wages						
2001	$38,794	$22,968	$31,611	$23,392	$58,574	$36,159
2005	$46,041	$27,194	$36,405	$28,117	$69,215	$40,499
2001-05 % change	18.7%	18.4%	15.2%	20.2%	18.2%	12.0%
Location Quotient						
2001	**2.23**	NA	0.41	NA	1.00	NA
2005	**2.66**	NA	0.35	NA	1.00	NA
Share of Private Sector Employment (Percent)						
2001	2.4%	100%	0.4%	100%	1.1%	100%
2005	2.9%	100%	0.4%	100%	1.1%	100%

Source: Battelle calculations based on Bureau of Labor Statistics, QCEW/ES202 program data and Minnesota IMPLAN Group, Inc. Specialized subsector location quotients are highlighted in red.

The non-hospital bioscience sector in Prescott is relatively small in size. Though it is home to 23 separate business establishments, local jobs in the sector number only 191 for 2005. Nearly all of these jobs are in

the research, testing, and medical laboratories subsector, which will be examined in more detail in the subsector analysis. Though modest in size, these bioscience workers still earn higher average wages than their counterparts in the rest of the private sector.

Nationally, average wages in the non-hospital subtotals are much higher than those observed in the total bioscience analysis. This is due to lower average wages paid to hospital workers compared with their counterparts in high-paying subsectors such as drugs and pharmaceuticals or in research and testing. ***In 2005, the average wage for U.S. workers in the non-hospital biosciences was $69,215, nearly $30,000 more than the national average for the private sector, and about $20,000 more than for the total bioscience sector including hospitals. These wage differentials highlight a primary reason why a region would benefit from targeting firms (and resulting new jobs) engaged in high value-added bioscience activities***.

Flagstaff's non-hospital biosciences represent 10 percent of the entire sector in Arizona in 2005. Compared with its 2 percent share of total private sector employment, this large relative contribution to the state's bioscience sector is significant. Flagstaff clearly has a significant impact on the statewide bioscience economy.

Payson's bioscience base today is primarily around its regional hospital. There is at least one small startup firm in the community.

To fully understand the regional bioscience economies in Northern Arizona, it is critical to examine in-depth the major component subsectors that make up the larger sector. The following section will highlight the major subsectors in each metropolitan area with respect to labor market size, concentration, and current trends.

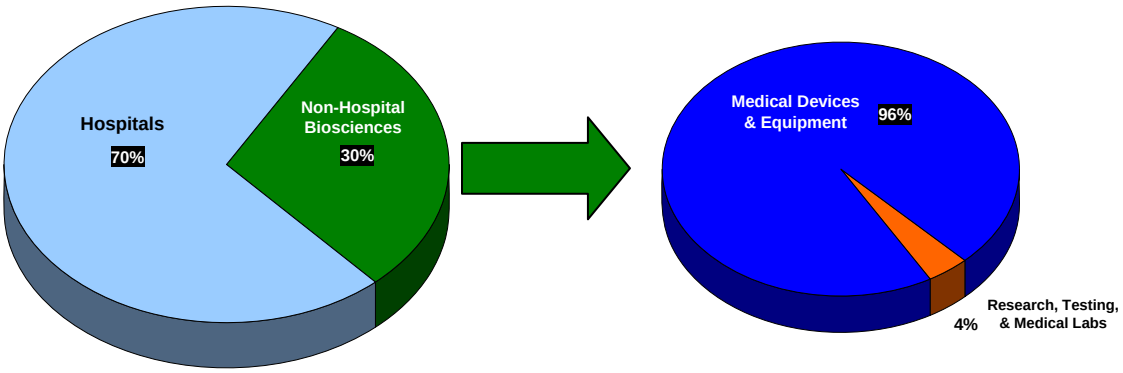
MAJOR BIOSCIENCE SUBSECTORS IN NORTHERN ARIZONA

The five major bioscience subsectors offer an incredibly diverse set of activities and characteristics including their respective life sciences research base, inputs and supply chains, and their commercial applications and end products. In addition, the subsectors vary in general size and economic impact with respect to jobs, wages, and production value. In order to explain the overall trends and magnitudes of a region's bioscience sector it is important, therefore, to undergo a detailed subsector analysis.

Flagstaff Bioscience Subsectors

The biosciences in the Flagstaff MSA lie almost exclusively within two major subsectors, hospitals and the production of medical devices and equipment. Figure 4 presents the employment composition of the regional bioscience economy. Hospitals employ 70 percent of the metropolitan area's bioscience workforce. The remaining 30 percent of jobs are nearly all (96 percent) in medical devices and equipment, with a small share employed in the research, testing, and medical laboratories subsector. As of 2005, Flagstaff had no employment in establishments identified in the agricultural feedstock and chemicals subsector, nor in the drugs and pharmaceuticals subsector.

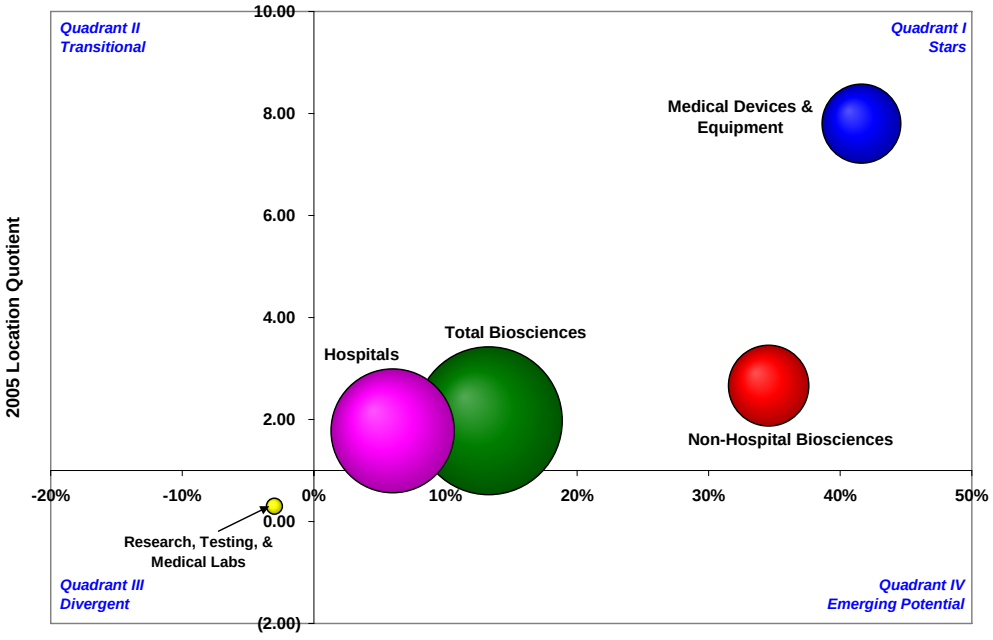
Figure 4. Subsector Employment Composition of the Flagstaff Bioscience Sector, 2005



The bubble chart in figure 5 shows the degree of employment concentration (specialization), employment growth relative to the nation, and employment levels for the three bioscience subsectors and the bioscience totals in Flagstaff. The chart plots 2005 location quotients against relative employment growth (or loss). The size of each bubble represents the employment size of the industry. The underlying employment data as well as establishment and wage data for each subsector are presented in table 4.

The strong relative performance of the Flagstaff MSA in the biosciences since 2001 is evident in the chart with nearly all of the bubbles in the northeast quadrant (quadrant I). Quadrant locations within the bubble chart reveal certain key characteristics and trajectories for each sector. The northeast quadrant, labeled "stars," highlights industries with positive relative job growth and employment concentrations that exceed that for the nation. While Flagstaff's total bioscience sector and its two major subsectors might be considered stars in the context of this graphic, it is important to note the relatively modest size of the sectors and to continue to push for further economic growth and new firm creation in the region.

Figure 5. Flagstaff, AZ Bioscience Subsectors, degree of specialization, employment growth, and size, 2001-2005



Note: Size of bubble represents employment.

Medical devices and equipment is the fastest growing bioscience subsector in Flagstaff and the most specialized. The subsector employed 1,206 in 2005, spanning 6 local business establishments, but with almost all of this employment associated with WL Gore. Though the sector is relatively mature in the metropolitan area, it continues grow. Subsector employers have added jobs at a steady pace since 2001, with total employment up 39 percent from 2001 to 2005. Nationally, the medical device subsector has experienced a different trend, shedding jobs continuously from 2001 through 2004 before finally gaining ground with new jobs added in 2005. On net, national subsector employment remains lower than its recent peak in 2001, down 2.3 percent to about 402,000.

Flagstaff's large medical device sector relative to its total private employment yields a very high location quotient—7.80 in 2005. The LQ highlights a specialized local industry that is nearly 8 times more concentrated than at the national level. ***In Battelle's 2006 national report for the Biotechnology Industry Organization (BIO), the Flagstaff metropolitan area ranked 3rd among all small metro areas (166 total) for its LQ in the medical devices and equipment subsector in 2004***.[9]

The major detailed industry component of the medical device subsector in Flagstaff is Surgical Appliance and Supplies Manufacturing (NAICS 339113). Almost every job in the local subsector can be found within this industry classification. The region's major medical device employer driving this subsector is W.L. Gore & Associates based in Flagstaff.

W.L. Gore's operations in Flagstaff are the "hub" of the company's Medical Products Division and one of the largest private employers in the region. In Flagstaff, Gore develops and manufactures implantable medical devices such as stents and catheters. Gore develops the materials and components for implants with applications in vascular, endovascular, interventional, general surgery, cardiothoracic, oral and orthopedic procedures. Its products generally help maintain blood flow and breathing for patients. Recently, Gore has developed innovative new stent-graft technology that is less intrusive in fixing arterial aneurysms.

Recent media reports cite employment at Gore's Flagstaff establishments to be about 1,600 in early 2007.[10] Available employment data used in this study for 2005 apply estimation procedures and generate an employment estimate of about 1,200.[11] While there is some error associated with the estimation of the 2005 data, it is reasonable to suggest that employment at Gore has risen significantly in recent years.

Gore announced in February 2007 plans to add an additional 40,000 square feet at its Kiltie Lane campus in west Flagstaff. In addition, the company reports plans to add another 100 jobs. These plans are in addition to a new production facility off Kiltie Lane set to open in April 2007 that measures 133,000 square feet.[12] In addition to expansion in Flagstaff, Gore is boosting operations in other parts of Arizona with new facilities in North Phoenix and added space in Tempe.

Hospitals are the largest employer in Flagstaff's bioscience sector and are considered to be regionally specialized. This subsector employed 2,944 in 2005 across 3 establishments. Reflecting the metropolitan area's strong population growth in recent years, local hospital jobs have increased by 13 percent since

[9] See "*Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006*," by Battelle Technology Partnership Practice and SSTI, April 2006. The full report can be accessed online at http://www.bio.org/local/battelle2006/.
[10] See "Bioscience growing amid the pines," by Ken Alltucker, *The Arizona Republic*, February 22, 2007.
[11] Publicly available BLS QCEW county-level data are often not reported due to disclosure issues. The BLS will not disclose data for a particular industry in a county if it is at all possible to identify the lone county employer within that industry. In this case, Battelle uses an employment figure estimated by the Minnesota IMPLAN Group.
[12] See "Gore keeps growing," by J. Ferguson, *Arizona Daily Sun*, Flagstaff, February 22, 2007.

2001. Job growth in the Flagstaff subsector has outpaced a robust national sector by nearly 2 to 1 since 2001 as the national sector added 7 percent to its employment base.

Compared with the national concentration of hospital jobs, Flagstaff has a highly concentrated subsector. The Flagstaff MSA has an LQ of 1.78 for 2005, a 78 percent greater concentration of jobs in its hospitals.

Flagstaff Medical Center operates as a not-for-profit hospital serving the local community. FMC provides key services including open heart surgery; a cancer center; advanced imaging technologies; a trauma center; and surgical and orthopedic services. The medical center has operated since 1936. Regional hospitals and medical centers like FMC have an opportunity to establish new partnerships with the entities involved in the bioscience initiatives planned for Flagstaff. An influx of life science researchers with the opening of the TGen North operations and the planned Science and Technology Park represent an opportunity for the biomedical community and others like Gore and Northern Arizona University to collaborate and expand their capabilities.

The research, testing, and medical laboratories subsector has a small presence in the Flagstaff metropolitan area. The subsector employs fewer than 50 individuals across 3 business establishments. Regional workers in this subsector are mostly employed in the biological research component of the subsector.

SenesTech, Inc. in Flagstaff is an example of a biological R&D company in the research and testing subsector. Founded in 2002, SenesTech uses advanced biotechnology to improve reproductive health and quality of life for women and other female mammals. According to the SenesTech website (http://www.senestech.com/), the company mission is as follows:

"To build on the platform technology of accelerated ovarian senescence to develop models to improve women's health and quality of life by providing endocrine relevant research models for pharmaceutical screening and simultaneously to use the technology to address feral animal overpopulation and support relevant community outreach programs."

SenesTech is developing applications for permanent pet sterilization that are alternatives to major surgical procedures. In addition, the firm is developing animal models in which to study transitions to menopause.

Table 4. Northern AZ MSAs and National Bioscience Subsector Employment, 2001-2005

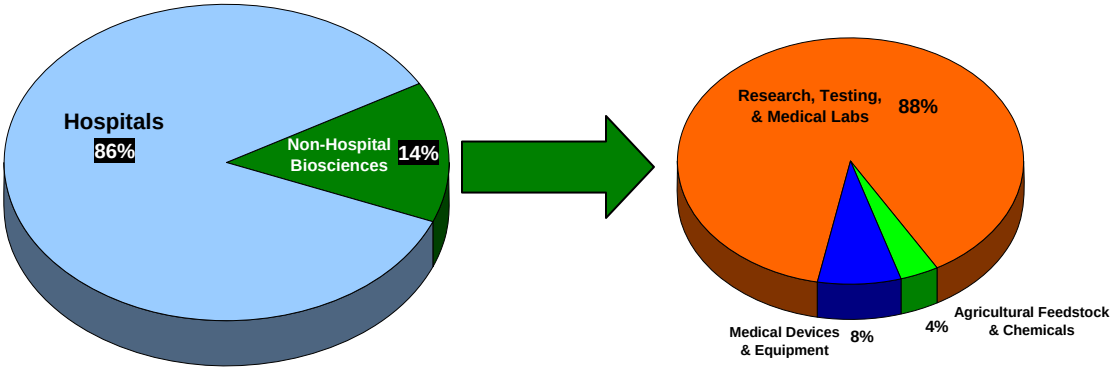
Employment Metric	Agricultural Feedstock & Chemicals	Drugs & Pharmaceuticals	Medical Devices & Equipment	Research, Testing, & Medical Labs	Hospitals
Flagstaff, AZ MSA					
Establishments					
2001	-	-	19	4	4
2005	-	-	6	3	3
2001-05 % change	-	-	-68.3%	-33.3%	-15.2%
Employment					
2001	-	-	866	45	2,599
2005	-	-	1,206	49	2,944
2001-05 % change	-	-	39.3%	9.4%	13.3%
Average Annual Wages					
2001	-	-	$38,954	$36,620	$35,590
2005	-	-	$46,466	$35,651	$45,074
2001-05 % change	-	-	19.3%	-2.6%	26.6%
Location Quotient					
2001	-	-	**6.10**	0.35	**1.88**
2005	-	-	**7.80**	0.30	**1.78**
Prescott, AZ MSA					
Establishments					
2001	1	1	7	8	1
2005	2	0	8	13	2
2001-05 % change	100.0%	-100.0%	16.1%	52.4%	45.7%
Employment					
2001	7	26	14	134	997
2005	7	0	15	169	1,132
2001-05 % change	-5.0%	-100.0%	5.9%	26.4%	13.6%
Average Annual Wages					
2001	$27,501	$33,242	$31,972	$31,479	$34,093
2005	$35,235	-	$44,806	$35,713	$46,774
2001-05 % change	28.1%	-	40.1%	13.4%	37.2%
Location Quotient					
2001	0.16	0.25	0.09	0.95	0.67
2005	0.14	-	0.08	0.90	0.60
United States					
Establishments					
2001	2,128	2,519	15,077	16,622	7,109
2005	2,077	2,542	15,109	21,173	7,516
2001-05 % change	-2.4%	0.9%	0.2%	27.4%	5.7%
Employment					
2001	121,187	280,608	411,569	378,255	4,009,338
2005	109,903	287,951	401,948	425,029	4,300,763
2001-05 % change	-9.3%	2.6%	-2.3%	12.4%	7.3%
Average Annual Wages					
2001	$58,011	$72,407	$48,707	$59,229	$35,933
2005	$66,161	$87,821	$57,399	$68,573	$43,915
2001-05 % change	14.0%	21.3%	17.8%	15.8%	22.2%

Source: Battelle calculations based on Bureau of Labor Statistics, QCEW/ES202 program data and Minnesota IMPLAN Group, Inc. Specialized subsector location quotients are highlighted in red.

Prescott Bioscience Subsectors

In the biosciences, Prescott private sector firms are primarily hospitals, with others operating as medical laboratories. The pie charts in figure 6 show the vast majority of overall sector employment, 86 percent, in hospitals. The remaining 14 percent in the non-hospital sector are mostly in research, testing, and medical labs with small shares in medical devices and in agricultural feedstock and chemicals. As of 2005, there were no local establishments manufacturing drugs and pharmaceuticals.

Figure 6. Subsector Employment Composition of the Flagstaff Bioscience Sector, 2005

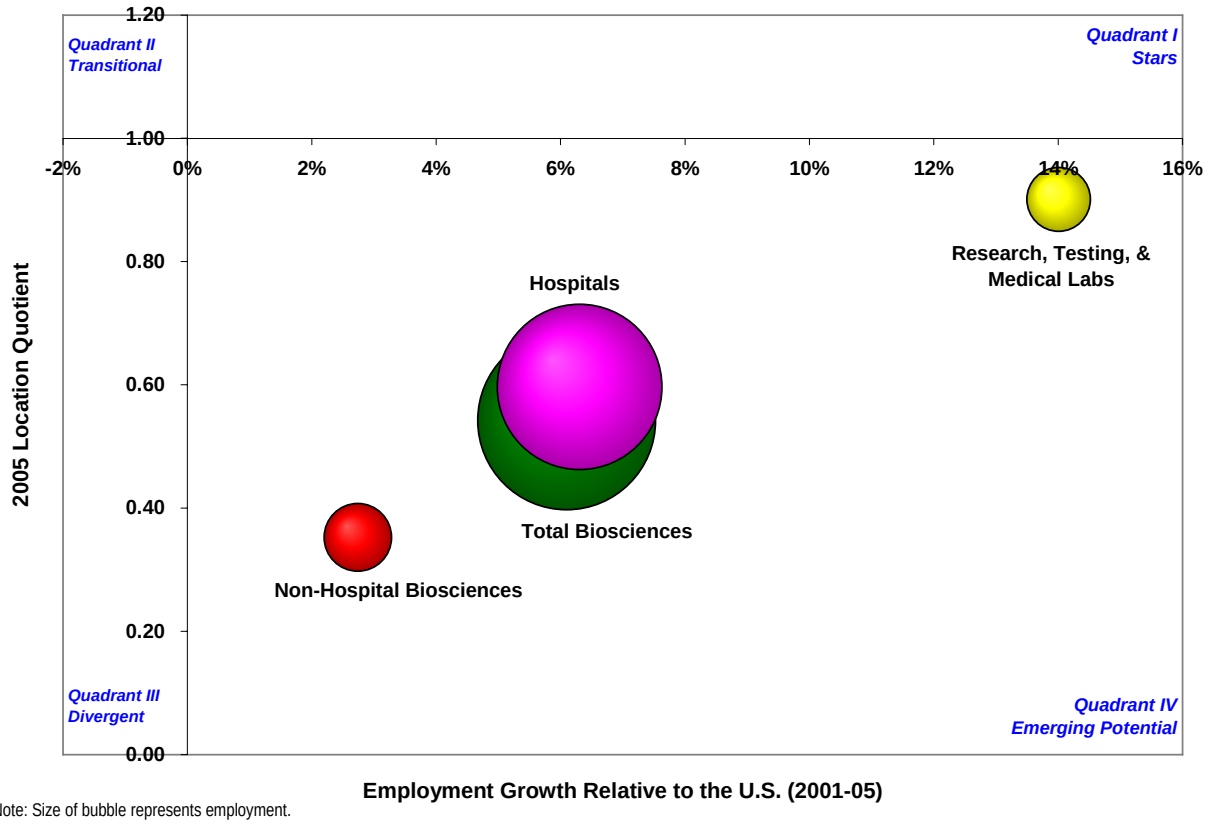


The relative labor market performance of Flagstaff's bioscience industry is shown in the bubble chart in figure 7. The chart plots current total bioscience and subsector LQs against job growth relative to the U.S. from 2001 to 2005. The size of the bubbles represents employment levels. The chart provides a snapshot of local bioscience employment magnitudes and trends as of 2005. Not shown in the chart are the medical device and agricultural feedstock and chemicals subsectors which both had fewer than 20 local jobs.

Both the hospitals and research, testing, and medical laboratories subsectors had strong employment growth in the early 2000s relative to the U.S. It is important to note, however, that the employment base in the region is relatively small and therefore growth rates will be higher given rather modest increases in employment.

With that said, the region's two primary bioscience subsectors have exhibited growth in recent years and lie in the southeast quadrant (quadrant IV) labeled "emerging potential." Industries in this quadrant have LQs that are less than 1.0, meaning their relative concentration of jobs is lower than the national average; but they are growing and therefore "emerging." The region should be encouraged by this characterization and work to keep the industry growing and attain a higher degree of employment concentration.

Figure 7. Prescott, AZ Bioscience Subsectors, degree of specialization, employment growth, and size, 2001-2005



Note: Size of bubble represents employment.

Hospitals are the largest local bioscience subsector in the Prescott MSA. In 2005, two hospital establishments employed 1,132 in Yavapai County (the metropolitan statistical area). The subsector LQ for 2005 was 0.60. Local hospitals added 135 jobs from 2001 to 2005, a 13.6 percent increase in its employment base.

Average wages for hospital workers were $46,774 in 2005, much higher than the local private sector average of $28,117. In addition, Prescott area hospital workers earn more than their subsector counterparts nationally who earn $43,915, on average. (See Table 4.)

Prescott's research, testing, and medical laboratories subsector employed 169 in 2005 in 13 local establishments. While industry employment has been up and down, the subsector added 35 jobs (up 26 percent) on net, since 2001. These jobs are nearly all within two detailed industries, medical laboratories (NAICS 621511) and diagnostic imaging centers (NAICS 621512). Medical labs are primarily involved in providing analytic or diagnostic services, including analysis of body fluids. Diagnostic imaging centers produce patient images for medical professionals for use in diagnosis.

Bradshaw Mountain Diagnostic Lab (BMDL) in Prescott recently celebrated its 25th year in business serving the medical and patient community in Yavapai County. According to its website, the lab employs nearly 100 in nine locations and offers a wide array of clinical and environmental/toxicology testing services. Its clinical testing services include: bacteriology, chemistry, coagulation, hematology, immunology, and urinalysis. BMDL's environmental/toxicology testing capabilities include water analysis, pre-screen and other drug abuse testing, and certified breath alcohol analysis.

SUBSECTOR ANNUAL WAGE ANALYSIS

Wage analysis across the major bioscience subsectors provides insight into the demand and relative supply of workers in Northern Arizona. In addition, it allows one to highlight those industries with the highest-paying jobs for the region to target in its development efforts. A higher paying sector implies a greater degree of value added to a good produced or a service provided. In developing its bioscience economy, the Flagstaff and Prescott metropolitan areas can look to wage rates as one key signal of the local market's allocation of capital.

Table 5 presents average annual wages for the two Northern Arizona metropolitan areas in 2005. The dramatic wage premiums paid to workers in the local biosciences are dramatic. ***Compared with their counterparts in the total private sector, Northern Arizona bioscience workers are earning nearly $20,000 more per year***. In addition, the major regional bioscience subsectors—hospitals and medical device manufacturing—are at or near the top in both regions.

Table 5. Average Annual Wages in N. Arizona MSAs for the Biosciences and other Major industries, 2005

Northern Arizona: Average Annual Wages by Industry, 2005		
Industry	**Flagstaff MSA**	**Prescott MSA**
Medical Devices & Equipment	**$46,466**	**$44,806**
Total Non-Hospital Biosciences	**$46,041**	**$36,405**
Total Biosciences	**$45,363**	**$45,279**
Hospitals	**$45,074**	**$46,774**
Management of Companies & Enterprises	$44,920	$69,120
Wholesale Trade	$44,733	$40,090
Manufacturing	$43,958	$33,850
Health Care & Social Assistance	$40,641	$32,965
Finance & Insurance	$40,472	$42,707
Information	$38,432	$43,751
Research, Testing, & Medical Labs	**$35,651**	**$35,713**
Prof., Scientific, & Technical Services	$35,273	$35,233
Transportation & Warehousing	$34,062	$30,137
Real Estate & Rental & Leasing	$32,449	$29,434
Construction	$28,258	$30,052
Total Private Sector	**$27,194**	**$28,026**
Retail Trade	$22,180	$23,978
Accommodation & Food Services	$14,564	$14,546

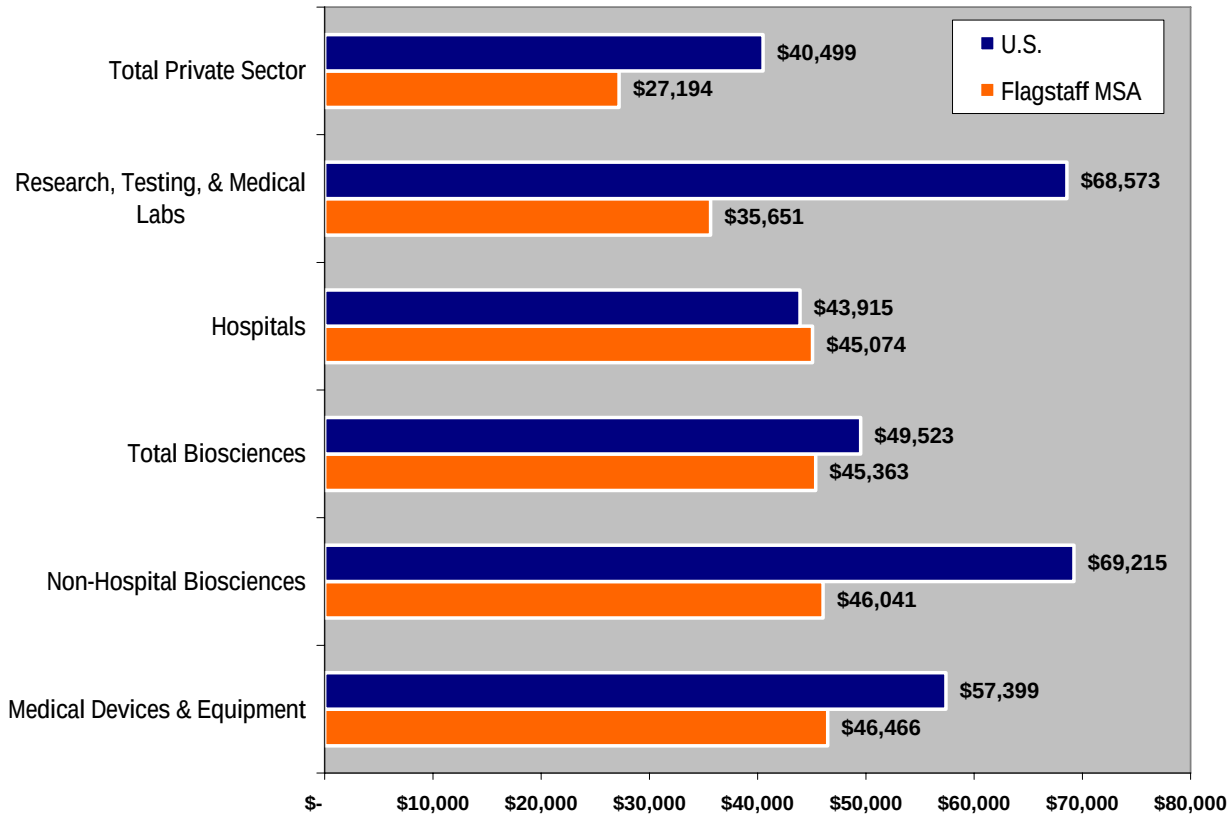
Source: Battelle calculations based on Bureau of Labor Statistics, QCEW program data from IMPLAN.

Bioscience wage comparisons for Flagstaff and the U.S. are illustrated in figure 8. Average private sector wages are considerably lower in the Flagstaff metropolitan area, $27,194 vs. $40,499 for the nation. Despite this disparity, annual wages in the biosciences and its major regional subsectors are more comparable. The average bioscience worker in Flagstaff earns $45,363 compared with $49,523 nationally.

