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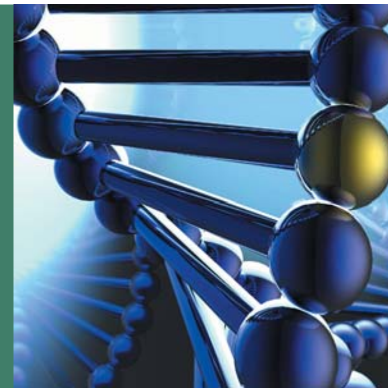
FINAL REPORT





ARIZONA'S BIOSCIENCE ROADMAP:
TOWARD 2012

PROGRESS AND DIRECTIONS FOR THE FUTURE

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Executive Summary

Arizona has set a bold new course to be a place of innovation in the biosciences. Other regions and states have been able to recast their economic futures around the biosciences—from New England to Maryland to San Diego and Colorado—in an effort to diversify their economies and establish a presence in the fast-growing bioscience market. The biosciences also offer one of many ways to help address an issue of importance to all citizens—health care prevention and treatment.

> The 2002 *Arizona's Bioscience Roadmap* established a 10-year vision for success in which "***Arizona is the leading southwestern state in select bioscience sectors, built around world-class research, clinical excellence, and a growing base of cutting-edge enterprises and supporting firms and organizations."*** The Roadmap proposed a detailed plan of action involving four strategies and 19 actions, along with specific and tangible measures of success. Since that time, Arizona's Bioscience Roadmap has been an ongoing initiative guided by a Steering Committee composed of Arizona's biomedical institutions, economic development organizations, and civic leaders.

Arizona's Bioscience Roadmap began in 2002 with community leaders and the academic, nonprofit research, and health care communities uniting around an organizing vision and a strategic plan, with financial support and sponsorship of the Flinn Foundation. The objectives were to build capacity, drive new economic and job growth, improve access and quality improvements in medical and health care to the State's citizenry, and compete in specific niches of the significant bioscience market.

What underpins Arizona's efforts in the biosciences might be termed ***"bold realism."*** Arizona is realistic in understanding that it is playing catch-up in bioscience development. The state has appropriately set its sights on positioning Arizona to become a significant national player and the major state in the Southwestern U.S. in select, focused areas of bioscience strength. Arizona has been bold in its approaches, particularly in advancing collaborations, emphasizing translational research, and building on areas of technology convergence within the biosciences—in fields like bioimaging and bioinformatics, genomics and proteomics—to surge from its strengths to new levels of national competitiveness and technology advancement. This is grounded in realistic achievements and not simply noble platitudes of global competition or chasing Federal government funding streams in disregard of their relevance to the Arizona economy.

This paper documents Arizona's five-year progress in the biosciences and identifies key gaps to be addressed during the next five years. Battelle's assessment of Arizona's Roadmap progress, and the changing landscape globally and nationally in the biosciences, suggests Arizona is well positioned to target "signature opportunities" that connect Arizona's bioscience research strengths and provide the base for Arizona to "leapfrog" other states. Arizona is now at a critical juncture where it can combine a continued focus on achieving national excellence in specific core competency areas and scientific platforms, with new opportunities to translate research into economic and health benefits for the citizens of Arizona, as well as raising Arizona to national and international leadership in targeted opportunity areas in the biosciences.

The emergence of research strengths at the State's universities and medical centers enables an additional focus to position Arizona in the biosciences for the next five years around "technology commercialization"—creating firms, businesses, products, and jobs from research turned into technology. Because of the stronger and deeper research base, Arizona's universities and medical centers and its communities can develop the tools, methods, and techniques to increase the scale and velocity of newly established firms, products and jobs in the State. The considerable momentum supporting the research base in Arizona must now be leveraged to address business formation and product innovation.

MEASURING ARIZONA'S PROGRESS IN BIOSCIENCES DEVELOPMENT

With only five years of focused activities, the initial investments in research infrastructure are showing progress and dividends in terms of leveraged Federal research dollars; commercialization of university bioscience research; industry growth and development in terms of jobs, establishments and wages; as well as concrete progress in implementation of Arizona's Bioscience Roadmap strategies and actions.

A five-year progress report on Arizona's Bioscience Roadmap finds:

- Commitment of public/private sector leadership has been sustained
- Strong private/public partnerships have mobilized to support the Roadmap
- Ongoing efforts continue to inform the general public about the biosciences including recently released regional roadmaps for Southern and Northern Arizona.

The implementation of Arizona's Bioscience Roadmap shows real progress, with 84 percent of the actions showing some progress and 40 percent showing substantial progress, a significant increase in the past year. New programs established by Science Foundation Arizona (SFAz) have added momentum. More than 60 percent of SFAz's first-year funding can be directly traced to bio-related projects and programs.

Table ES-1 summarizes Arizona's progress in Bioscience Roadmap implementation, showing strong performance in jobs, firms, wages, and in some measures of intellectual property. Research performance was strong until 2006, but shows at least a one-year deviation from what had otherwise been upward growth. Risk capital has continued to be a long term problem, but 2007 has the potential to show Arizona reaching the Roadmap target of $100 million in total investments in State bioscience enterprises.

Table ES-1: Progress in implementation of Arizona's Bioscience Roadmap

Metrics of Success: 2002 - 2006		
Metrics	**Performance**	**Comments**
NIH Funding	↑ 19% ('02-'06)	Arizona slightly lagging top 10 States (↑ 23%) and U.S. (↑ 21%)
Bio Jobs	↑ 18.5% ('02-'06)	Arizona's growth exceeding country
Bio Firms	↑ 16.7% ('02-'06)	Medical devices and Research, testing and medical labs are key segments
Bio Wages	↑ 25% ('02-'06)	Average salary: $48.7K
Metrics of Success: 2002–Q3, 2007		
Metrics	**Performance**	**Comments**
Bio Risk Capital	↓ 31% ('02-'Q3,07)	VC investments meet 77% of 2007 goal of $100 m. through Q3
Bio University IP		
• Bio Startups	↑ 150% ('02-'Q3,07)	2 → 5 and total of 39 firms
• Bio Licenses	↑ 30% ('02 -'Q3,07)	20 → 26 and total of 153
• Bio Income	↑ 54% ('02 -'Q3,07)	$1.8 m. → $3.0 m. and total of $12.9 m.

More detail on these performance measures, developed from Battelle's review of best practice metrics across the country, is presented in the pages which follow.

Research

Arizona has been meeting the performance measures for its research base set out in the 2002 *Arizona's Bioscience Roadmap* until recently. Two specific measures of research performance were laid out in *Arizona's Bioscience Roadmap:*

- An increase in bioscience R&D funding to Arizona research institutions at a rate equal to or greater than historic growth rate of the top 10 states over the next 5 years.
- An increase in NIH funding from $118 million to $214 million by 2007.

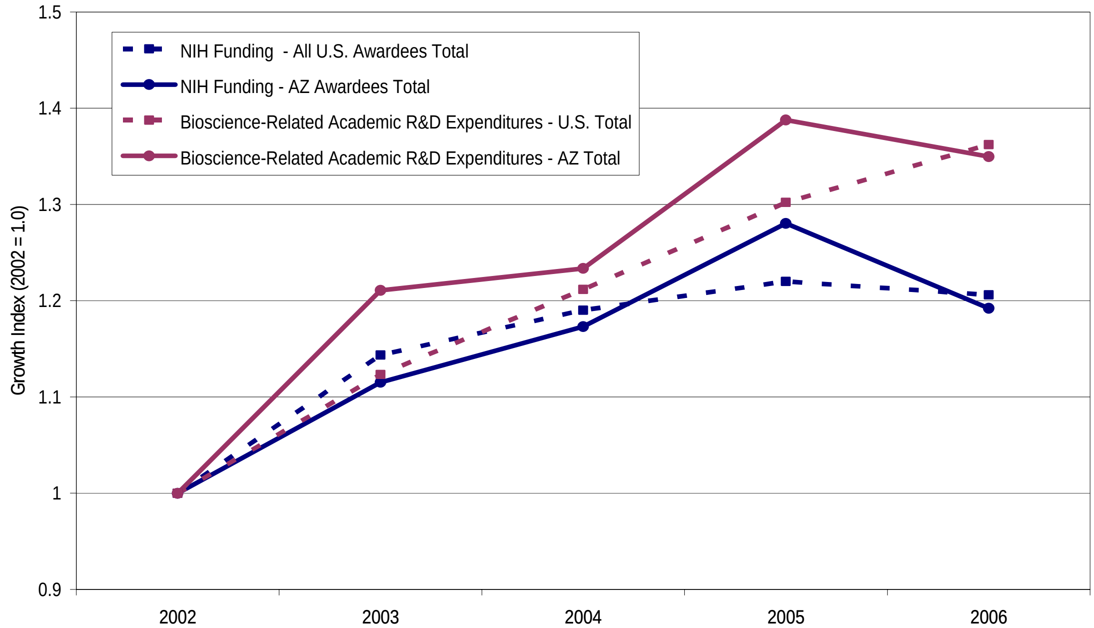
As Table ES-2 indicates, Arizona has a mixed record in meeting these performance goals.

Table ES-2. Progress on metric of success relating to research base set in Arizona's Bioscience Roadmap

Performance Indicator	Measurable Goal	Success to Date
Academic bioscience R&D funding (NSF) and NIH Funding Growth	Reach a rate of growth in NIH/academic bioscience R&D funding equal to or greater than top 10 states	• Arizona recorded a gain in overall bioscience R&D of 35.0% from 2002 to 2006, slightly below the national growth of 36.2% and the average of the top 10 states of 37.3% • With 2006 performance, Arizona's growth in NIH funding from 2002 to 2006 NIH is now slightly below the rate of the top 10 states in NIH funding—19% for Arizona compared with 23% for top 10 states.
NIH Funding Level	Reach $214 million by 2007	• By 2005, Arizona had reached $176 million in NIH funding—representing 82% of the 2007 target—but this has fallen to $164 m in 2006.

Figure ES-1 shows how Arizona has, in general, tracked with the U.S. on these measures over the 2002 to 2006 time period.

Figure ES-1. Growth of University R&D expenditures in the biosciences and NIH research grant funding for AZ and the U.S. (2002–2006)



As shown in Figure ES-2, the most dynamic driver of growth in Arizona is its base of nonprofit research organizations, hospitals, and to some extent firms, which grew an astonishing 81.5 percent in NIH funding from 2002 to 2006. While the three state universities account for $132 million in NIH funding in 2006, at $32 million **roughly $1 of every $5 in NIH funding in Arizona is now found among these non-university organizations.** Without the establishment of TGen and the increased pace at which Arizona's hospitals and medical centers have undertaken biomedical research, Arizona would not be keeping as close a pace with the nation in NIH funding.

Figure ES-2: Growth in NIH research grant funding in Arizona vs. Top-10 Funded States and the United States, 2002–2006

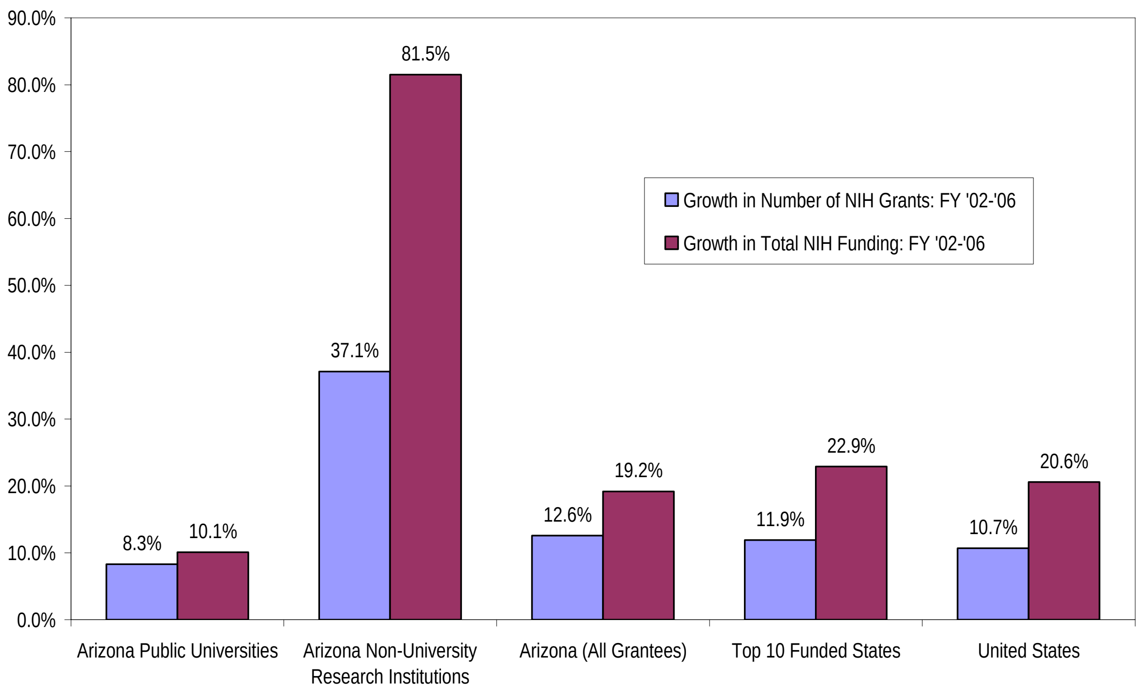
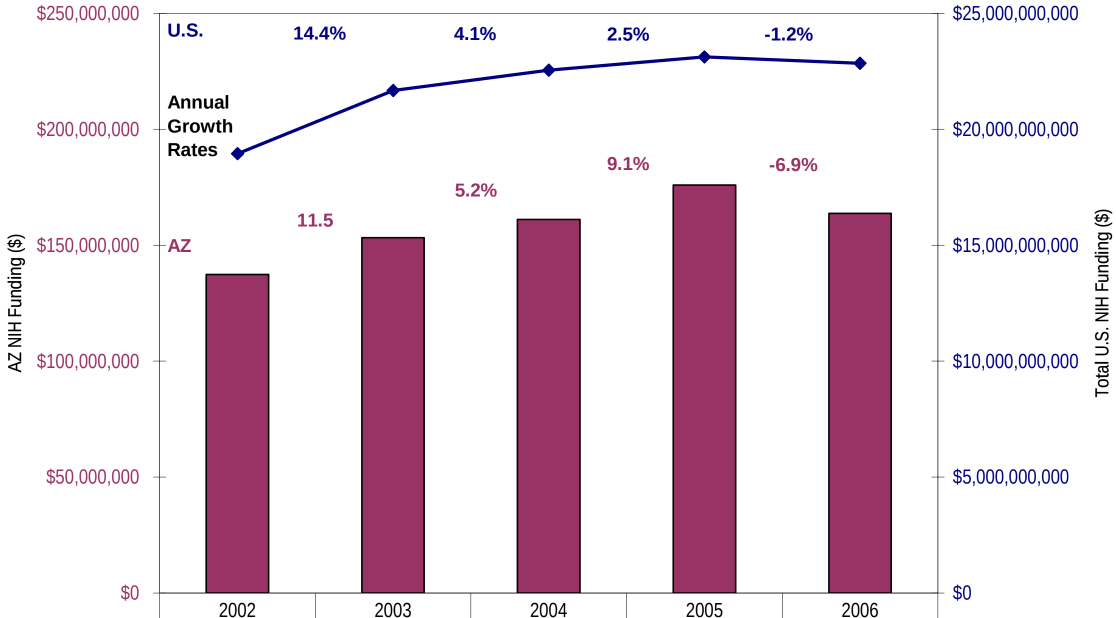


Figure ES-3 reveals that Arizona, like the U.S., has grown in NIH funding, and in the early years of Roadmap implementation outpaced U.S. growth. In 2006, for the first time, the state lagged. The most recent period, 2005 to 2006, shows that while overall NIH extramural funding declined, Arizona funding took a larger hit—declining by 6.9 percent or over $12 million in one year.

Figure ES-3. NIH funding trends for Arizona and U.S., 2002–2006

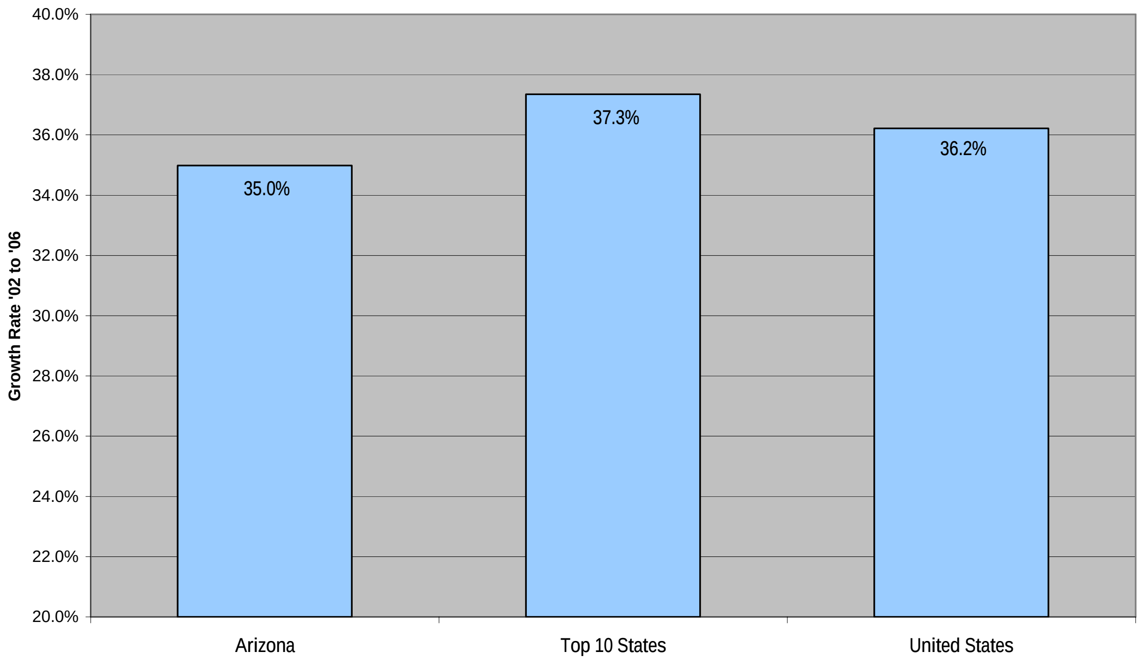


	2002	2003	2004	2005	2006
ARIZONA	$137,374,938	$153,197,688	$161,147,487	$175,880,998	$163,767,240
U.S.	$18,947,026,586	$21,669,025,252	$22,552,258,335	$23,116,571,209	$22,849,735,035

Arizona is still playing catch-up in biomedical sciences. While Arizona NIH funding has increased significantly in recent years, its proportionate share of the total NIH funding base has not increased. Arizona's NIH research funding accounts for only 0.72 percent of the total NIH research budget. This low level of funding in biomedical research is also reflected in a similar market share of 0.73 percent in the university research expenditures in the medical sciences—which includes federal, state, industry, and foundation sources of research support.

Using NSF's data on all academic R&D spending, Arizona's academic bioscience-related R&D accounts for less than 50 percent of all research performed in the state's academic institutions in 2006. Figure ES-4 shows that overall bioscience-related academic R&D actually declined by 2.7 percent from 2005 to 2006, with most of this decline coming from the biological sciences (declining 8.2 percent or $11.5 million) and agricultural sciences (declining 13.7 percent or $10.1 million) disciplines.

Figure ES-4: Growth in bioscience-related academic R&D expenditures, FYs 2002–06



Venture Capital

Arizona's bioscience-related VC investments through three quarters of 2007 already exceed the level of investments in all of 2006. Even with these strong three quarters, Arizona's growth rate in bioscience-related investments from 2002 to Q3, 2007 still shows a decline of 31 percent—compared to U.S. growth over the same period of 26 percent. ***However, it is important to consider trends to avoid single-year anomalies in reporting—removing a single large Arizona deal in 2002 would give Arizona a trend for 2002 to Q3, 2007 very similar to the U.S.*** At current rates, a strong fourth quarter could place Arizona bioscience venture investments almost equal to their level of 2002, a significant rebound from the previous four years in Arizona. Arizona's Bioscience Roadmap set a target of $100 million in venture capital bioscience investments in the State by 2007. With three quarters of the year completed Arizona is already at 77 percent of this target for 2007.

Figures ES-5 and ES-6 show the trends in venture capital backed investments made in Arizona and compare these to the nation during the same time period. Overall Arizona continues to lag the nation in venture capital investments, with the first three quarters of 2007 investments representing only 0.5% of the national pool of venture funds invested in biosciences compared to Arizona's 2.06% share of the national population (2006).