Flagstaff hospital workers have higher average wages than their industry counterparts nationally--$45,074 vs. $43,915. While this might surprise some given the differential in the private sector, it is apparent that local hospitals are paying a premium to attract talented workers and to provide adequate wages given the high cost of living in the Flagstaff metropolitan area. Local medical providers note the

shortages of nurses, physicians, and other healthcare specialists at the local level, requiring that they pay a premium to retain and attract these workers.

Figure 8. Flagstaff MSA and U.S. Average Annual Wages in the Biosciences and Subsector Industries, 2005



CONCLUSION

Northern Arizona is an important contributor to the state's bioscience industry sector. The region's bioscience sector exhibited strong growth from 2001 to 2005. This is particularly impressive as Northern Arizona's non-hospital bioscience employment is found primarily in the medical device subsector, which experienced employment losses nationally while growing rapidly in Northern Arizona. At the same time, bioscience employment in Northern Arizona is highly concentrated in one company, WL Gore, which accounted for most of the employment growth. Total employment and the number of bioscience establishments are small in Northern Arizona. Northern Arizona needs to build on its medical device and hospital sectors while at the same time diversifying its bioscience industry base in other areas.

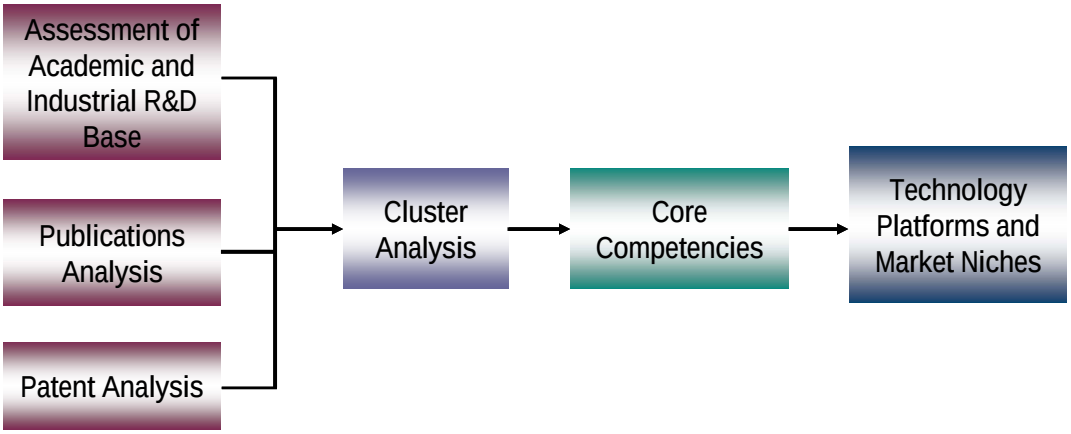
Northern Arizona's Bioscience Research & Technology Base

In addition to an understanding of a region's existing industry base, the development of a comprehensive bioscience roadmap requires an understanding of the bioscience-related research competencies within the region's universities and other research institutions. Universities are the national leaders in basic and applied bioscience research, and it is extremely important that bioscience-based economic development strategies are constructed based on an understanding of the capabilities of a region's research universities and associated institutes. Research universities are likewise at the forefront of developing and adopting enabling technologies for advancing bioscience R&D, and it is important to understand the investment in and availability of these tools and resources (such as imaging, instrumentation, advanced materials, combinatorial chemistry resources, etc.) since they contribute so strongly to development pathways. It should also be noted that university core competencies can serve as a magnet to attract commercial research linked to the universities' expertise and specialized focus areas—helping to build a localized environment conducive to specialized bioscience business development and growth.

The biosciences present so many opportunities for the future that it is extremely important for a state or region to understand where its opportunities will lie within a very broad universe of bioscience disciplines, opportunity areas, and possibilities. An extremely small number of states (most notably California and Massachusetts) have such a broad academic and industrial base in the biosciences that they may be able to build on strengths across the board; but, in most states and regions, opportunities will present themselves in more tightly defined fields and the state and its regions must be ready to support and help build capabilities in identified specialized niches.

To identify the specialized niches for Northern Arizona, Battelle employed a methodology that uses the "marketplace" of academe, including peer-driven recognition systems, e.g., publications, citations, and federal fund awards, along with an extensive number of interviews with research leaders, to identify targets of opportunity (Figure 9). Battelle uses its proprietary software, *OmniViz*™, to examine the presence of research "clusters." Using this unique text-analysis tool, along with detailed faculty interviews and a review of publications strengths and funding levels, Battelle documented Northern Arizona's research core competencies and recommended associated technology platforms, which can form the basis for the future growth of Northern Arizona's bioscience sector. The key findings from these analyses are described below. The full analysis is contained in Appendix B.

Figure 9: Methodology to Identify Technology Platforms and Market Niches

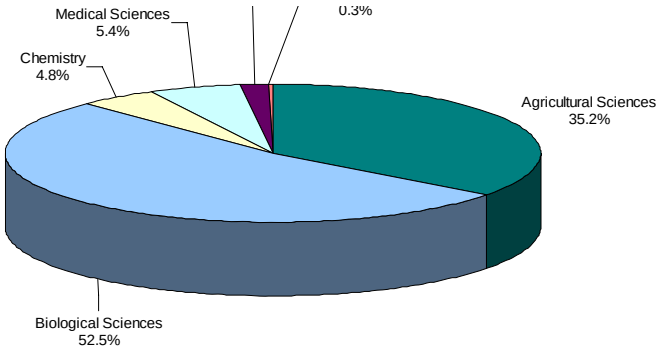


THE NORTHERN ARIZONA BIOSCIENCE RESEARCH CONTEXT

Total academic R&D expenditures in Northern Arizona were $23 million in FY 2005 or 3.2 percent of total academic R&D expenditures in the state of Arizona. The vast majority of this R&D activity was in the biosciences, which accounted for 70 percent of the total. Within the biosciences, biological and agricultural sciences accounted for approximately 88 percent of the total. See Figure 10 and Table 6.

The vast majority of the academic bioscience R&D in the region is conducted by Northern Arizona University; Prescott College conducted $87,000 in bioscience R&D in 2005.

Figure 10: No. Arizona Academic Bioscience R&D Expenditures by Research Area



Source: NSF Academic R&D Expenditures, 2005; Battelle calculations

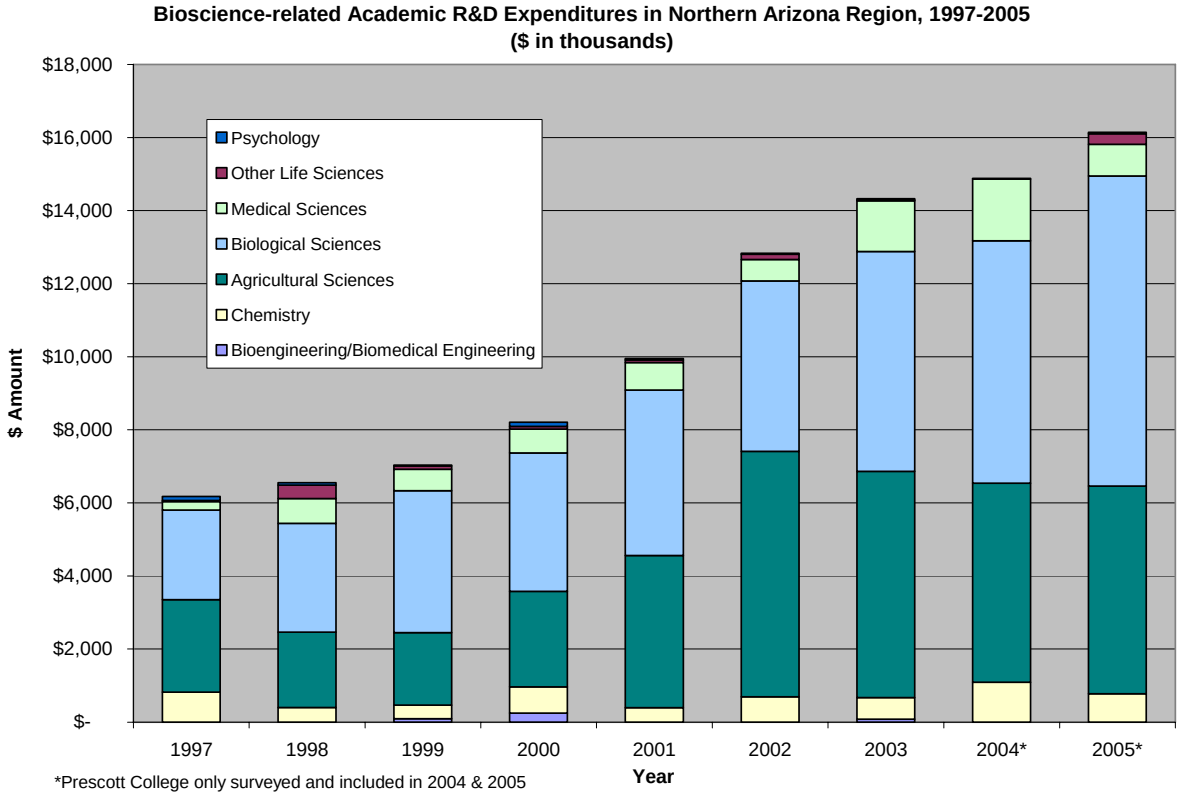
Table 6: Bioscience-related Academic R&D Expenditures for Northern Arizona, 2005

Bioscience-related Academic R&D Expenditures for Northern Arizona Region, 2005 ($ in thousands)					
Discipline	Northern Arizona University	Prescott College	Northern Arizona Region	Arizona Total	Northern Region Share of AZ
Agricultural Sciences	$5,688	$-	$5,688	$73,761	8%
Bioengineering/Biomedical Engineering	$-	$-	$-	$6,939	0%
Biological Sciences	$8,444	$39	$8,483	$140,193	6%
Chemistry	$749	$25	$774	$28,016	3%
Medical Sciences	$854	$13	$867	$117,506	1%
Other Life Sciences	$289	$-	$289	$7,774	4%
Psychology	$33	$10	$43	$14,511	0%
Total for Bioscience Related	$16,057	$87	$16,144	$388,700	4%

Source: NSF Academic R&D Expenditures, 2005; Battelle calculations

Northern Arizona's bioscience R&D base is growing rapidly but remains small. Northern Arizona's bioscience R&D base grew from approximately $6 million in FY 1997 to more than $16 million in FY 2005. This growth was driven primarily by growth in the biological sciences. See Figure 11. The total bioscience R&D base, however, remains small. In comparison, the bioscience R&D base in Southern Arizona was $255 million in FY 2004.

Figure 11: Bioscience-related R&D Expenditures in Northern Arizona, 1997- 2005



Source: NSF Academic R&D Expenditures, 2005; Battelle calculations

The quality of the bioscience research being conducted at NAU is high as demonstrated by NIH awards. NIH funding, generally considered the "gold standard" of funding for biomedical research and basic biological sciences, increased from $1.4 million to $2.6 million at NAU between 2001 and 2005. The average increase in NIH funding awarded to NAU researchers of 20 percent annually greatly exceeded the 10.2 percent increase in NIH funding at the national level.

In addition to biomedical research, Northern Arizona has a research base in environmental biology. Between 2000 and 2006, Northern Arizona received $8.1 million in NSF funding from the Division of Environmental Biology. Publication and citation data show a high rate of publications and citations in the Environment/Ecology field, as well. Other areas in which Northern Arizona has a strong publication record include plant sciences, earth sciences, and animal sciences.

CORE RESEARCH COMPETENCIES

The successful translation of research strengths into economic development opportunities requires the recognition of the importance of "market-driven" processes. The traditional model of commercialization assumes a "research-driven" approach to commercialization. This research-driven commercialization approach proceeds in a pipeline fashion—basic research, major scientific breakthrough, applied research, product development, manufacturing, and marketing. The research-driven approach is too divorced from commercialization and product development and has uncertain economic value. The market-driven approach recognizes that commercialization is a highly interactive process involving close ties between research activities and business development activities. Success depends, as the Council on Competitiveness points out, "on a team effort that includes carefully focused research, design for manufacturing, attention to quality, and continuous market feedback."[13]

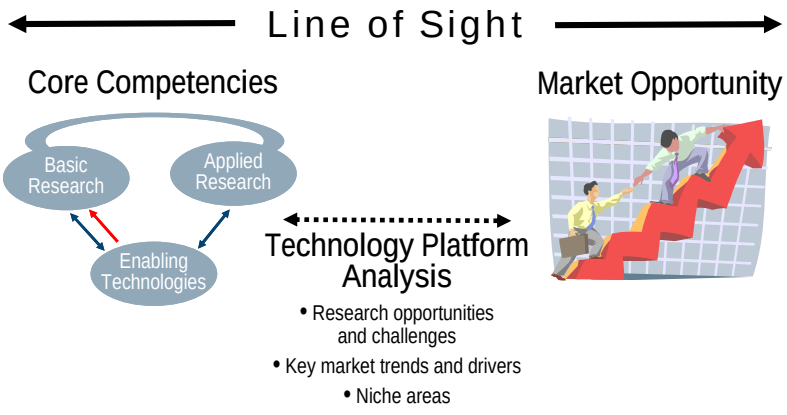
As seen in Figure 12, the components of a core competency bring together basic research, enabling technology, and applied research activities with a "line of sight" that moves seamlessly to address market opportunities and can form robust technology platforms. Core competencies that lack this linkage and connection to needs and market opportunities offer more limited development opportunities.

Identifying Core Competencies

No one single source of information identifies core research competencies and focus areas. Rather, various integrated and complementary analyses are required to identify an institution's current position and areas of focus that may lead or contribute to Northern Arizona's future bioscience growth.

In identifying core research focus areas in the biosciences, Battelle's objective was to identify those fields with an ongoing critical mass of activity and some measure of excellence. Other fields of bioscience excellence may exist within Northern Arizona institutions but in relatively limited pockets. Thus, they offer more limited opportunities but may still contribute in a notable manner.

Figure 12: Line of Sight Linking Technology Platforms to Core Competencies and Market Opportunities



As defined by Hamel and Prahalad in *Competing for the Future*, a competence is a bundle of skills and technologies, rather than a single discrete skill or technology. It represents the sum of learning across individual skill sets and individual organizational units. According to Hamel and

[13] Council on Competitiveness, *Picking Up the Pace: The Commercial Challenge to American Innovation* (Washington, DC: Council on Competitiveness), pp. 9-10.

Prahalad, "Core competencies are the gateways to future opportunities. Leadership in a core competence represents a potentiality that is released when imaginative new ways of exploiting that core competence are envisioned."[14]

Quantitative Analysis

Identifies research strengths through statistical analysis that includes the following:

- R&D grant awards
- Publications
- Patents
- Use of *OmniViz*™ clustering analysis of patent and grant awards to identify research and technology areas where both concentration of activity and excellence are demonstrated.

Core competencies guide university-based economic development initiatives in relating to established and emerging markets as technology platforms. Technology platforms draw upon multiple core competencies and have multiple development opportunities in significant market niches. Core competencies also inform how best to gain a position in emerging technologies.

Battelle has developed a rigorous and robust approach to assessing a region's core competencies. It involves (1) an in-depth analysis of patent and federal grant awards, (2) use of specialty technology industry and publications databases, and (3) validation from interviews with industry executives and university officials. It includes both quantitative and qualitative assessments to identify areas of research core competency. The quantitative assessment used statistical information on extramural grants, publications, and patent activities—as well as application of the Battelle-developed *OmniViz*™ software tool to identify research clusters—to develop an understanding of the trends and characteristics of bioscience research within Northern Arizona institutions. The qualitative work included extensive interviews with key administrators, scientists, and researchers at Northern Arizona University and the U.S. Geological Survey's Flagstaff Science Center. Interviews were also conducted with Prescott College, health care organizations, and for-profit commercial organizations. The goal of the core competency assessment was to identify significant strengths that form a substantial signature for the region around which substantial bioscience-driven economic development can occur.

Northern Arizona Core Competencies

Three core competency areas were identified based on the quantitative analysis of grant awards, publications and citations and patents. These include:

- **Environmental Sciences and Ecology.** Environmental Sciences and Ecology is an area of major emphasis for both Northern Arizona University and the USGS in Flagstaff. The region has a large number of research scientists focused on this area and is home to a number of major institutes, including the NAU Ecological Restoration Institute, the NAU Center for Sustainable Environments, the Merriam Powell Center for Environmental Research, the Western Regional Center—National Institute for Climatic Change Research and the USGS Flagstaff Science Center—Biological Sciences Center.
- **Plant Sciences.** Closely linked to the environmental and ecology area, the region has research strengths in plant sciences, much of which is focused in the NAU School of Forestry.
- **Animal Sciences.** The region has a strong publications and citations track record in animal sciences. NAU's Physiology and Functional Morphology Research Group conducts research in

[14] Hamel, G., and C. K. Prahalad. *Competing for the Future.* Harvard Business School Press: Boston, MA, 1994, pp. 90 and 217.

muscle physiology and comparative physiology, which has applications in physical rehabilitation and exercise technology.

To further investigate these fields and deepen our understanding of the core bioscience research competencies in Northern Arizona, extensive interviews were conducted with university administrators, faculty, scientists, clinicians, industry executives, and development agencies in the region. These interviews were essential in developing an understanding of how the data on publications, patents and grant awards translate into on-the-ground focus areas in Northern Arizona.

In total, telephone interviews and face-to-face interviews individually or in small group sessions were conducted with more than 50 individuals, including senior academic research scientists and faculty at the region's higher education institutions (predominantly Northern Arizona University) and other major R&D institutions, such as the USGS in Flagstaff. Key takeaways from these interviews and from interviews with commercial bioscience-related companies and associated industry promotion and economic development groups contributed to the identification and analysis of core competencies.

The interviews partly confirmed the areas where Northern Arizona possesses research strength that were identified in the quantitative analysis. They also highlighted several new and emerging areas of R&D and some key theme areas that were not readily apparent within the quantitative datasets. The analysis identified three key R&D strengths and five additional R&D Areas of Note, that is, areas in with Northern Arizona has demonstrated or emerging strengths that are more niche-focused or centered on a smaller number of faculty and research professionals.

The key R&D strengths of Northern Arizona are:

- **Infectious diseases.** The Keim Genetics Lab constitutes the top funded R&D program at NAU and has a focused emphasis on infectious disease genetics. The lab is engaged in multiple applied projects, including development of genotyping systems for bioterror agent identification. Another contributor to this research area is TGen North, which is affiliated with NAU and the Keim Lab. TGen North is focused on rapid disease diagnosis and pathogen detection. Other areas of R&D contained within NAU also are of direct relevance to infectious disease core competencies. This includes R&D in infectious disease biofilms, together with work in identification of novel antibiotics via analysis of extremophile bacteria. Some of NAU's MEMS and sensor work may also be directly applicable to bioscience diagnostics applications.
- **Environmental and Ecological Systems.** As shown in the quantitative analysis Northern Arizona has strengths in environmental and ecological systems. NAU has key strengths in six principal areas: impact of climate change on the biosphere; ecosystem genetics and environmental molecular genetics; environmental sensing and forensics; environment and ecosystem restoration; endocrine disruptors in the environment; and sustainable energy solutions.
- **Muscle Physiology.** Physiology is the branch of biology that deals with the functions and activities of life or of living matter and of the physical and chemical phenomena involved. Muscle physiology specifically addresses the function of muscles. NAU has 15 faculty conducting work in physiology and functional morphology and they have received $1.8 million in NSF funding as well as multiple NIH awards. The researchers at NAU also have a clinical research relationship with the University of Arizona's Physiology Department.

Additional R&D areas of note include:

- Bioengineering
- Computational modeling of cell signaling
- Native American health
- Chemistry
- Science education and workforce development.

TECHNOLOGY PLATFORMS, PRODUCTS AND MARKET NICHES FOR NORTHERN ARIZONA

The purpose of identifying a region's research strengths and core competencies is to be able to identify strategic areas of focus that offer the greatest opportunity for near term development—Battelle uses the term "technology platforms" to describe these.

Technology platforms serve as a bridge between research core competencies and their use in commercial applications and products. As such, platforms are highly translational in nature—working to facilitate strong directional movement of ideas and innovations from basic science discoveries through to applied technologies and practices.

The technology platform process can be understood through a systems approach in which innovations flow from core competencies resident in a region's research institutions, via the platforms, to commercial products, which then find their way into markets. These technology platforms are intended to be robust and evergreen and to integrate several of the core competencies to produce a continuous flow of innovative, and perhaps disruptive, technologies or products. Platforms also serve as a forum for building strong interactions and relationships between academic researchers and their counterparts in industry.

Criteria for Selecting Technology Platforms for Development

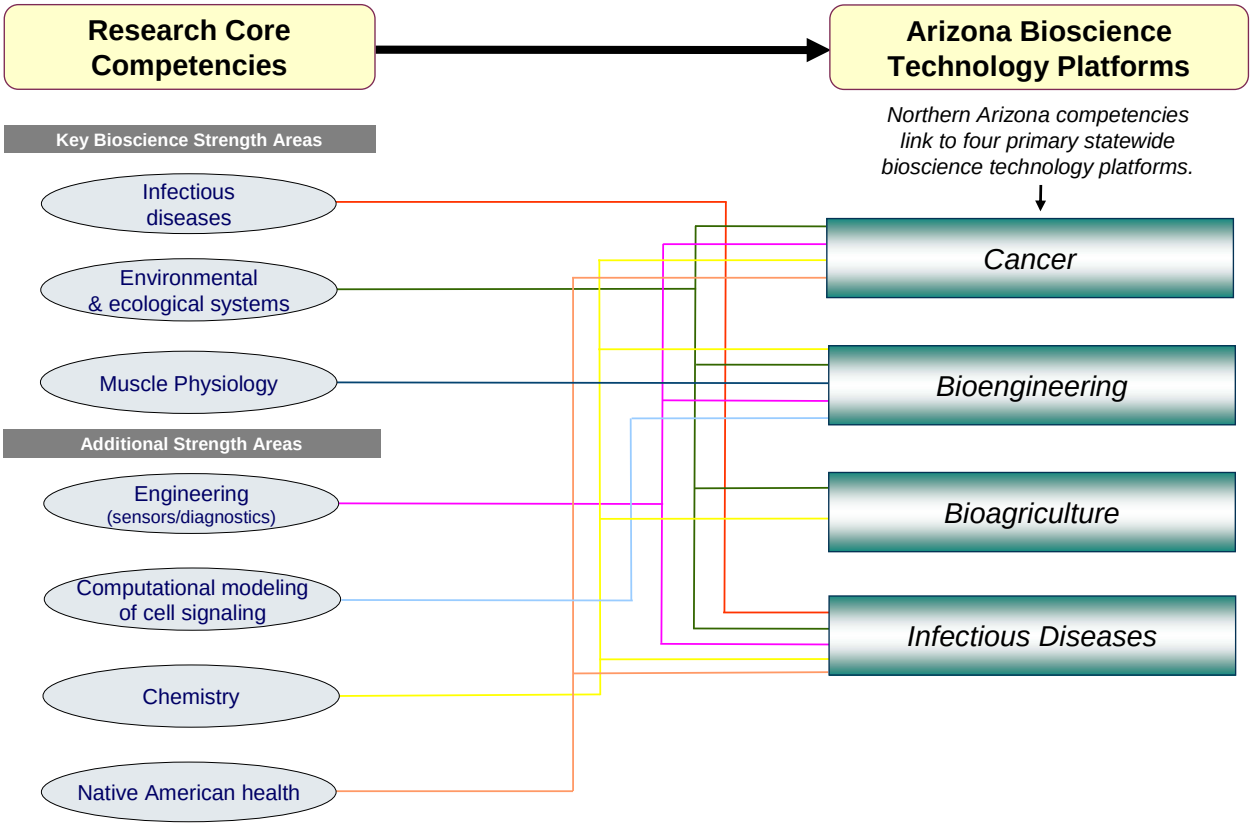
An area of focus must

- Build on existing strengths
- Have a base of related emerging or established commercial activity
- Provide opportunity to leverage state's comparative advantages
- Have significant product market potential
- Link to or reinforce other bioscience strengths and core competencies.

The areas of greatest opportunity for developing technology platforms are those in which a region has;

- Existing research strengths
- Commercial activity emerging or established within the region with genuine opportunity to create a base for business in the near future
- Distinct opportunities to leverage the region's comparative advantages to create competitive marketplace advantages
- Significant product market potential
- Links to, or reinforcements of, other bioscience strengths and core research competencies, thereby helping to enhance other fields as a platform expands.

Figure 13: Northern Arizona Crosswalk to Original Statewide Roadmap



Previous work conducted by Battelle for the Flinn Foundation has identified Arizona statewide bioscience technology platforms and much progress has been made in advancing development in the state along these platform pathways. Analysis of the bioscience R&D core competencies in Northern Arizona shows that the region plays an important contributory role in most of the ten statewide technology platforms. The four platforms in which Northern Arizona is a very important contributor are: cancer, bioengineering, bioagriculture and infectious diseases. See

figure 13.

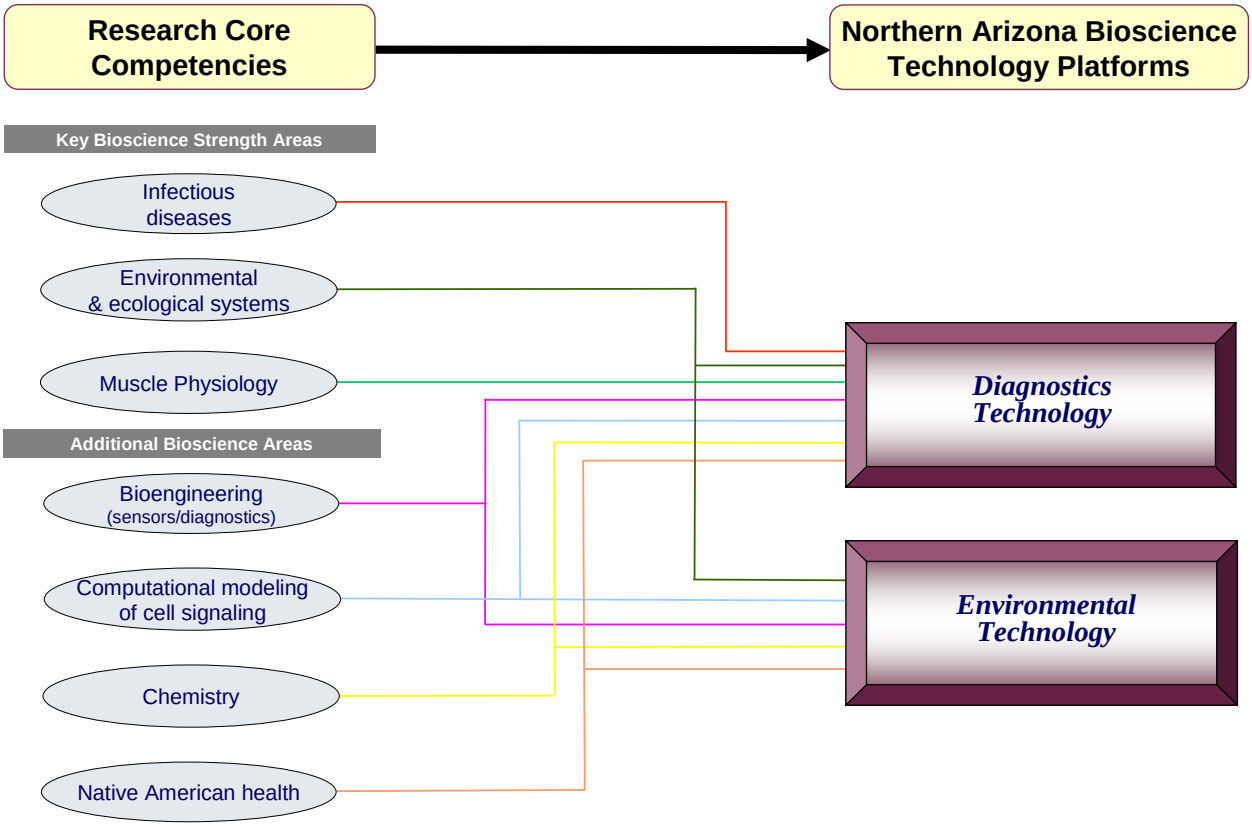
Northern Arizona- Specific Technology Platforms

In addition to contributing to the statewide competencies and platforms, the Battelle team identified the two unique technology platforms that build upon Northern Arizona's core research competencies and can be sources of innovative technologies and products for its economy. They are:

- Diagnostics Technology
- Environmental Technology.

Figure 14 shows the relationship between Northern Arizona's core competencies and these two platforms. Each platform is described below.

Figure 14: Relationship Between Northern Arizona's Research Strengths and Northern Arizona Technology Platforms



Diagnostics Technology

Within the Northern Arizona research community, expertise in several disciplines is coming together to provide significant opportunities for technology development in advanced diagnostics technology. The skills of Northern Arizona research scientists in the following areas, for example, provide a basis for interdisciplinary work in advanced diagnostics technologies and tools for multiple human, animal, plant, environmental and national biosecurity applications:

- MEMS and nano sensor engineering
- Molecular target identification through advanced genomic analysis (Northern Arizona expertise can be applied to multiple human biomedical, plant, animal and environmental genomic analysis areas).
- Infectious disease agent genomics and strain characterization.

Northern Arizona's niche could well be in the development of micro and nano sensor devices and sensor networks designed to provide rapid characterization of pathogens or other biological agents likely to impact human health, agriculture and the environment. This is a development pathway that is already being built in Northern Arizona through the investments in TGen-North and the Keim Genetics Laboratory and can be naturally extended through building linkages to engineering and bioengineering sciences for device development based on biomarker discovery.

It should be noted that there has been considerable investment across multiple Arizona higher education and research institutions in defining disease at the molecular level, which is now being translated into identification of molecular biomarkers. In the recently completed Southern Arizona bioscience

development strategy it was suggested that the University of Arizona could focus on the development of molecular therapeutics building upon this Arizona investment. For Northern Arizona, the opportunity lies in the no less important and synergistic area of diagnostics development.

For Northern Arizona potential technology from this platform may range from basic nano-cantilever based biodetection devices providing diagnostics of the presence of a particular chemical or biological agent or pathogen, through to complex biosecurity sensor networks providing real time monitoring of agrosecurity, human health security and environmental conditions.

Advanced diagnostics and sensing technologies represent a highly logical platform for Northern Arizona tying together key strengths across multiple biological, biomedical, environmental and engineering strength areas.

Environmental Technology

Northern Arizona has a distinctive cluster of faculty, scientists and technologists working in ecological and environmental fields. Key clusters of expertise are found within the academic research community, most notably at Northern Arizona University, and within federal biological sciences research laboratories operated by the USGS in Flagstaff. Expertise extends from basic science investigations of genetics through to highly applied projects in environmental protection, remediation and restoration.

R&D skills in ecological and environmental systems show potential for the development of interdisciplinary teams dedicated to the development of technology for a range of applications. Key categories representing platform development opportunities include:

- **Environmental Sensing and Monitoring Technology** – Northern Arizona expertise ranges from macro global climate change assessment through to the micro remote monitoring of individual ecosystem characteristics (such as daily monitoring of sediment suspension in the Colorado River. Because of this breadth of knowledge and expertise, Northern Arizona research teams are well positioned to work on the development of robust sensing and monitoring devices, controls, systems and networks designed to provide real-time evaluation of environmental and ecological system conditions. Such systems and technologies would have broad applications to needs in biosecurity, ecosystem security, contamination detection, and long-term climate change monitoring.
- **Environmental Testing and Certification Technology** – Modern advances in genetics and biotechnology are facilitating the development of new plant varieties (and potentially chimeric species) with unknown potential ecological impacts and consequences. Northern Arizona scientists demonstrate significant expertise in holistic evaluation of the ecological impacts of introducing species with new or altered genetic profiles into existing ecosystems. A range of technologies and services may be envisioned for providing testing and certification of genetically altered biological organisms before they are allowed to be released into non-sterile applications.

- ***Environmental Restoration Technologies*** – Mankind has had a tremendous impact on the natural environment. Industrialization, natural and mineral resource extraction and urbanization activities have dramatically altered the American landscape and released considerable levels of contaminants into the environment. The clean-up and restoration of America's environment and individual ecosystems is a clear priority for national and state governments and there is considerable economic opportunity for technologies and services dedicated to these tasks. Within Northern Arizona there are research teams specifically dedicated to R&D focused on contamination effects, environmental remediation and ecosystem restoration—with considerable opportunity for the development of commercializable technologies and economic opportunity.

- ***Sustainable Natural Resource Utilization***– Restoration of SW US ecosystems will require the removal of large amounts of biomass that have accumulated particularly in forested areas. Northern Arizona scientists are at the forefront in research dedicated to finding and developing economic opportunities from biomass through applications in bio-based materials, biocomposite materials and other wood/biomass based products.

Realizing the potential for this platform will require closer collaboration between academic and federal research teams in the Flagstaff area. In addition there is considerable R&D expertise in environmental and ecological sciences contained in the University of Arizona and Arizona State University which should be leveraged for the benefit of developing integrated environmental and ecological technology platform teams.

Market Analysis

The ultimate goal for Northern Arizona in supporting the development of bioscience platforms is economic development. R&D, in and of itself, ***is*** economic development in that millions of dollars flow into the region each year from federal and other external funding sources to support research. These dollars, in turn, create jobs and income for persons in Northern Arizona in, and related to, the R&D sector. **The goal of technology-based economic development, however, is to follow an integrated model whereby local research feeds a local commercialization and production cluster, thereby capturing increased value-added economic gains for the region from its R&D work.**

Given the increasing regional economic returns from the commercialization of R&D innovations, it is highly important that markets and commercialization opportunities related to each platform be considered during platform development. Tables 7 and 8 serve to integrate R&D strength areas with applications and potential products and general market characteristics for the two Northern Arizona-specific platforms. It is evident that each platform focus area addresses multibillion-dollar markets, providing considerable opportunity for growing the regional bioscience economy around these core competencies.

Table 7: Diagnostics Technology Platform

Basic Research	• Molecular genetics • Microbiology • Chemistry
Enabling Technology	• Bioengineering • Nanotechnology and MEMS technology
Technology Platform	**Diagnostics Technology**
Applications and Products	• Biosecurity products • Disease diagnostics technology and tools • Sensors, nanotechnology and MEMS devices
Markets	• Molecular diagnostics markets overlap with markets for non-molecular diagnostic technologies in the in vitro diagnostic market and are less well defined than those for pharmaceuticals. In the year 2005, the global market for molecular diagnostics was worth $6.5 billion, representing approximately 3.3% of the total diagnostics market and approximately 14% of the in vitro diagnostic market. (Source: Jain PharmaBiotech 2006) • The molecular diagnostics market will expand to $12 billion by 2010 and $35 billion by 2015. A major portion of it can be attributed to advances in genomics and proteomics. Biochip and nanobiotechnology are expected to make a significant contribution to the growth of molecular diagnostics. (Source: Jain PharmaBiotech 2006) • Fuji-Keizei USA specifically examined the biosensor market and estimates that the market size for worldwide biosensors at year end 2003 was about $7.3 billion. They project a growth rate of 10.4% to $10.8 billion in 2007.

Table 8: Environmental Technology Platform

Basic Research	• Plant sciences • Environmental and Ecological Sciences • Genetics and Genomics • Forestry
Enabling Technology	• High throughput genomic analysis • Stable isotope analysis
Technology Platform	**Environmental Technology**
Applications and Products	• Environmental restoration and remediation technology • Monitoring and sensing systems • Testing and certification tools and services
Markets	• The global market for environmental products and services is worth about $520 billion per year. At approximately $205 billion, the U.S. represents 39 percent of the global revenues and ranks number one in the world. It is almost twice the size of its nearest competitor, Japan. Last year, U.S. exports of environmental technology goods and services topped $21 billion, producing a positive trade balance of $10 billion and creating about 170,000 jobs. (Source: National Defense Industry Association) • The $453 billion global environmental market is growing faster than the global economy and is outpacing growth in the US environmental market. (Source: US National Defense University) • Fuji-Keizei USA specifically examined the biosensor market and estimates that the market size for worldwide biosensors at year end 2003 was about $7.3 billion. They project a growth rate of 10.4% to $10.8 billion in 2007. • The world carbon trading emissions market expanded to nearly $21.5 billion in the first nine months of 2006, up from about $11 billion for all of 2005 (Source: World Bank) • Phytoremediation is applicable to a number of hazardous waste and other remedial scenarios, which offer sizable potential markets. Markets for remediation of organics, metals and radionuclides from soils and water, combined with municipal and industrial wastewater treatment markets, the treatment of polluted runoff, primarily including landfill leachate, and the market for removing inorganic contaminants such as nitrate from drinking water supplies, offer a total potential market size of U.S. $33.8-49.7 billion per year. (Source: D. Glass Associates) •

Observed Gaps and Challenges

While NAU performs well in terms of research volume per faculty member, the comparatively small size of the University ($55 million in external research funding) means that there is a lack of a large critical mass of researchers in core competency areas. Each of the recommended platforms for bioscience development in Northern Arizona would benefit from selected augmentation through the hiring of additional research-oriented faculty. In some cases, key R&D strengths at NAU are too dependent on the research and reputation of a single faculty member. The risk attached to this is readily apparent when examining the strong

R&D track record of Paul Torrance who has made major contributions in life science and drug development work, but whose retirement is forcing NAU out of this area of focus.

The high cost of living in and around Flagstaff makes recruitment to the area increasingly challenging. While the quality of life within Flagstaff and the Northern Arizona region holds substantial appeal, a lack of affordable housing makes it difficult to bring in new, younger faculty members and researchers. NAU is working to address this issue, in part through examining options for affordable housing development by the university. At the opposite end of the equation, NAU enjoys high levels of faculty retention because of the high quality of life in the region.

To date, NAU has a limited number of graduate science degrees and can increasingly align these graduate efforts to their competencies and industry interest. The biology department at NAU offers a PhD in a science area—most graduate work at the university is limited to Master's degrees. As a regional university NAU can concentrate on terminal master degree programs and selective Ph.D. programs around core competencies identified in this report. Increased interaction with industry, medical and other institutes can help address areas of shortage where NAU can offer Master degree programs such as biomedical engineering.

The region has limited human biomedical clinical research activities. However, researchers at NAU have been able to form working relationships with clinician-scientists at ASU in order to extend the translational nature of their research.

There is a need for improved electronic connectivity between Arizona's research universities. NAU researchers, for example, would like to be able to connect live to seminars conducted at the ASU BioDesign Institute. It was also noted that many of the universities subscribe to different academic journals and it would be useful to have a single online library access system for enhanced resource sharing.

Conclusions

As would be expected given its lower population level, northern Arizona has a smaller base of bioscience R&D and associated industry activity than southern Arizona (the Tucson region) and central Arizona (centered on Phoenix). While northern Arizona's total base of bioscience activity is smaller than these other regions, NAU (the academic R&D focal institution for northern Arizona) is just as productive on a per faculty basis as Arizona's other leading research universities.

NAU provides a focused resource for advanced bioscience R&D in northern Arizona and demonstrates some distinctive R&D core competencies in infectious diseases, environmental and ecological systems, and muscle physiology. Additional emerging areas of R&D include bioengineering, computational modeling of cell signaling, Native American health, chemistry, and science education and workforce development.

Northern Arizona's R&D core competencies may be leveraged for specific bioscience platform development in two primary bioscience platforms:

- Diagnostics Technology
- Environmental Technology

In addition, northern Arizona should be considered an integral and important contributor to four of the existing statewide bioscience roadmap platforms—these being:

- Cancer
- Bioengineering
- BioAgriculture
- Infectious Diseases

Competitive Assessment

It is clear from the above analyses that Northern Arizona has key bioscience assets on which to build but the region also faces key challenges that will have to be address in order for the region to be positioned to take full advantage of Arizona's growing bioscience sector. Chief among these are the high cost of housing and insufficient workforce, which is making it increasingly difficult to retain or attract employees. The Battelle project team interviewed key public and private leaders in Northern Arizona, executives of bioscience companies, investors, educators and representatives of economic development organizations in Flagstaff, Payson, and Prescott to gather input on the strengths and weaknesses of the region as a location for bioscience and other technology companies. These interviews were supplemented with information gleaned from previous reports and published secondary data.

In addition to identifying key assets on which Northern Arizona can build and key gaps that need to be addressed, the team also identified strategic areas that appear to offer the greatest opportunity for bioscience development in the region. The key findings of the competitive assessment of Northern Arizona as a location for bioscience development follow.

ASSETS

Northern Arizona is a very attractive region with an excellent quality of life. Northern Arizona's strong quality of life enables it to attract a diversity of people and its outdoors orientation, small community atmosphere, and variety of arts, culture, and recreational opportunities retains and attracts people to the region.

The region has an emerging base of bioscience companies that offer good, well paying jobs for the region's workforce. The average wages for bioscience workers in Flagstaff was over $45,000 in 2005, compared to just over $27,000 for all private sector jobs. Medical devices and equipment average wages were nearly $46,500 and hospital wages averaged just over $45,000 as well. In Prescott, bioscience annual wages were also just over $45,000 in 2005 compared to average wages for all private jobs of just over $28,000.

Northern Arizona University is a key asset for the region. NAU, with its approximately 18,000 students, is an economic driver for the region. Its graduates are a source of talent for local companies and while the university is primarily an undergraduate education institution, it also offers

Competitive Advantages

- Quality of life that appeals to many talented individuals
- Emerging base of bioscience companies that offer high-wage jobs
- Northern Arizona University
  - Tech Platform Strengths
  - Students and Graduates
- Strong talent pool
  - CCC and Yavapai College
- Developing technology infrastructure
  - Science and Tech Park
  - Incubator
  - USGS campus
  - Tech Park at Embry Riddle
  - TGen North

research, graduate, and professional programs in the areas of forestry, business, engineering, nursing and health professions. NAU continues to increase its research base and capacity, showing competencies in infectious diseases, environmental and ecological systems and muscle physiology.

Northern Arizona has a strong talent pool. The region has a higher scientific brain trust on a per capita basis than many other regions of similar size. Additionally, the educational level of both high school and college graduates in Coconino County is 10% higher than the state or national averages. Almost 32 percent of the population 25 years and older in Coconino County held a BA or higher degree in 2005. Only 27 percent of the US population 25 years or older held at least a bachelor's degree. The figure is somewhat less for Yavapai County where 23 percent of its population hold a BA degree or higher but 87.4 percent of Yavapai's population holds a high school degree as compared to 84.2 percent nationally and 82.1 percent in Coconino County.[15]

Flagstaff has a relatively younger workforce with interest in the biosciences. Coconino Community College reports a very high demand for physics and chemistry classes, an increase that appears to be related to the requirement that high school students must now complete three years of science rather than just two years in Coconino County. Yavapai College also reports demand for science classes, particularly in anatomy and physics and is building a new science lab on its Valley Verde Campus. Flagstaff's median age of 26.8 is considerably younger than the U.S. median age of 35.3; however, the median age of Prescott (47.8) and Yavapai County (44.3) is considerably older reflecting the large number of retirees living in the area.

Northern Arizona's Community College's are able to respond quickly to industry needs and are expanding their bioscience offerings Both Coconino Community College and Yavapai College are extremely agile and work closely with industry and the community to meet workforce development needs. The colleges can get a program up and running in as little as 90 days and they work with individual employers to provide customized training. Both colleges have greatly expanded their nursing and health care offerings in response to demand for health care workers. Coconino Community, with support provided by the Flagstaff Medical Center, was able to offer a new nursing program. Yavapai College recently received a $1.4 million grant from the US Department of Labor to expand their Allied Health Program, which now has 250 nursing students.

Yavapai College's Chino Valley Agricultural Business and Science Technology Center houses programs in agribusiness technology, residential building technology, hydroponics, equine science, sports turf management and fishing management in addition to offering general education classes in English, math and science. The Center, which has an 80 acre greenhouse, trains workers for Hines Horticulture and Eurofresh Farms, both of which have significant operations in the region. Hines Horticulture is a national supplier of ornamental shrubs and plants. Eurofresh Farms is the leading year round producer of greenhouse tomatoes. Plant sciences also was identified as a strengths at NAU in the core competency analysis.

[15] Source: US Census Bureau, 2005 American Community Survey.

New investments are being made in both Flagstaff and Prescott to build the infrastructure that will be needed to grow the region's technology sector. Projects that are underway in Flagstaff include

- ***Redevelopment of the USGS campus***. The citizens of Flagstaff approved a $62 million bond package in 2004 to support the redevelopment of the USGS campus.
- ***Construction of the Northern Arizona Science and Technology Incubator***. The City of Flagstaff with support from the Northern Arizona Council of Governments, has received funding from the Economic Development Administration (EDA) of the US Department of Commerce to construct a 10,0000 sq.ft. incubator. The incubator will be located within the Science and Technology Park and the USGS campus.
- ***Development of a Science and Technology Park*** anchored by the USGS campus. The City of Flagstaff has signed an agreement with two private developers to develop a 9 acre Science and Technology Park. The park could provide up to 200,000 sq. ft. of office, wet lab and research space.
- ***Opening of TGen North facilities***. TGen North, a partnership between NAU and TGen opened its pathogen genomics and biodefense research facility in April 2007. The facility, which is located in the Airport Industrial Park, contains 4,500 sq. ft. of state-of-the-art research labs and office space.
- ***Airport runway expansion***. With funding from the Arizona Dept of Transportation and the Federal Aviation Administration (FAA), the runway at Flagstaff airport will be extended by 1,800 ft. The extension is scheduled to be completed by late 2007.
- ***Construction of the NAU/Flagstaff Conference Center***. Construction has begun on a 42,000 sq. ft. conference center, 150 room hotel and parking garage. The project is being developed by NAU, the City of Flagstaff, the Arizona Board of Regents and Drury Hotels.

In Prescott, Embry Riddle Aeronautical University (Embry Riddle) has proposed developing a technology park on 100 – 150 acres of land owned by the university. The City of Prescott has committed $250,000 to get the Tech Park started and Embry Riddle is in discussions with EDA and state government to obtain funding to build roads and install infrastructure for the park. Yavapai College recently purchased a 108,000 sq. ft. building at the airport, which they plan to use to offer high level technical training in machining, CNC, etc. Some space in the building may be reserved for the use of start-up companies.

CHALLENGES

Flagstaff's high cost of living, primarily due to its high cost of housing, makes it difficult to attract and retain talent. Overall, Flagstaff has a high cost of living. Compared to a national average index of 100; Flagstaff's composite index is 115.9, and Flagstaff exceeds the national average by 11.8% for groceries; 42% for housing; 13.3% for utilities; 3.7% for transportation; and 2.7% for health care. Flagstaff's cost of housing index was 142 for the 4th quarter of 2006.

The median price of a home in Flagstaff ranked second in the state at $395,000, requiring an hourly wage of $57.31. The average hourly wage of a teacher in Flagstaff is $16.73; manufacturing worker, $16.54; and nurse $16.39, meaning that many will not be able to afford a

home even with a second income. A two bedroom rent al unit in Flagstaff is calculated to take an average wage of $17.41. Neither developers nor financial institutions have been able to build sufficient affordable rental or ownership housing in Flagstaff. A survey commissioned by NAU found that 65% of its current employees say current Flagstaff housing prices are well above what they can afford; 73% of current employees are very or somewhat interested in a potential NAU housing program, although most would prefer to purchase rather than rent and can afford a median monthly payment of $1200 for housing. Finally, 92% of current employees say it is important for NAU to make affordable housing available to incoming faculty. Payson, too, is facing similar housing gaps and availability of quality housing for the working population

Challenges

- High cost of housing and worker shortages
- Lack of diversified bioscience employment base
- Inability to retain more of the graduates of the region's colleges and universities
- NAU has a small research base and limited interaction with industry
- K-12 schools are not graduating students with sufficient STEM skills and the schools have limited funding to address these needs
- Lack of entrepreneurial support infrastructure
  - Lack of risk capital
- Transportation improvements needed
- Business climate with City perceived as challenging in spite of City's innovative and creative approaches, e.g., USGS, S & T park, etc.

The cost of living index has been moving toward the national average in Prescott in the last few years. The overall cost of living index was 104.5 and the housing cost of living index was 115 for Prescott at the end of 2006. To address the issue of workforce housing, the Prescott Chamber has created a 501(c) 3 foundation. The Foundation is making an investment in a new for-profit initiative called Affordable Housing Inc., an entity through which a pool of investors will take a percentage of the mortgage of a first time homebuyer thereby reducing the cost to the purchaser. After five years, the homeowner will be expected to buy out the investors.

The lack of a diversified bioscience employment base makes it difficult for existing bioscience companies to attract workers to the region. Northern Arizona, while being nationally specialized in medical devices and equipment, has a disproportionate share of its bioscience workforce located within one company and does not have the diversity of bioscience-related employers it desires. As a result, it is difficult to attract skilled workers who want to be sure that there will be other opportunities for employment if needed, as well as to provide employment for trailing spouses. The number of bioscience establishments in Flagstaff is down 56% since 2001 and the total number of medical device establishments is only six.

On the other hand, Flagstaff ranks higher than such recognized bioscience regions as Salt Lake City, Philadelphia, San Diego, Raleigh and Boston in the share of non-hospital bioscience employment of total private sector employment. See Figure 15. And in comparison to other university-centric regions across the country with medical devices concentrations—Boulder; Fort Collins, Lafayette, Madison, State College and Tucson –Flagstaff has a larger employment base than all but Boulder and Madison but it is the least diversified in bioscience industry segments as any of these communities. See Figure 16. Building a stronger supplier chain to the device industry is one short term way to diversify as these other regions have done.

Figure 15: Non-Hospital Bioscience Employment as Share of Total Private Sector Employment

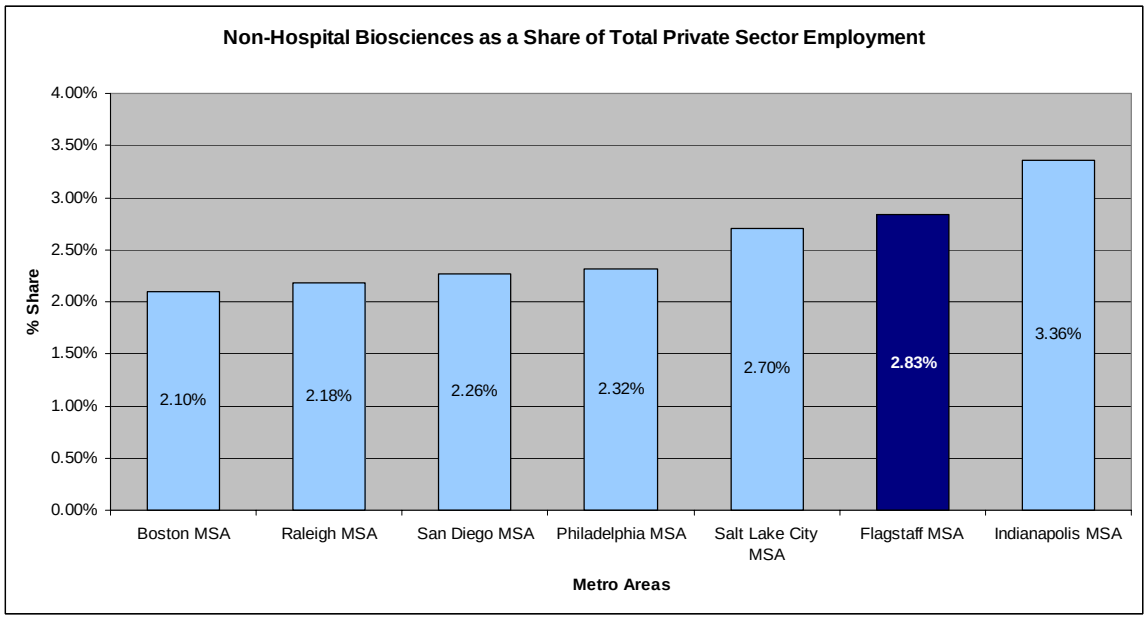
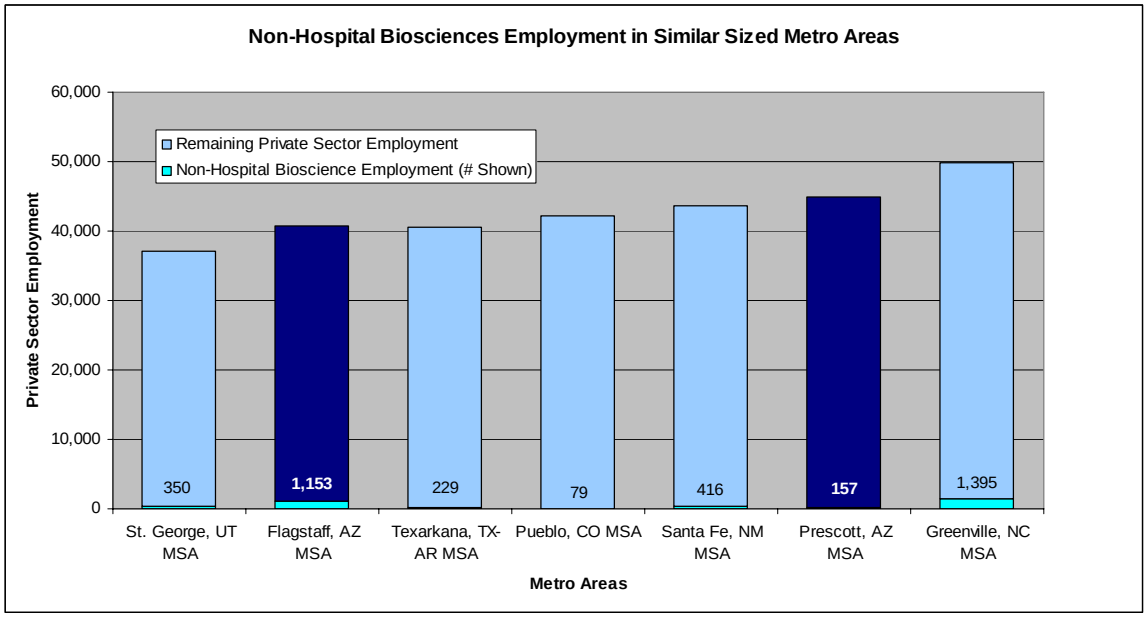


Figure 16: Non-hospital Bioscience Employment in Similar Sized Metro Areas



The region is unable to retain many of the graduates of its colleges and universities. NAU graduates offer a source of new workers but many that would like to remain in the region cannot find sufficient job opportunities, resulting in the region being an exporter of talent. Over 70% of Coconino Community College and 59% of NAU students indicated they planned to seek full time employment in the area but when asked what they plan to do upon graduation only 25% and 17% indicated an intention to stay once they graduated. Employers need to build relationships while these workers are in school as well as internal career paths once they have graduated so a greater

retention of the region's workforce can occur. Furthermore, this study found that 31% of the Community College's students were interested in a healthcare career and 21% were interested in the manufacturing sector; for NAU the percentages were 42% for health careers and 17% in manufacturing. *However, no specific healthcare or manufacturing entry level training is offered currently within the local workforce development programs financed publicly in Flagstaff.* A good example of efforts to take advantage of this talent base was the partnership of FMC and Coconino Community College to establish and jointly finance an associate degree program in nursing with considerable success by FMC in hiring and retaining graduates of this program. Expanding this program to other health areas requires needing a critical mass of personnel on a continuous basis as most healthcare jobs require some post secondary training and education.

NAU has a small research base and little interaction with industry. NAU lacks a deep research base even in its fields of strength and competency and does not have a sufficient focus on its graduate programs and its ability to build commercialization partnerships with industry and medical centers. The current university-industry interface is ad hoc and sporadic without any coordinating point at NAU to ease interaction and linkages between the two sectors.

The region's public and private schools are not graduating students with sufficient science, technology and math skills and the schools currently have limited funding sources to address these needs. There are an insufficient number of trained teachers; resources for curriculum change are limited and labs and equipment are insufficient. While there are efforts underway to address this issue, including securing federal and state grants to initiate a summer program to train science and math teachers, the school systems are limited due to lack of resources to revamp curriculum, increase the content of science and technology, or in other ways to help nurture and build the region's future workforce through a strategy of growing their own.

The region lacks an entrepreneurial support infrastructure and there are few sources of risk capital. In recent years, more start-ups and spin-offs have emerged in the region from its existing employer/employee base and with those associated with NAU. Such firms lack sufficient sources of risk capital to form and develop their businesses and lack of diversity of bioscience-related employers has limited networking among firms, faculty and others. The Forest Angels group has disappeared although there are wealthy angels still interested in making investments. The recently formed Biotechnology Enterprise Education and Research (B.E.E.R.) Bio Networking Group provides a base for increased networking among and between firms, entrepreneurs, and faculty but will need to be expanded. A network of knowledgeable service providers, including accountants, attorneys and others with expertise in the biosciences, will also be needed to support the growth of this industry sector.

Companies report that City of Flagstaff relationships need to improve, be more predictable and responsive. Whether perceived or real, enough concrete examples were provided in interviews to suggest that employers have considerable difficulty in getting timely, responsive and predictable support from the City of Flagstaff. Access, responsiveness, and predictability are areas that local government can address in how it supports technology driven businesses. Whether it's delays in obtaining regulatory permits or the inability to get fast track service, these are areas that local government can address. The irony in this situation is the widespread praise the City receives for its creative approaches to address the USGS campus, the science and technology park, the incubator and TGen using its bonding authority to become an important catalyst and facilitator of these efforts.