Figure ES-5: Distribution of Arizona bioscience VC investments by segment and year: 2002–Q3, 2007

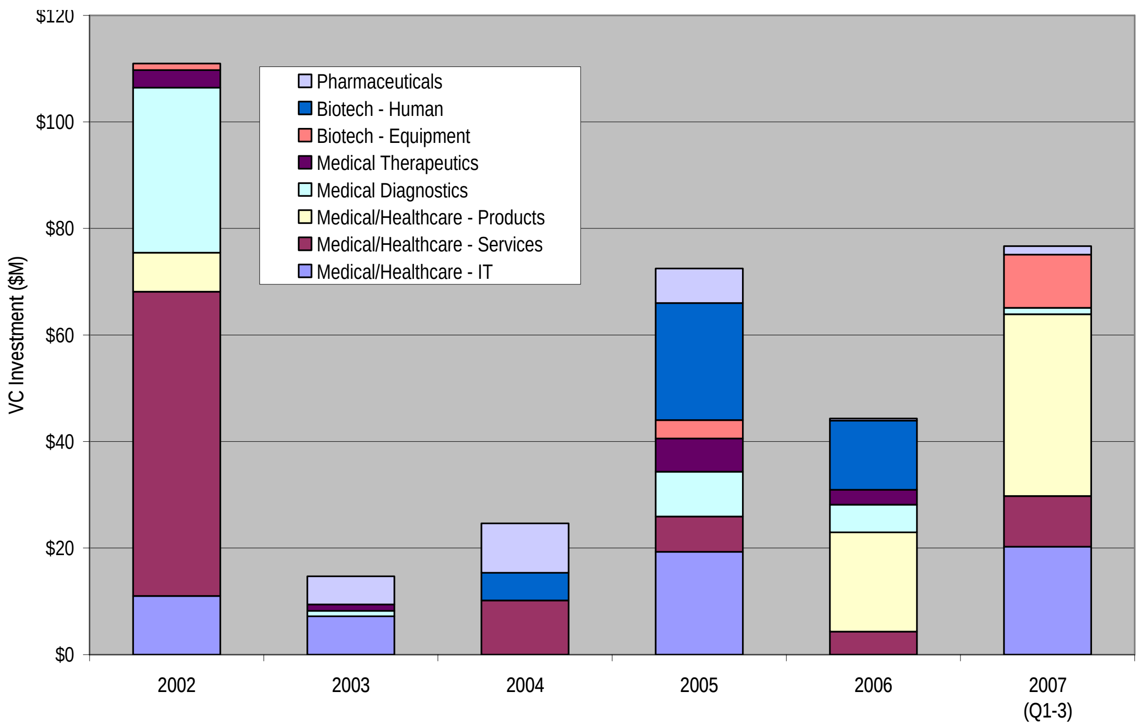
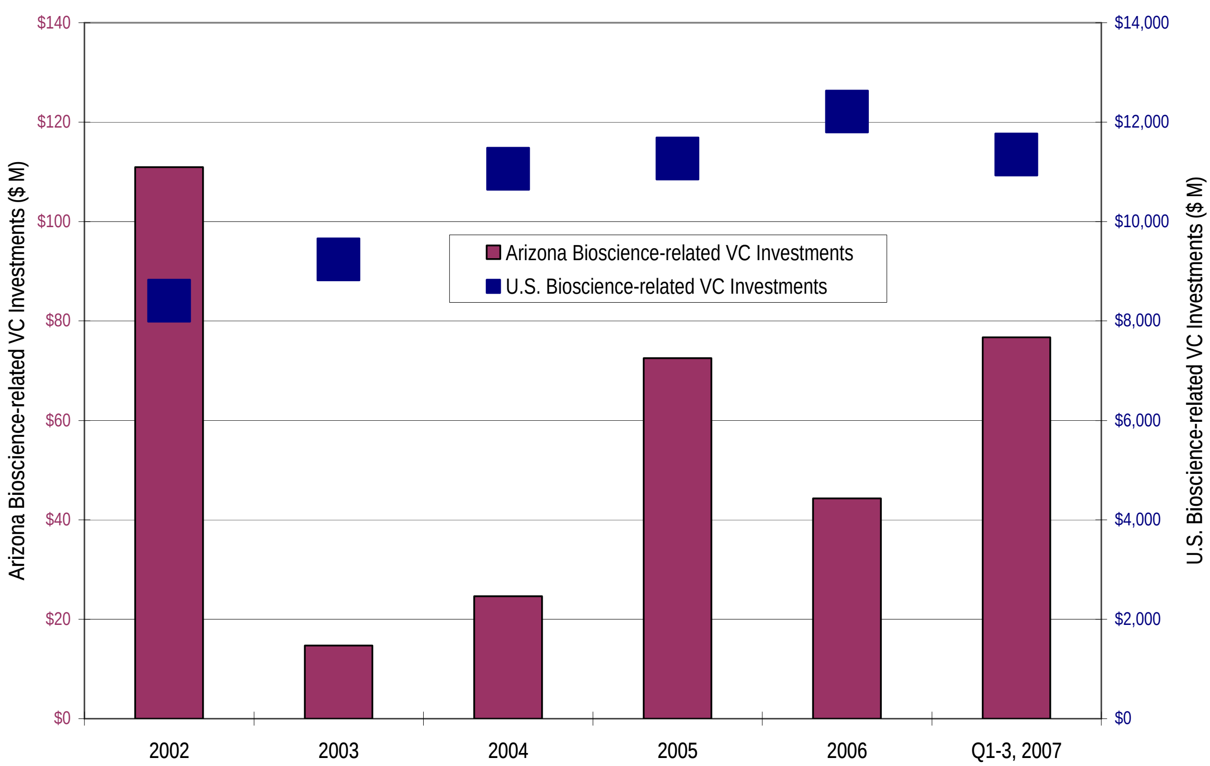


Figure ES-6: Comparison of Bioscience-related VC Investment Trends: Arizona & U.S., 2002–Q3, 2007



Bioscience Industry Employment

Arizona's bioscience firms continued to add jobs in 2006, with double-digit employment increases in four out of five major bioscience subsectors since 2002. In total, the state bioscience sector now employs nearly 81,000 persons (80,909) spanning 745 individual business establishments across the state (see Table ES-7). The labor market performance of the bioscience sector has been exceptional in recent years, as the base of state jobs increased by 18.5 percent since 2002 and the number of establishments increased by 16.7 percent. With these rapid gains, Arizona has far outpaced their counterparts in the national sector where employment increased by 5.9 percent during the same period. Arizona is truly emerging with respect to forming an industry bioscience cluster.

Over the year (2005 to 2006), Arizona added 57 bioscience establishments, up 8.3 percent. Employment rose by 3,643 jobs or 4.7 percent. Most of the new jobs were in the hospitals subsector—up 3,164 or 4.9 percent. Medical device firms increased their employment by 290 jobs from 2005 to 2006, a 6.5 percent job gain for the subsector.

A strong year for the AZ Biosciences, 2005–06:

Establishments: Up 57; 8.3%

Employment: Up 3,643; 4.7%

Table ES-7: Arizona bioscience employment metrics by major subsector, 2002–2006

Arizona Bioscience Employment Metrics					
Industry Subsector	2006 Establishments	Percent Change Estab, '02-06	2006 Employment	Percent Change Empl, '02-06	2006 Location Quotient
Total Biosciences	**745**	**16.7%**	**80,909**	**18.5%**	**0.72**
Non-Hospital Biosciences	632	12.5%	13,143	20.6%	0.52
Agricultural Feedstock & Chemicals	18	-47.1%	502	-9.5%	0.24
Drugs & Pharmaceuticals	35	30.7%	1,108	17.1%	0.18
Medical Devices & Equipment	262	4.5%	4,792	25.3%	0.58
Research, Testing, & Medical Labs	317	26.7%	6,741	21.0%	0.77
Hospitals	113	46.8%	67,766	18.0%	0.79

Source: Battelle analysis of BLS QCEW data from IMPLAN.

Figure ES-6: Growth in Arizona bioscience employment and establishments, 2002-2006

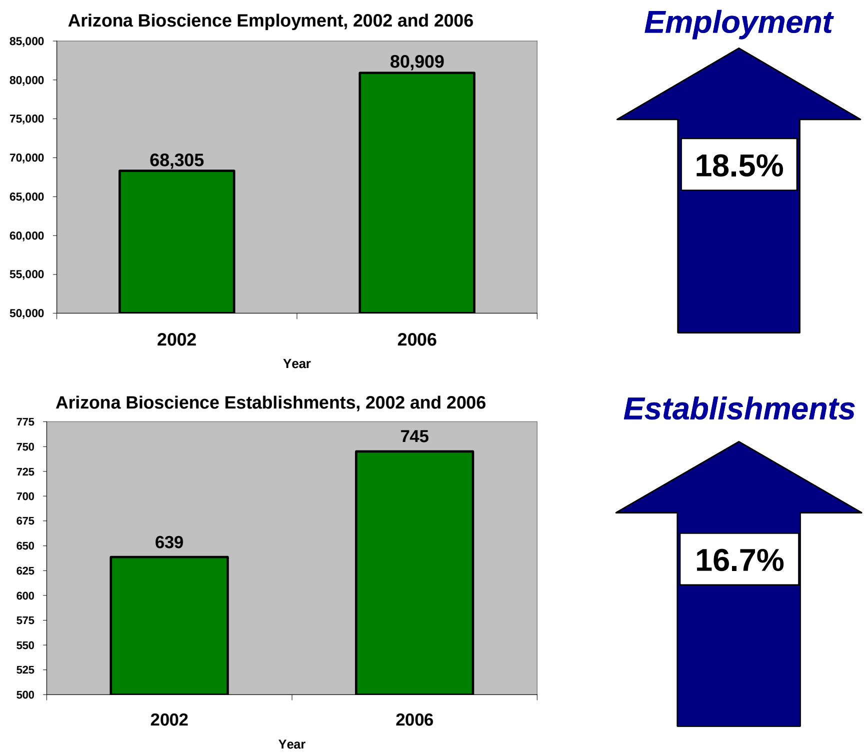
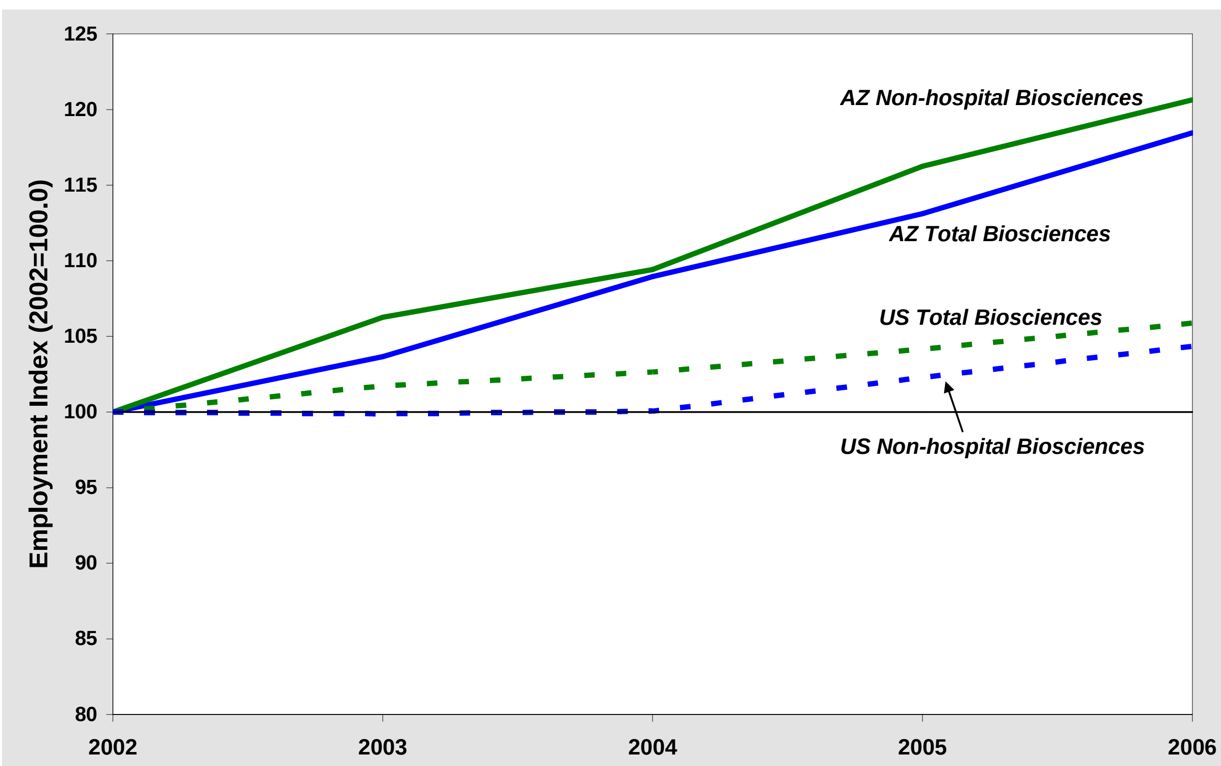
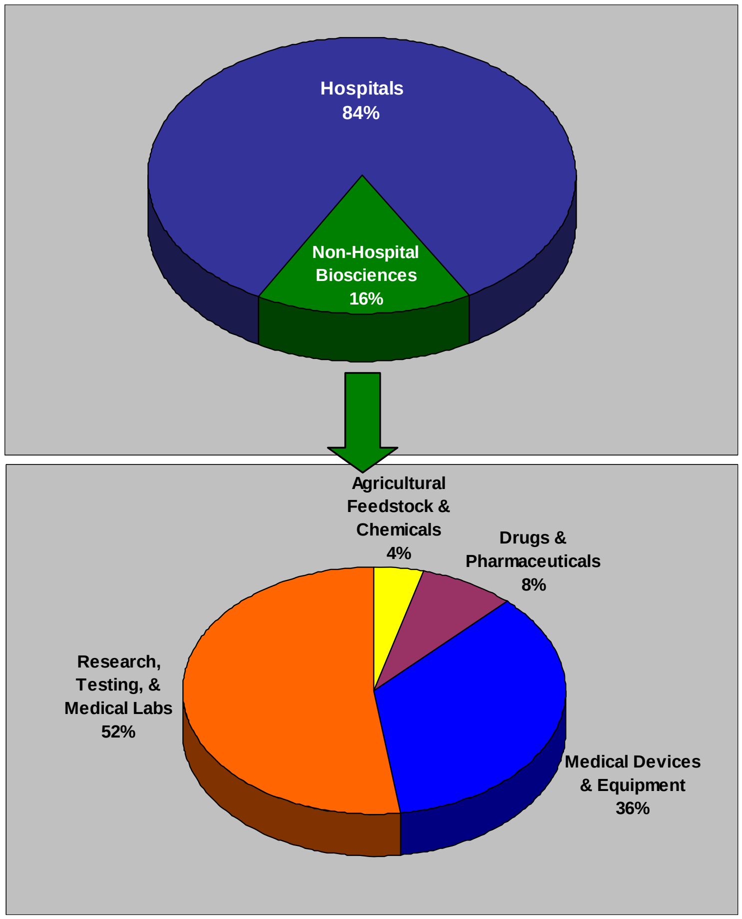


Figure ES-7: Trends in bioscience employment for Arizona and the U.S., 2002–2006 (Indexed, 2002=100)



The majority of Arizona’s bioscience industry jobs are in hospitals, accounting for 84 percent in 2006. The remaining 16 percent in the non-hospital sector include a sizable number in research, testing, and medical labs as well as in medical devices and equipment. The composition of the state’s bioscience industry in 2006 is shown in the pie charts in Figure ES-8.

Figure ES-8 Employment composition of the Arizona bioscience sector, 2006



Bioscience Wage Levels

State bioscience workers earn, on average, $48,674 in 2006 or $9,000 more than the average worker in the entire private sector (see Table ES-8). Driven by high-wage subsectors such as research and testing, and pharmaceutical manufacturing, the average non-hospital bioscience wage is even higher—$53,369 in 2006, or nearly $14,000 more than the average worker. Higher wages in these bioscience subsectors reflect the strong relative labor demand for this high-skilled, well-educated workforce.

Table ES-8: Average annual wages for Arizona bioscience workers and other major state industries, 2005 and 2006

Arizona Average Annual Wages by Industry, 2005 & 2006			
Industry	**2005**	**2006**	**Increase, 05-06**
Management of Companies & Enterprises	$ 63,473	$ 66,311	4.5%
Finance & Insurance	$ 57,142	$ 58,895	3.1%
Manufacturing	$ 54,617	$ 57,627	5.5%
Professional, Scientific, & Technical Services	$ 54,981	$ 57,527	4.6%
Research, Testing, & Medical Laboratories	**$ 50,559**	**$ 57,031**	**12.8%**
Drugs & Pharmaceuticals	**$ 54,188**	**$ 56,274**	**3.8%**
Total Non-Hospital Biosciences	**$ 49,329**	**$ 53,369**	**8.2%**
Information	$ 47,959	$ 51,151	6.7%
Medical Devices & Equipment	**$ 47,429**	**$ 48,958**	**3.2%**
Total Biosciences	**$ 45,182**	**$ 48,674**	**7.7%**
Hospitals	**$ 44,369**	**$ 47,763**	**7.7%**
Real Estate & Rental & Leasing	$ 39,965	$ 43,008	7.6%
Health Care & Social Assistance	$ 40,684	$ 42,962	5.6%
Transportation & Warehousing	$ 40,259	$ 42,151	4.7%
Construction	$ 38,067	$ 40,907	7.5%
Agricultural Feedstock & Chemicals	**$ 41,000**	**$ 39,875**	**-2.7%**
Total Private Sector	**$ 37,709**	**$ 39,526**	**4.8%**
Retail Trade	$ 27,479	$ 28,393	3.3%

University Intellectual Property

The trend line for Arizona's public universities in technology transfer and commercialization particularly in the biosciences is moving in the right direction. Table ES-9 shows that the number of bioscience startups from university intellectual property/research has gone from two in 2002 to five so far in 2007, with the cumulative number of bioscience startups over that five-year time period totaling 39 firms.

Table ES-9: All Arizona University Entrepreneurship: Biosciences Only Patents, Licenses and Startups from University IP

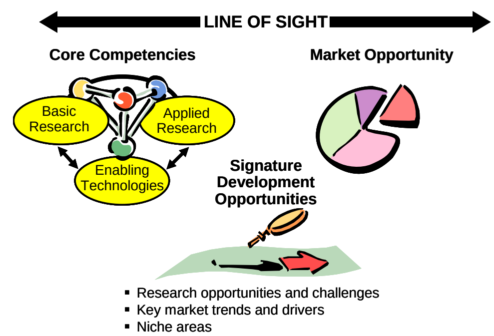
Metric	2002	2003	2004	2005	2006	Q'3.2007
Invention Disclosures Received	93	94	84	136	119	103
Total U.S. Patent Applications Filed	59	70	70	59	42	110
U.S. Patents Issued	13	12	19	16	20	25
Licenses & Options Executed	20	19	25	33	28	26
Adjusted Gross License Income Received	$1,845,889	$1,129,999	$1,727,272	$1,857,508	$3,318,339	$3,044,167
Bioscience Startups from University IP	2	6	11	10	5	5

Table ES-9 also shows that bioscience invention disclosures have continued to grow, as have patent applications filed, and patents issued. Licenses have increased by 30 percent with 28 executed in 2006 and a total of 153 licenses for biosciences-related intellectual property over the 2002–Q3, 2007 period. Finally, even as the number of startups increases (with return to the university increasingly being based on equity, not royalty income) royalty income received has increased significantly to over $3.3 million in 2006 and $3 million in three quarters of 2007 from a level of $1.8 million in 2002. Over the 2002–Q3, 2007 time period, total income totals $12.9 million, excluding value of equity taken in firms.

UPDATING ARIZONA'S BIOSCIENCE ROADMAP: FROM CORE COMPETENCIES TO SIGNATURE OPPORTUNITIES.

Arizona's Bioscience Roadmap is a dynamic plan. To remain effective, new developments and opportunities need to be understood and incorporated. Battelle concludes that Arizona is now at a critical juncture where it can be more selective in its focus on "signature opportunity areas," while it continues to build national excellence in bioscience research. The emergence of strengths in the research base also enables an additional focus around "technology commercialization"—creating firms, businesses, products and jobs from research turned into technology. The next phases of Bioscience Roadmap implementation will require a focus on these two areas. This will serve to maintain the strong momentum already underway and further position Arizona to achieve the vision laid out in 2002.

Figure ES-9: Translating core competencies into signature development opportunities



The significant investments of the past five years have helped Arizona realize a strong record of progress. At the same time, these investments are reshaping opportunities for bioscience development in the state.

Bioscience research competencies go hand-in-hand with growing signature opportunities for development in the broad, diverse, and emerging markets and industries comprising the biosciences. Core competencies by themselves do not generate "signature" areas of focus. Rather, core competencies serve as building blocks for development opportunities that draw upon multiple core competencies and allow a state to participate in growing and emerging market opportunities (Figure ES-9).

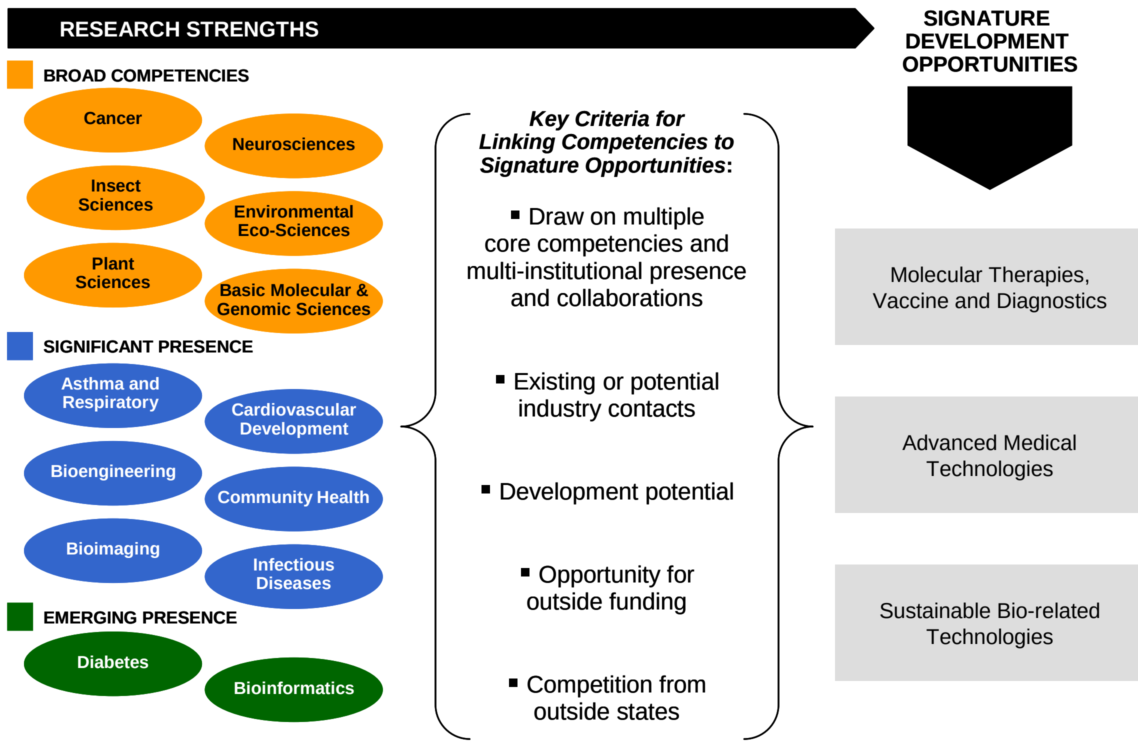
Investments since 2002 in Arizona's research infrastructure and programs at its universities, private research institutes, and medical centers has deepened and strengthened its platforms. Furthermore, Arizona also has research strengths such as electronics, optics, and advanced manufacturing—all critical to the biosciences. And, Arizona has been building and increasing its capacity in the three big "O's"—genomics, proteomics, and bioinformatics. Together Arizona is seeing a strong research convergence that enables the State and its partners to focus on signature opportunities cutting across platforms and disciplines.