Northern Arizona has transportation issues that need to be addressed including limited public transit, limited air service and interstate highways that need to be upgraded. Limited public transportation options make it difficult for technical and service support workers to get to employer sites in the region. This is particularly difficult for workers from the reservation, a largely untapped resource, who must travel 60 miles on a two lane road to reach Flagstaff. Flight options are limited from both Flagstaff and Prescott airports although improvements are expected in the near future due to lengthening the runway in Flagstaff and the selection of a new contractor to provide air service in Prescott. I-17 needs to be improved to facilitate access to Phoenix.

Lack of cultural and entertainment options for the adult working population in Flagstaff. As a university-centric town Flagstaff offers many strong attributes and is able to attract art, cultural and entertainment events. But such events are primarily geared to the student population and not the adult working population.

LEVERAGING THE REGION'S UNIQUE ASSETS

Northern Arizona has a number of unique assets on which to build its bioscience base. These include:

- **A growing base of medical device companies and health care institutions and a nascent research, testing and medical laboratory sector.** Overall, Flagstaff is almost twice as specialized in the biosciences as the nation and within medical devices and equipment is nearly eight times more specialized than the nation and ranks third among all smaller metropolitan areas in the country in medical devices and equipment employment specialization. Flagstaff ranks only second to Glenn Falls, NY among such competitor regions as Minneapolis, Bloomington, Indiana, and Kalamazoo, Michigan in medical device employment per establishment. Its medical device firms have nearly seven times the employment per establishment as the U.S. as a whole. **The region should build on the presence of WL Gore and seek to develop a stronger supplier chain of medical device firms in the region.**
- **NAU, USGS, and TGen North.** Northern Arizona has a small but excellent bioscience research base with expertise in specific areas of the biosciences. These institutions have the capacity to develop new, innovative technologies that could form the basis for new, start-up bioscience companies that could complement the region's existing base in medical devices and hospitals. NAU also offers strength in science education to help address workforce issues over the long term as well as offering courses and degrees responsive to the growing bioscience employer base.
- **Coconino Community College and Yavapai College**. The region's community colleges are expanding their offerings in the biosciences and working to meet the workforce needs of existing employers. The colleges are in a position to ensure that the region is able to develop a skilled bioscience workforce to meet the future needs of the region's expanding bioscience sector
- **Proximity to Phoenix**. To date, much of the growth in the biosciences in Arizona has occurred in the Tucson, and, to a lesser extent, Greater Phoenix area. Northern Arizona is well positioned to partner with bioscience institutions in Phoenix and to provide a location for

expansions as Phoenix's bioscience business community expands. The growth of the bioscience sector in Phoenix also means that bioscience companies in Northern Arizona will have more opportunities for partnering with firms in the Phoenix area and accessing specialized bioscience services.

- **Image as both a tourism destination and a region with a very attractive quality of life.** Northern Arizona's quality of life can be used to attract bioscience talent to the region, which will in turn make it a good location for bioscience companies. In addition, the region has a long history of attracting international travelers because of its location near the Grand Canyon and other outdoor attractions. Northern Arizona can take greater advantage of the fact that it is a destination site for global travelers to build its bioscience image and brand.

A VISION FOR NORTHERN ARIZONA

Ten years from now, in 2017, the world should characterize Northern Arizona's standings in the biosciences in the following ways:

The biosciences is a key driver of Northern Arizona's economy providing high wage jobs, high quality health care and career opportunities for its citizens. The region is home to a vibrant cluster of bioscience companies and a global leader in medical devices.

ACHIEVING THIS VISION

Achieving Northern Arizona's vision will require that the region's public and private sector leaders come together and commit to working collaboratively and making the investments that will be needed to address the region's needs and to create an environment in which bioscience companies can emerge and grow. Champions will be needed who understand what is required to grow a thriving bioscience sector and who are willing to organize the community and represent Northern Arizona's interests with state government, the legislature, the Governor's office and federal agencies. Northern Arizona will also need to partner with both Phoenix and Southern Arizona to see that issues such as access to early stage seed capital for bioscience companies are addressed at the state level.

Strategies and Actions

The strategies proposed for Northern Arizona focus on leveraging the region's assets—its colleges and universities, the presence of a global biomedical company, its proximity to Greater Phoenix, a growing health service sector and a very attractive quality of life—to grow its bioscience sector. Specific strategies proposed to accomplish this include:

Strategy One: Improve the business climate in Arizona for bioscience industry development and growth.

Strategy Two: Build the region's research base in the identified platforms and facilitate commercialization of research findings.

Strategy Three: Build the region's bioscience talent pool.

Strategy Four: Build an entrepreneurial culture that supports bioscience entrepreneurs and emerging bioscience companies.

These four strategies and the thirteen actions proposed to achieve them are outlined in Figure 17 and Table 9, followed by narrative detail in the ensuring pages. It is anticipated that a majority of these actions would be implemented over a five-year time period by the private and public sectors in Northern Arizona.

Figure 17: Overview of Strategies and Actions

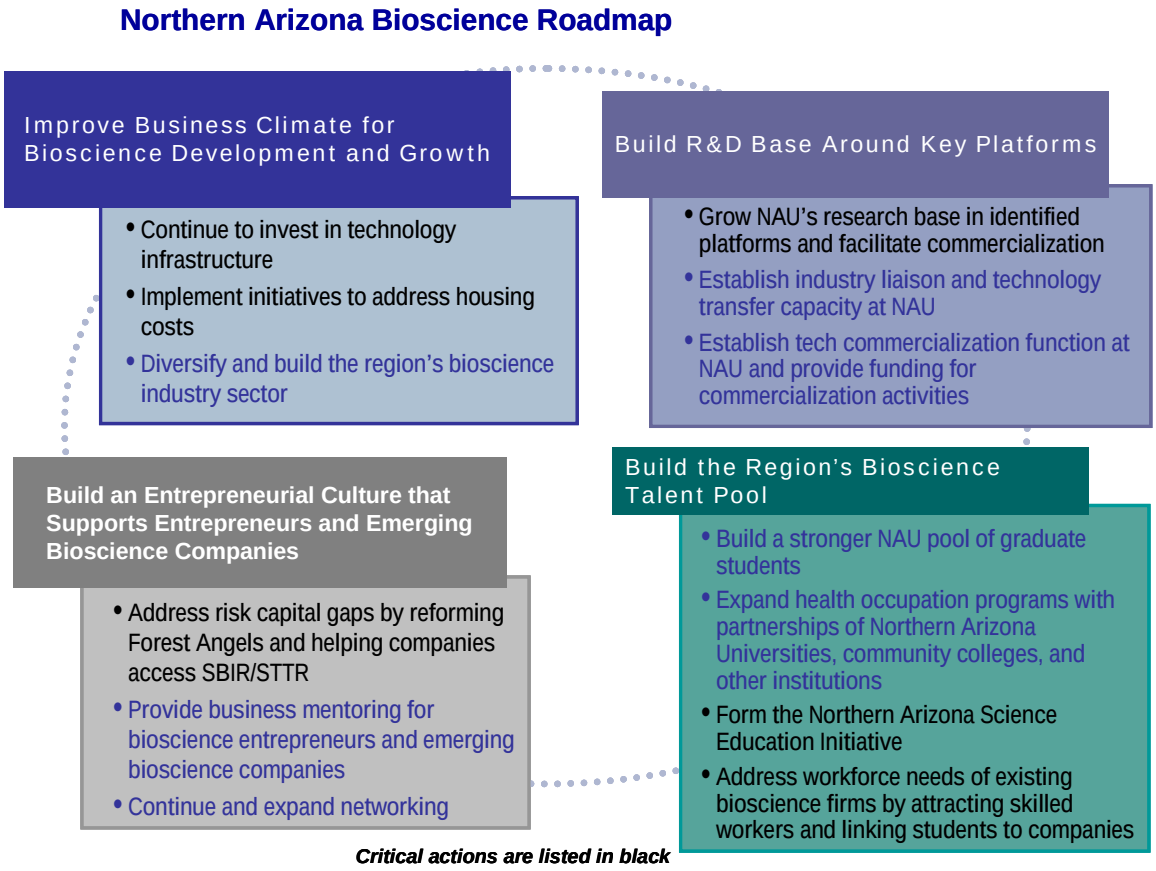


Table 9: Summary of Proposed Strategies and Actions

Strategy	Action
Strategy One: Improve the business climate in Northern Arizona for bioscience development and growth	Continue to invest in technology infrastructure, such as incubators, technology parks, and transportation improvements
	Implement creative ways to overcome the differentials in regional housing costs.
	Diversify and build the region's bioscience industry sector by growing its existing base in medical devices through an enhanced supplier chain, attracting biomanufacturing operations, and building a research, testing and medical labs industry base.
Strategy Two: Build the region's research base in the identified platforms and facilitate commercialization of research findings	Grow NAU's bioscience R&D base around the Northern Arizona technology platforms
	Establish a senior level capacity at NAU to steer, catalyze and cement its relationship with industry including coordinating IP management with ASU
	Establish a technology transfer/commercialization function at NAU and provide funding for early-stage commercialization activities
Strategy Three: Build the region's bioscience talent pool	Build a stronger NAU graduate pool of students both to meet industry needs and build NAU's research stature
	Expand health occupation programs in Northern Arizona in partnerships of Northern Arizona Universities, community colleges, and other institutions
	Form the Northern Arizona Science Education Initiative to undertake activities designed to create a science talent pipeline
	Address workforce needs of existing bioscience companies by undertaking activities to attract skilled workers to the region and better linking students to companies
Strategy Four: Build an entrepreneurial culture that supports bioscience entrepreneurs and emerging bioscience companies	Address risk capital gaps by encouraging re-formation of the Forest Angels investor group and helping companies to access the SBIR/STTR program
	Provide business mentoring for bioscience entrepreneurs and emerging bioscience companies
	Continue and expand networking of researchers, bioscience companies, and service providers

STRATEGY ONE: IMPROVE THE BUSINESS CLIMATE IN NORTHERN ARIZONA FOR BIOSCIENCE DEVELOPMENT AND GROWTH

The economic implications of bioscience innovations are significant. Those regions that invest and develop their emerging bioscience industry base can reap major economic benefits. Northern Arizona's non-hospitals bioscience industry is not yet well-developed, and the potential for

economic development that could be realized by commercializing the discoveries and inventions from the region's research institutions is not yet being fully realized.

For bioscience companies to emerge and grow in the region, they will need available talent, access to capital, access to facilities and room to expand, and a support infrastructure to help them through the early start-up phase.

Continue to invest in technology infrastructure, such as incubators, technology parks, and transportation improvements

Several steps are being taken already to position Northern Arizona for technology and bioscience-driven industry development. These include the Science and Technology Park, the new USGS campus and the Northern Arizona Business and Technology Incubator in Flagstaff and the proposed technology park at Embry-Riddle in Prescott. The region must continue to invest in these projects, including the completion of the incubator facility. Planning should begin on the development of a multi-tenant facility (accelerator) to be located in the Science and Technology Park that can accommodate bioscience companies. Such space will be needed to house graduates of the incubator and to accommodate small firms that might be attracted to the region to serve as suppliers for the region's existing health care and bioscience companies.

Implement creative ways to overcome the differentials in regional housing costs

Housing costs in Northern Arizona make it difficult to attract both employers and employees. This is most particularly a problem in Flagstaff, although it is difficult to obtain affordable workforce housing in Yavapai County and Payson as well. Flagstaff's housing price situation is similar to that of California where workforce housing is unaffordable. In California, its universities and cities have responded by directly or indirectly acquiring and/or writing-down the costs of housing for city and university employees in order to have sufficient skilled workers to fill critical needs.

Among possible options Flagstaff must consider to constructively address its housing challenge are rezoning to allow increased density within the City; providing direct or indirect subsidies to renters and/or homebuyers for workers employed by the university, the hospital center or other major employers; land banking and land swapping with equity participation by institutions and recruits; and promoting controlled growth strategies to increase housing availability in neighboring communities, such as Williams. In addition, employers may have to offer wage differentials to their employees in Flagstaff, which could in the long run reduce costs if it reduces staff turnover, which is very high in many firms as workers leave because they find it too expensive to live in the region at their current salary. This is an approach that the Coconino County government has been discussing.

Affordable Housing Resources Inc.

The mission of AHRI is to strengthen the communities in the Tri-Cities area of Yavapai County by developing workforce housing for families and individuals earning less than 80 percent of median income.

In Prescott, a non-profit entity, Affordable Housing Resources Inc. (AHRI), has been created to meet the workforce housing needs of moderate income families in the Tri-Cities area of Yavapai County. The program, which helps families and individuals earning less than 80 percent of the median income, is targeted to teachers, health care workers, retail workers, municipal workers, etc. AHRI both develops affordable housing and helps individuals and families become first time

home owners. AHRI has undertaken its first development project, which will result in nine duplex buildings consisting of two townhouses each. Through its Shared Equity Program, an outside investor invests in a fund that is used to close the gap between what the homeowner can afford in terms of a mortgage and the downpayment. The gap is filled by a silent second mortgage against which no payments are made until the home is refinanced or sold. When this happens, usually in 5 years, the investor receives an equity share of the housing.

In Payson, the city government has formed a task force to examine the affordable housing issue and is studying their options.

A combination of approaches is likely to be the best course rather than simply one solution. But without some solutions to the housing situation, major bioscience employers in the medical devices and hospital sectors will not be able to remain competitive, let alone grow in the region.

Diversify and build the region's bioscience industry sector by growing its existing base in medical devices through an enhanced supplier chain, attracting biomanufacturing operations, and building a research, testing and medical labs industry base.

Northern Arizona is well positioned to build on its existing base of medical device companies and to attract the production operations of emerging bioscience companies located elsewhere in Arizona. Northern Arizona has capabilities in design, testing and manufacturing. Existing companies in high precision machining and electronics that are not currently serving the bioscience market could be tapped to support emerging bioscience companies. Between August 2005 and August 2006 Flagstaff added 2,100 jobs, a growth of 3.4%; 600 of which were manufacturing jobs.

Examples of Small Medical Device Companies Located in Yavapai County

- Bellicott Inc. (medical instruments)
- Osborn Optical Systems
- Pilgrim Sales (medical devices)
- Trannel (dental equipment)
- Valley Dental Equipment
- Visual Pathways (retinal imaging system)

Overall, Flagstaff is almost twice as specialized in the biosciences as the nation and within medical devices and equipment is nearly 8 times more specialized than the nation and ranks third among all smaller metropolitan areas in the country in medical devices and equipment employment specialization. Flagstaff ranks second only to Glenn Falls, NY among such competitor regions as Minneapolis, MN; Bloomington, IN; and Kalamazoo, MI in medical device employment and has nearly 7 times the employment per establishment of the U.S. as a whole.

Flagstaff's medical devices sector experienced a 39% job growth since 2001, primarily accounted for by Gore's growth, although there are examples of new firms in the devices category located not only in Flagstaff but in Prescott as well. See text box. Building a stronger supplier chain of medical device firms in Northern Arizona and providing support to the region's emerging medical device companies may be one way to strengthen and grow the region's medical device base. Examples in Battelle's analysis of opportunities for suppliers include printing, packaging and extrusion.

Northern Arizona should also seek to grow its research, testing and medical labs base, which is already beginning, building on developments in other regions of Arizona. Research, testing and medical labs employment grew 26% in the Prescott MSA since 2001, ranking it 38th among all

small metropolitan areas in research, testing and medical labs specialization. The number of research, testing and medical lab establishments grew by 52 percent to 13 establishments between 2001 and 2005. The concentration of research, testing and medical labs in the Prescott MSA is slightly (10 percent) below the national average.

In addition to building on the growing number of firms in Yavapai County, startups and spin-offs are starting to emerge from NAU in research; testing and medical labs and the establishment of TGen North in Flagstaff may provide further impetus for additional firms. Finally, as NAU increases its presence in health sciences in Phoenix, synergies with the main campus in Flagstaff may also lead to new opportunities in bioscience research and testing, benefiting Northern Arizona.

As part of these recruitment efforts, the region needs to consider adopting a brand name around its strengths as a devices center, its quality of life, the Grand Canyon as a recognized place—together these words might relate somehow to where research is turned into technology to serve the globe.

STRATEGY TWO: BUILD THE REGION'S RESEARCH BASE AROUND THE IDENTIFIED TECHNOLOGY PLATFORMS AND FACILITATE COMMERCIALIZATION OF RESEARCH FINDINGS

Core competency analysis shows emerging opportunities in bioengineering (sensors, diagnostics, and nano), biofilm diagnostics, computational modeling of cell signaling, Native American health, muscle physiology, chemistry and science education/workforce development, in addition to its existing strengths in infectious diseases, environmental and ecological systems and plant sciences. NAU has the opportunity to build its research base from $16 million in biosciences-related research in 2005 to $50 million over the next five years by addressing such areas as increasing its graduate student pool, further encouraging multidisciplinary work across colleges and departments, and building on its strengths while taking advantage of its emerging opportunities.

Grow NAU's bioscience R&D base around Northern Arizona specific technology platforms

While NAU performs well in terms of research volume per faculty member, the comparatively small size of the University ($55 million in external research funding) means that there is a lack of a large critical mass of researchers in core competency areas. Each of the recommended platforms for bioscience development in Northern Arizona would benefit from selected augmentation through the hiring of additional research-oriented faculty. In some cases, key R&D strengths at NAU are too dependent on the research and reputation of a single faculty member. The risk attached to this is readily apparent when examining the strong R&D track record of Paul Torrance who has made major contributions in life science and drug development work, but whose retirement may limit how NAU is positioned in the future in this area of focus.

In addition to adding research faculty positions, investments will need to be made in facilities and equipment and greater focus should be placed on graduate level science programs. While NAU has been able to benefit from several major lab development projects in the past year, there are still some gaps in certain equipment in areas such as mass spectrometry, crystallography, and

small animal MRI. Support is also needed for enhanced biological modeling and simulation. A number of faculty also noted that there is not a campus budget for scientific equipment maintenance, and this then causes a major drain on laboratory resources.

Currently only the biology department offers a Ph.D. program, the vast majority of the graduate offerings are at the Masters level. The presence of a Ph.D generating research environment would be more likely to generate more research activity and IP.

Establish a senior level capacity at NAU to steer, catalyze and cement its relationship with industry including coordinating IP management with ASU

NAU has traditionally had limited institutional connectivity to industry. This may be due, in part, to the fact that the research conducted at the university is not aligned with the region's industry base but it is also the case that the university has not organized itself to reach out to industry. Yet in today's market, university –industry collaborations are seen as key to moving new discoveries into the marketplace and positioning universities as drivers of economic development. Furher, historically, NAU has contracted with ASU to serve as its technology transfer agent but the time has come for NAU to re-examine its roles and function relative to ASU in technology transfer. In general, it was noted by many faculty that NAU needs to improve its IP management.

It is proposed that NAU create a senior level capacity—reporting to the Vice President of Research and the President -- to serve as an industry liaison charged with promoting and facilitating university-industry partnerships and also serving as the coordinator to ASU on intellectual property matters. The liaison would

- *Serve as a single point of access for businesses.* It is often difficult, if not impossible for business people to know how to access university expertise and resources. This would provide a single point of access making it much easier for companies to interact with the university.
- *Market the university's resources and technologies and pro-actively seek out companies with which to partner*. The liaison would meet with regional companies to assess their technical needs and facilitate linkages to company representatives. NAU would continue to use ASU for the management of intellectual property functions, e.g., reviewing disclosures, handling patenting, handling licensing or other financial arrangements, but this senior person would be integrally involved with and oversee ASU activities. Over time as volume increases NAU can re-examine this arrangement with ASU and build stronger direct institutional capacity.

Purdue's Industrial Research and Technology Programs Office

Purdue's Industrial Research and Technology Programs Office serves as a single point of contact for all business inquiries. The IRTP Office provides "door opening" and facilitation services that demonstrate the University's flexibility and responsiveness to businesses. It also offers training seminars for faculty members on the differences in expectations and requirements between industry and government research sponsors. The IRTP Office publishes its own, outreach-oriented newsletter with circulation of 2,000 in the U. S. and abroad. It also helps develop and maintain a series of web pages profiling University research laboratories and centers that are in search of business sponsorship.

- *Work to increase faculty understanding of business needs.* The industrial liaison would seek to bridge the gap between university and business expectations by conducting training and awareness programs to prepare faculty to work with business.
- *Maintain close ties to colleges and their faculty*. The industrial liaison should be familiar with the areas of expertise of individual faculty and able to quickly identify appropriate faculty able to address a company's needs.

Establish a technology commercialization function at NAU and provide funding for early-stage commercialization activities

NAU does not have a long history of university engagement in technology commercialization or encouragement of faculty entrepreneurship. That said, it is evident that the university and the Flagstaff region are working together to encourage the development of innovation-based industry from university discoveries. The university has been holding intellectual property workshops for faculty, incubator space for new start-up enterprises will soon become available through the City of Flagstaff, and NAU has made space available to one start-up firm. NAU now is home to several faculty members who have engaged in entrepreneurial technology business start-up activity, but further attention is required to create a smooth pipeline for technology commercialization.

It is proposed that a technology commercialization fund be created, which would award small grants to support proof of concept and other commercialization activities. This fund would make awards of $50,000 to $100,0000 to undertake due diligence to determine whether there is any commercial value in an invention. The end result of a technology commercialization project would be a prototype, further research that helps determine market value, or other deliverables.

STRATEGY THREE: BUILD THE REGION'S TALENT POOL

It is becoming increasing difficult for bioscience firms throughout the country to meet their employment needs. This is also true in Northern Arizona. The danger if this issue is not resolved is that the region will improve its ability to start new firms, but will be unable to retain them (and their subsequent employment growth) due to a lack of employees. To address future workforce needs, the region needs to encourage more students to consider careers in the biosciences and to take the courses that will prepare them for such careers. In addition, because of rapid changes in technology, it is essential for the bioscience workforce to constantly be educated on a lifelong basis—which necessitates the building of career ladders whereby a student from high school on can enter and exit with various skill levels, moving from a technician level to a post doc or scientist if he or she should desire at some point in his or her career.

Build a stronger NAU graduate pool of students both to meet industry needs and build NAU's research stature

To build strong research universities requires attracting good students. Given NAU's position as trying to grow its research base, there are several steps that would help achieve this reputation faster. First, stipends provided to NAU graduate students are minimal and they received a waiver of only $1,200 of their $3,500 tuition. This has made it difficult to attract high quality students although they are able to attract research assistants by using extramural R&D grants to cover the students' out-of-state tuition. In addition to making it difficult to recruit students, NAU will have

a problem qualifying for graduate fellowships that will be offered by Science Foundation Arizona as higher tuition coverage and higher stipends will be required by the program. It is recommended that NAU waive all tuition for teaching assistants and raise the stipends for both research and teaching assistants. Second, to reach the research target of $50 million in external research funding in five years the University needs to enhance the number of research faculty it has through a targeted investment and growth program. Third, moving from a teaching to a research university status will mean more year long appointments particularly of research faculty. Fourth, the University needs to consider and adopt incentives that reward faculty for doing sponsored industry research, securing external funding, and building the interdisciplinary programs desired by industry in search of talent. Together these four steps would position NAU and if focused around platforms (health professions, infectious diseases, engineering, medical products, environment and ecology) and tied to other actions in this strategy related to building the region's talent pool, could improve the region's attractiveness to biosciences and other technology firms.

To fund such efforts NAU will need to seek state, federal, philanthropic and industry funding sources as well as perhaps an alumni capital campaign. The intent is to selectively build NAU's graduate programs in select fields of interest to industry and citizens of the state such as in select areas of the biological and health sciences, and engineering, with a primary focus on terminal Master's programs. Ph.D. programs will continue to be limited around the university's core competencies, outlined elsewhere in this report.

Expand health occupation and sciences programs in partnerships of Northern Arizona Universities, community colleges, and other institutions

In the past two years, Northern Arizona University (NAU), working with partners in Phoenix, Tucson, and rural portions of the State, has developed a plan and started its implementation with a focus on providing needed professionals in health science fields, including Nursing, Communication Sciences and Disorders, Physical Therapy, Occupational Therapy, and Physician Assistants. This initiative involves not only the state's two metropolitan areas as well as in Flagstaff, Yuma, and nearly 20 statewide sites. Coupling face-to-face instruction with web classes, and clinical practice will result in a significant increase in trained health professionals. Some of these programs such as nursing (both baccalaureate and masters – nurse practitioners) and physical therapy are expansions, both on the Flagstaff campus and at metropolitan and rural sites. Programs will be expanded on-demand by adding students to cohorts in these programs and by beginning new cohorts. Other programs, where there is demand include occupational therapy and physician's assistant, and will be new endeavors.

As the biosciences -based sector of our economy moves forward, there will be a need for additional employees at several levels to work in laboratories and manufacturing. To date, the state has placed an emphasis on training researchers with doctoral degrees. As one of its initiatives, NAU will expand its existing training opportunities for B.S. and M.S. degree candidates. The Human Health Initiative being planned will include sections on human genetics and biomedical engineering. NAU already has courses in biology and chemistry that provide students with hands-on experience with state-of-the-art equipment. NAU has a well deserved reputation for involving undergraduates in scientific research. It plans to enhance this with additional class and laboratory experiences with the theories behind and practice of current methods and technologies.

The Arizona Institute for Health Research and Policy (AzIHRP) is being founded by three NAU faculty: Paul V. Dutton, Fred Solop, and Kristi Hagen. Funding was provided by NAU to explore the scope and mission for the new institute. By investigating the structure, function and foci of similar endeavors in other regions of the U.S. a plan will be developed for the Arizona initiative. In addition, a critical task will be to reach out to the Arizona stakeholders to form collaborations with the Health Policy Advisor for Governor Napolitano, the Arizona Rural Health Association, and Community Outreach meetings in Flagstaff, Phoenix, and Tucson. A plan, scheduled for submission in December 2007, will serve as the launching point for the new institute.

A group on the Northern Arizona University campus has begun work on establishing a research, policy, and outreach organization regarding women's health. The effort is an outgrowth of several ongoing efforts including the Native American Cancer Research Partnership, a patent on a drug that mimics menopause, studies on weight control, and others.

In addition to partnerships that are part of our other initiatives, NAU is part of a group from all three Arizona Universities working on a Clinical and Translational Science Award (CTSA) for the NIH. If awarded, this funding would provide the bases for establishing centers in various statewide locations for all scientists to use to facilitate research in areas like medical diagnostics, behavioral health, genomics, and research education.

Form the Northern Arizona Science Education Initiative to undertake activities designed to create a science talent pipeline

Partnerships with community colleges could be used to build the talent base coming out of public schools in science, math and technology and and NAU's strengths in science education could be tapped to train new teachers and retrain existing public school teachers. Part of this effort would identify ways to increase the focus of career education and workforce programs on the biosciences and to develop a bioscience career training continuum from high school through the community college to NAU. A recent workforce study suggests that generic and core competency skills in areas such as reading, written and oral communication, basic business math, problem solving, critical thinking or reasoning, interpersonal and team skills, customer relations, basic quality practices and basic work attitude and discipline skills—all of which are required of bioscience workers—were found most lacking and are areas in which education institutions need to focus.

Key components of this Initiative include:

- Teacher education and training in the sciences;
- Science education research and integration into the classroom;
- Science Academies (K-12);
- Career Education (11–12th grade to C.C. to NAU);
- Revamping Job Training Programs to Employer Needs.

Address workforce needs of existing bioscience companies by undertaking activities to attract skilled workers to the region and better linking students to companies

It will be important for employers in Northern Arizona to think creatively and boldly of how to recruit and retain employees as talent becomes a critical discriminating variable in firm competitiveness and growth. Northern Arizona employers are currently facing major shortages of

sufficiently qualified applicants to fill hundreds of jobs in the health and medical device industries. Over the long term, employers are going to have to take greater personal responsibility to encourage the future workforce to pursue science, math and technology careers and to educate and inform future workers of the needs for minimal core competency skills in writing, communications, problem solving, and computational skills. The health and medical device employers must engage in a stronger dialogue with education and workforce providers around educational policies, programs and curriculum to assist students and teachers with a clear understanding of the knowledge, skills and education and training required for careers in healthcare and manufacturing in the region.

In the shorter term, Northern Arizona employers have a talent base coming out of its public and private schools, community colleges and NAU that is not always matched to employer immediate skill needs and requirements. But, just as California employers have learned, it may be necessary to develop new career paths for non-experienced entry level workers and it may be necessary to form and develop work experience and internships as well as part-time employment opportunities for students while still in school. Such networking opportunities are becoming critical to attracting and growing your own work force.

A recent workforce survey found that both CCC and NAU students citied relevant work experience, internships, and networking as the top three important attributes in landing a job. **This strongly suggests that Flagstaff's employers would be wise to increasingly look at the pipeline of talent coming out of the educational systems in the region and provide significant work experience, internship and part-time employment opportunities for them.** Over 70% of Coconino Community College and 59% of NAU students indicated they planned to seek full time employment in the region but when asked what they plan to do upon graduation only 25% and 17% respectively indicated an intention to stay once they graduated. Employers obviously need to build relationships while these students are in school.

It may require hiring less experienced personnel initially but it is less likely to suffer the turnover and recruitment costs of major employers' traditional approach of recruitment from outside into Flagstaff, which is increasingly meeting strong resistance. Just as other university-centric towns have taken advantage of a large student workforce to improve their competitiveness, Flagstaff manufacturers including device firms might want to look at the part-time employment model that has worked for many years for IBM in Research Triangle Park, N.C., or UPS in Columbus, Ohio, among other examples.

A prime example of how this might be done is building a graduate biomedical engineering program at NAU around its core strengths in engineering and biology and with a small investment being able to then provide terminal M.S. degrees to adult workers who have been full or part-time employees at nearby medical device firms. While not supplanting the need to continue to recruit outside the region for such talent, this "home grown" approach can, over time, begin to address engineering shortages in the device industry in Northern Arizona.

Lastly, Northern Arizona is going to have to be aggressive in actively recruiting talent to the region. One source of such talent would be former residents who left the region to pursue careers elsewhere; many of these people might be attracted back to the region if an opportunity to do so was presented and the salary was sufficient to cover the higher cost of living.

Creating a regional web site with job and internship listings as Cleveland, Ohio and Syracuse, New York recently did to secure the talent their employers need is another step worthy of taking by economic development groups in the region. Other approaches include Job Fairs with employers in the region and selective advertising at health and medical device centers elsewhere in the U.S.

STRATEGY FOUR: BUILD AN ENTREPRENEURIAL CULTURE THAT SUPPORTS BIOSCIENCE ENTREPRENEURS AND EMERGING BIOSCIENCE COMPANIES

To grow a critical mass of bioscience companies, Northern Arizona must encourage entrepreneurs, provide in-depth support to new bioscience companies, and create a climate that is supportive of bioscience companies. Northern Arizona can foster the growth of start-up bioscience companies by ensuring the availability of venture capital at all stage's of a company's life cycle, providing support for entrepreneurs and emerging bioscience companies, and facilitating networking among bioscience firms and between academic researchers and their industry counterparts.

Address risk capital gaps by encouraging the re-formation of the Forest Angels group and helping companies to access the SBIR/STTR program

Most people realize that the discovery of new knowledge resulting in the development of new technologies is a very expensive process running, in some cases, into million of dollars. What many people do not realize is that the costs associated with developing and taking a technology, product or service to market are also very substantial. Major costs incurred after the research has been completed include the cost of assessing the market to determine the competition, the likely market, and the price points for competitive advantage; developing a prototype; preparing a marketing and sales plan; and scaling up for manufacturing. Finally, actual product distribution, sales, and marketing must be undertaken. Sufficient capital must be available to fund these activities in order for business growth and economic development to occur.

Yet, few sources of funding bridge the gap between the point at which a discovery has been identified and demonstrated and the point at which a business case has been validated and venture capital or debt capital can be obtained. The sources typically tapped to address this gap include angel investors, venture funds that invest at the seed and early stage, and publicly and privately supported university and non-university programs specifically created for this purpose. A source of funding at the federal level is the Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program. SBIR/STTR funding can be used to prove feasibility and validate ideas for potential markets, including the government.

Lack of risk capital has been an issue for not only Northern Arizona but for the entire state. Between 1996 and 2006 no bioscience firms in either the Flagstaff or Prescott MSAs received a venture capital investment. In addition, the one angel investor group that did exist, Forest Angels Group, has disappeared. At the same time, however, there are many wealthy private investors in Northern Arizona that have had interest and experience with bioscience opportunities. Re-establishing an angel group in Northern Arizona as well as partnering with efforts in Phoenix and Tucson to establish a Statewide Bioscience Angel Initiative could help address the earliest stages of pre-seed investment that will be needed to support the establishment and growth of new bioscience companies.

In addition to angel financing, Arizona is facing a declining pool of resident venture capital available that necessitates not only replenishing this pool but also suggests that in the mid-term coupling Northern Arizona's interests with those in Tucson and Phoenix to form a statewide BioSeed Program or Fund. Northern Arizona's efforts to address its needs in risk capital are most likely to be achieved through linkages and coupling of efforts with those underway in other parts of the state, to address the earliest stages of risk capital initially but all stages ultimately. Additional assistance in encouraging firms to apply for SBIR; taking advantage of State support for SBIR; and utilizing the assistance of ASU and other universities already providing SBIR education and training should be considered.

Provide business mentoring for bioscience entrepreneurs and emerging bioscience companies

If Northern Arizona is to succeed in creating and growing more bioscience companies, its entrepreneurs and start-up companies will need support. Helping firms determine their markets and where their technology is best suited; helping find and form the initial management teams to build these enterprises; addressing how to distribute, price and sell a product; and securing financing to grow a firm to its full potential are the types of issues that CEOs of new companies need to address. Northern Arizona, with its large base of retirees, has a cadre of individuals who have built successful businesses who understand what it takes to succeed. These experienced business people should be enlisted to serve as mentors to the region's up and coming bioscience firms. Organizing these mentors may involve bringing together the efforts of B.E.E.R., the re-constituted Forest Angels, and utilize the completion of the incubator as the physical site and location from where entrepreneurs can both launch their companies and obtain mentoring support.

Continue and expand networking of researchers, bioscience companies, and service providers

Bioscience firms tend to like to mingle with their colleagues, meet related businesses, connect with university personnel, and otherwise engage in what is termed "technical networking". This is much more the case for bioscience firms than for information technology or manufacturing firms that tend to view their colleagues as competitors rather than potential collaborators. B.E.E.R. has been started by interested biosciences related faculty, entrepreneurs, and service providers but has attracted participation from Gore employees and others. And, just as in other regions, bioscience firms find because they have many different niches in which to operate, and often similar challenges, networking spurs complementary efforts among them. Given the small size of the bioscience industry base in Northern Arizona, it would make sense for the region's businesses and researchers to participate in programs held by the statewide Arizona BioIndustry Association but there is also a need to hold some networking events within the region in order to facilitate greater collaboration between NAU, TGen North, USGS, and the region's bioscience companies as B.E.E.R. has started to do. The region's service providers—accountants, lawyers, etc—should also be included in order to help them build capacity in the biosciences.

Implementation Plan

Various members of Northern Arizona's bioscience community came together under the leadership of the Greater Flagstaff Economic Development Council, NAU and the City of Flagstaff to develop this Bioscience Roadmap. The Northern Arizona Bioscience Steering Committee included senior officials from the region's educational institutions, business leaders, economic and workforce development staff, and representatives of city and county governments and the Navajo nation. Developing this Roadmap, however, is just the first step. For this strategy to be successful, numerous groups and organizations must commit to working in partnership over the long term. Significant public and private investments will be needed to accomplish the strategies and actions proposed.

This implementation plan identifies critical actions and immediate workplan priorities, i.e., actions that should be undertaken immediately. It also proposes a set of measures for monitoring progress and suggests an organizational structure that should be put in place to oversee implementation.

Critical Actions

The successful implementation of six of the proposed 13 actions will ultimately determine whether Northern Arizona will be able to capture a share of the bioscience development in the state. This does not mean the other seven actions should not be undertaken, because they should. It just means the actions with the greatest impact on bioscience success are the critical actions, listed below in priority order::

- Address workforce needs of existing bioscience companies by attracting skilled workers to the region and better linking students to companies.
- Implement creative actions to overcome the differentials in regional housing costs.
- Address risk capital gaps by encouraging angel investor groups and helping companies to access the SBIR/STTR program.
- Continue to invest in technology infrastructure including the Science and Technology Park, the Northern Arizona incubator; the technology park at Embry Riddle University and improvements to the airport and I 17.
- Grow NAU's R&D base in the statewide platforms and the Northern Arizona specific platforms
- Form the Northern Arizona Science Education Initiative to undertake activities designed to create a science talent pipeline

IMMEDIATE WORK PLAN PRIORITIES

Immediate work plan priorities are those steps the private and public sectors in Northern Arizona should undertake within the first 12 months of implementation. Several critical priorities need to be implemented right away, while others will need to be planned and resources secured before they can move forward.

The following actions should be undertaken in the first year of implementation of the strategy:

- City of Flagstaff, NAU, Flag 40, and other groups need to reach a consensus on near-, mid- and long-term approaches to address the housing situation — it is unlikely there is one magic bullet option which will meet all needs and requirements;
- Convene angel investors to determine interest in re-constituting the Forest Angel Group and what support or assistance, if any, they need;
- Convene public and charter schools, community colleges and NAU to develop pathways for bioscience careers addressing curriculum, articulation, resources, and other impediments to making Northern Arizona a science education center of excellence that will be able to build and retain its own talent pool over the long-term;
- Continue to implement the S&T Park, including incubator build-out and planning for an accelerator/multi-tenant space;
- Work with the Arizona Dept. of Commerce and the US EDA to get funding for the development of the tech park at Embry Riddle in Prescott; and
- Work with Science Foundation Arizona to which actions if any they will invest dollars in to move this Roadmap forward including: building NAU's research base and graduate pool, the Science Education Initiative, technology transfer, industry liaison, and technology commercialization support, and initiatives to take greater advantage of the Native American community to address workforce shortages in Northern Arizona.
- Work with the Arizona Board of Regents and Department of Commerce officials as well as Science Foundation Arizona and private sponsors to secure resources for 1) enhancing technology transfer and commercialization capabilities at NAU; 2) creating a technology commercialization fund at NAU and 3) increasing support for NAU graduate students.
- Work with the state Bioscience Committee and Coalition to address need for BioSeed Fund and other risk capital

RESOURCES

Because so many of the actions will require further discussion it is not possible to put a price tag on these actions. However, it should be noted that a number of these actions are already underway, e.g., incubator, science and technology park, etc., thus the public investment that will be required to implement the actions in the Roadmap will be primarily in the areas of research, technology and its commercialization, and education and training. The private investments required will include risk capital. Because of the progress already being made, Northern Arizona is not likely to have a huge resource requirement to move forward with this Roadmap. More important are the issues of stewarding the Roadmap and its implementation.

ORGANIZATION AND STRUCTURE

The Steering Committee formed to provide guidance and oversight in the formulation of the Northern Arizona Bioscience Roadmap has been extremely valuable and useful to this effort.

The next step in evolution of the Northern Arizona Bioscience Strategy will involve the active participation of the Northern Arizona Economic Advisory Committee appointed by the City of Flagstaff and including representation from city, county, and state governments; major employers, NAU, the Medical Center, the Community College, Chamber of Commerce, and others. The Executive Committee of the Advisory Committee should have primary responsibility for stewardship of this Roadmap, monitoring its progress and implementation. The Executive Committee includes the major players that can turn this strategy into action. Membership of the Executive Committee should be broadened to include ex officio representation from Prescott and Payson when it meets to discuss Roadmap implementation.

MEASURES OF SUCCESS AND ACCOUNTABILITY

The overall Roadmap should be updated every three to five years to adjust for changes in implementation progress, market conditions and the competitive position of Northern Arizona.

Specific measures to guide progress in Roadmap implementation include:

- Assessing Flagstaff's and Prescott's cost of living relative to other communities in Arizona and the West, including housing affordability (Indexes);
- Maintaining Flagstaff's specialization in medical devices and broadening Northern Arizona's bioscience specialization to at least one other industry area (measured by LQ levels);
- Tracking graduates in bio-related areas by level: Associate, Bachelor's , Graduate and Northern Arizona's retention rate of such graduates; and
- Tracking statistics on success in commercialization of research: disclosures, patents, licenses, equity, and spin-offs

Conclusion

Northern Arizona has the most specialized industry base in the state, one which continues to grow. But it needs to do more to diversify this base in the biosciences to other areas whether its plant agriculture or research and testing. A more diversified bio-related economic base will enable the region to attract and retain more skilled workers.

Flagstaff is making considerable progress on items important to the region's future in the biosciences. The region, due to the strong presence of WLGore, is a recognized global player already in the biosciences. The growth of Northern Arizona University's (NAU) research base; increased faculty interest in entrepreneurship; world class research around strengths in infectious diseases, environmental and ecological systems and plant sciences; and the opportunity to build on their science education reputation to address regional needs, such as biomedical engineering, place Northern Arizona in a favorable position to grow its bioscience sector.

But there are challenges to address led by the inter-related issues of cost of living/housing costs and shortages of workers with most major employers in the community having a significant number of job openings. Some of this shortage is due to limitations in what is produced from the education system at the high school, community college and university levels. But, some of it is also due to national shortages of skilled and experienced bioscience workers.

Two fundamental issues will determine whether Northern Arizona succeeds in the biosciences. Novel and creative solutions will be needed to address the issues of affordable housing and worker shortages. While there has been much discussion and debate over the housing issue, and it is not the purpose of this Roadmap to solve that problem, suffice it to say that if this problem is not solved it will be increasingly difficult for employers—biosciences or others—to stay, let alone expand. And it will limit efforts to recruit and attract suppliers to existing medical device firms to come to Flagstaff. Building a private-public consensus on solutions is critical, as Prescott has found in its efforts, and it will require creative and flexible responses by business, university, and city government leaders. Addressing, if not totally solving the housing issue, will directly and indirectly help address the worker shortages. But, ultimately, the worker shortage suggests the region rethink how it builds its talent pool in the long term. This is hardly a short term solution but the more opportunities for part time employment are presented to college and high school students and increasing the scale of internships and co-op programs will increase the ability of the region's employers to attract these students upon graduation. In turn, this requires building career ladders and requires employers to adjust deployment of personnel as they build their workforce from within the community. Education institutions, in turn, have to more rapidly respond to such a strategy by considering biomedical engineering programs at NAU; health occupation programs at Coconino Community College (CCC), Yavapai College, and NAU; as well as entrepreneurship programs coming out of the College of Business at NAU and elsewhere, to name a few examples.

The four strategies and 13 actions proposed in this Roadmap suggest the additional private-public agenda required to position Northern Arizona in the biosciences.

Appendix A: List of Northern Arizona Bioscience Steering Committee Members

The Honorable Joe C. Donaldson
Co-Chair
Mayor, City of Flagstaff

John D. Haeger, Ph.D.
Co-Chair
President
Northern Arizona University

Stephanie McKinney
Co-Chair
Former President & CEO
Greater Flagstaff Economic Council

Monica Baker
Dean of Academics
Coconino Community College

Paul Begovac, Ph.D
Development
W.L. Gore & Associates, Inc.

Bill Bradel
President
Flagstaff Medical Center

W. David Chambers
President
Grand Canyon Railway

Marc Chopin, Ph.D.
Associate Dean & Associate Professor of Economics
College of Business Administration
Northern Arizona University

Kathleen Corak, Ph.D.
Vice President of Academic Affairs
Coconino Community College

Lee Drickamer, Ph.D.
Interim Vice President of Research
Northern Arizona University

Joseph Engelken
Chief Executive Officer
Tuba City Regional Health Care Corporation

David Engelthaler
Director of Programs
TGen North

William Grabe, Ph.D.
Professor of English
Northern Arizona University
Former Interim Vice Provost for Research and Dean of Graduate Studies
Northern Arizona University

John Holmes
Manager
City of Flagstaff

Laura Huenneke, Ph.D.
Dean
College of Engineering and Natural Sciences
Northern Arizona University

Thomas Jordan, Ph.D.
President
Coconino Community College

Paul Keim, Ph.D.
Cowden Chair & Regent Professor
Biological Sciences Department
Northern Arizona University

Michael Kerski
Community Investment Director
City of Flagstaff

Mark Landsiedel
Community Development Director
City of Flagstaff

Ingrid Lee, Ph.D.
Dean of Arts and Sciences
Coconino Community College

Stan Lindstedt, Ph.D.
Associate Dean
College of Engineering & Natural Sciences
Northern Arizona University

James Manley, Ed.D.
Lecturer
College of Education
Northern Arizona University

Michael Manson
Representative
Brookstone Ventures, LLC

Willard Ott
Lecturer
The W.A. Franke College of Business
Northern Arizona University
Former President
Northern Arizona Technology and Business Incubater

Cecilia Owen
Superintendent of Schools
Coconino County

Julie M. Pastrick
President and Chief Executive Officer
Flagstaff Chamber of Commerce

Tim Porter, Ph.D.
SABRE Director & Professor
Physics and Astronomy
Northern Arizona University

George Ritchie
Finance Director
Flagstaff Unified School District

Ann Roggenbuck, M.Ph., M.B.A., Ph.D.
Chief Executive Officer
North Country Community Health Care

Roger Schuler
Vice President, Ancillary Services
Flagstaff Medical Center

Peter Stuart, M.D.
Chief Medical Officer
Navajo Indian Health Services

Appendix B: Assessment of Core Competencies and Identification of Northern Arizona Bioscience Technology

Universities are the national leaders in basic and applied bioscience research and it is extremely important that bioscience-based economic development strategies be constructed on a firm base of understanding of the capabilities of a state's research universities and associated institutes. Research universities are likewise at the forefront of developing and adopting enabling technologies for advancing bioscience R&D and it is important to understand the availability and investment in these tools and resources (such as imaging, instrumentation, advanced materials, combinatorial chemistry resources, etc.) since they make such a strong contribution to development pathways. It should also be noted that university core competencies can serve as a magnet for the attraction of commercial research linked to the universities' expertise and specialized focus areas—helping to build a localized environment conducive to specialized bioscience business development and growth.

The biosciences present so many opportunities for the future (Table 1) that it is extremely important for a state or region to have a strong basis of understanding of where its opportunities will lie within a very broad universe of bioscience disciplines, opportunity areas and possibilities. An extremely small number of states (most notably California and Massachusetts) have such a broad academic and industry base in biosciences that they may be able to build on strengths across the board, but in most technologically savvy states (such as Arizona) opportunities will present themselves in more tightly defined fields and the state must be ready to support and help build capabilities in identified specialized niches.

It is the identification of these niche areas of opportunity, built around an understanding of Northern Arizona's bioscience core competencies that are the focus of this report. This core competency focuses primarily on Northern Arizona University in Flagstaff, but also considers other research drivers such as Prescott College, health care organizations and for-profit commercial organizations. It also is informed by earlier work Battelle conducted in developing the Arizona Biosciences Roadmap in 2002 and advancing the Scientific Platforms in cancer research, bioengineering, bioimaging and neurosciences in more recent years.

Table 1: Potential Bioscience Breakthrough Areas

Human Biosciences	Plant Biosciences	Animal Biosciences
• The prevention of diseases with underlying genetic causes • The development of early stage disease diagnostics • The ability to detect genetic predisposition to disease and develop prevention and treatment regimens • The production of advanced imaging technologies to promote new discovery and enhance therapeutic delivery • The discovery and development of new drugs and biologics for enhanced treatment outcomes • Drugs and therapies targeted to individual genomic characteristics leading to greatly improved outcomes and reduced side-effects • The development of replacement tissue and organ systems to replace those injured or failing • The biological integration of advanced technologies, such as nanotechnology, biomaterials and MEMS devices • Advanced bioinformatics and health informatics tools to drive knowledge-based medicine. • The ability to eradicate, inoculate against and more effectively treat established and emerging infectious diseases • Enhanced biosecurity	• Pest and disease resistant crops • Increased crop yield and desirable qualities characteristics • Lengthened growing seasons via cold resistance or reduced light requirements • Enhanced shape, texture, flavor and processability characteristics • Technologies to reduce the required application of fungicides, herbicides and insecticides • Functional foods and nutraceuticals • Plant genetic resources for development of biologics, drugs and pharmaceuticals • Genetic resource (germplasm) preservation and storage technologies • Development of biosensors for industrial and commercial applications • “Biopharming” and the production of novel and useful chemicals via plant pathways • Development of sustainable bio-based fuels • Development of advanced biomaterials for use in construction and other industrial applications • Development of degradable plastics from plant starch, protein and fermentation-produced monomers • Bioremediation and environmental protection via plants • Enhanced biosecurity	• New approaches to animal disease diagnostics, prevention and treatment • Increased food animal meat yield and desirable quality characteristics • Improved technologies for food preservation and the prevention of spoilage and food-borne diseases • Genetic resources for development of biologics, drugs and pharmaceuticals for human and veterinary applications • Xenotransplantation and tissue engineering, providing organs and tissue for human medical applications via animal pathways • Development of engineered species, such as customized predator insects, to control pests and diseases • Development of biosensors for industrial and commercial applications • Bioremediation and environmental protection via microbial pathways • The use of animal waste and byproducts as renewable energy and chemical production resources • Enhanced biosecurity • The novel application of animal and plant genetic resources to new technologies such as biological computing

The potential for discovery and innovation in the broad areas of opportunity shown in Table 1 is tremendous. Multiple forms of economic development may take place around such bioscience opportunity areas, including but not limited to the following:

- The formation, growth and attraction of companies engaged in
  - Drug development and manufacturing
  - Biologics development and manufacturing
  - Vaccine production
  - Gene therapy development
  - Diagnostic test development and production
  - Diagnostics and imaging instrumentation manufacturing and development
  - Laboratory and diagnostics services and healthcare services
  - Medical implants and invasive devices
  - Tissue engineering and organ systems development
  - Seed and plant varietal development and production
  - Improved food animal species and enhanced animal health
  - Agricultural and food processing technologies
  - Biomaterials and biocomposites development
  - Biofuels and bio-sourced chemicals
  - Production of novel and useful compounds via plant pathways
  - Agricultural equipment and precision agriculture devices
  - Bioinformatics and health informatics tools and software
  - Biosecurity
  - Waste management and environmental clean-up and protection
  - Nanotechnology and MEMS devices
  - Other bio and bio-related commercial applications yet to be developed or imagined.
- The diversification of existing commodity producers, such as farms, into enhanced value-added products.
- Direct economic benefits from research itself, brought by the attraction of external research funds and the scientists and staff they support.
- Enhanced education and workforce development in and around biosciences and technology.
- Increased health, wellbeing and human capital capacity generated through healthcare and wellness innovations, clinical care and healthcare products.

Because research is the driving force behind bioscience innovation and commercialization—and therefore, the driving force behind the realization of the potential economic development

opportunities highlighted above—it is imperative that Northern Arizona's decisions regarding science and technology policy for advancing the biosciences be constructed upon a formal understanding of the state's bioscience research core competencies.

As noted previously, a core competency analysis for the state was conducted in 2002—but for this report Battelle has performed a new in-depth assessment and evaluation of the Northern Arizona region's bioscience core competencies and resulting technology platforms. This analysis will allow stakeholders in Northern Arizona to see where previously identified competencies have been retained and strengthened, where new competencies are emerging, and where further investments may be required to achieve the desired level of strength and capabilities.

METHODOLOGICAL APPROACH TO ASSESSING NORTHERN ARIZONA'S CORE RESEARCH COMPETENCIES

Underpinning the successful translation of bioscience research strengths into economic development opportunities requires recognition of the importance of "market-driven" processes. The traditional model of commercialization assumes a "research-driven" approach to commercialization. This research-driven commercialization process proceeds in a pipeline fashion from basic research leading to a major scientific breakthrough, to applied research leading to product development, and ending with industrial manufacturing and marketing. The shortcomings of the research-driven approach are that it is too divorced from commercialization and product development needs and has uncertain economic value. The market-driven approach recognizes that commercialization is a highly interactive process involving close ties between research activities and business development activities. Success depends, as the Council on Competitiveness points out, "on a team effort that includes carefully focused research, design for manufacturing, attention to quality and continuous market feedback."[16]

The components of a core competency area can bring together basic research, enabling technology, and applied research activities with a "line of sight" that moves seamlessly to address clinical needs and market opportunities, and can form robust technology platforms. Core competency areas that lack this linkage and connection to needs and market opportunities offer more limited development opportunities.

Defining Core Competencies

There is no one single source of information that serves to identify core research competencies and focus areas. Rather, a variety of integrated and complementary analyses are required to help identify an institution's current position and areas of focus that may lead or contribute to Northern Arizona's future bioscience growth.

In identifying core research focus areas in the biosciences, Battelle's objective was to identify those fields where there is an ongoing critical mass of activity along with some measure of excellence. This does not mean, however, that other fields of bioscience excellence may not be present within Northern Arizona institutions. What it does mean is that these other bioscience

[16] Council on Competitiveness, *Picking Up the Pace: The Commercial Challenge to American Innovation* (Washington, DC: Council on Competitiveness), pp. 9-10.

strengths are found in relatively limited pockets and so offer more limited opportunities upon which to build (but they may still contribute in a notable manner).

To take the analysis further, Battelle applies an industrially focused core competency definition that is widely used by technology-based firms. As defined by Hamel and Prahalad, in "Competing for the Future,"[17] a competence is a bundle of skills and technologies, rather than a single discrete skill or technology. It represents the sum of learning across individual skill sets and individual organizational units.

Three tests can be used to identify a core competency:

1. Is it a significant source of competitive differentiation? Does it provide a unique signature for the state?
2. Does it transcend a single business? Does it cover a range of businesses, both current and new?
3. Is it hard for competitors to imitate?

Approach to Identifying Northern Arizona's Bioscience Research Core Competencies

Core research focus areas are identified using both quantitative and qualitative methods:

- Quantitative assessment uses statistical information on extramural grants, publications, and patent activities.
- Qualitative work includes extensive field-work interviews with key administrators, scientists, and researchers across the research drivers found in Northern Arizona organizations and institutions.

The questions that the research team explored in the core competency assessment focused on the following:

1. What is Northern Arizona's overall volume of bioscience research and what trends, positive or negative, are being demonstrated?
2. In which fields of bioscience and related activities are Northern Arizona R&D institutions receiving significant levels of funding, especially funding from "gold standard" sources such as the National Institutes of Health (NIH), the U.S. Department of Agriculture (USDA), National Science Foundation (NSF), etc.?
3. In what bioscience and related fields do Northern Arizona academic institutions demonstrate a substantive and influential record of publication?
4. In which bioscience areas are Northern Arizona research organizations generating patents and intellectual property?
5. Which areas of bioscience and related fields does Northern Arizona University self-identify as core competencies?

[17] Hamel, G. and Prahalad, C. K. 1994. Competing for the Future. Harvard Business School Press: Boston, MA.

6. Based on identified core competencies, what development opportunities can be identified for the near-term (over the next five years) for growing the biosciences and related industries and technologies in Northern Arizona?
7. Which bioscience core competencies show the most promise for becoming growth poles for incorporation into Northern Arizona's statewide technology and economic development policy?
8. Which core areas of bioscience focus require additional investment in Northern Arizona in order to realize their development potential?

In evaluating the answers to these questions, the team can provide insights into the current strengths of the Northern Arizona biosciences research base and draw implications as to how these research strengths may best intersect with the state's industry and economic base, economic competitiveness factors, and market trends to produce economic opportunity. Ultimately the goal of the core competency assessment is to identify significant strengths that form a substantial signature for the state around which substantial bioscience-driven economic development can occur.

Quantitative Assessment of the Northern Arizona Bioscience Base: Identification of Potential Core Competency Areas

In this section we examine the specific areas of bioscience and bioscience-related activities in Northern Arizona that receive extramural funding. The volume of funding and numbers of investigators are used to indicate the most active bioscience fields in Northern Arizona's research institutions, of which Northern Arizona University in Flagstaff is the primary organization. NIH, USDA, and NSF data are used for this analysis.

The ISI citations database—a source providing detail on research "output" in terms of number of papers published, by discipline, and the average number of citations received per paper—is also used. ISI maintains a detailed database of U.S. scientific papers and associated citations, allowing Northern Arizona's academic paper output in biosciences and related disciplines to be compared with national norms and indexed for relative impact. ISI data also allows for the calculation of the relative concentration of individual bioscience fields within institutions against national norms.

These statistical sources were used to derive an overview of research core competencies and to give a more specific description of the bioscience expertise within Northern Arizona research institutions. An area is identified as a core competency area when it has the following:

- A significant number of bioscience-related research grants awarded through rigorous peer-review processes such as those at the NSF, USDA and NIH
- A broad base of principal investigators, along with prominent biomedical researchers who hold multiple peer-review grants
- A substantial level and impact of publications.

Research Core Competency Areas Suggested by Federal Funding Data

Federal R&D Funding Obligations and University Expenditures

A summary of federally funded academic R&D expenditures by agency to Northern Arizona University in 2005 reveals that the majority of funds are for activities in the life sciences, which include agricultural, biological, medical and other life science-related fields (Table 2). Of note, "other" federal agencies, including the Department of the Interior and the EPA, are the greatest providers of research dollars overall, and at $3.57 million, supported the majority of NAU's life sciences-related research. The NIH, through the Department of Health and Human Services, supported $2.93 million of life sciences-related research and the NSF, $1.96 million.