But, bioscience research is not an end in itself, but rather a means for Arizona to move ahead in overall bioscience development. The core competency developed to date needs to be translated into "signature opportunity areas for Arizona that align the state's bioscience research core competencies to its local bioscience industry base and the development potential of growing bioscience markets (see Figure ES-10). Battelle has identified three signature opportunities:

- Molecular therapeutics, vaccines, and diagnostics
- Advanced medical technologies

- Sustainable bio-related technologies.

Figure ES-10: Linkage of Arizona's bioscience research core competencies to signature development opportunities



To realize the potential of these signature development opportunities, Arizona must continue to invest and achieve national stature in its areas of research competency. It must also leverage these bioscience research core competencies for broader bioscience development by linking with the ongoing economic development activities of the Roadmap, such as accelerating technology commercialization, increasing venture capital, addressing workforce development, and supporting commercial bioscience wet-lab development.

COMMERCIALIZING TECHNOLOGY – TRANSFERRING DISCOVERIES TO THE MARKETPLACE

Research alone will not offer well-paying jobs for the state's citizenry, nor improve health care prevention, unless it can link the bench with the bedside through new products, treatments, diagnostics, and prevention. It is clear that the dual objectives of the Roadmap—building a critical mass of research and a critical mass of bioscience enterprises—will not be achieved by addressing research exclusively.

As Arizona continues to invest in the research enterprise, as it should, it must also increase its focus and commitment to technology commercialization. Very small strategic investments in technology commercialization can provide exponential return on the monies invested while contributing to the improved health care dividend desired.

Technology transfer and technology commercialization are not the same thing

Technology transfer is the passive management of a research organization's intellectual property. Technology transfer involves disclosure of discoveries, the determination of the need for patent protection, and the licensing of the intellectual property (to either a third-party organization or to create a new business) to pursue the development of a product, process or other intervention based on the discovery, and its associated license. Each of Arizona's public universities has a technology transfer function to handle the intellectual property discoveries and innovations resulting from their faculty and student's research (ASU and UA have their own offices; NAU's technology transfer function is administered by ASU). The State's private research institutions, such as TGen, also have offices responsible for technology transfer, and, many of the State's hospitals and medical centers are developing a similar capability.

Technology commercialization, however, involves moving beyond legal protection and licensing. It requires developing the technology into a product/service to meet the need(s) of customers in the marketplace. Technology commercialization is often called applied research. Unlike the stages of technology transfer (shown in Table ES-10) where the research is created from the search for improved knowledge and understanding, technology commercialization targets the needs of a specific customer and, ultimately, results in a profit from its sales and use.

Table ES-10: Technology Transfer vs. Technology Commercialization – Stages

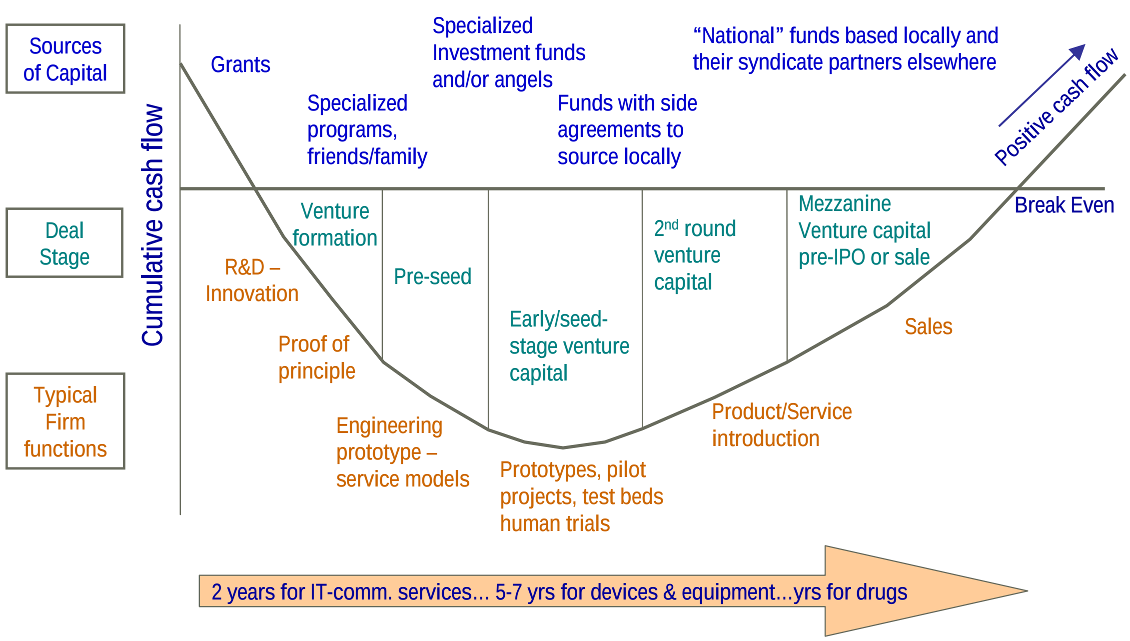
	Technology Transfer		***Technology Commercialization***		
Technology Development Stage	Discovery	Translational Research	Technology Development	Product Development	Production/Marketing
Outcome	• Invention Disclosure • Publication	• Proof of Concept • Patent/Trade Secret • License	• Engineering Optimization • Product Prototype • Pre-seed business	• Initial Product • Start-up business or new program (for established companies)	• Mass Production • Established company

Source: Adapted from NIST, "ATP and Venture Capital Funding Criteria Differ," http://www.atp.nist.gov/factsheets/1-c-9.htm

Moving From Research Discovery to Addressing the Valley of Death

The focus of technology commercialization is turning basic research into firms and products with sales in the marketplace. Many refer to the funding cycle issues as the "Valley of Death" as illustrated in Figure ES-11. Battelle suggests that *gaps within the Valley of Death are impeding Arizona's ability to maximize its investments from its successes* in building a stronger research base in its universities, private research institutes, and its medical centers and hospitals.

Figure ES-11: Research Discoveries -Valley of Death



This "Valley of Death" helps illustrate the need for a continuum of support, services, and assistance from the private and public sectors as a technology enterprise is conceived, developed, formed, grown, and reaches maturity. Tools needed include due diligence, proof of concept, and engineering optimization in developing the technology and identifying the product. In addition, bioscience entrepreneurs in Arizona must address a fairly long continuum of risk capital needs to start, develop, and grow their firms.

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. The development of new technologies is a very expensive process running, in some cases, into millions of dollars.

The State's research and medical institutions are increasingly seeing research turned into technology and firms. And they demonstrate the increasing deal flow and opportunities biosciences represent. **But the State is not optimizing its research base nor seeing the same impact of deal flow, venture financing, and growing technology companies as found in other high tech bioscience hot spots such as Boston, Seattle, Salt Lake City, or San Diego.**

Three inter-related gaps face Arizona in technology commercialization**:**

1. **Commercialization Tools.** Resources to undertake the market and technology assessments, prototype development and engineering optimization to determine if the research can be turned into a product and/or a firm.
2. **Business Mentoring.** Business service support and mentoring to help with business planning, sales and marketing, and other aspects of incubating a new firm and accelerating its product innovation.
3. **Risk Capital Creation.** Risk capital available to fund the initial startup and operations phases of a business.

Actions to address these gaps are summarized below:

1. Commercialization Tools

The key components include the necessary resources available for research organizations and others to offer the following tools:

- Due diligence
- Proof of concept fund support including testing, experiments
- Market and technology assessments
- Prototype support
- Engineering optimization

2. Business Mentoring

The key components for addressing how business mentoring support is offered and practiced include:

- Bioscience Entrepreneur Network
- Entrepreneurs in Residence/Executive Corps programs
- Startup angel capital funding through a statewide Biosciences Angel Initiative

3. Risk Capital Creation

Five specific actions are suggested:

- Create a stronger resident venture capital industry with a stronger set of funds to attract outside the state dollars and the sources of capital to Arizona entrepreneurs

- Explore an accelerator model addressing issues of risk capital, space, and serial entrepreneurial management talent concurrently
- Increase support to entrepreneurs to seek and win more SBIR/STTR awards
- Recruit and educate venture and other risk capital investors outside of Arizona about the State's biosciences base
- Encourage an increased base of capital formation for Arizona individual and institutional investments in risk capital including an Arizona BioSeed Fund

ARIZONA'S BIOSCIENCE ROADMAP: THE NEXT FIVE YEARS TO 2012

Arizona's maturing research base enables the state to more closely focus on signature opportunities that bring together collaborators from the research and clinical settings; from academe, industry and nonprofits; from diverse fields of expertise and study. Because of this maturity, Arizona is now in a better position than five years ago to make serious efforts to grow the critical mass of focused biomedical research and of bioscience firms. The State has recognized bio stars in firms such as W.L. Gore, Medtronic, Ventana, and Sanofi-aventis—already located here—but it is clear that an increased rate of bio business opportunities can emerge if the State can enhance its technology commercialization infrastructure. This suggests some refinement in the goals, objectives and actions for Roadmap implementation over the next five years.

Battelle's revised goal for Arizona is to:

Develop Arizona as a global biomedical research and bioscience commercial center over the next 20 years

This can be accomplished through the following objectives and actions:

- **OBJECTIVES**
  - Leapfrog research opportunities
  - Catalyze bioscience commercialization
- **ACTIONS**
  - Make strategic investments in research infrastructure
  - Make strategic investments in commercialization
  - Recruit intellectual capital
  - Provide guidance, support and information on the biosciences

Going forward, research and technology commercialization become the twin focal points for the Bioscience Roadmap. This requires focusing on "signature opportunities" and continuing to build Arizona's translational research capacity. Strong efforts are required to advance bioscience commercialization, bringing together the many participants from developers and builders to venture capitalists, higher education institutions, medical centers, and private research institutes.

SUMMARY

Arizona is at a critical juncture in its quest to become the major Southwest bioscience center. Significant progress has been made; resources have been secured; and there has been a considerable alignment across medical institutions, research institutes, higher education institutions, government, and others. While it continues to be important to focus strategically on the research base around competencies, research does not by itself create the technologies and innovations in the marketplace, create jobs, introduce products, or impact health care treatment and prevention.

Arizona's private and public sectors must jointly address gaps and deficiencies in "technology commercialization" to gain the economic and health benefits that might be derived from this research. The dollars required to create new cutting edge enterprises are not huge—indeed they are less than is needed to build a strong "research engine"—but they are critically important. Without sufficient investment in building its technology commercialization enterprise, Arizona will be challenged to create a sufficient and critical mass of firms and products, and it will not fully realize its potential to improve the quality of health care and diversify Arizona's economy.

1: ARIZONA HAS SET A BOLD NEW COURSE IN THE BIOSCIENCES

Arizona is has set a bold new course to be a place of innovation in the biosciences. Other regions and states have been able to recast their economic futures around the biosciences—from New England to Maryland to San Diego and Colorado—in an effort to diversify their economies and establish a presence in the fast-growing bioscience market. The biosciences also offer one of many ways to help address an issue of importance to all citizens—health care prevention and treatment.

> The 2002 *Arizona's Bioscience Roadmap* established a 10-year vision for success in which "***Arizona is the leading southwestern state in select bioscience sectors, built around world-class research, clinical excellence, and a growing base of cutting-edge enterprises and supporting firms and organizations."*** The Roadmap proposed a detailed plan of action involving four strategies and 19 actions, along with specific and tangible measures of success. Since that time, Arizona's Bioscience Roadmap has been an ongoing initiative guided by a Steering Committee composed of Arizona's biomedical institutions, economic development organizations, and civic leaders.

Arizona's Bioscience Roadmap began in 2002 with community leaders and the academic, nonprofit research, and health care communities united around an organizing vision and a strategic plan**,** with financial support and sponsorship of the Flinn Foundation. The objectives were to build capacity, drive new economic and job growth, improve access and quality improvements in medical and health care to the State's citizenry, and compete in specific niches of the significant bioscience market.

What underpins Arizona's efforts in the biosciences is what might be termed, ***"bold realism."*** Arizona is realistic in understanding that it is playing catch-up in bioscience development. The state has appropriately set its sights on positioning itself to become a significant national player and the major state in the Southwestern U.S. in select, focused areas of strength. Arizona has been bold in its approaches, particularly in advancing collaborations, emphasizing translational research, and building on areas of technology convergence with the biosciences—in fields like bioimaging and bioinformatics, genomics, and proteomics—to surge from its strengths to new levels of national competitiveness and technology advancement. This is grounded in realistic achievements and not simply noble platitudes of global competition or simply chasing Federal government funding streams in disregard of their relevance to the Arizona economy.

Numerous studies and reports document that the 21st Century is one driven by innovation and knowledge—in the jobs of the future, the industries of the future, and products of the future. But this innovation occurs increasingly through the interaction of people in a place or location—not simply by surfing the Internet. Those places that have already emerged as places of innovation demonstrate a strong intellectual climate, strong research drivers, and a culture of networking, firm startups, and constant changes as to where people work, what skills they use, and what their career or occupation is at that moment. **Arizona can be one of those places of innovation.**

The traditional 5 C's of Arizona's economy were based on geography, climate, and natural resources. Increasingly those natural resources are replaced by its population base and the talent the State attracts and nurtures. States successful in innovation invest in the intellectual climate that fosters such innovation including leading-edge research universities, independent research institutes, and medical centers; build a talent pipeline, encourage enterprises to be formed and created through entrepreneurial networks and management talent; and offer a culture and quality of life with vibrant downtowns, outdoor recreation, and a strong arts and culture environment.

To be effective as an ongoing strategic plan, Arizona's Bioscience Roadmap must stay apprised of new developments and the opportunities they present. The 2002 *Arizona's Bioscience Roadmap* provided a snapshot of the state's position in core research focus areas offering the best prospects for growing the state's bioscience research base and overall bioscience stature. Through ongoing efforts of the Scientific Platform committees of Arizona's Bioscience Roadmap, it was further refined and contributed to developing areas of research strength in Arizona and spurring collaboration and communication among research leaders from across Arizona's universities, nonprofit research institutions, and hospitals and medical centers.

Battelle, in the past two years, has compiled a comprehensive update of the Arizona's core competencies in the biosciences to measure progress and to assess where the state should be positioned for the future. The pioneering work done from 2002-2005 in forming platform committees around the State's research strengths and opportunities for national stature led to preparation of detailed platform plans in each of the near-term strengths identified in the 2002 Roadmap. From that base much collaboration among and between Arizona's research institutions, private research institutes, medical centers, and hospitals have occurred. In fact, because of Arizona's growth and maturity in the biosciences, Battelle's core competency suggests Arizona is well positioned to target "signature opportunities" that connect Arizona bioscience research strengths and provide the base for Arizona to "leapfrog" other states. Arizona is now at a critical juncture where it can combine a continued focus on achieving national excellence in specific core competency areas and scientific platforms, with new opportunities to translate research into economic and health benefits for the citizens of Arizona as well as raising Arizona to national and international leadership in targeted opportunity areas in the biosciences.

The emergence of research strengths at the State's universities, private research institutes, and medical centers enables an additional focus to position Arizona in the biosciences for the next five years around "technology commercialization"—creating firms, businesses, products, and jobs from research turned into technology. Because of the stronger and deeper research base, Arizona's universities, private research institutes, and medical centers can develop the tools, methods, and techniques to increase the scale and velocity of newly established firms, products, and jobs in the State. The considerable momentum supporting the research base in Arizona must now be leveraged to address business formation and product innovation.

2: ARIZONA TAKING ACTION

At the time that Arizona's Bioscience Roadmap was developed, the seeds for generating bioscience development were apparent. There was a small but rapidly growing bioscience industry base, led by medical device companies, as well as a base of research institutions and medical centers with a range of research strengths, particularly in the areas of neurosciences, cancer research, and bioengineering, and committed institutional leadership seeking to grow the bioscience research enterprise.

More importantly, there was a growing focus and emphasis on establishing anchors for bioscience development in the future, including the commitment from the public and private sectors of more than $120 million to attract the **Translational Genomics Research Institute (TGen)** and the **International Genomics Consortium (IGC)** to Arizona. The State and its university leaders were also committed to focusing a significant portion of the dedicated sales tax revenues from the newly enacted Technology and Research Initiative Fund (TRIF) under Proposition 301 to enhancing university research in the biosciences.

But, significant challenges were also facing Arizona. It was lagging behind national trends in bioscience research growth, a stark contrast to the state's rise in the physical sciences and in electronics and optics over the 1990s. The size of Arizona's bioscience industry base was approximately 30 percent lower than the national average, and the state lacked a focused approach—with an appropriate range of developmental tools—to grow its bioscience industry base. And the State was obtaining significantly less Federal funds for the biosciences as it should have compared to its population and research expertise. Overall, it was clear that, while the prospects were strong, Arizona was playing catch-up in bioscience development.

The following are among the key actions accomplished since 2002:

- **A $440 million bond issue, passed in 2003, provided the funding to create needed bioscience-building infrastructure.** A dozen new bioscience-related research facilities at Arizona universities have been built with this money, among them the buildings that house Arizona State University's (ASU) Biodesign Institute and University of Arizona's (UA) BIO5 Institute.
- Support for **multidisciplinary, biomedical translational research** in the state has encouraged collaboration across the state's broad biomedical community of universities, nonprofit research institutions, and hospitals and medical centers through the **Arizona Biomedical Research Commission (ABRC).**
- More than $100 million has been invested by Arizona's research universities in bioscience research enhancements through the **Technology and Research Initiative Fund established under Proposition 301**, including the Biodesign Institute, BIO5, and enhanced bioscience research programs at Northern Arizona University (NAU).
- Arizona has addressed the critical need for **expanding the UA College of Medicine-Phoenix in partnership with ASU.** The school's first class of students began in fall 2007. The advent of the school will bring UA's clinical expertise together with Phoenix's technological strengths found across its university and nonprofit research organizations and facilitate their integration toward successful translational research working with the broad base of hospitals and medical centers in the Phoenix area.

- Arizona’s philanthropic community has continued to make significant investments in the technology and research infrastructure to enable Arizona to achieve this vision, led first by the Flinn Foundation’s investments in TGen and the Roadmap, followed later by investments in the Critical Path Institute (C-Path) and in proteomics with the **Virginia G. Piper Charitable Trust**.
- The **Arizona 21st Century Fund** was established in 2006 by the State of Arizona was established to make timely investments in new medical, scientific, and engineering programs in 2006. The initial appropriation for 2006 was $35 million, followed by a four-year commitment of $100 million in future years, to be matched by private investments dollar for dollar. The 21st Century Fund flows to the newly formed **Science Foundation of Arizona (SFAz)**—organized by Arizona’s principal business leadership organizations—to build and nurture continued research excellence in Arizona. While not all SFAz funding goes to the biosciences, it provides another critical resource for growing Arizona’s bioscience research base, particularly for increasing the competitiveness of Arizona for federal funding opportunities.

The significant investments of the past five years have helped Arizona realize a strong record of progress. At the same time, these investments are reshaping the competencies, expertise, and, consequently, the opportunities for bioscience development in the state.

WHY BIOSCIENCE DEVELOPMENT IS IMPORTANT FOR ARIZONA

Arizona's commitment to the biosciences recognizes the significant economic opportunities that the biosciences can generate in the future. The 21st century is being viewed worldwide as the "Bio Century." The biosciences are not only at the forefront of creativity and innovation, but represent a convergence point for engineering, information technology, the nanosciences, and communications/media. Following the successful completion of the Human Genome Project, another era of innovation is being introduced, creating new areas of research and application from personalized medicine to molecular therapeutics to regenerative medicine.

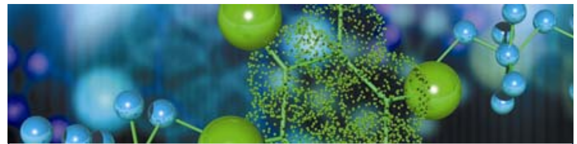
States are focusing on bioscience development because it is a large, fast-growing, diverse, and crosscutting sector involving a wide range of manufacturing, service, and research activities that not only promotes economic vitality, but also public health.

For Arizona, the biosciences represent a historically untapped driver, and one that can accomplish the following:

Build on Arizona's existing strengths in electronics and optics and contribute to the growth of these sectors as well. The diversity of the bioscience sector places it at the center of the technology economy, serving as a focal point for the continuing convergence of technologies from information and computing to advanced manufacturing. Developing the biosciences in Arizona can build upon existing university research and industry strengths of the state—such as electronics, optics, and information technology—and offer opportunities for bringing together competencies to establish depth as well as breadth of expertise.

Offer economic stability. As an economic driver, the bioscience sector in its diversity ensures relative stability. Because the field extends into various activities spread across the economic spectrum, development of the biosciences insulates against the fluctuations of business cycles. Arizona's traditional economic strengths in hospitality and tourism, construction, and real estate provide little such protection.

Ensure the growth of quality, high-paying jobs. The jobs created and sustained by the biosciences tend to be high-paying and relatively secure, helping to build and retain local wealth and prosperity. Drug and chemical jobs pay salaries and wages well above the average even for other technology fields, while jobs in medical devices are on a par with other manufacturing industries. Even hospitals and laboratories, though engaging many part-time workers, support jobs spanning the range of the pay scale.



The Biotechnology Industry Organization in its *Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006* explains why states are focusing on the biosciences as an economic driver:

The bioscience sector is a rapidly growing, global industry characterized by scientific discovery and technological innovation. According to the latest Bureau of Labor Statistics data, over the 10-year period ending in 2014, the overall bioscience industry will see average annual employment increases of 1.6 percent, greater than the overall employment growth projection of 1.4 percent annually. Key bioscience subsectors—research, testing, and medical labs, and drugs and pharmaceuticals—are projected to grow at very high rates, 2.9 percent and 2.6 percent annually.

The biosciences offer high-paying, quality jobs across a range of occupations from lower skilled technicians and manufacturing workers to high skilled research scientists and medical doctors. In 2004, bioscience workers, on average, were paid more than $26,000 above the overall national average wage.

The biosciences have a large national impact through the multiplied effects of direct and indirect employment and expenditures. The non-hospital biosciences' 1.2 million jobs in 2004 had an indirect employment impact of an additional 5.8 million jobs, revealing a total direct-effect employment multiplier of 5.7.