Table 2: Federally funded Academic R&D Expenditures for Northern Arizona University, by Major Field and Agency, FY 2005 ($ thousands)

Federal Agency	Total	Computer Sciences	Environ-Mental Sciences	Life Sciences	Mathem-atical Sciences	Physical Sciences	Psych-ology	Social Sciences	Other Sciences nec	Engin-eering
USDA	1,651	0	21	1,570	0	3	0	10	0	47
NSF	3,073	33	497	1,964	17	236	0	290	36	0
NASA	131	0	0	0	0	92	0	0	0	39
HHS (NIH)	3,076	0	0	2,930	0	125	21	0	0	0
DOE	882	0	208	503	0	46	0	0	0	125
DOD	817	0	0	617	0	82	0	0	0	118
Other	4,917	0	618	3,565	0	157	0	557	20	0
All federal R&D expenditures	14,547	33	1,344	11,149	17	741	21	857	56	329

Source: NSF Survey of Academic R&D Expenditures, 2005 – Tables 74-79; compilation by Battelle.

An academic bioscience research base can be thought of as the whole of agricultural, biological, medical and other life sciences along with biomedical engineering, chemistry and psychology. Agricultural and biological sciences dominated NAU's bioscience research base in 2005 (Table 3). Prescott College's bioscience research base was small, but diversified across several different subfields. Together, NAU and Prescott College's bioscience-related academic R&D expenditures are 4% of the statewide level of bioscience-related academic R&D expenditures.

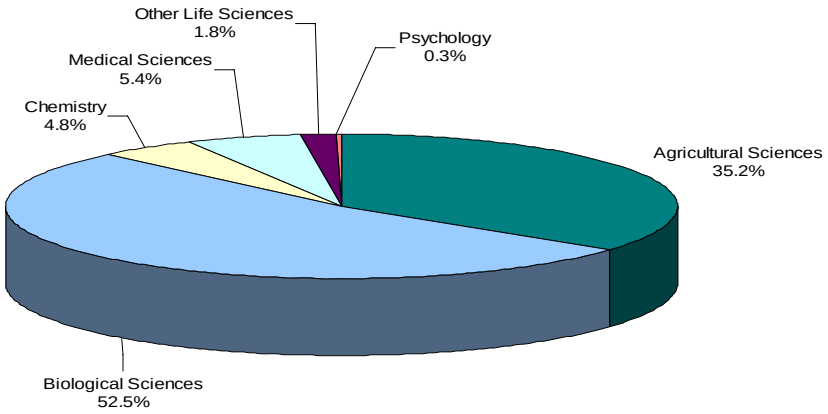
Table 3: Bioscience-related Academic R&D Expenditures for Northern Arizona University and Prescott College, 2005 ($ thousands)

Discipline	Northern Arizona University	Prescott College	Northern Arizona Region	Arizona Total	Northern Region Share of AZ
Agricultural Sciences	5,688	-	5,688	73,761	8%
Bioengineering/Biomedical Engineering	-	-	-	6,939	-
Biological Sciences	8,444	39	8,483	140,193	6%
Chemistry	749	25	774	28,016	3%
Medical Sciences	854	13	867	117,506	1%
Other Life Sciences	289	-	289	7,774	4%
Psychology	33	10	43	14,511	0%
Total for Bioscience Related	16,057	87	16,144	388,700	4%

Source: NSF Academic R&D Expenditure by Discipline, 2005; calculations by Battelle.

The distribution of expenditures suggests where a region's R&D strengths lie. 88% of Life Sciences R&D expenditures in the Northern Arizona region are contributed by just two subfields: Biological Sciences at 52.5% and Agricultural Sciences at 35.2% (Figure 1).

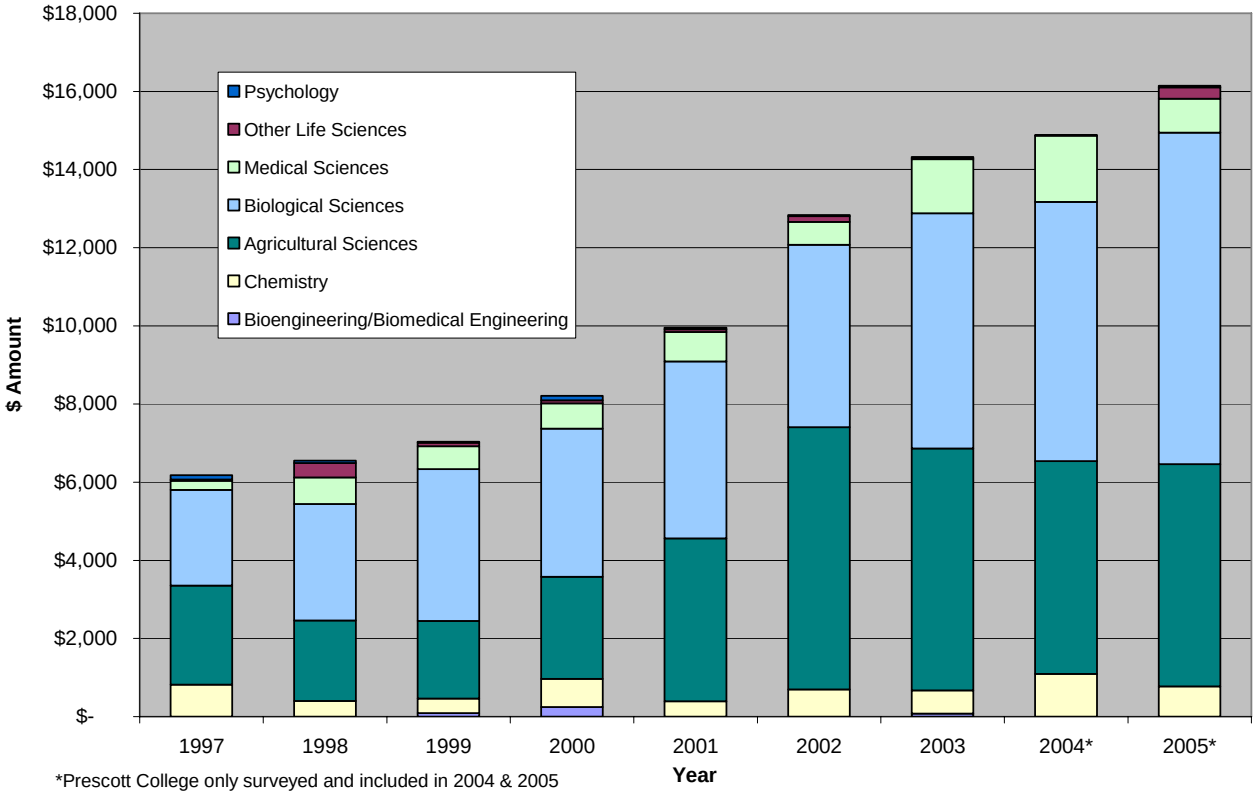
Figure 1: Distribution of Life Sciences Research Funding by Sub-fields for Northern Arizona Region, 2005



Source: NSF Academic R&D Expenditure by Discipline, 2005; calculations by Battelle.

From 1997-2005, the level of bioscience-related R&D expenditures for Northern Arizona steadily increased, at roughly 20% annually or 161% over the 8-year horizon (Figure 2). In comparison, growth in bioscience-related R&D expenditures for the nation was approximately 13% annually, or 103% from 1997 to 2005 (data not shown). In the Northern Arizona region, biological and agricultural sciences consistently dominated all other bioscience subfields.

Figure 2: Bioscience-related R&D Expenditures by Discipline for Northern Arizona Region, 1997-2005 ($ thousands)



Source: Academic R&D Expenditure by Discipline, NSF; calculations by Battelle.

Next we examine NIH, USDA and NSF funding at the department level, which suggest specific areas of research strength in Northern Arizona.

NIH Funding

The NIH is generally considered the "gold standard" of funding for biomedical research and basic biological sciences research oriented towards human biology and health sciences. From 2003-2006, three Northern Arizona organizations received NIH funding: NAU, Persyst Development Corporation and Tuba City Regional Health Care Corporation (Table 4). Of these, NAU received the majority of NIH funds with $9.5 million, primarily from the National Cancer Institute and National Institute for General Medical Sciences. Altogether, the three Northern Arizona organizations received NIH funds equivalent to 1.6% of all NIH funding received by the state for the four-year period.

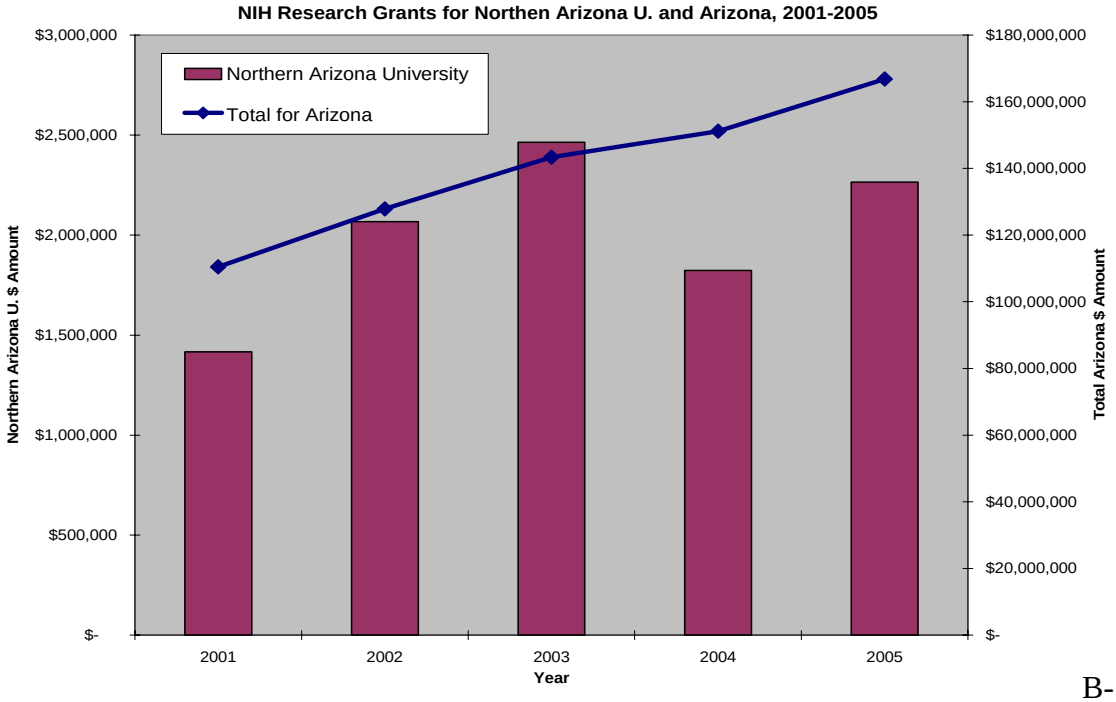
Table 4: NIH Funding by Institute to Organizations in Northern Arizona, 2003-2006

Institution	NIH Institute/Organization	# Awards	$ Amount	Share of Arizona
Northern Arizona University	National Cancer Institute (NCI)	6	4,014,079	2.2%
	General Medical Sciences (NIGMS)	11	3,902,754	8.0%
	Allergy and Infectious Diseases (NIAID)	8	1,220,901	2.6%
	Environmental Health Sciences (NIEHS)	2	233,002	1.0%
	Diabetes and Digestive and Kidney Diseases (NIDDK)	1	91,169	0.3%
Persyst Development Corp.	Neurological Disorders and Stroke (NINDS)	1	156,645	0.4%
Tuba City Regional Health Care Corp.	Dental and Craniofacial Research (NIDCR)	1	543,208	23.2%
Total for Northern AZ Region		30	10,161,758	1.6%

Source: NIH Extramural Awards by Insitution; calculations by Battelle.

From 2001 to 2005, NIH research award funding to Northern Arizona University increased from $1.4 million to $2.3 million and by an average of 20% per year (Figure 3). In comparison, nationwide NIH funding increased by an average of 10.2% per year from 2001 to 2005. Thus, NAU's NIH funding growth exceeded that of the national average. It should be noted that the university suffered a decline in NIH research funding from 2003-2004. The decline from $2.8 million to $2.2 million represented a 22% decrease, an unusual event considering the overall NIH research award funding for the nation increased by 4.7% that year (data not shown). This decline can be explained largely by 1) a decrease in the number of active, NIH-funded research awards to NAU from 6 to 5; and 2) a significant drop from 2003 to 2004 in the value of the Comprehensive NAU/AZCC Cancer Research Partnership award.

Figure 3: NIH Research Funding Levels to Northern Arizona University and Arizona, 2001-2005 ($ thousands)

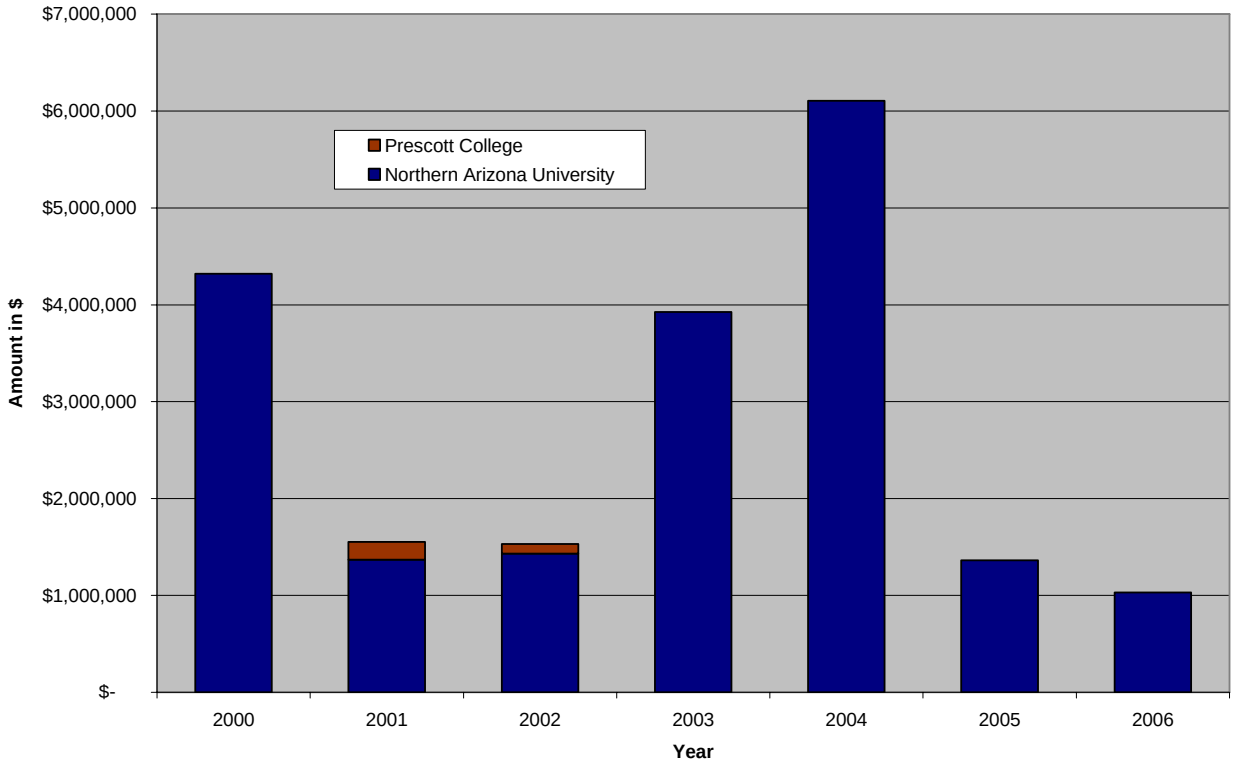


Source: NSF Funding; calculations by Battelle

NSF Biosciences Funding

Data describing active bioscience-related research awards to the academic institutions in the Northern Arizona region and their NSF-specific funding sources were obtained from the NSF website. Figure 4 reveals that NSF funding has fallen off in recent years, from a high of over $8 million in 2004 to just over $1 million in 2006. This degree of variability is largely related to the beginning and ending of a few substantial NSF grant awards.

Figure 4: Bioscience-related NSF Research Awards for Northern Arizona Region, 2000-2006



Source: NSF Funding; calculations by Battelle.

Table 5 summarizes the number and value of NSF bioscience-related research awards to the Northern Arizona region from 2000 to 2006. The primary source of R&D funding came from the NSF Directorate for Biosciences (BIO), which funds much of the nation's research on plant biology, environmental biology and biodiversity. Divisions within the BIO Directorate include the Divisions of Biological Infrastructure, Integrative Organismal Biology, Molecular and Cellular Biosciences, Behavioral and Neural Sciences, and Cellular Biosciences. Of these, the Division of Environmental Biology is the largest provider of academic research grants, with $8.1 million over the 6-year period going to NAU. The Division of Emerging Frontiers, which supports multidisciplinary research, is the second largest provider, with $6.8 million to NAU; the Division of Biological Infrastructure, which supports contemporary research in biology, research resources and human resources, is the third largest source of NSF funding with funds supporting

R&D at both NAU and Prescott College. For the 6-year period, the Northern Arizona region earned 16.8% of all bioscience-related NSF funding awarded to the state and 0.5% of all bioscience-related NSF funding for the nation. Of note, the region captured 65.4% of all Emerging Frontiers research grants awarded to the state, primarily for research in wireless sensor networks for ecosystem monitoring and ecological genomics.

Table 5: Bioscience-related NSF Research Awards for Northern Arizona Region, 2000-2006

NSF Directorate	NSF Division	Northern Arizona University	Prescott College	Arizona Totals	Northern AZ Share of AZ	Northern AZ Share of US	AZ Share of US
Biological Sciences	Biological Infrastructure	2,494,643	281,807	38,369,603	7.2%	0.3%	3.6%
	Environmental Biology	8,142,564	-	26,814,736	30.4%	1.1%	3.7%
	Integrative Organismal Biology	1,828,095	-	20,957,605	8.7%	0.3%	3.0%
	Molecular and Cellular Biosciences	57,954	-	11,531,148	0.5%	0.0%	1.5%
	Emerging Frontiers	6,812,000	-	10,422,903	65.4%	2.6%	3.9%
Engineering	Chemical, Bioengineering, Environmental, and Transports Systems	210,000	-	9,741,691	2.2%	0.0%	1.3%
Total Bioscience-related Awards		19,545,256	281,807	117,837,686	16.8%	0.5%	2.8%

Source: NSF Funding; calculations by Battelle.

USDA Biosciences Funding

USDA funding is used to support research that addresses issues in agriculture, the environment, human health, and communities. According to the USDA's CRIS database, the Northern Arizona region received 10 awards (compared to 165 projects received by the entire state) from the USDA, primarily to support research in the NAU School of Forestry (Table 6).

Table 6: USDA Awards for Northern Arizona Region, 2000-2005

Institution	Department/School	# of Grants	Total Funding
Northern Arizona University	School Of Forestry	5	$1,205,034
	Criminal Justice	1	$50,000
	Ecological Restoration Institute	1	$310,000
	Biological Sciences	1	$350,000
Prescott College	Environmental Studies	1	$36,040
Yavapai College	Agriculture	1	$23,266
Total for Northern AZ Region		10	$1,974,340
Total for Arizona		165	$45,484,698

Source: USDA; calculations by Battelle.

CORE COMPETENCY RESEARCH AREAS SUGGESTED BY ISI CITATIONS DATA

ISI provides specific insight regarding the volume of publications produced by departments and the influence, in terms of citations, that each department's work is having within its field. The ISI data contributes to an overview of where Northern Arizona University's institutional strengths in science and technology may lie.

Battelle accessed the ISI data for 2001 through 2005. In determining areas of strength within NAU's academic biosciences, the focus was on bioscience and related fields in which the university has published **at least 15 papers** that meet at least one of the following ISI indices parameters:

- The relative impact of the published papers should be **1.25 or higher**, where 1.0 equals the average impact of a U.S. paper in the field. "Relative Impact" represents the institution's citation impact in the field (number of citations its papers receive in a field divided by its total number of papers) divided by average national impact of a paper in that field. A number above 1.0 can be read as a percentage, i.e., 1.25 equates to a 25 percent higher-than-average impact, while a 0.9 impact is 10 percent lower than average.
- The papers quotient or citation quotient of **1.25 or higher** indicates a concentration of effort in the area within the institution. The ratio measures the degree of concentration in a field within an institution versus the U.S. average. A ratio of 1.0 equals the national average, while greater than 1.0 indicates a higher concentration in NAU versus the nation.

ISI data for Northern Arizona University from 2001-2005 are presented in Table 7, with variables highlighted in **red** to highlight those bioscience fields for which selection thresholds are met.

It is evident from the publications analysis that Northern Arizona University has strengths ranging from basic research to applied sciences. The majority of publications are in environmental and ecological sciences, but the relative impact of these papers is roughly equal to that of the nation. Fields with a significant relative impact are animal sciences and animal & plant sciences, suggesting that NAU produces papers in these fields that are cited more frequently than other papers in the same fields nationwide. Overall, NAU's publications have a 28% lower impact in all fields relative to that of the nation.

Table 7: ISI Bioscience Publication Data for Northern Arizona University, 2001-2005

Field	Citations	Citations Quotient	Papers > 15	Papers Quotient	Impact Relative to Field
Environment/Ecology	927	**10.83**	208	**7.85**	0.99
Plant Sciences	474	**7.88**	84	**5.79**	0.98
Earth Sciences	217	**2.31**	81	**3.12**	0.53
Animal Sciences	249	**11.70**	70	**6.64**	**1.26**
Biology	306	**5.80**	48	**4.75**	0.88
Psychology	122	**1.64**	37	**1.26**	0.93
Microbiology	289	**2.12**	29	**1.47**	1.03
Experimental Biology	148	**3.79**	24	**3.55**	0.76
Aquatic Sciences	40	**1.50**	22	**2.18**	0.49
Neurosciences & Behavior	125	0.40	22	0.50	0.57
Entomology/Pest Control	37	**3.42**	20	**3.30**	0.74

Environmental Studies, Geography & Development	34	6.22	19	4.61	0.97
Molecular Biology & Genetics	175	0.98	17	0.97	0.72
Animal & Plant Sciences	269	7.08	16	2.43	2.09
Total for All Publications	**5,361**	**1.00**	**1,119**	**1.00**	**0.72**

Source: Institute of Scientific Information; calculations by Battelle.

CORE COMPETENCY RESEARCH AREAS SUGGESTED BY ISSUED PATENTS

Battelle also investigated Northern Arizona patent data in order to identify key areas of R&D that yield intellectual property. Between 2000 and April of 2006, 126 bioscience-related patents were either invented in or assigned to the Northern Arizona region. This dataset reflects the intellectual property that was either generated in the region, brought into the region by way of purchasing rights, or both. Table 8 depicts the bioscience patent classes in which at least 3 patents were issued. The majority of patents were related to surgery and prosthesis, indicating that the region has strengths in the development of new surgical methods and products; patents related to pharmacological compositions were also common.

Table 9 depicts the inventors and/or assignees who obtained at least 3 bioscience-related patents from 2000 – 4/25/2006. Gore Enterprise Holdings of W.L Gore, a polymer and materials technology firm, holds the majority of these.

Table 8: Bioscience-related Patents Invented by or Assigned to a Northern Arizona Research Organization or Institution, by Field (2000 - 4/25/2006)

Key US Patent Class	# of Patents
Surgery	40
Prosthesis (i.e., artificial body members), parts thereof, or aids and accessories	31
Drug, bio-affecting and body treating compositions	23
Chemistry: molecular biology and microbiology	4
Optics: eye examining, vision testing and correcting	4
Measuring and testing	3
Surgery: light, thermal, and electrical application	3

Source: Analysis of USPTO patent data obtained through Delphion Patent Research Service (Thompson Corp.)

Table 9: Northern Arizona Organizations or Institutions where >3 Bioscience-related Patents were Invented or Assigned (2000 - 4/25/2006)

Organization/Institution	# of Patents
Gore Enterprise Holdings, Inc.	38
Eli Lilly and Co.	19
Ethicon Endo-Surgery, Inc.	7
W.L. Gore and Associates, Inc.	6
Visual Pathways, Inc.	3

Source: Analysis of USPTO patent data obtained through Delphion Patent Research Service (Thompson Corp.)

SUMMARY OF CORE COMPETENCY AREAS SUGGESTED BY QUANTITATIVE ANALYSIS

The quantitative data sources (grant awards, ISI publications and citations, and patents) provide insight into the R&D strengths of Northern Arizona in the biosciences and related fields. Contained within these data are broad themes that serve as "direction finders" to the state's bioscience core competencies (both broadly-based and human medicine/health-specific). Table 10 details each of the broadly-based core focus areas and expertise areas suggested by the quantitative data.

Table 10: Broadly-based Core Focus Areas Suggested by Quantitative Data

Competency Area	Publications/Citations Strength (ISI Data)	Major Funded Centers or Institutes	Notes
Environmental Sciences and Ecology	Highest number of papers, with 208 Strong publication and citations quotients	• USGS Flagstaff Science Center – Biological Science Center • Western Regional Center – National Institute for Climatic Change Research • NAU Ecological Restoration Institute • NAU Center for Sustainable Environments • Merriam Powell Center for Environmental Research	Major emphasis for Northern Arizona University and the USGS in Flagstaff. Large volume of research scientists and multi-disciplinary R&D capabilities. Limited observed industry R&D presence.
Plant Sciences	84 papers with strong publication and citation quotients	• NAU Forestry	Closely linked to environmental science and ecology subject areas
Animal Sciences	70 papers and 1.26 relative impact Strong publications and citations quotients	• NAU Physiology and Functional Morphology Research Group	Emphasis in muscle physiology, and comparative physiology using extremophile animals. Applications in physical rehabilitation and exercise technology.

The quantitative data show that Northern Arizona is particularly well resourced in terms of R&D in environmental sciences and ecology. The region is home to multiple major research centers and institutes, has a critical mass of research scientists and has a significant track record in terms of publications in environmental sciences and ecological sciences. Northern Arizona also demonstrates significant strengths in both plant sciences and animal sciences. Plant science expertise is quite strongly linked to the complementary strengths in ecology and environmental sciences, whereas animal science R&D is particularly strong in terms of animal/comparative physiology, muscle physiology and extremophile animals.

The competency areas resulting from the Northern Arizona quantitative analysis are used to direct the focus of field-work interviews for additional investigation and to identify core competencies and technology platforms.

The following section details Battelle's findings from the qualitative interview research conducted with bioscience institutions in the Northern Arizona region. Both the quantitative and qualitative findings are evaluated by Battelle experts to determine core technology platforms upon which bioscience developments may be built. The technology platforms are discussed in detail in the following sections of this document.

Qualitative Assessment of the Region's Bioscience Base: Interview and Fieldwork Findings

The analysis of grant, publishing, and research abstract data provides a context for understanding where Northern Arizona's core competencies in bioscience research are focused. To further investigate these fields and deepen our understanding of the core bioscience research competencies in Northern Arizona, extensive interviews were conducted with university administrators, faculty, scientists, clinicians, industry executives, and development agencies in the region. These interviews were essential in developing an understanding of how the data on publications, patents and grant awards translate into on-the-ground focus areas in Northern Arizona.

In total, telephone interviews and face-to-face interviews individually or in small group sessions were conducted with more than 50 individuals, including senior academic research scientists and faculty at the region's higher education institutions (predominantly Northern Arizona University) and other major R&D institutions, such as the USGS in Flagstaff. Key takeaways from these interviews and from interviews with commercial bioscience-related companies and associated industry promotion and economic development groups contributed to the identification and analysis of core competencies.

The interviews partly confirmed the areas where Northern Arizona possesses research strength that were identified in the quantitative analysis. They also highlighted several new and emerging areas of R&D and some key theme areas that were not readily apparent within the quantitative datasets. One challenge in using quantitative data is the rapid rate of change in the scientific enterprise. Peer review systems—whether used for federal grant awards, citation analysis, or in reputation rankings—tend to lag emerging new fields of inquiry, and may fail to recognize the contributions of younger and new scientific talent. Therefore, one objective of the qualitative interviews was to capture emerging areas, faculty, and fields of inquiry at Northern Arizona's research institutions.

The core content of the field interviews was synthesized and key areas of research strength and expertise were identified. Both these qualitative interviews and the quantitative research are of substantial importance in determining core competencies—they go hand-in-hand to facilitate identification of:

- Where Northern Arizona is heading in terms of building upon and leveraging its core bioscience strengths, and developing and enhancing new and emerging areas of bioscience focus
- What the current pipeline of bioscience R&D activity is within academic research institutions in the region
- Which areas of bioscience are generating patents and intellectual property that may lead to commercial opportunities for Northern Arizona

The field interviews provide information relevant to each of these question categories, but they are most important in providing an in-depth understanding of current and emerging R&D strengths and opportunities.

Based on the interviews, and in reference to the quantitative analysis, findings were organized into two basic levels:

Key R&D Strengths in which Northern Arizona has a clear presence through a significant number of well-funded researchers, scientists and/or clinician scientists working in basic, applied, or clinical research.

Additional R&D Areas of Notes in which Northern Arizona has demonstrated or emerging strengths that are more niche focused or centered on a smaller number of faculty and research professionals of activity.

Based on these general parameters, the team identified the following research competency areas:

Key R&D Strengths	Additional R&D Areas of Note
• Infectious diseases • Environmental and ecological systems • Muscle Physiology	• Bioengineering • Computational modeling of cell signaling • Native American health • Chemistry • Science education and workforce development

It should be noted that in modern biosciences it is seldom the case that an area of focus stands purely on its own. Rather, just as organisms form complex systems, bioscience itself should be viewed as a complex system of interrelated disciplines and areas of study that support and assist in the advancement of one another. It is for this reason that the NIH and similar funding organizations are focusing increasing grant-making attention on interdisciplinary institutes, centers and research teams. As such, the formation of focused interdisciplinary teams, centers and institutes should be an institutional imperative for success in accessing large-scale federal grant funding.

The team examined the main bioscience strength areas that were identified for Northern Arizona. Each of the areas was summarized in terms of:

- A definition of the field or specialty area
- A general profile of the sub-disciplinary strengths evident in the region
- Supporting quantitative statistics (where available)
- Details regarding the strengths in Northern Arizona that were identified by interviewees

Table 11: Key R&D Strength Area: Infectious Diseases

Infectious Diseases		
Overview		Infectious diseases, or communicable diseases, are caused by a biological agent such as a virus, microbe, prion or parasite. Infectious diseases impact human health but are also issues for agriculture in terms of animal and plant infectious diseases.
Competitive Position	Research Funding	2003-2006 $1.22 million in funding through the NIH National Institute for Allergy and Infectious Diseases (NIAID). Funding for infectious disease genetics spread across multiple federal agencies (NIH, NSF, DHS, DOE, FBI and DOI). Additional MMGen funding via Arizona Board of Regents
	Publications Analysis	29 papers in microbiology published between 2001-2005 with citations quotient of 2.12 and papers quotient of 1.47. 48 papers in biology with citations quotient of 5.8 and papers quotient of 4.75. 17 papers in molecular biology and genetics.
	Major Funded Centers or Programs	• Keim Genetics Lab • MGGen – Arizona Board of Regents Center for Microbial Ggenetics and Genomics • TGen North
Insights from and Niches Identified from Interviews		• The Keim Genetics Lab constitutes the top funded R&D program at NAU and has a focused emphasis on infectious disease genetics. A key focus of the program is on pathogen genetics, with emphasis on bacterial pathogens and pathogen diversity. The lab is engaged in multiple applied projects, including development of genotyping systems for bioterror agent identification. The lab is also well-resourced with new laboratory facilities and large strain libraries, useful in multiple applications such as vaccine testing. • MMGen is focused on using genomics to identify regions of genetic variation among species of interest and then using that variation to construct high-resolution and high-sensitivity arrays for the detection and characterization of these species. • TGen North, affiliated with NAU and the Keim genetics Lab, is focused on rapid disease diagnosis and pathogen detection. A key goal of TGen North is the translation of genomic analysis into advanced diagnostic devices • Other areas of R&D contained within NAU are of direct relevance to infectious disease core competencies. This includes R&D in infectious disease biofilms, together with work in identification of novel antibiotics via analysis of extremophile bacteria. Some of NAU's MEMS and sensor work may also be directly applicable to bioscience diagnostics applications.

	• Biofilm infection detection technology is a key emphasis in the infectious biofilm work. An NAU research team has been concentrating on the development of a patentable lateral flow assay to detect biofilm infections in humans. Nanotechnology is also being investigated as a tool for in vivo diagnostics and treatments related to biofilms. NAU has also been engaged in work to develop novel biofilm treatment compounds useful for medical device applications to prevent the growth of biofilms.

Technology Opportunity Examples: Infectious Diseases
• Pathogen detection and characterization technology
• Biosecurity systems
• Disease diagnostics and advanced diagnostic system and devices
• Biofilm infection detection, diagnostics and treatment technology
• Vaccine testing and development
• Novel antibiotic development and testing

Table 12: Key R&D Strength Area – Environmental and Ecological Systems

Environmental and Ecological Systems		
Overview		Ecology is the scientific study of the distribution and abundance of living organisms and how the distribution and abundance are affected by interactions between the organisms and their environment. The environment of an organism includes both physical properties, which can be described as the sum of local abiotic factors such as insolation (sunlight), climate, and geology, as well as the other organisms that share its habitat.
Competitive Position	Research Funding	$8.1 million in NSF reported funding characterized as environmental biology Total of $16 million in bioscience related academic research funding across all bioscience disciplines, including environmental/ecological. NAU School of Forestry with $1.2 million in funding from USDA, and Ecological Restoration Institute $0.31 million.
	Publications Analysis	208 papers in “environment/ecology” published between 2001-2005 with citations quotient of 10.83 and papers quotient of 7.85. 19 papers in “environmental studies, geography and development” with citations quotient of 6.22 and papers quotient of 4.61. 84 papers in “plant sciences” published between 2001-2005 with citations quotient of 7.88 and papers quotient of 5.79. 16 papers in “animal & plant sciences” with citations quotient of 7.08, a papers quotient of 2.43 and a relative impact of 2.09. 48 papers in “biology” with citations quotient of 5.8 and a papers quotient of 4.75.
	Major Funded Centers or Programs	• USGS Southwest Biological Science Center performs research for the SW USA relating to environmental processes and the management of biological resources. The Center operates four field research stations. • DOE funded 13 state climate change center at NAU – the Western Regional Center of the National Institute for Climatic Change Research. The goal of NICCR is to mobilize university researchers, from all regions of the country, in support of the climatic change research objectives of DOE/BER. • Ecological Restoration Institute performs research relating to solving the problem of unnaturally severe wildfire and degraded forest health. The ERI focuses principally on landscapes where unprecedented wildfires, insect infestations and disease outbreaks threaten ecological and human community sustainability. • Center for Sustainable Environments – CSE focuses on "sustainability science." Core programs are focused on two critical issues: reducing the impacts of food production, transport and processing on biodiversity, food security, water and energy consumption; and reducing the ecological impacts of energy use, water use and waste production associated with building, communities and transportation systems.

	• Merriam Powell Center for Environmental Research promotes interdisciplinary environmental research focused on understanding the processes required for healthy functioning ecosystems and developing strategies to assure ecosystem health and sustainability.
Insights from and Niches Identified in Interviews	Key strength areas at NAU revolve around six principal areas: • Impact of climate change on the biosphere • Ecosystem genetics and environmental molecular genetics – Work in this area is uncovering the wide-ranging impacts on ecosystem diversity stemming from changes in the genetic profile of individual species within the environment. Work is facilitated by the Environmental Genetics and Genomics Facility, a high throughput facility, providing resources for the study of plant evolution, ecological community genetics, conservation genetics, microbial diversity, molecular epidemiology and molecular forensics. • Environmental sensing and forensics – One area of focus is in development of smart wireless sensor networks for applications in environmental monitoring. This has application to ecosystems research, environmental management and precision agriculture. This work is supported by the NSF. In the forensics arena, NAU research teams are at the forefront of the use of stable isotope analysis for biological, geological and environmental sciences. • Environment and ecosystem restoration – with internal organizations such as the Bioremediation Initiative, NAU is using various bioremediation technologies and strategies to remove contamination from the environment. A major focus is being placed on restoring the natural ponderosa pine forest environment and on finding new economic uses for forest thinnings from this restoration work. • Endocrine disruptors in the environment – Work is taking place within the NAU Environmental Endocrinology Laboratory where investigations focus on the impact of environmental elements on development, reproduction and behavior. Particular emphasis is placed on man-made chemical contamination in the environment and its impact on vertebrates. There is also a special focus on endocrine disruption in women caused by uranium pollution. • Sustainable energy solutions – working towards the development of alternative sustainable energy sources. This includes work in multiple alternative energy sources, including biodiesel from algae. NAU researchers are also active in consulting related to carbon emissions and investing in technologies for the reduction of greenhouse gas emissions. Environmental and ecological sciences at NAU spread across multiple disciplines and is, perhaps, the signature R&D strength of the university. In addition to the research focus areas highlighted above NAU has distinctive expertise in: • Conservation biology and wildlife ecology.

	• Natural resources of the Colorado Plateau • Cottonwood tree ecology • Forest impacts of fluxes in CO2 and CH4 • Forestry, with an emphasis on forest health and restoration • Pinyon ecology • Plant sciences expertise at NAU is closely linked with environmental sciences. Key areas of focus include: • Plant genetics, with a particular emphasis on cottonwood/poplar tree genetics and the impact on the ecosystem of changes in the genetics of tree species. • Plant root systems and mycorrhyzae, with an emphasis on mycorrhyzae biology and beneficial plant development and growth impacts. Additional work in enhancement of positive mycorrhyzae via soil inoculant technologies. The USGS Southwest Biological Science Center undertakes research in water use and the effects of livestock grazing, wild land fires, invasive species, environmental contaminants, declining populations of native species and urban development in the Southwest region. Key R&D strength areas are in: • Soil ecology • Adaptive management • Wildlife ecology • Threatened and endangered species ecology • Riparian ecology of the southwest • Sediment transport and hydrology (and its effects on biological systems)

Technology Opportunity Examples: Environmental and Ecological Systems
• Environmental restoration and remediation technologies
• Environmental monitoring and sensing systems
• Environmental testing and certification tools and services
• Economic opportunities from forest resources
• Forensics tools and technologies
• Inoculants technologies for soil and plant improvement
• Plant engineering for phytoremediation applications
• Transgenic and modified plant testing and certification tools and services

Table 13: Key R&D Strength Area – Muscle Physiology

Muscle Physiology		
Overview		Physiology is the branch of biology that deals with the functions and activities of life or of living matter (as organs, tissues, or cells) and of the physical and chemical phenomena involved. It involves the organic processes and phenomena of an organism or any of its parts or of a particular bodily process. Muscle physiology specifically addresses the function of muscles.
Competitive Position	Research Funding	$1.8 million in NSF funding to NAU via NSF division of Integrative Organismal Biology. Multiple NIH grants to physiology researchers at NAU. Two grants recently awarded through Science Foundation Arizona
	Publications Analysis	No data
	Major Funded Centers or Programs	• NAU Physiology and Functional Morphology Research Group
Insights from and Niches Identified in Interviews		• NIH funding in muscle extension research and associated physical rehabilitation applications and technology. Work in this area has resulted in the development of eccentric muscle exercise devices and the creation of a spin-out company to commercialize the technology. • Analysis of neuromechanics examining the coordination of movement between muscles, senses and the brain. The goal here is to elucidate mechanisms that may be at work in abnormal motor control such as occur with neuromuscular diseases. • Analysis of extremophile animals for comparative physiology • Advanced R&D relating to muscles as storage systems for recoil potential energy. NAU has 15 faculty conducting work in physiology and functional morphology. There is a clinical research relationship with the University of Arizona Physiology Department.

Technology Opportunity Examples: Muscle Physiology
• Rehabilitation technology • Exercise technology • Diagnostics and therapeutics • Interventions in muscular dysfunction (such as muscular dystrophy) and root causes.

Table 14: Area of Note – Bioengineering

Bioengineering		
Overview		Bioengineering (also called biosystems engineering and biological engineering) deals with engineering biological processes in general. It is a broad-based engineering discipline that also may involve product design, sustainability and analysis of biological systems. Generally, bioengineering may deal with either the medical or the agricultural fields, but it is increasingly relevant to other fields such as chemicals and renewable energy development. Because other engineering disciplines overlap bioengineering living organisms (e.g., prosthetics in mechanical engineering), the term can be applied more broadly to include food engineering and biotechnology.
Competitive Position	Research Funding	$0.3 million in federal R&D funding for academic based engineering R&D at NAU. Major proprietary research budgets at northern Arizona based biomedical device and materials companies such as Gore.
	Publications Analysis	No data
	Major Funded Centers or Programs	• Major industry presence with significant R&D and patent activity taking place within companies, particularly Gore. • Contained within individual faculty laboratories at NAU.
Insights from and Niches Identified in Interviews		• Engineering of biocompatible materials and surgical products is a major focus within the flagstaff economy. • MEMS/nano based chemical and biological microsensors are a distinctive area of expertise and opportunity at NAU. A key invention has come through the development of piezoresistive Si microcantilevers—inexpensive and robust devices with multiple potential applications in the detection of gases, chemicals in the environment and biological agents and organisms. • Additional nanotechnology work is taking place in the Biochemical Nanotechnology Laboratory with a particular emphasis on the development of nanoparticles based rapid assays and associated technologies. Applications include nanoparticles-based products for testing for the presence of chemicals and biological organisms and for the delivery of drugs. NAU has a new master's degree program in engineering with plans under consideration to incorporate a bioengineering track.

Technology Opportunity Examples: Bioengineering
• Biocompatible materials
• Surgical equipment, tools and technologies
• Implantable biosensor devices and diagnostic technologies
• Biosecurity sensing devices
• Nanotechnology-based rapid assay/diagnostic technologies and drug delivery systems.

Table 15: Area of Note – Computational Modeling of Biological Systems

Computational Modeling		
Overview		This comprises computationally-supported investigative technique that uses a mathematical or physical representation of a system or theory that accounts for all or some of its known properties. Models are often used to test the effects of changes of system components on the overall performance of the system.
Competitive Position	Research Funding	No specific data
	Publications Analysis	No specific ISI category
	Major Funded Centers or Programs	Contained within individual faculty laboratories. Active collaborations with TGen and Los Alamos National Laboratory.
Insights from and Niches Identified in Interviews		• NIH RO1 in modeling of cancer cell signaling. NAU has R01 funded research in computational modeling of cell signaling networks. Have developed a new technology using a rules based software program to analyze networks with massive state counts. Multifunctional signaling networks are involved in many diseases, including cancer and it is the complexity of the networks and pathways that lead to the need for complex therapeutics combinations. The team is in early talks with pharma companies about the technology and is considering setting up a company in the northern Arizona incubator. • Expertise at NAU in the development of rule based approaches for modeling signal transduction systems that incorporate combinatorial complexity. This type of modeling modality is gaining significant interest in regards to applications in drug discovery because understanding the dynamics of signaling pathways will allow detailed predictions to be made regarding the effect of blocking a particular point in the signaling cascade. • Reverse engineering of genetic regulatory networks. This work integrates tools and concepts from computer logic, probabilistic inference, and systems biology to develop a general framework for reverse engineering of functional genetic modules directly from time-course microarray gene expression data. • Mathematical modeling and simulation of cell signaling and signal transduction is also being pursued at NAU in NIH/NSF funded research relating to chemoreceptors and the respiratory system.

Technology Opportunity Examples: Computational Modeling of Biological Systems
• Computer software and modeling systems • Drug target identification and drug discovery

Table 16: Area of Note – Native American Health

Native American Health		
Overview		Native American refers to peoples indigenous to the Americas, living there prior to European colonization. In the case of Northern Arizona the principal groups include the Hopi and Navajo nations, together with the Hualapai and Havasupai tribes. Arizona contains 21 federally recognized native American tribes.
Competitive Position	Research Funding	$7.25 million for Native American Cancer Research Partnership.
	Publications Analysis	No specific data
	Major Funded Centers or Programs	• The Native American Cancer Research Partnership (NACRP) – this is a $7.25 million collaboration between NAU and the Arizona Cancer Center funded through the National Cancer Institute. Research is focused on reducing the disparity in cancer incidence and mortality in Native Americans.
Insights from and Niches Identified in Interviews		• NCI funding in Native American cancers and environmental contamination Key elements of bioscience research relating to Native Americans link to both the environmental research strength area at NAU, and also into the statewide cancer platform.

Technology Opportunity Examples: Native American Health
• Cancer prevention
• Cancer screening and diagnostics
• Environmental assessment and screening technologies
• Environmental remediation and restoration technologies

Table 17: Area of Note – Chemistry

Chemistry		
Overview		Discipline of Science dealing with the composition of substances, and of their effects upon one another. Organic chemistry deals with the numerous compounds of carbon, Inorganic of all other elements. Biochemistry deals with the chemical problems of living things.
Competitive Position	Research Funding	NAU academic R&D activity in "chemistry" funded at $0.75 million
	Publications Analysis	No ISI strength identified
	Major Funded Centers or Programs	• Contained within individual faculty laboratories.
Insights from and Niches Identified in Interviews		• Notable focus on small molecule G-quadriplexes, P53 proteins, and basic synthetic chemistry (for application to drug development, peptides and diagnostic imaging agents). A particular focus of the work is on cancer drug discovery in collaboration with laboratories at the University of Arizona.

Technology Opportunity Examples: Chemistry
• Drug development
• Imaging agent development
• Biotechnology

Table 18: Area of Note – Science Education and Workforce Development

Science Education and Workforce Development	
Overview	NAU places a heavy emphasis on undergraduate education and specifically integrates undergraduates in the College of Engineering and Natural Sciences into research programs on campus. Through exposure to research activity, NAU trained scientists and engineers are better prepared for entering the workforce in their respective disciplines.
Insights from and Niches Identified in Interviews	• Major contributions for Arizona workforce development through undergraduate science education with a strong integration of science and engineering students in formal research projects. • NAU holds annual celebration of undergraduate research.

FROM RESEARCH CORE COMPETENCIES TO COMMERCIALIZATION -- ACTIVITIES IN TECHNOLOGY COMMERCIALIZATION

As seen above, Northern Arizona has strengths in multiple research and development areas that have significant potential for technology development and commercialization. As home to a small base of biomedical device, materials and associated technology companies, Northern Arizona is already producing commercializable intellectual property, as evidenced by the following patent activity between 2000 and 2006:

- Gore Enterprise Holdings, Inc. – 38 patents
- Eli Lilly & Company – 19 patents
- Ethicon Endo-Surgery, Inc. – 7 patents
- W.L. Gore and Associates, Inc. – 6
- Visual Pathways, Inc. – 3

Within the Northern Arizona academic R&D sector innovation is also leading to commercialization of new technologies. Battelle's interviews with NAU R&D teams, for example, identified several areas producing new business ventures, including:

- Chemical sterilization technologies for animal applications
- Software for computational cell signaling network monitoring
- Piezoresistive MEMS cantilevers and sensors
- Exercise equipment for physical rehabilitation applications
- Carbon cycle and carbon sequestration technologies and consulting services
- Environmental and veterinary diagnostics
- Cancer drug targets.

SUMMARY

Tables 11 to 18 provide insight into the bioscience areas of focus and core competencies within Northern Arizona. Conclusions regarding these strengths and competencies are incorporated, together with the findings of the quantitative analysis, to develop and refine "technology platforms" upon which a bioscience economy may be further built in Northern Arizona. The recommended technology platforms and the research core competencies to leverage in building them are discussed in detail in the following section.

Technology Platforms, Products and Market Niches for Northern Arizona

Background on Technology Platforms

The purpose of identifying a region's research strengths and core competencies is to be able to identify strategic areas of focus that offer the greatest opportunity for near term development—Battelle uses the term "technology platforms" to describe these.

Technology platforms serve as a bridge between research core competencies and their use in commercial applications and products. As such, platforms are highly translational in nature—working to facilitate strong directional movement of ideas and innovations from basic science discoveries through to applied technologies and practices.

The technology platform process can be understood through a systems approach in which innovations flow from core competencies resident in a region's research institutions, via the platforms, to commercial products, which then find their way into markets. These technology platforms are intended to be robust and evergreen and to integrate several of the core competencies to produce a continuous flow of innovative, and perhaps disruptive, technologies or products. Platforms also serve as a forum for building strong interactions and relationships between academic researchers and their counterparts in industry.

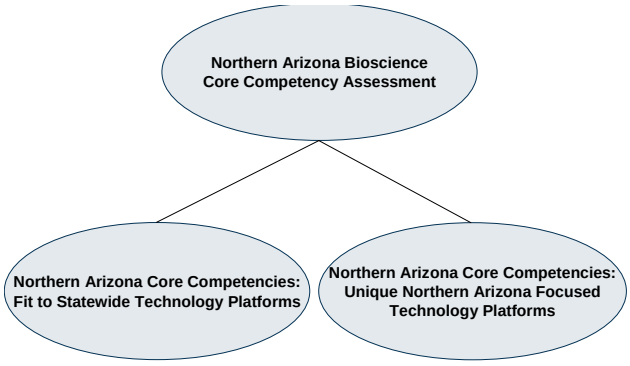
The areas of greatest opportunity for developing technology platforms are those in which a region has;

- Existing research strengths
- Commercial activity emerging or established within the region with genuine opportunity to create a base for business in the near future
- Distinct opportunities to leverage the region's comparative advantages to create competitive marketplace advantages
- Significant product market potential
- Links to, or reinforcements of, other bioscience strengths and core research competencies, thereby helping to enhance other fields as a platform expands.

The Arizona Statewide Technology Platforms

Previous work by Battelle for the Flinn Foundation has identified Arizona statewide bioscience technology platforms, and much progress has been made in advancing development in the state along these platform pathways. Because of this, the assessment of Northern Arizona core competencies investigated both the core competencies and associated platforms that are uniquely Northern Arizona focused, and the

Figure 5: Methodology for Identifying Northern Arizona's Technology Platforms



core competency contributions of Northern Arizona for linkage to statewide platforms. See Figure 5.

The statewide technology platforms identified in prior Battelle work included the following:

Near-Term Platforms	Mid-Term Platforms	Cross-Cutting Platforms
• Cancer • Neurosciences • Bioengineering	• Asthma • BioAgriculture • Infectious Diseases • Diabetes	• Bioimaging • Translational • Tissue

Analysis of the bioscience R&D core competencies at Northern Arizona research institutions shows that the Northern Arizona region plays an important contributory role in most of the ten statewide technology platforms.

Northern Arizona plays an important contributory role in the Cancer, Bioengineering, Bioagriculture and Infectious Diseases statewide platforms.

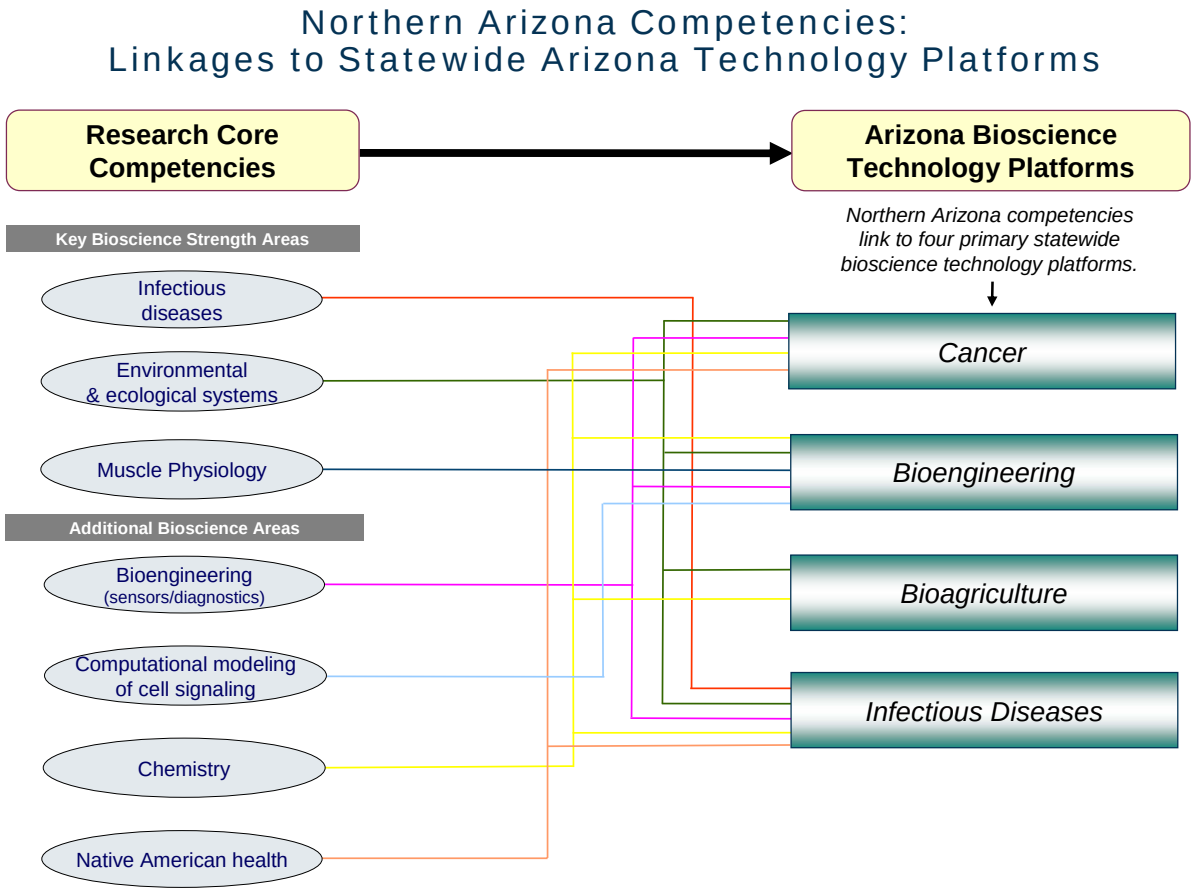
Figure 6: Northern Arizona Contributions to Arizona's Statewide Bioscience Platforms

- Statewide Arizona Biosciences Roadmap platforms:
  - **Near Term**
    - Cancer (Therapeutics) → **Northern Arizona contributor**
    - Bioengineering → **Northern Arizona contributor**
    - Neurosciences → *Northern Arizona moderate involvement*
  - **Mid Term**
    - Asthma → *Northern Arizona moderate involvement*
    - Bioagriculture → **Northern Arizona contributor**
    - Infectious Diseases → **Northern Arizona contributor**
    - Diabetes → *Northern Arizona moderate involvement*
  - **Cross Cutting**
    - Bioimaging → *Northern Arizona moderate involvement*
    - Translational → *Northern Arizona moderate involvement*
    - Tissue → *Northern Arizona moderate involvement*

Translating Northern Arizona Core Competencies into Technology Platforms

As previous chapters show, Northern Arizona is a base for multiple areas of notable bioscience R&D core competencies. These core competencies are summarized on Figure 7 (showing connectivity between Northern Arizona core competencies and related statewide bioscience platforms) and Figure 8 which shows connectivity to specific bioscience development platforms for Northern Arizona identified via the Battelle analysis. Translating R&D strengths into platforms requires understanding the cross-disciplinary relationships and connections that exist upon which broad-based platforms can be built.

Figure 7: Relationship of Northern Arizona Core Competencies and Statewide Bioscience Platforms



It can be seen from Figure 8, that in addition to the Northern Arizona core competencies that link directly to four of the ten existing statewide technology platforms, core competencies also suggest the development of two Northern Arizona-specific technology platforms comprising:

- Diagnostics Technology
- Environmental Technology

These represent platforms where most (but not all) Arizona activity is strongly focused within the Northern Arizona University, and which present potential opportunities for technology-based economic development to occur in the Flagstaff region.

The technology platforms represent the base from which a significant R&D, business base, and bioscience economy may be built. They each specifically draw upon the Northern Arizona region's institutional expertise in multiple fields, since it is multidisciplinary research that is increasingly gaining importance in driving new study areas, technologies, and commercializable innovations and discoveries. The assembly of multidisciplinary platforms is also likely to increase the opportunity for winning federal agency grant awards.