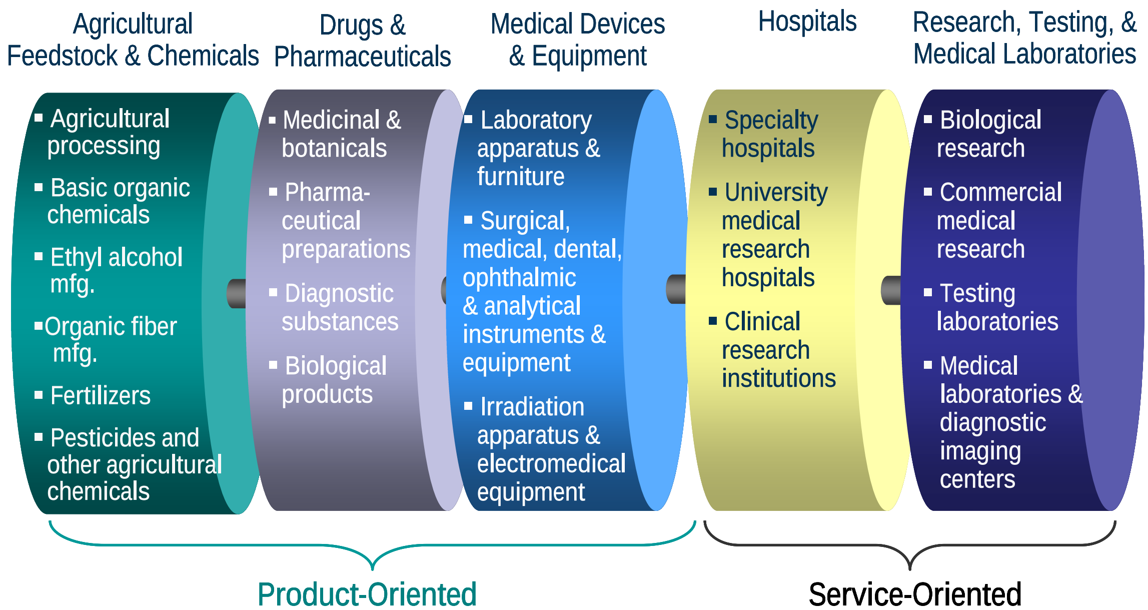
The biosciences not only involve a diversity of markets but cut across manufacturing, services, and research activities.

The biosciences contribute to the growth of other technology sectors, such as information technology, electronics, optics, and advanced manufacturing.

Investment in the biosciences can lead to benefits for a state's citizens in terms of improved health care, cleaner environments, and healthier foods.

Biotechnology Industry Organization, Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006

Figure 1. Defining the Biosciences



Source: Battelle

3: ARIZONA'S CHANGING POSITION AND PATTERNS OF DEVELOPMENT IN BIOSCIENCES: METRICS OF SUCCESS

MEASURING ARIZONA'S PROGRESS IN BIOSCIENCES DEVELOPMENT

With only five years of focused activities, the initial investments in research infrastructure are showing progress and dividends in terms of leveraged Federal research dollars; commercialization of university bioscience research; industry growth and development in terms of jobs, establishments, and wages; as well as concrete progress in implementation of Arizona's Bioscience Roadmap strategies and actions.

A five-year progress report on Arizona's Bioscience Roadmap finds:

- Commitment of public/private sector leadership has been sustained
- Strong private/public partnerships have mobilized to support the Roadmap
- Ongoing efforts continue to inform the general public about the biosciences including recently released regional roadmaps for Southern and Northern Arizona.

The implementation of Arizona's Bioscience Roadmap shows real progress, with 84 percent of the actions showing some progress and 40 percent showing substantial progress, a significant increase in the past year. New programs established by Science Foundation Arizona (SFAz) have added momentum. More than 60 percent of SFAz's first-year funding can be directly traced to bio-related projects and programs.

Table 1 summarizes Arizona's progress in Bioscience Roadmap implementation, showing strong performance in jobs, firms, wages, and in some measures of intellectual property. Research performance was strong until 2006, but shows at least a one-year deviation from what had otherwise been upward growth. Risk capital has continued to be a long term problem, but 2007 has the potential to show Arizona reaching the Roadmap target of $100 million in total investments in State bioscience enterprises.

Table 1: Progress in implementation of Arizona's Bioscience Roadmap

Metrics of Success: 2002 - 2006		
Metrics	**Performance**	**Comments**
NIH Funding	↑ 19% ('02-'06)	Arizona slightly lagging Top 10 States (↑ 23%) and U.S. (↑ 21%)
Bio Jobs	↑ 18.5% ('02-'06)	Arizona's growth exceeding country
Bio Firms	↑ 16.7% ('02-'06)	Medical devices and Research, testing and medical labs are key segments
Bio Wages	↑ 25% ('02-'06)	Average salary: $48.7K
Metrics of Success: 2002–Q3, 2007		
Metrics	**Performance**	**Comments**
Bio Risk Capital	↓ 31% ('02-'Q3,07)	VC investments meet 77% of 2007 goal of $100 m. through Q3
Bio University IP		
• Bio Startups	↑ 150% ('02-'Q3,07)	2 → 5 and total of 39 firms
• Bio Licenses	↑ 30% ('02 -'Q3,07)	20 → 26 and total of 153
• Bio Income	↑ 54% ('02 -'Q3,07)	$1.8 m. → $3.0 m. and total of $12.9 m.

More detail on these performance measures, developed from Battelle's review of best practice metrics across the country, is presented in the pages which follow.

Research

Arizona has been meeting the performance measures for its research base set out in the 2002 *Arizona's Bioscience Roadmap* until recently. Two specific measures of research performance were laid out in the Roadmap*:*

- An increase in bioscience R&D funding to Arizona research institutions at a rate equal to or greater than historic growth rate of the top 10 states over the next five years.
- An increase in NIH funding from $118 million to $214 million by 2007.

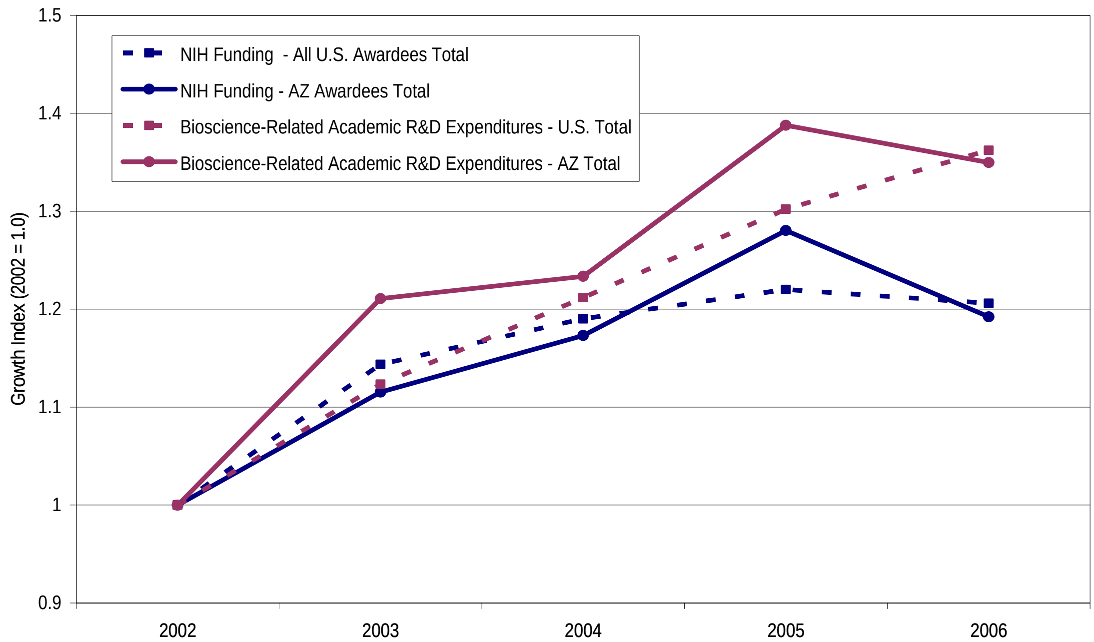
As Table 2 indicates, Arizona has a mixed record in meeting these performance goals.

Table 2. Progress on metric of success relating to research base set in Arizona's Bioscience Roadmap

Performance Indicator	Measurable Goal	Success to Date
Academic bioscience R&D funding (NSF) and NIH Funding Growth	Reach a rate of growth in NIH/academic bioscience R&D funding equal to or greater than top 10 states	• Arizona recorded a gain in overall bioscience R&D of 35.0% from 2002 to 2006, slightly below the national growth of 36.2% and the average of the top 10 states of 37.3% • With 2006 performance, Arizona's growth in NIH funding from 2002 to 2006 NIH is now slightly below the rate of the top 10 states in NIH funding—19% for Arizona compared with 23% for top 10 states.
NIH Funding Level	Reach $214 million by 2007	• By 2005, Arizona had reached $176 million in NIH funding—representing 82% of the 2007 target—but this has fallen to $164 m. in 2006.

Figure 2 shows how Arizona has, in general, tracked with the U.S. on these measures over the 2002 to 2006 time period.

Figure 2. Growth of University R&D expenditures in the biosciences and NIH research grant funding for AZ and the U.S. (2002–2006)



As shown in Figure 3, the most dynamic driver of growth in Arizona is its base of nonprofit research organizations, hospitals, and to some extent firms, which grew an astonishing 81.5 percent in NIH funding from 2002 to 2006. While the three state universities account for $132 million in NIH funding in 2006, at $32 million **roughly $1 of every $5 in NIH funding in Arizona is now found among these non-university organizations.** Without the establishment of TGen and the increased pace at which Arizona's hospitals and medical centers have undertaken biomedical research, Arizona would not be keeping as close a pace with the nation in NIH funding.

Figure 3: Growth in NIH research grant funding in Arizona vs. Top-10 Funded States and the United States, 2002–2006

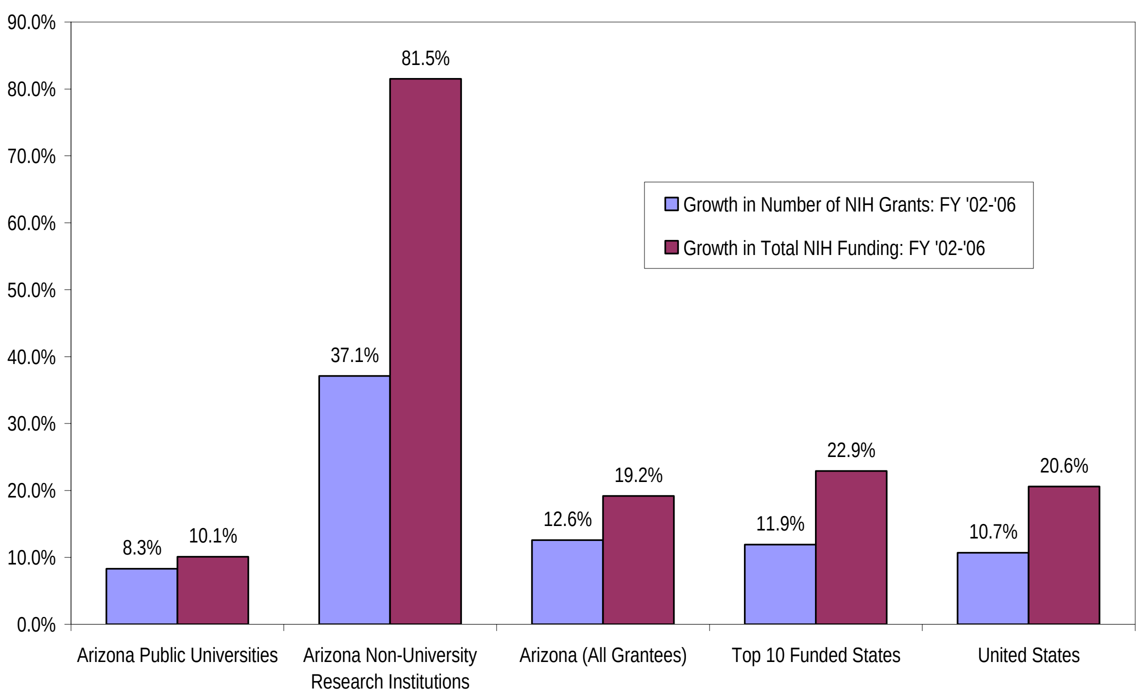
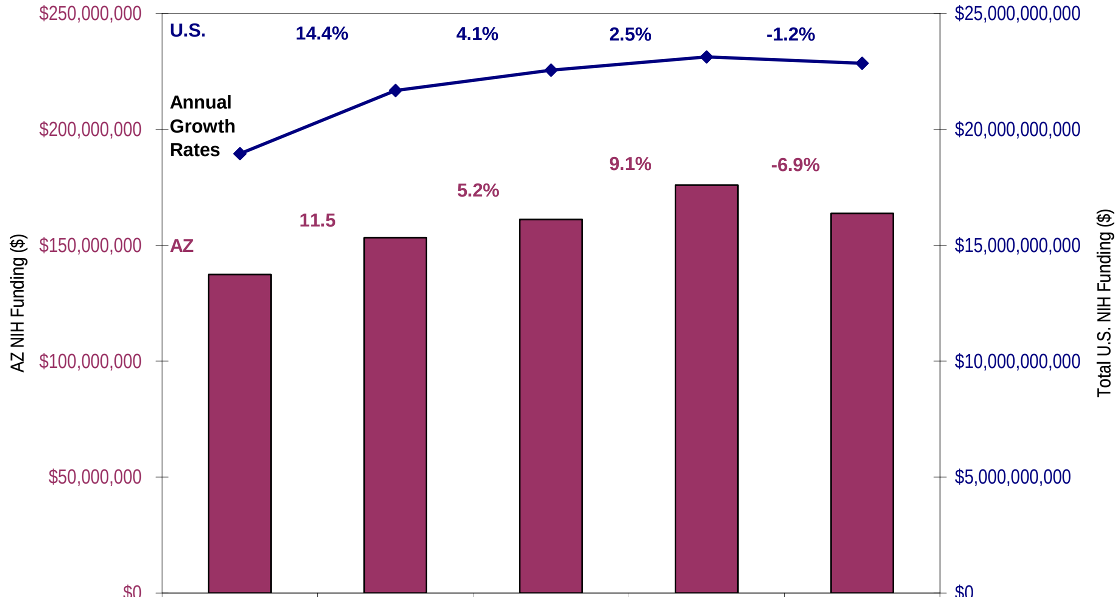


Figure 4 reveals that Arizona, like the U.S., has grown in NIH funding, and in the early years of Roadmap implementation outpaced U.S. growth. In 2006, for the first time, the state lagged. The most recent period, 2005 to 2006, shows that while overall NIH extramural funding declined, Arizona funding took a larger hit—declining by 6.9 percent or over $12 million in one year.

Figure 4. NIH funding trends for Arizona and U.S., 2002–2006

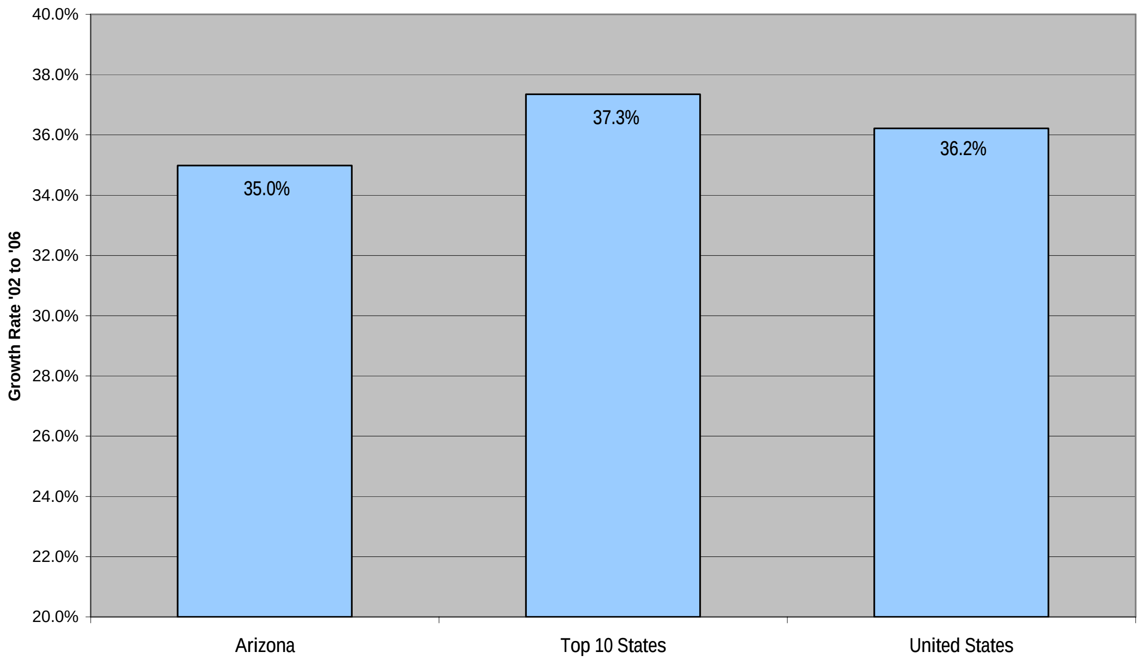


	2002	2003	2004	2005	2006
ARIZONA	$137,374,938	$153,197,688	$161,147,487	$175,880,998	$163,767,240
U.S.	$18,947,026,586	$21,669,025,252	$22,552,258,335	$23,116,571,209	$22,849,735,035

Arizona is still playing catch-up in biomedical sciences. While Arizona NIH funding has increased significantly in recent years, its proportionate share of the total NIH funding base has not increased. Arizona's NIH research funding accounts for only 0.72 percent of the total NIH research budget. This low level of funding in biomedical research is also reflected in a similar market share of 0.73 percent in the university research expenditures in the medical sciences—which includes federal, state, industry, and foundation sources of research support.

Using NSF's data on all academic R&D spending, Arizona's academic bioscience-related R&D accounts for less than 50 percent of all research performed in the state's academic institutions in 2006. Figure 5 shows that overall bioscience-related academic R&D actually declined by 2.7 percent from 2005 to 2006, with most of this decline coming from the biological sciences (declining 8.2 percent or $11.5 million) and agricultural sciences (declining 13.7 percent or $10.1 million) disciplines.

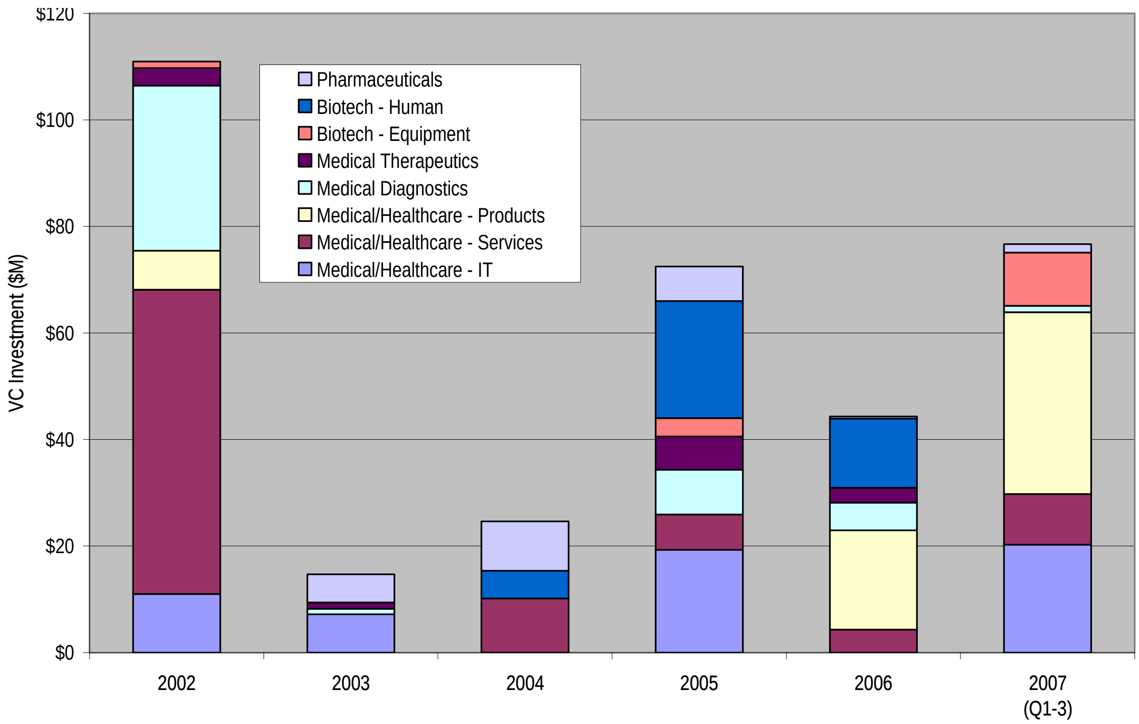
Figure 5: Growth in bioscience-related academic R&D expenditures, FYs 2002–06



Venture Capital

Arizona's bioscience-related VC investments through three quarters of 2007 already exceed the level of investments in all of 2006. Even with these strong three quarters, Arizona's growth rate in bioscience-related investments from 2002 to Q3, 2007 still shows a decline of 31 percent—compared to U.S. growth over the same period of 26 percent. ***However, it is important to consider trends to avoid single-year anomalies in reporting—removing a single large Arizona deal in 2002 would give Arizona a trend for 2002 to Q3, 2007 very similar to the U.S.*** Figure 6 shows that at current rates, a strong fourth quarter could place Arizona bioscience venture investments almost equal to their level of 2002, a significant rebound from the previous four years in Arizona. Furthermore, Arizona's Bioscience Roadmap set a target of $100 million in venture capital bioscience investments in the State by 2007. With three quarters of the year completed Arizona is already at 77 percent of this target for 2007.

Figure 6: Distribution of Arizona bioscience VC investments by segment and year: 2002–Q3, 2007



Bioscience Industry Employment

Arizona's bioscience firms continued to add jobs in 2006, with double-digit employment increases in four out of five major bioscience subsectors since 2002. In total, the state bioscience sector now employs nearly 81,000 persons (80,909) spanning 745 individual business establishments across the state (see Table 3). The labor market performance of the bioscience sector has been exceptional in recent years, as the base of state jobs increased by 18.5 percent since 2002 and the number of establishments increased by 16.7 percent (see Figures 7 and 8). With these rapid gains, Arizona has far outpaced their counterparts in the national sector where employment increased by 5.9 percent during the same period. Arizona is truly emerging with respect to forming an industry bioscience cluster.