Figure 8: Northern Arizona Bioscience Technology Platforms

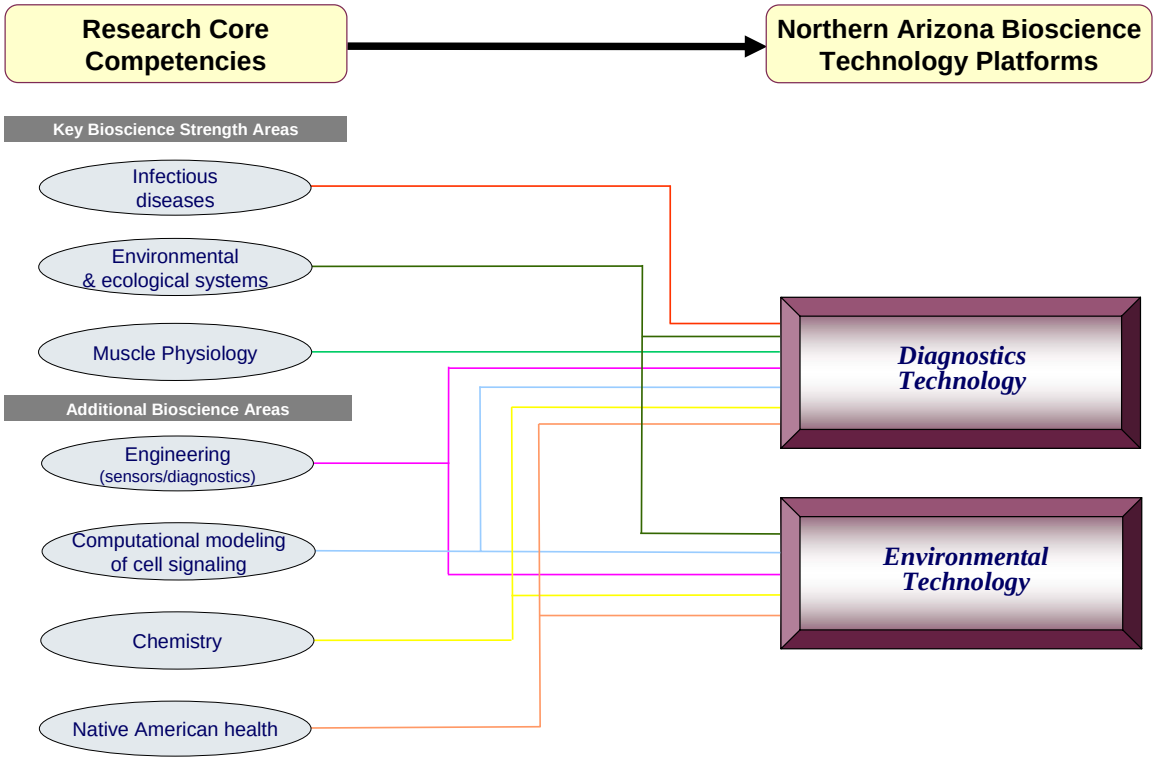


Figure 8 shows how the Northern Arizona region's bioscience research strengths, determined through both quantitative and qualitative analyses, lead to the recommended technology platforms. Each of the Northern-Arizona specific platforms is discussed in following narratives. Each narrative includes a figure designed to show the specific linkages between the quantitatively based and qualitatively based core competency disciplines and recommended platforms and opportunity areas. The figures graphically illustrate the way in which these platforms are reinforced by the R&D talent across disciplines within Northern Arizona.

Overview of Northern Arizona-Specific Platforms

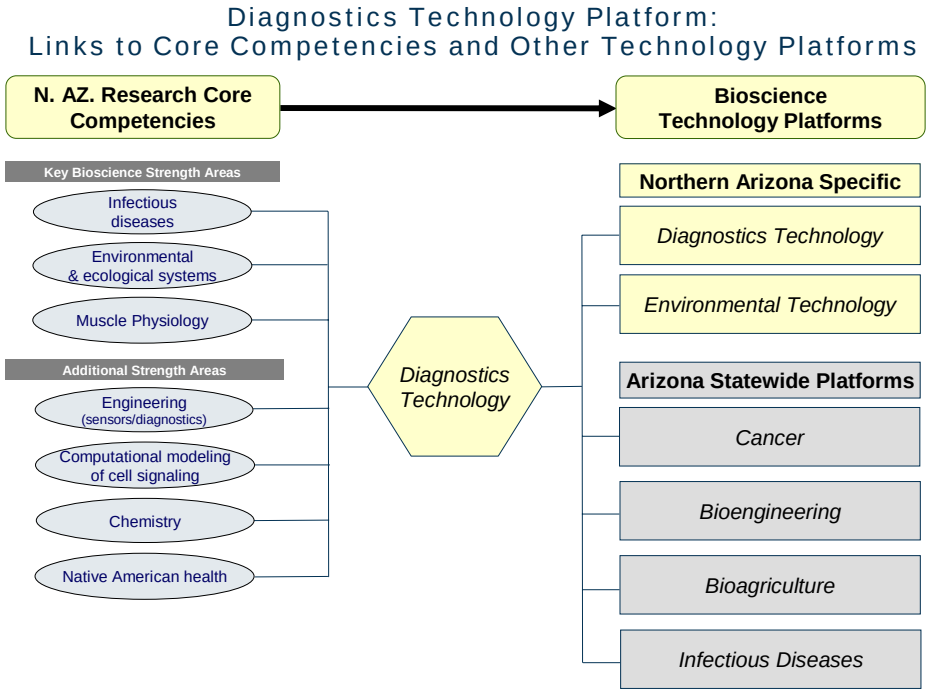
Diagnostics Technology

Within the Northern Arizona research community expertise in several disciplines is coming together to provide significant opportunities for technology development in advanced diagnostics technology. See Figure 9. The skills of Northern Arizona research scientists in the following areas, for example, provide a basis for interdisciplinary work in advanced diagnostics technologies and tools for multiple human, animal, plant, environmental and national biosecurity applications:

- MEMS and nano sensor engineering
- Molecular target identification through advanced genomic analysis (Northern Arizona expertise can be applied to multiple human biomedical, plant, animal and environmental genomic analysis areas).
- Infectious disease agent genomics and strain characterization.

Northern Arizona's niche could well be in the development of micro and nano sensor devices and sensor networks designed to provide rapid characterization of pathogens or other biological agents likely to impact human health, agriculture and the environment. This is a development pathway that is already being built in Northern Arizona through the investments in TGen-North and the Keim Genetics Laboratory and can be naturally extended through building linkages to engineering and bioengineering sciences for device development based on biomarker discovery.

Figure 9: Linkages Diagnostics Technology Platform and Core Competencies and Other Bioscience Technology Platforms



It should be noted that there has been considerable investment across multiple Arizona higher education and research institutions in defining disease at the molecular level, which is now being translated into identification of molecular biomarkers. In the recently completed Southern Arizona bioscience development strategy it was suggested that the University of Arizona could focus on the development of molecular therapeutics building upon this Arizona investment. For Northern Arizona, the opportunity lies in the no less important and synergistic area of diagnostics development.

For Northern Arizona potential technology from this platform may range from basic nano-cantilever based biodetection devices providing diagnostics of the presence of a particular chemical or biological agent or pathogen, through to complex biosecurity sensor networks

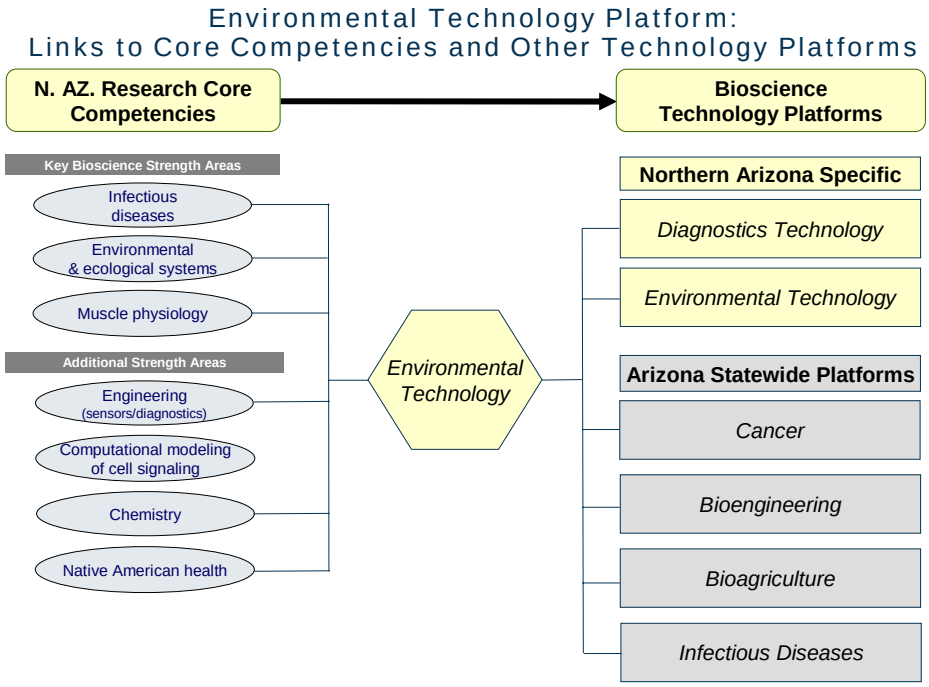
providing real time monitoring of agrosecurity, human health security and environmental conditions.

Advanced diagnostics and sensing technologies represent a highly logical platform for northern Arizona tying together key strengths across multiple biological, biomedical, environmental and engineering strength areas.

Environmental Technology

Northern Arizona has a distinctive cluster of faculty, scientists and technologists working in ecological and environmental fields. Key clusters of expertise are found within the academic research community, most notably at Northern Arizona University, and within federal biological sciences research laboratories operated by the USGS in Flagstaff. Expertise extends from basic science investigations of genetics through to highly applied projects in environmental protection, remediation and restoration. See Figure 10.

Figure 10 : Links Between Environmental Technology Platform and Core Competencies and Other Platforms



R&D skills in ecological and environmental systems show potential for the development of interdisciplinary teams dedicated to the development of technology for a range of applications. Key categories representing platform development opportunities include:

- Environmental Sensing and Monitoring Technology – Northern Arizona expertise ranges from macro global climate change assessment through to the micro remote monitoring of individual ecosystem characteristics (such as daily monitoring of sediment suspension in the Colorado River. Because of this breadth of knowledge and expertise, Northern Arizona research teams are well positioned to work on the development of robust sensing and monitoring devices, controls, systems and networks designed to provide real-time evaluation of environmental and ecological system conditions. Such systems and technologies would

have broad applications to needs in biosecurity, ecosystem security, contamination detection, and long-term climate change monitoring.

- Environmental Testing and Certification Technology – Modern advances in genetics and biotechnology are facilitating the development of new plant varieties (and potentially chimeric species) with unknown potential ecological impacts and consequences. Northern Arizona scientists demonstrate significant expertise in holistic evaluation of the ecological impacts of introducing species with new or altered genetic profiles into existing ecosystems. A range of technologies and services may be envisioned for providing testing and certification of genetically altered biological organisms before they are allowed to be released into non-sterile applications.

- Environmental Restoration Technologies – Mankind has had a tremendous impact on the natural environment. Industrialization, natural and mineral resource extraction and urbanization activities have dramatically altered the American landscape and released considerable levels of contaminants into the environment. The clean-up and restoration of America's environment and individual ecosystems is a clear priority for national and state governments and there is considerable economic opportunity for technologies and services dedicated to these tasks. Within Northern Arizona there are research teams specifically dedicated to R&D focused on contamination effects, environmental remediation and ecosystem restoration—with considerable opportunity for the development of commercializable technologies and economic opportunity.

- Sustainable Natural Resource Utilization– Restoration of SW US ecosystems will require the removal of large amounts of biomass that have accumulated particularly in forested areas. Northern Arizona scientists are at the forefront in research dedicated to finding and developing economic opportunities from biomass through applications in bio-based materials, biocomposite materials and other wood/biomass based products.

Realizing the potential for this platform will require closer collaboration between academic and federal research teams in the Flagstaff area. In addition there is considerable R&D expertise in environmental and ecological sciences contained in the University of Arizona and Arizona State University which should be leveraged for the benefit of developing integrated environmental and ecological technology platform teams.

NORTHERN ARIZONA CONTRIBUTIONS TO STATEWIDE PLATFORMS

Previous Battelle reports have profiled conclusions and recommendations regarding statewide bioscience platforms for Arizona. Readers are referred to those prior reports (available on the Flinn Foundation website) for detailed platform information. In this report for the Northern Arizona Steering Committee, the focus is on outlining the particular areas of R&D focus, within Northern Arizona institutions, that directly relate to the statewide platforms. Based on the review of quantitative data, and in-depth interviews conducted with research leaders in the potential platform areas, the following platform focus areas are key strengths for Northern Arizona:

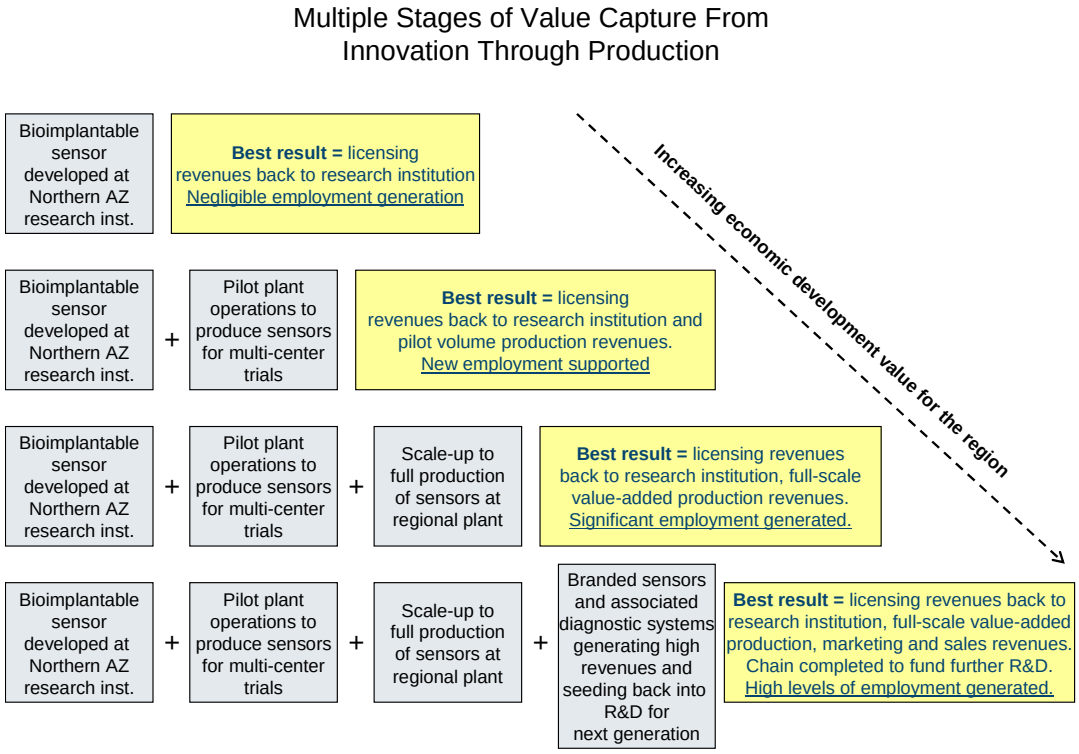
Table 19: Technology Platform Linkages from Core Competencies to Markets

Statewide Platform	Northern Arizona Engaged Institutions	Key Contributions and Focus Areas
Cancer	NAU	NAU chemistry focused on cancer drug discovery in collaboration with laboratories at the University of Arizona. The Native American Cancer Research Partnership (NCI funded). Research focused on reducing cancer incidence and mortality in Native Americans. Cell signaling and cell signal computational modeling relevant to cancer modeling at NAU
Bioengineering	Flagstaff Industry NAU	Major device/biomaterials commercial sector in Flagstaff Nanotechnology based R&D at NAU relevant to drug delivery systems Micro sensor development for implantable diagnostics at NAU Engineering of physical rehabilitation and exercise equipment at NAU via muscle physiology research.
Bioagriculture	NAU	Forestry research Plant/crop genetics Plant root system and associated mycorrhyzae system improvement
Infectious Diseases	NAU USGS	Pathogen genetics at NAU/TGen North Pathogen characterization and rapid diagnostics at NAU/Tgen North Biofilm detection and control Infectious disease carrying vector control in the environment at USGS Novel antibiotic discovery at NAU
Sustainable Systems		Note: This is an Arizona development platform separate from the bioscience platform initiatives. The core competencies and research capabilities highlighted under the environmental technology platform are directly relevant to the statewide sustainable systems platform.

MARKET ANALYSIS

The ultimate goal for the Northern Arizona region in supporting the development of bioscience platforms is economic development. R&D, in and of itself, ***is*** economic development in that millions of dollars flow into the region each year from federal and other external funding sources to support research. These dollars, in turn, create jobs and income for persons in the Flagstaff area in, and related to, the R&D sector. The goal of technology-based economic development, however, is to move into an integrated model whereby local research feeds a local commercialization and production cluster, thereby capturing increased value-added economic gains for the region from its R&D work. Figure __ shows the increasing returns to commercial development of bioscience R&D into full-scale production of bioproducts.

Figure 11: Increasing Economic Returns through Production of Bioproducts



Given the increasing regional economic returns through the commercialization of R&D innovations it is highly important that the development of platforms be made with an eye to markets and commercialization opportunities related to each platform. Tables __ through __ serve to integrate R&D strength areas with applications and potential products and general market characteristics. It is evident that each of the platform focus areas addresses multi-billion markets, providing considerable opportunity for growing the Northern Arizona regional bioscience economy around these core competencies.

Table 20: Technology Platform Linkages from Core Competencies to Markets.

Northern Arizona Specific Bioscience Platforms

N. AZ. Basic Research	N. AZ. Enabling Technology	Technology Platform	Applications and Products	Markets
Molecular genetics Microbiology Chemistry	Bioengineering Nanotechnology and MEMS technology	**Diagnostics Technology**	Biosecurity products Disease diagnostics technology and tools Sensors, nanotechnology and MEMS devices	• Molecular diagnostics markets overlap with markets for non-molecular diagnostic technologies in the in vitro diagnostic market and are less well defined than those for pharmaceuticals. In the year 2005, the global market for molecular diagnostics was worth $6.5 billion, representing approximately 3.3% of the total diagnostics market and approximately 14% of the in vitro diagnostic market. (source: Jain PharmaBiotech 2006) • The molecular diagnostics market will expand to $12 billion by 2010 and $35 billion by 2015. A major portion of it can be attributed to advances in genomics and proteomics. Biochip and nanobiotechnology are expected to make a significant contribution to the growth of molecular diagnostics. (source: Jain PharmaBiotech 2006) • Fuji-Keizei USA specifically examined the biosensor market and estimates that the market size for worldwide biosensors at year end 2003 was about $7.3 billion. They project a growth rate of 10.4% to $10.8 billion in 2007.

N. AZ. Basic Research	N. AZ. Enabling Technology	Technology Platform	Applications and Products	Markets
Plant sciences Environmental and Ecological Sciences Genetics and Genomics Forestry	High throughput genomic analysis Stable isotope analysis	**Environmental Technology**	Environmental restoration and remediation technology Monitoring and sensing systems Testing and certification tools and services Forensics technology Novel products from natural resources	• The global market for environmental products and services is worth about $520 billion per year. At approximately $205 billion, the U.S. represents 39 percent of the global revenues and ranks number one in the world. It is almost twice the size of its nearest competitor, Japan. Last year, U.S. exports of environmental technology goods and services topped $21 billion, producing a positive trade balance of $10 billion and creating about 170,000 jobs. (source: National Defense Industry Association) • The $453billion global environmental market is growing faster than the global economy and is outpacing growth in the US environmental market. (source: US National Defense University) • Fuji-Keizei USA specifically examined the biosensor market and estimates that the market size for worldwide biosensors at year end 2003 was about $7.3 billion. They project a growth rate of 10.4% to $10.8 billion in 2007. • The world carbon trading emissions market expanded to nearly $21.5 billion in the first nine months of 2006, up from about $11 billion for all of 2005 (source: World Bank) • Phytoremediation is applicable to a number of hazardous waste and other remedial scenarios, which offer sizable potential markets. Markets for remediation of organics, metals and radionuclides from soils and water, combined with municipal and industrial wastewater treatment markets, the treatment of polluted runoff, primarily including landfill leachate, and the market for removing inorganic contaminants such as nitrate from drinking water supplies, offer a total potential market size of U.S. $33.8-49.7 billion per year. (source: D. Glass Associates)

Statewide Platforms

N. AZ. Basic Research	N. AZ. Enabling Technology	Technology Platform	Applications and Products	Markets
Molecular biology Cell signaling	Computational modeling	**Cancer**	Drugs Biologics Diagnostics	• The market for cancer treatments in the United States is currently $1.65 billion and is growing by 10% per annum. • The oncology treatment sector is worth an estimated $35 billion worldwide (2004), and Datamonitor projects this to grow to $60 billion by 2008, yielding a compound annual growth rate of 8% over this period • In 2004, the top 20 cancer drugs in each of the seven major pharmaceutical markets generated combined sales exceeding $27 billion. • The American Cancer Society tracks new cancer cases on an annual basis and shows that in 2004 almost 1.4 million new cases of cancer occurred in Americans • A point in time estimate conducted by the National Cancer Institute in 2000 calculated that 9.6 million Americans had diagnosed cancer(s) at that time • WHO reported in 2000 that global cancer rates are expected to increase 50 percent by the year 2020. Over 22 million people in the world were treated for cancer in 2000.

N. AZ. Basic Research	N. AZ. Enabling Technology	Technology Platform	Applications and Products	Markets
Engineering	Sensor technology Nanotechnology and MEMS Biomaterials and biocompatible materials	**Bioengineering**	Engineered tissue and organ systems Biomaterials and bio-compatible materials Implantable medical devices Non invasive biomedical devices and instrumentation Drug and therapeutics delivery systems Sensors, nanotechnology and MEMS materials and devices	• The current world market for replacement organ therapies is in excess of $350 billion, and the projected U.S. market for regenerative medicine is estimated at $100 billion. (source: US Dept of Health and Human Services) • Biocompatible materials used in implantable medical devices currently comprise a $1 billion market. While the implantable device market itself is a global $50 billion industry. Current major materials, including medical-grade polymers, metals, advanced ceramics, pyrolytic carbon, composites, and natural materials. End-use devices include implants, valves, grafts, pacemakers, bone repair and replacement devices, artificial organs, dental materials, drug-delivery systems, dialysis/separation/filtration systems, and catheters and stents. (source: BCC Research). • Nanomaterials accounted for $9.4 billion in 2005 and over $10.5 billion in 2006, growing to about $25.2 billion by 2011 (an AAGR of 19.1% between 2006 and 2011). (source: electonics.ca publications). • Fuji-Keizei USA specifically examined the biosensor market and estimates that the market size for worldwide biosensors at year end 2003 was about $7.3 billion. They project a growth rate of 10.4% to $10.8 billion in 2007.

N. AZ. Basic Research	N. AZ. Enabling Technology	Technology Platform	Applications and Products	Markets
Plant biology Genetics and Genomics Soil Science		**Bioagriculture**	Improved crop plants Transgenic plants Functional foods and nutraceuticals Plant produced pharmaceuticals and chemicals	• The worldwide market for agricultural biotechnology currently stands at approximately $2.2 billion. (source: Bharat Research) • World demand for transgenic seeds will grow 12 percent annually through 2006. The US, Argentina, Canada and China will continue to dominate transgenic crop cultivation. Genetically modified (GM) soybeans, corn and cotton will remain the leading seeds, with GM rice to be introduced in 2003 and expected to reach US$1.3 billion in sales by 2011. (source: Bharat Research) • In 2003, the global market value of GM crops is estimated to be $4.50 to $4.75 billion, having increased from $4.0 billion in 2002 when it represented 15% of the $31 billion global crop protection market and 13% of the $30 billion global commercial seed market. The market value of the global transgenic crop market is based on the sale price of transgenic seed plus any technology fees that apply. The global value of the GM crop market is projected at $5 billion or more, for 2005. (source: International Service for the Acquisition of Agri-biotech Applications) • Biomass for energy applications is likely to grow considerably as a response to unstable international oil prices. According to Frost & Sullivan Research, demand for biomass energy, raw materials and services exceeded $3.4 billion in 2005. • In 2003 biomass was the leading source of renewable energy in the United States, providing 2.9 Quadrillion Btu of energy. Biomass was the source for 47% of all renewable energy or 4% of the total energy produced in the United States. (Source: US Dept of Energy) • BioPharming (the production of drugs via plant pathways) is expected, within the next 8 years, to have significantly impacted production of therapeutic biologics in development and on the market. Over this time period, BioPharming is expected to grow into a $100 billion to $125 billion production industry. Newer developments made possible by biopharming may be responsible for a further 15% expansion of the market to $140 billion in 2010. (source: Theta Reports)

N. AZ. Basic Research	N. AZ. Enabling Technology	Technology Platform	Applications and Products	Markets
Genetics & Genomics Pathogen and Microbial Genetics Biofilms	Micro Array Technology	**Infectious Diseases**	Drugs Biologics Diagnostics Vaccines Biosecurity Antibiotics	• In the United States two of the ten leading causes of death are infectious diseases (HIV and pneumonia/influenza). The Centers for Disease Control and Prevention (CDC) reports that 160,000 Americans die each year with an infectious disease as the underlying cause of death • When all infectious disease treatment costs, and lost productivity associated with illness, are taken into account it is estimated that the annual cost of infectious agents in the US is greater than $120 billion each year. • Opportunities exist across multiple product categories including: disease diagnostics; vaccines; antibiotics; vector repellants and devices (including drug and vaccine delivery systems, and even simple devices such as bed nets to prevent malaria). • Prophylactic vaccines are currently valued at between $5 and 7 billion, and are expected to show a compound annual growth rate of between 9% and 11%. • The total world market for antibiotics in 2002 was estimated at over $26 billion. Total market growth rate is predicted to progress at 2.4% annually. • Diagnostics also represent a substantial potential market. • Infectious diseases remain the leading cause of death worldwide. In 1996, infectious diseases killed over 17 million people worldwide. Malaria, tuberculosis and AIDS together cause over 300 million illnesses annually.

OBSERVED GAPS AND CHALLENGES

- While NAU performs well in terms of research volume per faculty member, the comparatively small size of the University ($55 million in external research funding) means that there is a lack of a large critical mass of researchers in core competency areas. Each of the recommended platforms for bioscience development in Northern Arizona would benefit from selected augmentation through the hiring of additional research-oriented faculty. In some cases, key R&D strengths at NAU are too dependent on the research and reputation of a single faculty member. The risk attached to this is readily apparent when examining the

strong R&D track record of Paul Torrance who has made major contributions in life science and drug development work, but whose retirement is forcing NAU out of this area of focus.

- The high cost of living in and around Flagstaff makes recruitment to the area increasingly challenging. While the quality of life within Flagstaff and the Northern Arizona region holds substantial appeal, a lack of affordable housing makes it difficult to bring in new, younger faculty members and researchers. NAU is working to address this issue, in part through examining options for affordable housing development by the university. At the opposite end of the equation, NAU enjoys high levels of faculty retention because of the high quality of life in the region.
- The growth of four-year degree programs within Arizona's community colleges may impact the traditional teaching focus and student base of NAU. This is not a problem from an economic development standpoint as long as NAU is able to adjust through developing a larger presence in the university R&D space to compensate. The shift in the competitive environment for four-year degree education in the state may provide NAU with more impetus to boost its graduate degree options, particularly in science and technology related areas. Currently, only the biology department at NAU offers a PhD in a science area—most graduate work at the university is limited to Master's degrees. A lack of a PhD generating research environment limits the research abilities of faculty as well students.
- NAU does not have a long history of university engagement in technology commercialization or encouragement of faculty entrepreneurship. That said, it is evident that the university and the Flagstaff region are working together to encourage the development of innovation-based industry from university discoveries. The university has been holding intellectual property workshops for faculty, and incubator space for new start-up enterprises is available. NAU now is home to several members of faculty who have engaged in entrepreneurial technology business start-up activity, but further attention is required to create a smooth pipeline for technology commercialization. In general, it was noted by many faculty that NAU needs to improve its IP management.
- A lack of academic medical center presence in the Flagstaff region limits human biomedical clinical research activities. However, researchers at NAU have been able to form working relationships with clinician-scientists at ASU in order to extend the translational nature of their research.
- While NAU has been able to benefit from several major lab development projects in the past year, there are still some gaps in equipment availability –in the area of mass spectrometry, for example. A number of faculty also noted that there is not a campus budget for scientific equipment maintenance, and this then causes a major drain on laboratory resources.
- Northern Arizona has a comparatively small bioscience industry base with which academic based researchers can interact. The main exception to this is Gore, which has major operations in Flagstaff.
- There is a need for improved electronic connectivity between Arizona's research universities. NAU researchers, for example, would like to be able to connect live to seminars conducted at the ASU BioDesign Institute. It was also noted that many of the universities subscribe to different academic journals and it would be useful to have a single online library access system for enhanced resource sharing.

Conclusions

As would be expected given its lower population level, northern Arizona has a smaller base of bioscience R&D and associated industry activity than southern Arizona (the Tucson region) and central Arizona (centered on Phoenix). While northern Arizona's total base of bioscience activity is smaller than these other regions, NAU (the academic R&D focal institution for northern Arizona) is just as productive on a per faculty basis as Arizona's other leading research universities.

NAU provides a focused resource for advanced bioscience R&D in northern Arizona and demonstrates some distinctive R&D core competencies:

Key R&D Strengths	Additional R&D Areas of Note
• Infectious diseases • Environmental and ecological systems • Muscle Physiology	• Bioengineering • Computational modeling of cell signaling • Native American health • Chemistry • Science education and workforce development

Northern Arizona's R&D core competencies may be leveraged for specific bioscience platform development. Specific to northern Arizona's development will be two primary bioscience platforms, notably in:

- Diagnostics Technology
- Environmental Technology

In addition, northern Arizona should be considered an integral and important contributor to four of the existing statewide bioscience roadmap platforms—these being:

- Cancer
- Bioengineering
- BioAgriculture
- Infectious Disease