Over the year (2005 to 2006), Arizona added 57 bioscience establishments, up 8.3 percent. Employment rose by 3,643 jobs or 4.7 percent. Most of the new jobs were in the hospitals subsector—up 3,164 or 4.9 percent. Medical device firms increased their employment by 290 jobs from 2005 to 2006, a 6.5 percent job gain for the subsector.

A strong year for the AZ Biosciences, 2005–06:

Establishments: Up 57; 8.3%

Employment: Up 3,643; 4.7%

Table 3: Arizona bioscience employment metrics by major subsector, 2002–2006

Arizona Bioscience Employment Metrics					
Industry Subsector	**2006 Establishments**	**Percent Change Estab, '02–06**	**2006 Employment**	**Percent Change Empl, '02–06**	**2006 Location Quotient**
Total Biosciences	**745**	**16.7%**	**80,909**	**18.5%**	**0.72**
Non-Hospital Biosciences	632	12.5%	13,143	20.6%	0.52
Agricultural Feedstock & Chemicals	18	-47.1%	502	-9.5%	0.24
Drugs & Pharmaceuticals	35	30.7%	1,108	17.1%	0.18
Medical Devices & Equipment	262	4.5%	4,792	25.3%	0.58
Research, Testing, & Medical Labs	317	26.7%	6,741	21.0%	0.77
Hospitals	113	46.8%	67,766	18.0%	0.79

Source: Battelle analysis of BLS QCEW data from IMPLAN.

Figure 7: Growth in Arizona bioscience employment and establishments, 2002-2006

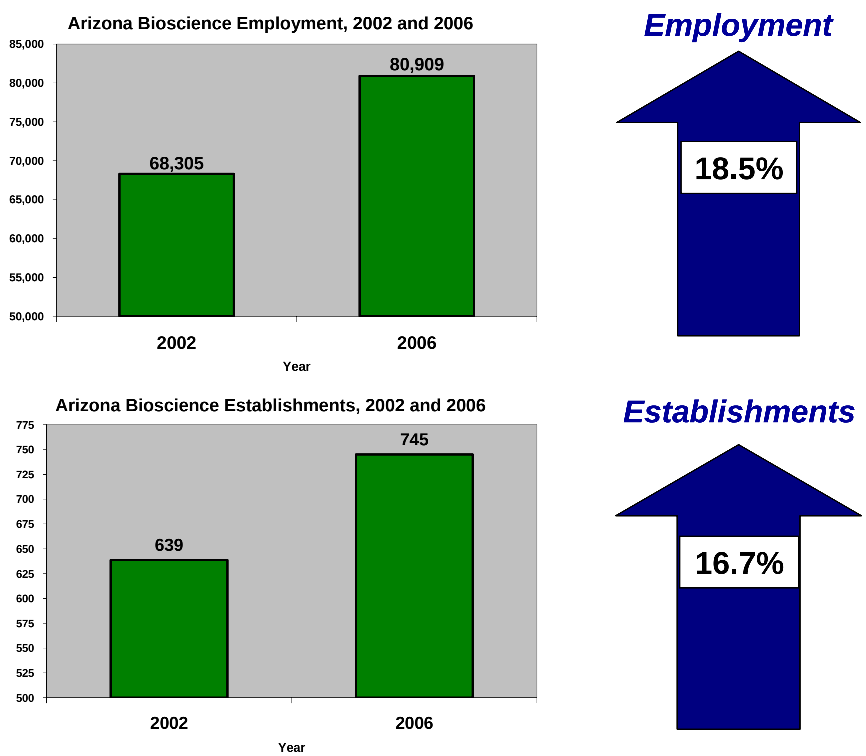
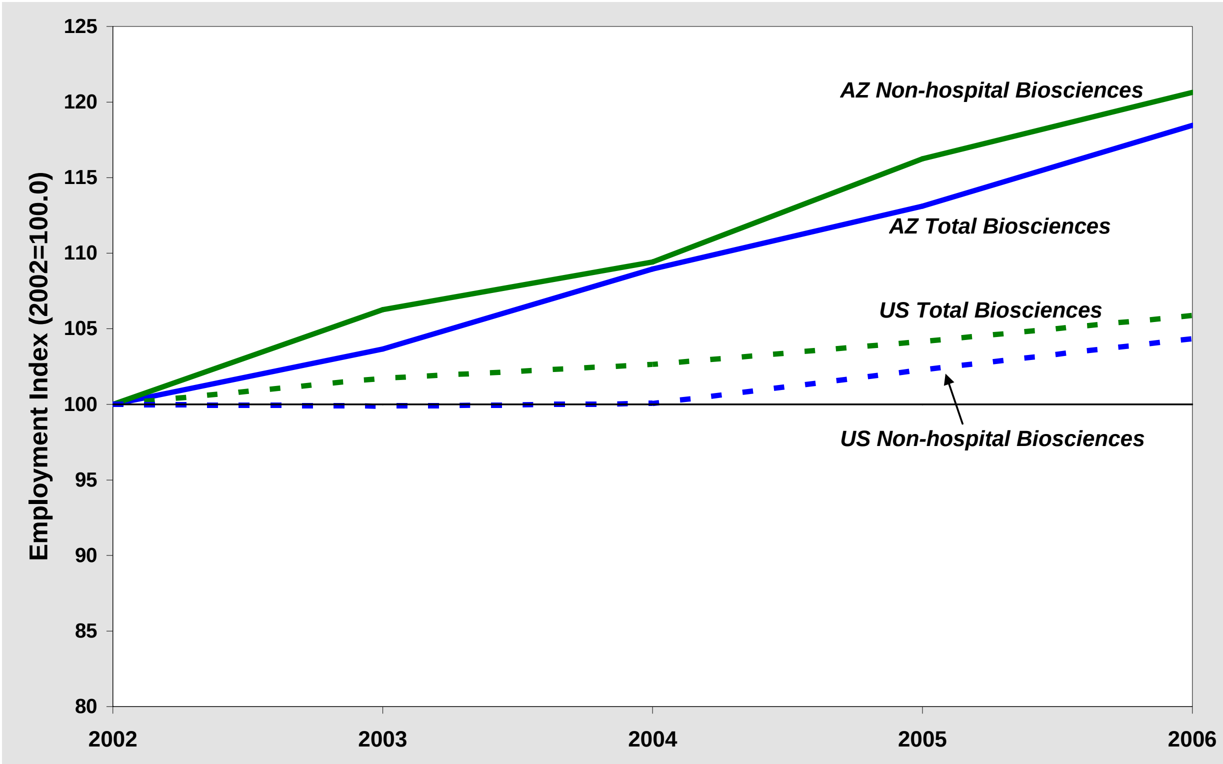
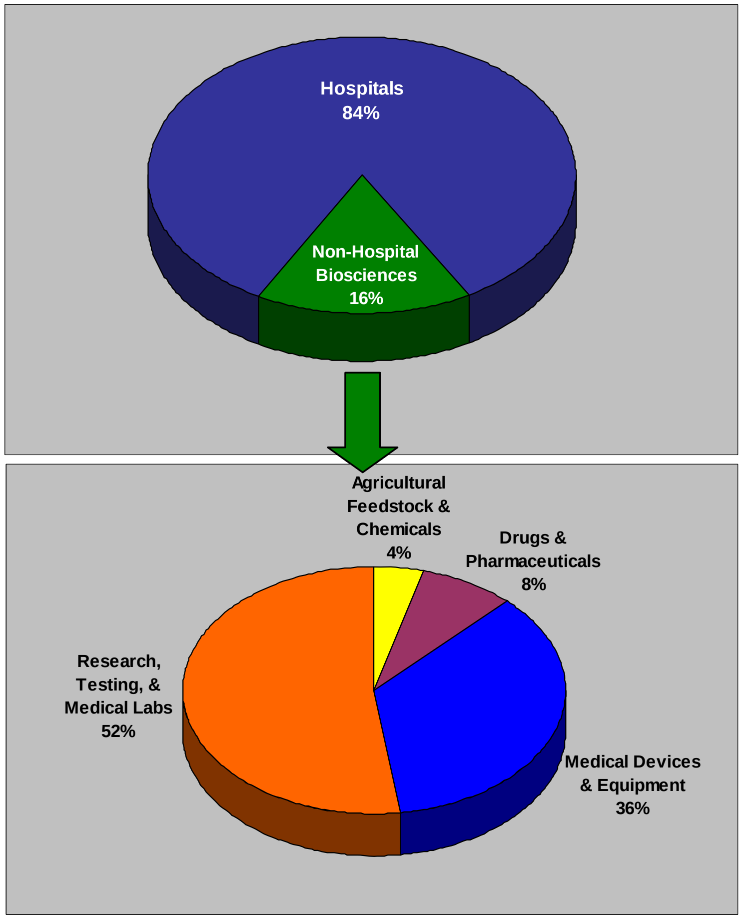


Figure 8: Trends in bioscience employment for Arizona and the U.S., 2002–2006 (Indexed, 2002=100)



The majority of Arizona's bioscience industry jobs are in hospitals, accounting for 84 percent in 2006. The remaining 16 percent in the non-hospital sector include a sizable number in research, testing, and medical labs as well as in medical devices and equipment. The composition of the state's bioscience industry in 2006 is shown in the pie charts in Figure 9.

Figure 9: Employment composition of the Arizona bioscience sector, 2006



Bioscience Wage Levels

State bioscience workers earn, on average, $48,674 in 2006 or $9,000 more than the average worker in the entire private sector (see Table 4). Driven by high-wage subsectors such as research and testing, and pharmaceutical manufacturing, the average non-hospital bioscience wage is even higher—$53,369 in 2006, or nearly $14,000 more than the average worker. Higher wages in these bioscience subsectors reflect the strong relative labor demand for this high-skilled, well-educated workforce.

Table 4: Average annual wages for Arizona bioscience workers and other major state industries, 2005 and 2006

Arizona Average Annual Wages by Industry, 2005 & 2006			
Industry	**2005**	**2006**	**Increase, 05-06**
Management of Companies & Enterprises	$ 63,473	$ 66,311	4.5%
Finance & Insurance	$ 57,142	$ 58,895	3.1%
Manufacturing	$ 54,617	$ 57,627	5.5%
Professional, Scientific, & Technical Services	$ 54,981	$ 57,527	4.6%
Research, Testing, & Medical Laboratories	**$ 50,559**	**$ 57,031**	**12.8%**
Drugs & Pharmaceuticals	**$ 54,188**	**$ 56,274**	**3.8%**
Total Non-Hospital Biosciences	**$ 49,329**	**$ 53,369**	**8.2%**
Information	$ 47,959	$ 51,151	6.7%
Medical Devices & Equipment	**$ 47,429**	**$ 48,958**	**3.2%**
Total Biosciences	**$ 45,182**	**$ 48,674**	**7.7%**
Hospitals	**$ 44,369**	**$ 47,763**	**7.7%**
Real Estate & Rental & Leasing	$ 39,965	$ 43,008	7.6%
Health Care & Social Assistance	$ 40,684	$ 42,962	5.6%
Transportation & Warehousing	$ 40,259	$ 42,151	4.7%
Construction	$ 38,067	$ 40,907	7.5%
Agricultural Feedstock & Chemicals	**$ 41,000**	**$ 39,875**	**-2.7%**
Total Private Sector	**$ 37,709**	**$ 39,526**	**4.8%**
Retail Trade	$ 27,479	$ 28,393	3.3%

Regional Distribution of Bioscience Firms

Regional employment analysis reveals varied niches and specializations in the biosciences across Arizona's metropolitan statistical areas (see Table 5). From a highly specialized and growing medical device subsector in Flagstaff, to a large and growing job base in research, testing, and medical labs in Tucson, the state can continue to build a diverse bioscience industry by leveraging regional specializations.

Table 5: Arizona metropolitan areas by key bioscience subsector in 2006

Arizona Metropolitan Area	Key Bioscience Subsector	Establishments, Employment Level & Concentration (2006)	Regional Strengths/Highlights
Flagstaff	**Medical Devices & Equipment**	**Establishments:** 6 **Employed**: 1,552 **Empl. Growth ('02-06):** 60% **Location Quotient**: 9.70	• Flagstaff is highly specialized in medical devices, with nearly 10 times the national employment concentration • The regional sector continues to grow at a rapid pace, up 60% since 2002
Phoenix-Mesa-Scottsdale	**Research, Testing, & Medical Laboratories**	**Establishments:** 204 **Employed:** 5,119 **Empl. Growth ('02-06):** 19% **Location Quotient:** 0.79	• Phoenix metro area has a large number employed in research, testing, and medical labs—three-quarters of State total • The region added 19% to its job base since 2001, driving state growth in the sector
Tucson	**Research, Testing, & Medical Laboratories**	**Establishments:** 64 **Employed:** 1,102 **Empl. Growth ('02-06):** 17% **Location Quotient:** 0.93	• Tucson's research, testing, & medical labs sector employment is well concentrated, nearly matching the national average • The region has added 20 establishments in the sector since 2002
	Medical Devices & Equipment	**Establishments:** 58 **Employed:** 864 **Empl. Growth ('02-06):** 19% **Location Quotient:** 0.79	• Tucson has an established, growing medical device & equipment subsector with 864 jobs in 2006 across 58 establishments • Since 2002, the metro area has boosted sector employment by nearly 20%
Yuma	**Agricultural Feedstock & Chemicals**	**Establishments:** 2 **Employed:** 239 **Empl. Growth ('02-06):** 14% **Location Quotient:** 4.72	• Yuma is highly specialized in the agricultural feedstock & chemicals sector, with nearly 5 times the employment concentration of the nation • Regional agbioscience jobs have increased by 14% since 2002

4: BUILDING UPON ARIZONA'S BIOSCIENCE RESEARCH CORE COMPETENCIES—MOVING TOWARD SIGNATURE OPPORTUNITIES

AN "ARIZONA-SPECIFIC" APPROACH TO BIOSCIENCE DEVELOPMENT

These measures of accomplishment in growing Arizona's bioscience research base are most promising. But, it is how Arizona is emerging that strongly endorses the state's growing position.

Arizona is defining its own approach to bioscience development that seeks to leapfrog rather than follow in the footsteps of traditional academic health leaders. Arizona must overcome its newness to biomedical research excellence and the corresponding lack of depth in many traditional areas of basic biological research and lack of a mature clinical research infrastructure. Yet, it offers a less-entrenched system, able to work outside traditional academic "silos" and to target opportunity areas in which to build upon existing strengths in a more systematic statewide manner across biomedical institutions.

Focusing on the following will be critical to Arizona's growing success:

- **Collaboration as a critical means for advancement.** The willingness of Arizona's institutions to work together and leverage their collective strengths and resources to the betterment of the state is becoming deeply rooted in Arizona. The rewards from this growing spirit of collaboration are found in many ongoing centers of excellence and initiatives in Arizona: home to the only "statewide" NIH-funded Alzheimer's Research Center; the recent award by the Michael J. Fox Foundation to the statewide Parkinson's Disease Consortium; the only statewide consortium receiving a planning grant to develop a Clinical and Translational Science Institute; the national recognition of the Arizona Telemedicine Program linking 27 sites across the state to deliver clinical care and advance clinical research; and the formation of TGen involving state and local government, foundation, private sector, and Native American support.
- **Leading with technology and interdisciplinary strengths to advance biomedical discovery and development at the scale of a state.** Arizona's long-recognized strengths in the physical sciences and engineering are now paying off with its innovations and centers of excellence in bioimaging, drug development, vaccine technology, bionanotechnology, bioinformatics, and tissue banking and molecular diagnostics, among other interdisciplinary fields.

But, even with all of the progress made over the past five years, Arizona is still not a leading state in biomedical research or industry development. Arizona must keep in mind that the road to national prominence in the biosciences takes a long-term commitment. Arizona must persevere in its efforts or risk falling behind.

The 2002 *Arizona's Bioscience Roadmap* recognized that Arizona needed to focus on and build stature in a few select areas to become a major player in the biosciences. The rationale was straightforward:

- Arizona—while late to focus on bioscience development—can build on its assets and opportunities for excellence in select areas where it has the greatest potential; and
- Having a clear focus can help position Arizona nationally and internationally, such as with the recently released NIH Roadmap.

This focus on building excellence in select areas of bioscience research recognizes that the biosciences represent multiple research fields, increasingly converging with broader enabling technologies in information technology, physical sciences, and engineering. Bioscience development, similarly, is perhaps one of the largest and most diverse sectors of the technology economy encompassing pharmaceutical, medical device, research and testing, agricultural, and health services markets. **So, states and regions can thrive in the biosciences, not by copying each other's development, but by distinguishing themselves in specific areas of bioscience R&D.**

> Battelle knows of no other state that has taken such a fundamental, comprehensive approach to identifying its strengths and competencies and moving forward to develop plans across institutions to further build its research stature.

Earlier Identification of Bioscience Research Core Competencies

Given the importance of identifying research strengths to build upon, a detailed analysis was undertaken in the development of the 2002 *Arizona's Bioscience Roadmap* to identify the core research focus areas for further development of the state's bioscience research base and establishment of national excellence.

The Roadmap proposed three core research areas offering Arizona the best chance to propel its research stature in the near term and another four emerging areas showing promise as longer-term opportunities for development.

Near-term core research focus areas for Arizona:

- Cancer Research
- Neurosciences
- Bioengineering

Longer-term core research focus areas for Arizona:

- Asthma-Related Disorders
- Infectious Diseases
- Diabetes
- Bioagriculture

In addition, three crosscutting research core competencies were identified through ***Scientific Platform*** deliberations focused on intensively engaging the leading scientists, clinicians, and research administrators in each of the near-term areas to establish full-fledged investment plans that leveraged Arizona's particular strengths in these core research areas and building stronger relationships to promote collaborations:

- ***Bioimaging*** where the use and development of imaging has become a critical tool in Arizona for advancing research, particularly in cancer and neurosciences. Arizona had the ability to advance not only the use of imaging for bioscience research but the development of imaging technology for commercialization.

> **Examples of Success in Advancing Collaborations in Targeted Areas of Bioscience Research Core Competencies**
>
> Building upon the analysis of the 2002 *Arizona's Bioscience Roadmap* in identifying research core competencies in Arizona, Scientific Platform Committees were formed engaging scientists, clinicians, and others in focusing on how to advance collaborations and niche areas of excellence. Here's a sample of collaborative activities across the Scientific Platforms:
>
> - Neurosciences – Key successes in collaboration include bringing genomics into existing neurological disease research centers, continuing to grow Alzheimer's Disease Consortium and advancing a new Parkinson's Disease Consortium attracting funding from Michael J. Fox Foundation.
> - Cancer – Key successes in collaboration found in advancing pre-clinical development and clinical research for early-phase trials.
> - BioImaging – Key successes include new collaborations between ASU and Barrow Neurological Institute, development of a statewide bioimaging consortium, and formation of a new Advanced Research Institute for Biomedical Imaging.
> - Translational Research – A defined *Pathway* initiative is underway seeking to harmonize and streamline IRB and business practices and advancing outreach to community physicians. Arizona was the only state in the nation to receive a planning grant to assist it in pursuing an NIH Roadmap Clinical and Translational Science Award.

- ***Tissue Repositories*** which are integrally related to the application of genomics for advancing predictive and personalized medicine. Arizona is in a particularly strong position, with the presence of the Sun Health Research Institute Brain Bank (and now whole organ bank) and other tissue resources at Barrow Neurological Institute and UA, as well as the IGC, a unique organization advancing the use of tissue resources for biomedical research.
- ***Translational Research Infrastructure*** which involves the broad "bench to bedside" capacities for developing research discoveries into new medical interventions, undertaking preclinical studies, and conducting human subject clinical trials. Arizona was seen as needing a translational research infrastructure that could enable collaboration by harmonizing business practices and streamlining clinical research review and contracting processes within institutions.

Battelle knows of no other state that has taken such a fundamental, comprehensive approach to identifying its strengths and competencies and moving forward to develop plans across institutions to further build its research stature. While other states and regions talk about their research bases, few have brought the relevant research, clinical, and business partners together.

Building Upon a Growing Bioscience Base to Advance Signature Opportunities

As Arizona steps forward in the future, the growing base of bioscience research core competencies will be a key asset. In particular, these bioscience research core competencies can be leveraged for signature development opportunities in the broad, diverse, and emerging markets and industries comprising the biosciences.

An updated assessment of Arizona's core bioscience research strengths by Battelle in 2007 finds that the growing base and maturity of bioscience research in Arizona has not only generally enhanced the depth of the original identified eight core competencies, but has developed a more robust set of core research strengths involving crosscutting research competencies, broad competencies, and niche competencies:

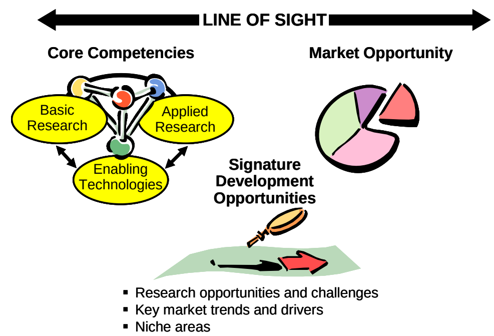
- **Crosscutting research competencies** that represent areas of enabling technology strength in Arizona that fuel not only research advances, but underpin the broader biosciences research activities in Arizona. Two prior crosscutting research competencies were found in bioengineering and bio-imaging. The updated analysis points to the growing strength in enabling and crosscutting areas of basic molecular and genomic sciences, insect sciences, and bioinformatics in Arizona.
- **Broad competencies** that not only have a significant presence in Arizona but demonstrate excellence nationally. Many of these broad competencies were identified in the 2002 Roadmap, including cancer research, neurosciences, agbiosciences, and environmental sciences.
- **Niche competencies** that have a clearly defined focus in Arizona but are smaller in size or not yet demonstrating national excellence. These niche bioscience research competencies include earlier identified competencies of asthma and inflammatory processes, diabetes, and infectious diseases and vaccine development. Among the new competencies identified through this updated analysis are cardiovascular development and repair and community health.

Assessment Criteria for Updated Core Bioscience Research Analysis

- Presence in cluster analysis of grant awards
- Position in publications and citation analysis
- Presence of major competitively funded research programs and centers
- Rankings by reputation in research and clinical fields
- Insights from more than 100 interviews with researchers and key administrators across Arizona's bioscience research institutions

But, bioscience research is not an end in itself, but rather a means for Arizona to move ahead in overall bioscience development. ***Bioscience research competencies also go hand-in-hand with growing signature opportunities for development in the broad, diverse, and emerging markets and industries comprising the biosciences.*** Core competencies by themselves do not generate "signature" areas of focus. Instead, core competencies serve as building blocks for development opportunities that draw upon multiple core competencies and allow a state to participate in growing and emerging market opportunities (Figure 10).

Figure 10: Translating Core Competencies into Signature Development Opportunities



What are these select bioscience sectors or signature development opportunities that can emerge to lead Arizona's growth in bioscience development? The answer lies in understanding Arizona's best positions for growth across its base of research and industry with a view to potential market opportunities. Identification of such opportunities within the biosciences in Arizona needs to take into account several criteria:

- **Opportunities drawing upon multiple competencies and institutions.** The development opportunity should be transformative, ensuring that Arizona's bioscience research base is more than a collection of stand-alone research strengths, but a fertile, multidisciplinary, crosscutting, and collaborative environment drawing upon research strengths.
- **Presence of existing or emerging industry connections.** The development opportunity should align institutional research strengths and local industries, creating new linkages and strengthening existing connections.
- **Significant development potential.** A favorable development timeframe and a substantial, growing market are characteristics of successful development opportunities. Signature development opportunities in the biosciences in Arizona should be realizable within 5 to 10 years, target multibillion dollar markets, and possibly evolve into and/or spawn new development opportunities.
- **Opportunity for external funding.** The opportunity area should relate to pressing issues, problems, or needs and thus be likely to attract major external R&D funding and investments.
- **Limited competition from other states/regions.** A successful development opportunity is one that faces limited competition from other regions. Specific competitive advantages such as geography, market base, tacit knowledge base, exclusive resources, or policies should render the development opportunity unique to a particular area.

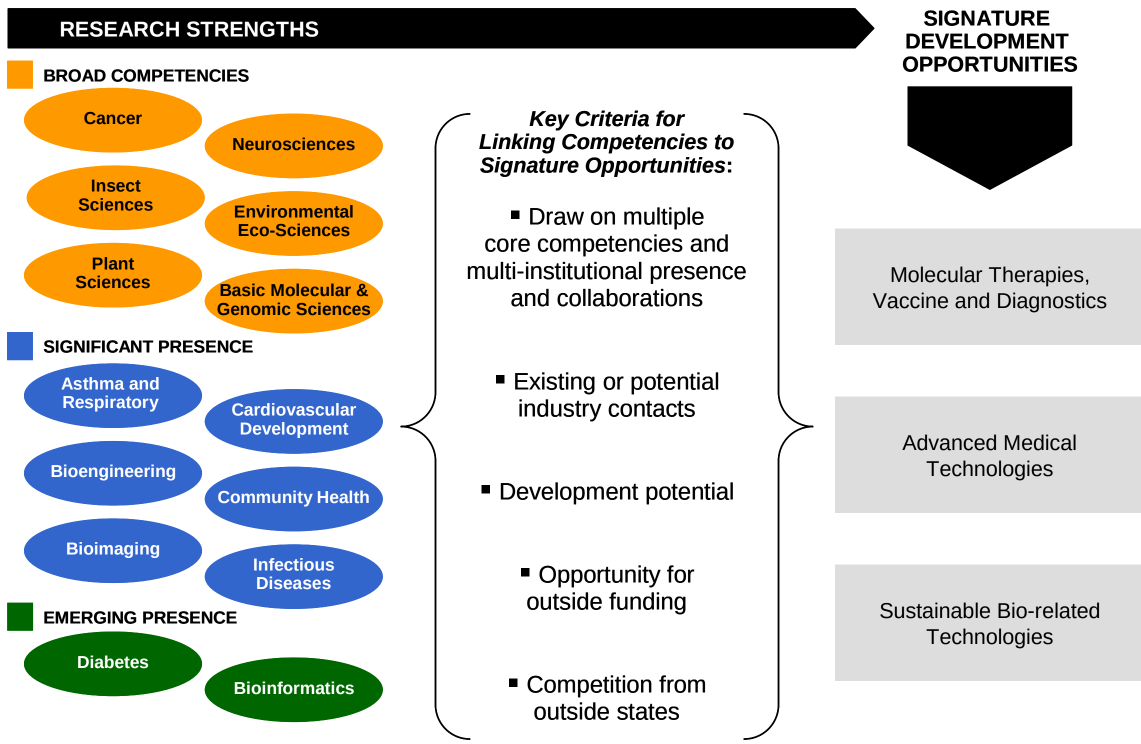
Investments since 2002 in Arizona's research infrastructure and programs at its universities, private research institutes, and medical centers has deepened and strengthened its platforms. Furthermore, Arizona also has research strengths as electronics, optics, and advanced manufacturing—all critical to the biosciences. And, Arizona has been building and increasing its capacity in the three big "O's"—genomics, proteomics, and bioinformatics. Together, Arizona is seeing a strong research convergence that enables the State and its partners to focus on signature opportunities cutting across platforms and disciplines.

Applying these criteria suggests three signature development opportunity areas (see Figure 11) for Arizona that align the state's bioscience research core competencies to its local bioscience industry base and the development potential of growing bioscience markets:

- Molecular therapeutics, vaccines, and diagnostics

- Advanced medical technologies
- Sustainable bio-related technologies.

Figure 11: Linkage of Arizona's bioscience research Core Competencies to Signature Development Opportunities



Each of these areas are discussed in the tables 6–8 below.

Table 6: Molecular Therapeutics, Vaccines and Diagnostics Signature Opportunity Analysis

MOLECULAR THERAPEUTICS, VACCINES and DIAGNOSTICS	
OPPORTUNITY	▪ Advances in genomics and proteomics are revolutionizing how we treat, prevent, and predict the onset of diseases. o First, drug development is relying more and more on genomic and proteomic analyses to identify specific molecular targets for therapeutic intervention. o Second, vaccine development—providing protection from diseases—has moved beyond the traditional use of live or attenuated pathogens and is focusing on specific genes and proteins. o Third, genomic and proteomic technologies are enabling the diagnosis, evaluation, and monitoring of human disease. Biomarker identification is central to this process. Biomarkers are gene or protein "signatures" that indicate a disease state or a physiological response to a therapeutic intervention. The discovery and application of biomarkers for molecular diagnostics are growing in areas such as cancer, infectious diseases such as HIV, and pulmonary and cardiovascular diseases. Altogether, the field of molecular therapeutics, vaccines, and diagnostics is growing rapidly and is an important and valuable development opportunity in the biosciences.
MULTIPLE COMPETENCIES AND INSTITUTIONS:	▪ The field of molecular therapeutics, vaccines, and diagnostics scores high on this metric. Six of Arizona's 14 demonstrated research core competencies support this opportunity area. Arizona's broad and deep capabilities in basic molecular and genomic sciences are fundamental to the successful realization of this opportunity. Capabilities in cardiovascular disease, neurosciences, asthma and inflammatory processes, and diabetes are also crucially important because they provide specific disease targets on which to focus. Strengths in imaging and bioimaging are vital for evaluating the effects of therapeutics and vaccines on treating or preventing disease symptoms.
EXISTING OR EMERGING INDUSTRY CONNECTIONS	▪ The research and testing sector of the biosciences industry is increasing dramatically in Arizona, growing 27 percent in number of establishments (up by 67) and 21 percent in employment (up by 1,171 jobs) from 2002 to 2006. Compared with the industry nationally, it is also the most specialized non-hospital bioscience sector in Arizona. However, the connections between the institutional R&D bases and corresponding industry groups could be stronger. ▪ Analysis of Arizona patents in the biosciences using Battelle's OmniViz™ software revealed clusters related to arrays and assays, drug development, imaging, and protein chemistry and molecular biology. ▪ These results demonstrate Arizona's strengths in developing and/or acquiring technologies related to molecular therapeutics, vaccines, and diagnostics.
DEVELOPMENT POTENTIAL:	▪ Application of molecular and genomics-based therapeutics, diagnostics, and vaccines is becoming one of the fastest-growing market sectors in the biosciences. Genomics-based drug discovery is mounting as an important component of overall drug discovery, providing a rapid and cost-effective method to correlate genes with specific diseases to discover drug targets. Dorland expects the genomics and post-genomics drug discovery market to reach just over $9 billion by 2007, with a 17.5 percent compounded annual growth rate over the 2002 to 2007 period.[1]
OPPORTUNITY FOR EXTERNAL FUNDING:	▪ Because of the growing incidence of familiar diseases, as well as the advent of new diseases, the need for effective treatments, vaccines, and diagnostics is immense. Therefore, the funding prospects from organizations such as NIH, the Gates Foundation, and others are substantial. These fields also attract investments such as venture capital because of the potential for a large return. The recent announcement of the New Partnership for Personalized Medicine, supported by awards of $45 m. from Virginia Piper and Flinn Foundations to a joint TGen/ASU partnership has already assembled a stellar research and leadership team to place Arizona as a key international hub of proteomic research and discovery. Personalized medicine and this investment provide the opportunity to facilitate management of diseases at all stages while improving health outcomes and reducing costs.
COMPETITION FROM OTHER STATES:	▪ Many states and regions are extremely active in this field, successfully attracting external funding, developing new technologies and products, launching new ventures, and attracting talent. Nearly every major academic medical center has a focus in some aspect of molecular therapeutics, vaccines, or diagnostics.

[1] *The Medical and Healthcare Marketplace Guide*, Dorland Healthcare Information, 2006.

Table 7: Advanced Medical Technologies

ADVANCED MEDICAL TECHNOLOGIES	
OPPORTUNITY	Convergence of the biosciences with fields such as imaging, information technology, nanotechnology, and other engineering disciplines has yielded considerable advances in medical technologies. Advanced medical technologies span the range of tissue, bone, and organ generation and engineering to the design of tools for diagnosis and treatment of diseases or disorders. Corresponding markets include tissue engineering, surgical systems, neurological assistive systems, and imaging devices. Leading technologies being adapted for use in innovative medical systems include the following: ▪ *Materials*: Biopolymers may soon replace metals and plastics in many medical devices intended for use within the human body. Biopolymers hold promise as being durable, biodegradable, and less likely to invoke immune system responses than traditional materials. In the long term, organic tissues may be the material of choice involving technologies such as autologous tissue generation (culturing a patient's own cells) and organ culturing. ▪ *Microelectronics*: Microelectronics made its entry into medical devices with the introduction of cardiac pacemakers in the 1970s. Today, cardiac implants remain a dominant user of microelectronics, along with growing use for neurological, cancer, hearing impairment, and diabetes. In addition, microprocessors are the mainstay for monitoring, scanning, imaging, and other diagnostic devices. ▪ *Nanotechnology*: Applying molecular engineering involving microfabrication and micromanipulation technologies to create nanoscale medical devices is an entirely new emerging field. Already on the market are high-density gene and protein chips, three-dimensional microarrays, automated high-throughput screening devices, fluorescent DNA probes, nanoparticle assemblies, and atomic force microscope systems capable of mapping individual chromosomes. One of the hottest areas in nanotechnology involves the R&D of microelectromechanical systems for biomedical uses called BioMEMs. In the future, tailor-made nanoparticles and MEMS will be used for assays, sensors, drug delivery, nanocrystals to target cells, implants, and much more. ▪ *Imaging*: Imaging techniques are the technological basis of many medical devices, including x-rays, MRI, endoscopy, and computer-aided tomography (CAT) scanning. Non-invasive methods for gathering biological information are in great demand. Some related technologies, such as ultrasound therapy and precision laser surgery, are also useful as non-invasive treatments. ▪ *Biosensors*: Biosensors represent an important new direction in analytical measurement technology because they can measure constantly the presence or absence and concentration of substances, in rapid response time. Biosensors incorporate a biological sensing element integrated within a compact analytical device. In addition, through the use of fiber optics in medical devices, optical biosensors are growing, which are useful, for instance, in diagnosing joint injuries. ▪ *Robotics*: Robotics already plays a key role in advancing drug discovery through its use in high-throughput screening technologies. In health care, robotics combined with computerized surgical systems is expected to increase the precision and dexterity needed to perform complex, minimally invasive surgical procedures and generally create better outcomes.
MULTIPLE COMPETENCIES AND INSTITUTIONS:	▪ The field of advanced medical technologies scores high on this metric—four of Arizona's 14 demonstrated research core competencies from both academia and industry support this signature development opportunity. Two broad research competencies are in the areas of cardiovascular development and repair (focusing on properties of vascular tissue, blood, and heart) and bioimaging (focusing on optics, sensors, image processing, and radiology). More niche or crosscutting strengths lie in the areas of bioengineering and insect sciences. The field of insect sciences—not entomology, but using insects as model systems for understanding sensory systems, neural networks, behavior, and other complex phenomena—differentiates Arizona from its peers.
EXISTING OR EMERGING INDUSTRY CONNECTIONS	▪ As a sector, medical device technologies are one of the largest within the bioscience industry in Arizona. Between 2002 and 2006 the number of establishments grew by 4.5 percent or 11 establishments and the number of jobs in medical devices grew by 25 percent or 968 jobs. Analysis of Arizona patents in the biosciences using Battelle's OmniViz™ software revealed clusters related to catheters and stents, electromedical devices, miscellaneous medical devices or prostheses, and skeletal devices. ▪ Overall, the field of advanced medical technologies scores high and is a source of distinction for Arizona, not only because of the size of this industry but also the degree of connectivity between industry and academia.

Table 7: Advanced Medical Technologies (cont.)

DEVELOPMENT POTENTIAL:	▪ Advanced medical technologies offer a diverse set of markets with significant growth opportunities.
OPPORTUNITY FOR EXTERNAL FUNDING:	▪ The National Institute of Biomedical Imaging and Bioengineering is a separate NIH institute; but, its annual research budget of only $280 million in fiscal year (FY) 2005 was a fraction of the overall $23 billion NIH research funds. The Department of Defense also has an extensive interest in a wide range of advanced medical technologies, including biosensors, in-field diagnostic kits, wound healing, and prosthetics. Nanomedicine, also a key area of federal funding both at NIH and NSF, is attracting venture capital investment.
COMPETITION FROM OTHER STATES:	▪ While many research institutions have growing bioengineering programs, few are at the scale that would prevent others from competing. This reflects in large part the available funding and convergence of technology underpinning these efforts.

Table 8: Sustainable Bio-Related Technologies

SUSTAINABLE BIO-RELATED TECHNOLOGIES	
OPPORTUNITY	▪ The development of technologies for producing material resources, energy, and manufactured products without depleting or damaging the earth's resources has gained momentum in recent years, attracting attention from activists and legislators to scientists and engineers. Examples of such sustainable technologies include bio-based materials, renewable energy resources, green design, materials recycling, environmental restoration, and the production of valuable resources from waste materials. Sustainable ***bio***-related technologies are those that derive from organisms such as microbes, plants, and animals. Within Arizona, niche opportunities for sustainable bio-related technologies include the following: ▪ *High-Value Bioproducts* – Applying Arizona's scientific leadership to the development of high-value bio-based products such as: o Renewable energy from microbial biomass and existing waste streams o Drugs and vaccines produced through modified plant production pathways o Nutraceuticals and high-value natural products from Arizona native plants o Specialty foods and functional foods ▪ *Sustainable Agriculture* – Leveraging Arizona's expertise in controlled-environment agriculture and water-resource conservation technologies to further expand the state's substantial fruit and vegetable industry. ▪ *Sustainable Forests* – Using the forestry, ecology, and environmental science expertise among Arizona's research universities to find solutions to a broad range of forest issues such as fire management, ecosystem restoration and ecosystem genetics, and the development of economic uses for forest undergrowth and forestry by-products. ▪ *Infectious Disease Treatment and Control* – Using Arizona's expertise in ecosystems, insect vectors, infectious diseases, immunology and vaccinology, and public health to produce new approaches to disease management, control, and treatment. Concerns over environmental variability and change and its impact on human health are steadily growing around the world. Many possible threats are becoming more widespread in arid and semiarid regions around the world, providing a unique opportunity for Arizona. ▪ *Insect Control Products* – Applying Arizona's broad and deep expertise in insect sciences, insect neurobiology, and entomology and also plant biology and plant defense mechanisms to develop new approaches to insect pest control for both agricultural and urban-environment applications. ▪ *Integrated Resource Management* – Leveraging Arizona's scientific expertise to improve the sustainability and profitability of forage-based agriculture and natural resource systems. Today's successful resource manager must critically evaluate how food production, recreation, urban development, water, wildlife, human, and financial resources affect sustainability of the land. Sustainable bio-related technologies are a robust development opportunity, potentially providing many technology product opportunities to serve multiple market segments. Sustainable technologies represent a high-growth market opportunity—a market that can only expand as global population and development pressures place increasing strain on the environment. The segments that are particularly attractive and show the greatest growth potential for commercial products include renewable energy, high-value crops, and high-value bioproducts.

Table 8: Sustainable Bio-Related Technologies (cont.)

MULTIPLE COMPETENCIES AND INSTITUTIONS:	▪ The field of sustainable bio-related technologies scores high on this metric. Three of Arizona's 14 demonstrated research core competencies support this opportunity area. These core competencies are plant sciences, environmental sciences, and insect sciences and stem from activities at each of the three ABOR universities. ▪ *Ecological Sciences* – This is Arizona's strongest core competence, with three areas of world-class research and scholarship. ▪ *Arid/Semiarid Lands Ecology* – Battelle could not find another university system that possessed the same depth of knowledge. ▪ *Plant Sciences, Plant Genomics, and Epigenomics* – UofA has world-class expertise in these areas, with great potential for development of modified plants suited to various biorenewable applications. In addition, ASU is home to international leaders in the use of plant pathways for production of vaccines and other biomedical value-added products. Both the Biodesign Institute and BIO5 are moving forward rapidly in applied research in these areas. ▪ *Urban Ecology* – Leadership in Arizona is provided by the Consortium for the Study of Rapidly Urbanizing Regions at ASU. ▪ *Remote Sensing and Urban Environmental Systems* – ASU is a leader in the application of these studies to many cities around the world. ▪ *Hydrology and Water Resources* – UofA is first nationally in hydrology; add to that distinction the four water centers, each dealing with a different problem area, and ASU's and NAU's contributions, and Arizona has what is arguably the world's biggest and best water resource portfolio. The field of plant sciences also has two strong research areas, which could be very powerful if integrated and linked to sustainable agriculture: ▪ *Insects* – The CIS has unique capabilities and resources for the study of insects, leading to unique opportunities for considering insect applications in disease control, environmental preservation and restoration, controlled environment pollination, and renewable energy resources.
EXISTING OR EMERGING INDUSTRY CONNECTIONS	▪ Arizona itself promises to be a very significant market for these technologies, although the current industrial base is not adequate to service it. An analysis of patent activities revealed a small group of three clusters with 78 patents in plants, cultivars, and botanicals, led by BASF Plant Sciences and International Flora Technologies. ▪ Three segments appear to be gaining strength in Arizona: (1) controlled-environment agricultural production (greenhouses), particularly for growing vegetables and flowers; (2) microbial, waste, and alternative biomass–based energy production; and (3) the forest-based renewable industry, using biomass from forest thinning as a "platform" to manufacture value-added products, from building construction products (e.g., composite wood products and moldings) to garden and horticultural products (e.g., stakes, mulch, composts, etc.).
DEVELOPMENT POTENTIAL:	▪ The breadth and potential of this signature area lead to a wide variety of applicable market niche opportunities for Arizona, such as the following: o *Biomass and Bioenergy Production (using microbial systems and plant systems)* o *Controlled Environment Agriculture (CEA)* o *Natural Products from Native Arid and Semiarid Plants* o *Insect Pest Control for Agricultural, Forest, and Urban Environments*
OPPORTUNITY FOR EXTERNAL FUNDING:	▪ Multiple federal agencies are engaged in funding research pertaining to the environment, environmental sustainability, and sustainable systems and associated technology. The National Council for Science and the Environment estimates total federal funding for environmental R&D to be $7.9 billion, and recent Presidential initiatives and private industry initiatives related to biofuels are providing significant new funding pathways. In general, the level of external funding available for projects related to biosustainability is likely to increase because of a heightened awareness of diminishing natural resources, the effects of urbanization, and a need for independence from foreign energy sources.

Table 8: Sustainable Bio-Related Technologies (cont.)

COMPETITION FROM OTHER STATES:	▪ Arizona is far from alone in noting the increasing opportunities and worldwide need for sustainability R&D. Considerable attention is being paid to competing for bioenergy and biorenewable R&D funds, with major initiatives in multiple states. Some examples of competing state and university initiatives include the following: o The Iowa Bioeconomy Initiative comprises industry, state government, and academe working in collaboration to build strengths in agriculture-based biofuels, chemical catalysts, and new economic applications for crop residues. o Focused initiatives in Nebraska are centered on the University of Nebraska's Institute for Agriculture and Natural Resources focused on high-efficiency ethanol production via integrated corn, feedlot, and biogas, feed, and biofuel systems. o Ohio is using part of its large-scale Third Frontier Initiative technology-based economic development funding to build capabilities at the Ohio Agricultural Research and Development Center in leading-edge areas of sustainable biofuels, composting and growing media, and sustainable greenhouse operations for horticulture. o Pittsburgh area institutions are focusing on opportunities to introduce green products to existing heavy industry, such as green chemistry technology for the large chemical industry sector. There is also significant emphasis in Pittsburgh's universities on green building materials and construction. o The focus of the large agricultural states and associated land-grant research institutions has been heavily directed at finding biorenewable/biofuel applications that will enhance the value of their existing agricultural commodities and agricultural commodity by-products. Arizona, by virtue of an economy less dependent on traditional commodity agriculture, has greater freedom to pursue more niches, innovative applications in sustainable development, including, for example, work in forest biomass, microbial biomass systems, natural product extraction, and ecosystem restoration.

SUMMARY

As Arizona steps forward in the future, the growing base of bioscience research core competencies will be a key asset. In particular, these bioscience research core competencies can be leveraged for signature development opportunities in the broad, diverse, and emerging markets and industries comprising the biosciences. Three signature opportunities promise to align Arizona's bioscience research core competencies to its local bioscience industry base and the development potential of growing bioscience markets:

- Molecular therapeutics, vaccines, and diagnostics
- Advanced medical technologies
- Sustainable bio-related technologies.

For Arizona to realize the potential of these signature opportunities, it must continue both to invest and achieve national stature in its areas of research competency and to leverage these bioscience research core competencies for broader bioscience development by linking with the ongoing economic development activities of the Roadmap, such as accelerating technology commercialization, increasing venture capital, addressing workforce development, and supporting commercial bioscience wet-lab development.

5: COMMERCIALIZING TECHNOLOGY – TRANSFERRING DISCOVERIES TO THE MARKETPLACE

In the previous sections we have outlined the ways and progress Arizona is making in building a critical mass of research programs, faculty, infrastructure, and collaborative teams. And we charted the remarkable progress Arizona has made to date in overall implementation of the Bioscience Roadmap since 2002.

Research alone will not offer well-paying jobs for the state's citizenry, nor improve health care prevention, unless it can link the bench with the bedside through new products, treatments, diagnostics, and prevention. It is clear that the dual objectives of the Roadmap—building a critical mass of research and a critical mass of bioscience enterprises—will not be achieved by addressing research exclusively.

As Arizona continues to invest in the research enterprise, as it should, it must also increase its focus and commitment to technology commercialization. Very small strategic investments in technology commercialization can provide exponential return on the monies invested while contributing to the improved health care dividend desired.

The progress Arizona has made to improving Arizona's research stature now provides the opportunity to focus on and address issues concerning the state's capacity for turning more of that research into technology, firms, products, and jobs—what we term in this paper as *"technology commercialization."* An opportune time has arrived for Arizona to address the technology commercialization challenge.

Arizona's universities, private research institutes, and medical centers are giving increased attention and focus to technology transfer. The Arizona Board of Regents has continued to make policy changes that encourage technology transfer and faculty entrepreneurship. University intellectual property portfolio performance for the biosciences shows increasing successes with start-ups and spin-offs as outlined previously. Interest and support from the state has been steady. The private sector is increasingly taking steps to address market needs.

Battelle has interviewed the state's risk capital leaders and observers as well as the state's technology transfer leaders at its universities and research institutes. It has also benchmarked technology commercialization approaches across the country and beyond and identified best practices.

SO WHAT IS TECHNOLOGY COMMERCIALIZATION?

Technology transfer and technology commercialization are not the same thing.

Technology transfer is the passive management of a research organization's intellectual property. Technology transfer involves disclosure of discoveries, the determination of the need for patent protection, and the licensing of the intellectual property (to either a third-party organization or to create a new business) to pursue the development of a product, process, or other intervention based on the discovery, and its associated license. Each of Arizona's public universities has a technology transfer function to handle the intellectual property discoveries and innovations resulting from their faculty and student's research (ASU and UA have their own offices; NAU's technology transfer function is administered by ASU). The State's private research institutions, such as TGen, also have offices responsible for technology transfer, and, many of the State's hospitals and medical centers are developing a similar capability.

Technology commercialization, however, involves moving beyond legal protection and licensing. It requires developing the technology into a product/service to meet the need(s) of customers in the marketplace. Technology commercialization is often called applied research. Unlike the stages of technology transfer (shown in Table 9) where the research is created from the search for improved knowledge and understanding, technology commercialization is being developed to meet the needs of a specific customer and, ultimately, result in a profit from its sales and use.

Table 9: Technology Transfer vs. Technology Commercialization – Stages

	Technology Transfer		***Technology Commercialization***		
Technology Development Stage	Discovery	Translational Research	Technology Development	Product Development	Production/Marketing
Outcome	• Invention Disclosure • Publication	• Proof of Concept • Patent/Trade Secret • License	• Engineering Optimization • Product Prototype • Pre-seed business	• Initial Product • Start-up business or new program (for established companies)	• Mass Production • Established company

Source: Adapted from NIST, "ATP and Venture Capital Funding Criteria Differ," http://www.atp.nist.gov/factsheets/1-c-9.htm

Technology commercialization is primarily concerned with building and growing new products and processes in existing or new firms. It involves a number of activities, such as **assessing the technology and its potential markets** against current products in the marketplace (e.g., technology and market assessments). It involves **developing the product itself**, and **optimizing its engineering and design** to meet price points of the marketplace, if sales and growth are to occur. It **involves putting the business and management team** in place and **securing the sources of equity and working capital** that will carry the product and/or firm through various stages of maturity until it becomes an established company/product in larger domestic and global markets.

Technology commercialization brings together the technology derived from the research interest; risk capital to develop and engineer the product for manufacture and distribution; and entrepreneurial management talent to manage and steer the firm or product into and through the marketplace. Three key elements of technology commercialization then are:

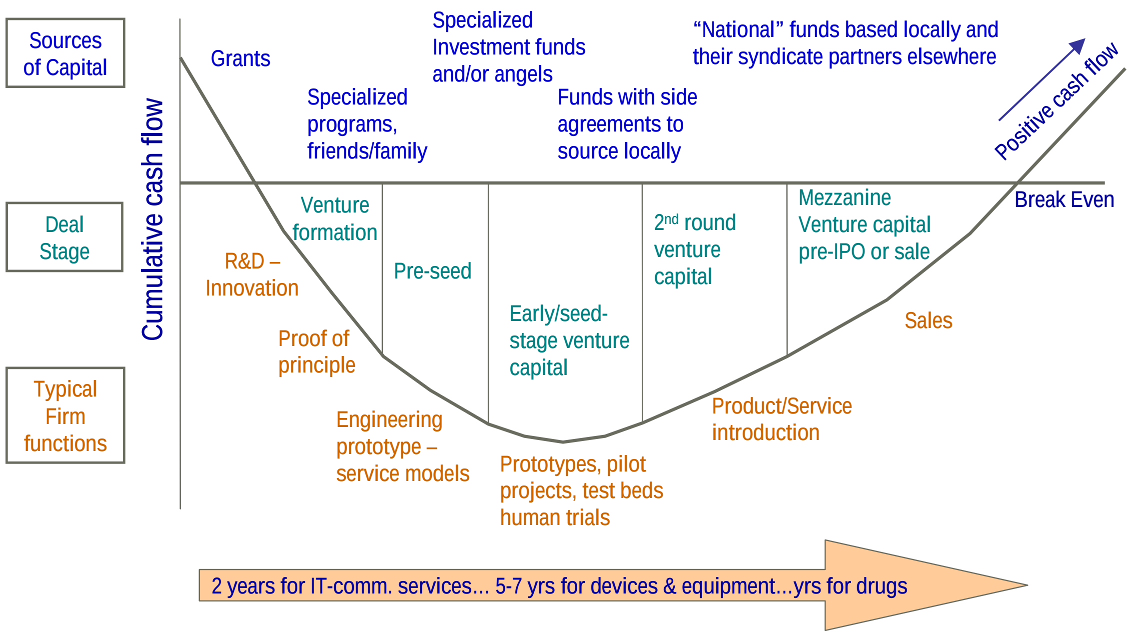
1. Technology itself (which is not the same as research)
2. Risk capital
3. Entrepreneurial management talent

Technology commercialization is a key method for linking industry with research being developed in the research organization, whether it is the base for the creation of new enterprises or new products and processes by existing firms. By successfully commercializing the discoveries and inventions created by research institutions in Arizona—whether they are hospitals and medical centers, private institutes, or higher education institutions—the research outputs of these institutions can be leveraged to help create a critical mass of industries, leading to improved economic growth and quality of life for the citizens of the State. **If technology commercialization does not occur, research will not be turned into medical treatments, preventive medicine, and creation of new medical products or treatments.**

Moving From Research Discovery to Addressing the Valley of Death

The focus of technology commercialization is turning basic research into firms and products with sales in the marketplace. Many refer to the funding cycle issues as the "Valley of Death" as illustrated in Figure 17. Battelle suggests that *gaps within the Valley of Death are impeding Arizona's ability to maximize its investments from its successes* in building stronger research base in its universities, private research institutes, and its medical centers and hospitals.

Figure 17: Research Discoveries – Valley of Death



This "Valley of Death" helps illustrate the need for a continuum of support, services, and assistance from the private and public sectors as a technology enterprise is conceived, developed, formed, grown, and reaches maturity. Tools needed include due diligence, proof of concept, and engineering optimization in developing the technology and identifying the product. In addition, bioscience entrepreneurs in Arizona must address a fairly long continuum of risk capital needs to start, develop, and grow their firms.

The development of new technologies is a very expensive process running, in some cases, into millions 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; preparing a marketing and sales plan; and scaling up for manufacturing. Finally, actual product distribution, sales, and marketing must be undertaken.

Technology commercialization is receiving considerable emphasis in states and regions across the U.S. Much attention is being paid to providing support for those activities that must be undertaken in order to move research discoveries into the marketplace. This is in part due to the recognition that to ensure the greatest chance of success entrepreneurs must have access to a comprehensive continuum of support as they progress through the stages necessary to establish a thriving enterprise. It is also due to a desire to capitalize on research findings in our universities, medical, and research institutions by facilitating their application in new products and spinning off new companies. A variety of models are being established to facilitate technology commercialization internationally and in states and regions in the United States. But there is no single, proven model for technology commercialization.

Assets of Successful States and Regions

- Universities and Research Labs create new ideas
- Superior infrastructure (labs, communication, transportation)
- Investment capital and entrepreneurial culture
- Smart people and quality of life to attract them

By itself, research will not translate into commercialization, just as investing in university buildings and faculty by themselves will not create business and commercial success on any substantial scale. The federal government funds primarily the research enterprise but not the technology commercialization infrastructure. Too often universities and other non-profits focus on receiving funds available from the federal government and corporate sponsors for their research, while companies (start-up and established) focus on receiving funding from venture capitalists and internal sponsors for commercial-ready technologies. This situation creates little or no incentive for either the research institution or industry to move basic research into commercialized products.

Historically, educational, civic, and political leaders grasped the concept of investing in the communications infrastructure of high speed lines and connections so that commerce and business can function. The last half-mile connection from the street to the home has been the difficult challenge. Similarly, the last half-mile problem for higher education and other research organizations is to invest in the technology commercialization infrastructure. This will maximize commercial contributions from the research by applying and developing the research into products and new industries of the future. This is the half-mile problem related to business-university connectivity.

It is up to higher education leaders, elected officials, and the civic and philanthropic communities to identify ways to address these technology commercialization gaps. Arizona's higher education and medical institution leaders need to increase the resources available to their technology transfer offices, as, shown through the successful examples of the University of Florida and the University of Massachusetts. Elected officials need to focus resources on this issue, such as Pennsylvania, Missouri, Georgia, and Ohio have done. The civic and philanthropic communities need to tackle those aspects of technology commercialization infrastructure outside of the research organization such as risk capital and business mentoring. Leading examples include the BioGenerator in St. Louis and the Life Sciences Greenhouse in Pittsburgh.

Arizona State University established the first state university technology transfer office in Arizona in 1985; the University of Arizona began its office in 1988. However, Arizona's state universities did not become aggressively involved in technology transfer until 1996 when the governing body for the three state universities, the Arizona Board of Regents, made a change to the patent policy to allow the state universities to assign title or rights to the patents that they owned.

Table 10: All Arizona university entrepreneurship: biosciences only patents, licenses and startups from university IP

Metric	2002	2003	2004	2005	2006	Q3, 2007
Invention Disclosures Received	93	94	84	136	119	103
Total U.S. Patent Applications Filed	59	70	70	59	42	110
U.S. Patents Issued	13	12	19	16	20	25
Licenses & Options Executed	20	19	25	33	28	26
Adjusted Gross License Income Received	$1,845,889	$1,129,999	$1,727,272	$1,857,508	$3,318,339	$3,044,167
Bioscience Startups from University IP	2	6	11	10	5	5

The trend line for Arizona's public universities in technology transfer and commercialization particularly in the biosciences is moving in the right direction. Table 10 shows that the number of bioscience startups from university intellectual property/research has gone from two in 2002 to five into Q3 of 2007, with the cumulative number of bioscience startups over that five-year time period totaling 39 firms. Table 10 also shows that bioscience invention disclosures have continued to grow, as have patent applications filed, and patents issued. Licenses have increased by 30 percent with 28 executed in 2006. The trend line for Arizona's public universities in technology transfer and commercialization particularly in the biosciences is moving in the right direction.

Finally, even as the number of startups increases (with return to the university increasingly being based on equity, not royalty income) royalty income received has increased significantly to over $3.3 million in 2006 and $3 million in three quarters of 2007 from a level of $1.8 million in 2002. Over the 2002–Q3, 2007 time period, total income totals $12.9 million, excluding value of equity taken in firms.

Table 11: University entrepreneurship comparisons among leading research institutions: patents, licenses and startups from university IP

		Cumulative Total Performance: 2003-2005						
Name of Institution	State	Invention Disclosures Received	U.S. Patent Applications Filed	U.S. Patents Issued	Licenses & Options Executed	Adjusted (*) Gross License Income Received	Start-ups initiated	Sponsored Research Expenditures
Arizona State University	AZ	180	388	61	51	$ 4,801,780	10	$ 294,866,969
University of Arizona	AZ	205	192	40	75	$ 3,215,547	11	$ 1,463,854,000
Arizona's State Universities	AZ	385	580	101	126	$ 8,017,327	21	$ 1,758,720,969
University of California System	CA	2,223	1,990	903	746	$ 234,196,000	46	$ 5,539,834,000
Johns Hopkins University	MD	697	1,261	265	353	$ 25,403,132	15	$ 3,135,782,848
University of Washington	WA	432	311	124	246	$ 81,408,159	14	$ 2,513,668,475
University of Wisconsin-Madison	WI	811	559	269	596	$ 134,506,796	6	$ 2,283,222,000
University of Michigan	MI	542	491	218	235	$ 36,455,319	29	$ 2,279,933,281
University of Pittsburgh	PA	214	234	81	155	$ 11,057,290	26	$ 1,674,606,000
Duke University	NC	252	248	107	119	$ 10,300,349	14	$ 1,477,366,335
Washington University - St. Louis	MO	193	274	153	156	$ 34,052,378	8	$ 1,395,306,000
Stanford University	CA	712	762	204	217	$ 92,655,586	21	$ 1,333,425,379
University of Pennsylvania	PA	321	730	87	166	$ 19,148,273	21	$ 1,322,436,678

Source: Association of University Technology Managers Licensing Surveys 2003–2005

Table 11 shows the considerable ways Arizona must move to catch up with other major universities in the U.S. While considerable progress has been made by Arizona's research universities, private research institutes, and medical centers since 2002, Arizona would place just above the University of Pittsburgh in Table 11 if the efforts of all Arizona institutions in technology transfer were combined.

Examples of Technology Commercialization in Arizona:

As technology transfer organizations at the State's research institutions have matured, Arizona has increasingly seen stories of technology commercialization development or success—similar to examples with which many are familiar but associate with locations such as San Diego, Silicon Valley, and Boston. These examples capture the data in Table 5 in real-world examples:

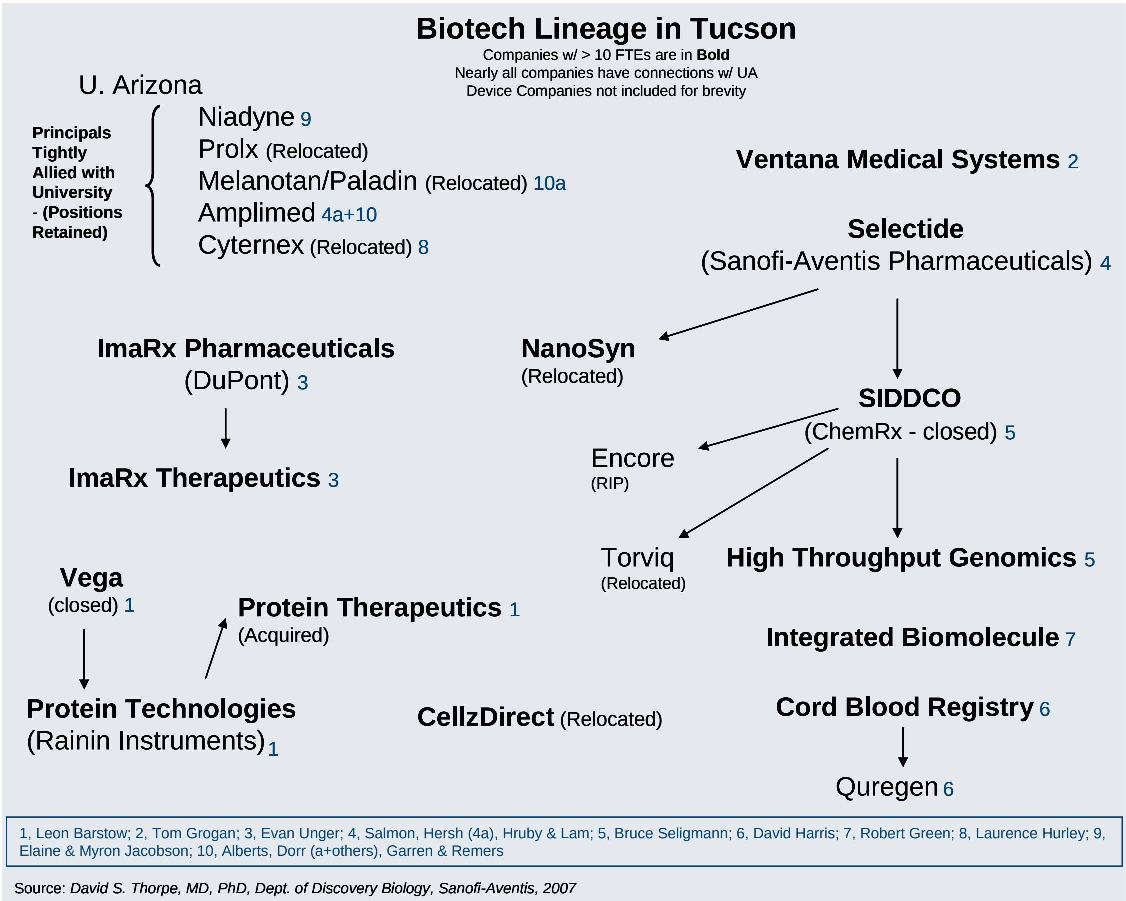
BioSense International, **LLC**, founded in 2005, is a startup company in the water instruments/monitoring and analytic testing business. The company is engaged in the design and manufacture of highly sophisticated electro-optical instruments and reagents used for the rapid detection and characterization of pathogens in liquids. The core technology was invented at the Arizona State University Water Quality Center (patent pending) and licensed to the company. BioSense's first products will rapidly detect microorganisms in liquids or bio films.

Cantimer, **Inc.** is developing a line of hydration sensors composed of a base module and replaceable polymer testing tips. The hydration sensor is based on a patented technology exclusively licensed from Northern Arizona University (NAU), and expanded by Bay Materials, LLC. The initial market will focus on healthcare, including geriatrics, pediatrics, anesthesiology, and the U.S. Military.

W.L.Gore/**Neural Intervention Technologies** goal involves the treatment of aneurysms, arteriovenous malformations (AVMs), and tumors. Its line of ALGEL(R) embolization products include vascular occlusion and sealant products that are non-adhesive, non-toxic, and have tissue-like mechanical and biocompatible properties. NIT was acquired by W.L. Gore in July 2006.

Other examples demonstrating the State's capabilities to move its research into technology licensing and new firm startups in the biosciences at the University of Arizona include **Niadyne, ProlX, Melanotan, AmpliMed, Cyternew, and Sabino Biosystems.** Figure 18 shows that in Southern Arizona alone the beginnings of the "genealogy tree" of firms begetting other firms, as made other technology regional hot spots famous.

Figure 18: Genealogy tree of biosciences firms in southern Arizona



The State's research institutions are increasingly seeing research turned into technology and firms. And they demonstrate the increasing deal flow and opportunities biosciences represent. While Arizona has not reached a critical mass of biosciences firms yet, it is making steady progress. **However, the State is not totally optimizing its research base nor seeing the same impact of deal flow, venture financing, and growing technology companies as found in other high tech bioscience hot spots such as Boston, Seattle, Salt Lake City, or San Diego.**

One set of key impediments or gaps holding Arizona back from this optimization is the lack of a comprehensive tool kit of technology commercialization services and support found in leading edge states and regions. Examples include the BioGenerator in St. Louis; Life Science Greenhouses in three Pennsylvania regions; the Deshpande Center for Technological Innovation at MIT; the Stephens Institute at USC; Baylor and Mayo Medical Ventures in Texas and Minnesota, respectively; and several other examples around the country. Table 12 summarizes best practice examples as to core functions, their role in risk capital, funding support, track record and benefits.

Table 12: Examples of Bio-Focused Technology Commercialization Organizations

Technology Commercialization Services	St. Louis BioGenerator	PA Life Sciences Greenhouses	MIT Deshpande Center	USC Stevens Institute	BCM Technologies Inc. (BCMT)	Mayo Medical Ventures
Core Functions	Due Diligence, Prototype Development, Market & Technology Assessments	Varies by Greenhouse: Executive in Residence, prototype development, due diligence, assessments	Grants for proof of concept and pre-business development. Involves existing industry and catalyzes new company formation.	Modeled after MIT Deshpande, will do grants, symposia, mentoring and also runs university tech transfer	Now 23 years old has evolved into an early stage venture fund and makes investments beyond Baylor.	For-profit subsidiary handles licensing and also acts as early stage venture investor in companies based on Mayo technology.
Risk Capital Role	Pre-seed equity or near equity investments at company formation stage	Both pre-commercialization grants up to $250,000 within the university context and near-equity investments in seed-stage companies up to $1m for high-risk research. Also manages hand-off to formal venture funds financed by same tobacco settlement source	Pre-commercialization grants for academic/industrial teams, but within the university context only. Proof of concept ("ignition") up to $50,000. Pre-business development ("innovation") up to $250,000.	Link entrepreneurs and ideas to external financial communities. Pre-commercialization grant program under development.	Capitalized by Baylor College of Medicine endowment, originally to make pre-seed investments in Baylor spin-offs and position them for follow-on, now making seed and first-round investments more broadly.	Capitalized at $25m by Mayo endowment as captive venture fund that makes early-stage investments in range of $1m in syndication with independent venture funds.
Funding Sources	Philanthropic and state tax credits	State and philanthropic funds	One alumnus contributed $20 m.	One alumnus contributed $22 m.	Medical Center/reinvested successes	Medical Center
Track Record	Focused in early years primarily on capital function	State plans to continue and reinvest.	5 years old—365 proposals received; 64 funded to date with $7 m. in grants, creating 10 companies capitalized at $88.7m, and 1 license.	Newly formed	Launched over 41 companies with 9 listed on NASDAQ.	Spin-offs may be and often are based outside Minnesota
Benefits	Complements region's aggressive efforts to address risk capital with more than $500m. raised	Covers state geographical with different models in each region	Complements MIT's Industrial Liaison Program and Licensing Office by providing a track for creating new enterprises	Job is to link researchers to the commercial world.	Links medical center, clinical care and funding source for entrepreneurs	Links medical center, clinical care and funding source for entrepreneurs

What characterizes best practices in technology commercialization?

Technology commercialization is receiving considerable emphasis in states and regions across the United States, with much attention being paid to providing support for those activities that must be undertaken to move research discoveries into the marketplace. Entrepreneurs must have access to a comprehensive continuum of support as they progress through the stages necessary to establish a thriving enterprise. Research leaders desire to capitalize on research findings in universities, medical centers, industries, and nonprofit research institutions, by facilitating their application into new products and spinning off new companies.

It is clear that technology commercialization remains an art form, not a science. There is no single, fully proven model. Battelle profiled successful programs to identify the most important individual elements of the technology commercialization process. The elements examined include:

- Addressing the need for risk capital at all stages of the technology development and commercialization life cycle
- Providing in-depth support at all stages of the enterprise creation and business launch cycle
- Accelerating the commercialization of university- and medical center-developed technologies.

Examples of "best practice" approaches to ensure that companies will succeed in commercializing technology include the following:

- Providing access to proof-of-concept funding to assess the potential of technology, demonstrate proof of concept, or to protect intellectual property (IP)
- Helping companies mature to "investment-grade status" i.e., they have a strong business plan, an experienced management team, a well-thought-out marketing strategy, etc.
- Encouraging strategic partnerships between large companies and start-ups
- Advising companies with regard to IP strategy and tactics
- Offering prototyping facilities and services to produce engineering prototypes or to produce test runs for marketing or evaluation purposes
- Supporting staff with business experience to engage university and medical researchers to scout for university discoveries that may have commercial potential.

We have addressed the importance of technology commercialization as well as providing insight into its various components: the commercialization process, supporting entrepreneurs, and addressing risk capital. We next turn to the gaps facing Arizona in technology commercialization along with directions and actions to address these gaps.

ADDRESSING GAPS: KEY ACTIONS

There are a number of actions be undertaken through joint private and public sector efforts in Arizona. These actions are designed to position Arizona to maximize its investments from the research enterprise at the state's public universities, medical centers, and private research institutes in terms of firms created, products introduced, jobs formed, access to early stage clinical trials, and improved health care prevention and treatment for Arizona's citizenry.

Three inter-related gaps face Arizona in technology commercialization**:**

1. **Commercialization Tools.** Resources to undertake the market and technology assessments, prototype development and engineering optimization to determine if the research can be turned into a product and/or a firm.
2. **Business Mentoring.** Business service support and mentoring to help with business planning, sales and marketing, and other aspects of incubating a new firm and accelerating its product innovation.
3. **Risk Capital Creation.** Risk capital available to fund the initial startup and operations phases of a business.

Actions to address these gaps are contained in the pages that follow:

Gap Area One:

Commercialization Tools

The key components needed for bioscience technology commercialization in Arizona include increasing the resources available for research organizations and others to offer the following tools:

- **Due diligence**
- **Proof of concept fund support including testing, experiments**
- **Market and technology assessments**
- **Prototype support**
- **Engineering optimization**

Rationale

Biosciences accounts for a majority of university research expenditures in Arizona and is growing. But to take full advantage of this deeper and stronger research base, further enhanced by the State's 2003 commitment to additional research facilities, requires a commensurate increase in funding support for the tools of technology commercialization. Arizona has provided some resources to help facilitate translational research at a few of the state universities (i.e., Technology and Growth Initiative at University of Arizona and Technopolis at Arizona State University) using Proposition 301 and other limited funding sources, but simply not enough resources are available to optimize the benefits to be derived from technology commercialization. As the state's research base is growing rapidly, so too must the investments for technology commercialization if the State is to harvest this research into firms, products and medical treatments in Arizona. Efforts need to be undertaken to enhance intellectual property and value-creating opportunities in Arizona by establishing more resources to undertake due diligence, proof of concept, prototype support, and engineering optimization, particularly for the biosciences.

Proposal

Arizona needs to provide additional resources to the technology transfer offices at its public research universities and other private and public research organizations and medical centers need to similarly increase the availability of resources for these five components of technology commercialization to be optimally deployed including:

- **Due diligence**

Key Technology Commercialization Tools

- Due Diligence
- Proof of Concept
- Market & Technology Assessments
- Prototype support Engineering Optimization

The Federal government will fund primarily basic or mission based research and is not generally interested in its commercial potential. So universities, medical centers, and research institutes need to have funds to bring in outside experts to assess the research, to undertake other due diligence including identification of potential niches and markets, and, at times, undertake limited development work to identify technologies from the research. Both ASU and UA have internal funds to do some of this work, but these funds are extremely limited.

- **Proof of concept fund support including testing, experiments**

In biosciences additional clinical studies and testing may be needed to encourage investor interest in licensing or forming a company. Again, existing funding is limited.

- **Market and technology assessments**

To determine if the technologies emerging from completed research have potential, it is important to determine what other technology alternatives are in the marketplace as well as potential markets and uses for the technology. Again, funding sources to undertake this work are limited.

- **Prototype support**

Increasingly those with sources of capital are requiring a further developed product before they will invest in a new enterprise. Similarly existing firms want to see something real before looking at a project as a licensing opportunity. Again, funding sources to undertake this work are limited.

- **Engineering optimization**

Once a product and its markets are identified, it may be necessary to determine how to cost-effectively enter this market where other related technologies may already exist. Engineering the product in such cases is necessary to prove its viability in terms of price and market penetration.

ASU, NAU, and the UA utilize limited funds for this work today, and are constrained by lack of resources to do more. Medical centers and hospitals have even less access to these tools, but as they increase their work in clinical trails and other translational research these tools represent good return on investments to develop research into products, jobs and firms. If an additional $2–3 million per year was directed to this area, the State could be expected to see an exponential return on its dollars. Funding sources include philanthropic organizations, the State, and the internal resources of universities and medical centers.

Potential Impact

The likely potential impact of these additional investments in the technology commercialization tool kit includes:

- Increase in the number of technologies that are the basis of spin-out companies in Arizona
- Increase in industry partnering and licensing from universities and medical centers
- Improved and easier pipeline transition from basic research to product design and development

Gap Area Two:

Business Mentoring

The resources that technology entrepreneurs need include management talent, technology, linkage to sources of capital, professional expertise, and a host of other support services. They often need assistance in determining economic feasibility and identifying markets and distribution channels. They may need access to specialized equipment and laboratories and to expertise to solve technical issues that arise during product development. They must be able to recruit key personnel and have access to sources of concept, translational, pre-seed, seed, and other risk capital. They need access to business service support and mentoring, from help with business plans and sales and marketing to other services involved in incubating new firms or products.

The key components for addressing how business mentoring support is offered and practiced include:

- Bioscience Entrepreneur Network
- Entrepreneurs in Residence/Executive Corps programs
- Startup angel capital funding through a statewide Biosciences Angel Initiative

Rationale

States and regions that have a history of entrepreneurial development have a network of entrepreneurs to help less experienced entrepreneurs with advice and counsel and to establish new companies (i.e., serial entrepreneurs). Business and technical resources are also readily available in successful regions to support new enterprises with assessing the market and/or their technology, through service providers and other consultants with knowledge of the industry. One clear lesson of a vibrant technology-driven region is active networking among university, medical, and industrial representatives. These three inter-related actions help grow a firm and provide the mentoring and support to increase firm survival.

Proposal

Arizona needs to establish three efforts:

1. Biosciences Entrepreneur Networks

Efforts are underway to further build and link the State's two bioindustry organizations—the Arizona BioIndustry Association (AZBio) and the Bioindustry Organization of Southern Arizona (BIO-SA)—and both of these have a range of networking functions and activities, primarily in Tucson and Phoenix and to a more limited extent in Flagstaff. In addition, in Flagstaff a group has formed and meets monthly called Biotechnology Enterprise Education and Research (B.E.E.R.). Because Arizona does not yet have a critical mass of bioscience firms it also lacks a deep set of knowledgeable service providers that understand the biosciences. But as places such as Maryland and San Diego demonstrate, service providers will become knowledgeable as the bioscience business grows. These networks and service providers are an important part of the technology commercialization process. Flagstaff, Tucson, and Phoenix all need to expand these efforts. The critical resource issue is sufficient funding for each of these organizations to have full time staff and an expanded set of networking and business development activities.

2. Establish Entrepreneurs in Residence/Executive Corps Program

Arizona needs a concerted effort to establish a core of experienced, seasoned serial entrepreneurial managers to populate, develop, and grow new technology enterprises. Until a critical mass is reached, a region tends not to have sufficient senior experienced personnel who have successfully or unsuccessfully done similar things with other technology companies. In specific cities, there are retired senior executives with such experience that might be attracted on a full or part-time basis to serve as a core of mentors and then placed in a firm as a COO, CEO, chief sales and marketing or chief regulatory official. In other parts of the State the entrepreneur in residence might need to be recruited and serve first as a mentor before being placed within a firm within a one-year period. Not having to search and recruit individuals to fill these key positions saves time, energy, and resources. An alternative might be to take advantage of Arizona's proximity to California; identifying a corps of commuting executives is not as severe a problem as regions in the Midwest and Southern U.S.

3. Startup Angel Financing through a Statewide Biosciences Angel Initiative

Angel financing is needed primarily to develop an idea into a startup firm. Because the bioscience business model is so different than that of other industries—long and expensive timeframes, large burn rates, regulatory hurdles, etc.—consideration should be given to a statewide BioAngel Initiative to complement regional angel initiatives.

This would enable angel investors throughout the State, who understand and appreciate the bio business model, to pool their interests and expertise. It would enable bioscience entrepreneurs to work with a group attuned to their needs and interests. The concept is to work with those individuals in each regional angel network with interest in biosciences to "pool" such interests statewide to sufficient scale to better address angel financing for bioscience startups in Arizona. The bioscience business model requires appropriate angel investing by those with interest, patience, and commitment.

Potential Impact

Several potential impacts can be achieved through these efforts:

- Growth of a network of entrepreneurs to start, manage, and support a critical mass of bioscience enterprises
- Access to knowledge and experience about growing firms, hopefully resulting in a higher birth rate, lower death rate, and increased survival for Arizona bioscience entrepreneurs
- Greater leveraging of resources and assets through networking and collaboration

Gap Area Three:

Risk Capital Creation

ARIZONA'S RISK CAPITAL SITUATION TODAY

Two key challenges face the State: (l) lack of pre-seed and seed dollars for funding in the $250,000 to $2 million range prior to formal venture capital; and (2) a robust venture capital industry to move these pre-seed investments to later stages whether it is IPOs, strategic alliances, or merger and acquisitions.

Historically, Arizona reached a peak of indigenous (Arizona-based funds) sources of venture capital totaling over $200 million at the beginning of this decade. For the most part these funds have little or no resources remaining to invest in new deals. In that sense, Arizona is reaching a crisis situation. If it does not replenish the venture capital funds operated in the State, it will not be able to invest in firms emerging from the research enterprise. Those spin-offs will be forced to either secure funds from outside the state while remaining in the state or ultimately move closer to their financial sources; something that has affected other states and regions. Figure 19 traces the venture capital investments made in Arizona compared to national trends.

In terms of the first challenge—lack of pre-seed/seed capital funding sources—there are few sources of funding in Arizona dedicated to bridging the gap between the point of discovery and the point at which a business case has been validated and risk capital can be obtained. It is also difficult to obtain seed and early-stage investments. These investments are not likely to come from venture funds, as they have become larger, tending to make larger, later-stage investments. And angel investors have also moved downstream (further away from pre-seed and seed investments), making more post-seed and later-stage investments than has historically been the case. So, in addition to the difficulty of obtaining translational research and pre-commercialization funding, there is a gap at the early stage phase for bioscience firms needing $500,000 to $2 million.

Table 12 shows the amounts and types of capital needed by bioscience companies at various stages of their development.

Table 12: Biosciences technology commercialization financing needs

	R&D	Translational Research and Commercialization	Pre-seed/Seed	Start-up	Expansion
ACTIVITIES	Conduct R&D Identify discoveries with possible commercial potential	Assess potential of technology Identify market Demonstrate proof of concept at lab scale Protect IP Engineering optimization Licensing or business formation	Develop prototype Testing and validation Prepare business strategy Establish business function Secure initial financing	Put management team in place Secure follow-on financing Staff up for sales and marketing Initial sales and marketing	Full scale production
FINANCING SOURCES	Conventional peer reviewed federal grant support	• Within university: Grants funded with university, state or industry dollars • Non-University: Grants funded by public and philanthropic support • SBIR I	• Friends and Family • Pre-Seed/Seed funds • Angel investors • SBIR Ph II	• Early-seed stage venture capital • Publicly supported investment funds	• Venture funds • Equity • Commercial debt • Industry (strategic alliances, mergers and acquisitions)
LEVEL OF INVESTMENT	Varies	$25,000 to $250,000	$250,000 -$1 million	$1 – $2 million	> $2million

Battelle's analysis was informed by interviewing Arizona experts about Arizona's current risk capital environment, Conclusions about risk capital in Arizona today include:

- Arizona has a **stable to declining risk capital environment** for biosciences and other technologies.
- The most important factors contributing to Arizona's current risk capital environment are:
  - *Depletion of existing funds* – Arizona resident venture funds had upwards of over $200 million to invest five to seven years ago; there are almost no funds left today for new investments through the venture funds resident in the state

- *Lack of serial entrepreneurial mangers to run firms* – due to the infancy of the bioscience and other technology firms there are not enough senior managers that have previous experience growing and running startups; this is less true in other high tech areas such as information and communications or advanced manufacturing.
- *Lack of enough good deals was expressed by some but not all experts* – however, in the biosciences, there seem to be more good deals than would be expected by the size of the industry base today, and
- *Lack of interest in investing by the State's traditional financial community and wealthy investors* – traditional sectors are reluctant to invest in technology which they know little about.

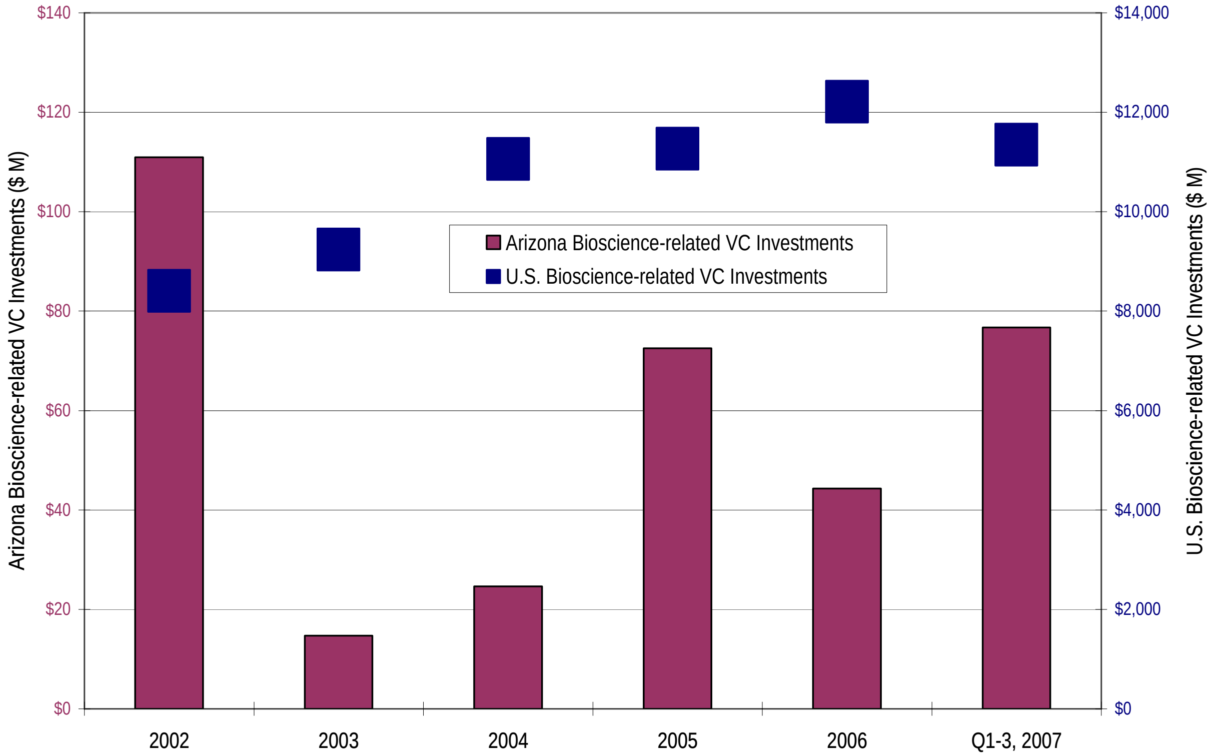
In summary, all stages of financing are facing gaps along the Valley of Death continuum in Figure 17.

ARIZONA HAS LAGGED THE COUNTRY IN VENTURE CAPITAL INVESTMENTS

Arizona lags the country in state-based venture fund managers and funds and in the amount, size, and number of venture investments in technology enterprises. In the past several years since the 2002 dot.com bust, Arizona has seen gradual growth in its venture investments and deals within the State. This is consistent with the national experience. Nevertheless, if Arizona wants to maximize its investments in businesses formed from its research efforts, solutions to increase risk capital available at all stages of the continuum (as outlined previously in the Valley of Death in Figure 17) must be identified.

Overall, total venture investments in Arizona total $251.9 million through the first three quarters of 2007, as compared to $199.3 million in 2002 or 0.9 percent of the total national pool, compared to Arizona's 2.06 percent share of total population (2006). While bioscience-related investments have continued to represent an increased share of total venture investments in Arizona during this time period, reaching $76.7 million through the first three quarters of 2007 the state's share of the national pool now representing only 0.5 percent of the national total invested in biosciences. Arizona lags other Western States such as Colorado and Washington while other states such as Florida and Texas are building a base of venture firms and making venture investments. Figure 19 tracks Arizona's venture investments in the biosciences relative to national trends.

Figure 19: Comparison of Bioscience-related VC Investment Trends: Arizona & U.S., 2002–Q3, 2007



The average new venture fund formed in 2006 was over $200 million. The average deal was $12 million or more. And the venture industry is facing continued challenges in the speed at which its members can enter and exit the initial public offering market.

Arizona's risk capital issue includes but is not limited to formal venture capital. The "seed/startup stage" as contained in national data sources for the industry overstates funding available at this level as the average seed stage investment in this category from 2002–06 was $2.8 million—far beyond what is defined as the seed stage in Figure 17, Valley of Death. The State of Arizona has enacted an angel tax credit program to encourage individual investors to invest in small, young growing firms and angel groups have formed and made investments at the earliest stages of the Valley of Death, in both Tucson and Phoenix. The earlier "Forest Angels" angel group has been dormant for some time in Flagstaff.

Bioscience-related VC investments through three quarters of 2007 already exceed all of 2006 which showed a decline from the steady increases in venture capital bioscience investments in the previous three years. At current rates and a strong fourth quarter could place Arizona bioscience venture investments almost equal to their level of 2002, a significant rebound from the previous four years in Arizona. In the tables that follow we also identify trends in venture investments in the State in terms of stage and types of investments.

Figure 20: VC Investments in the biosciences by industry for AZ and the U.S., 2002 through Q3, 2007

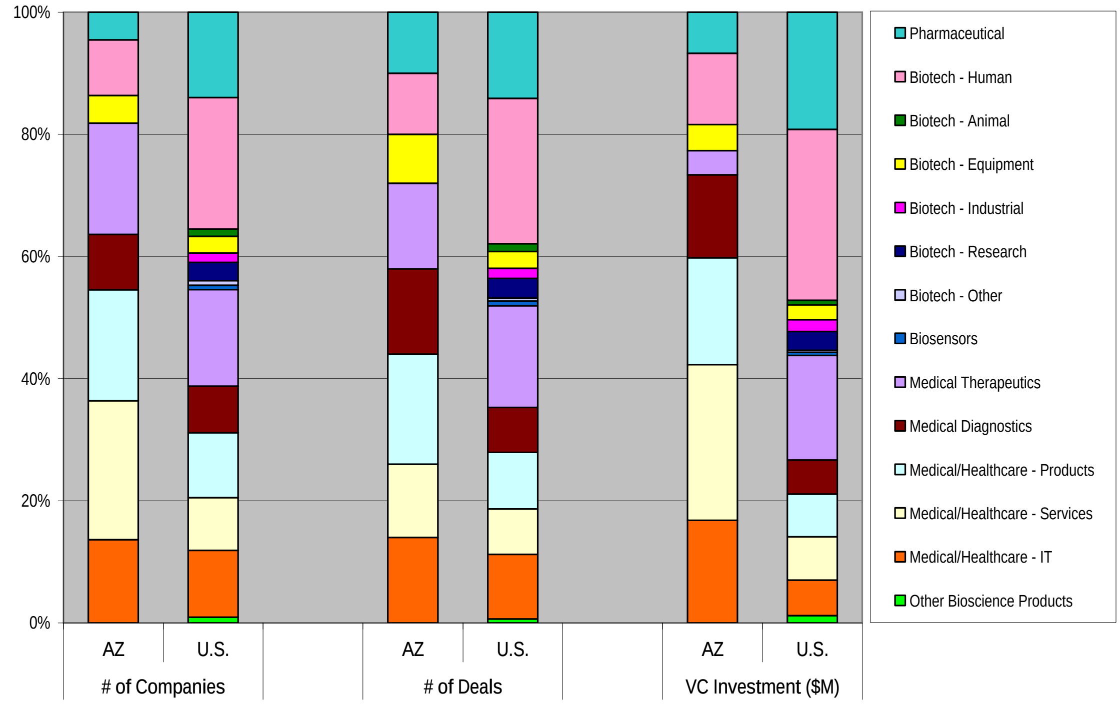


Figure 20 shows that Arizona venture deals have been made in a wide variety of biomedical industries and niches, with no one area standing out, in contrast to the U.S. where the majority of investments have been in human applications, medical therapeutics, and pharmaceuticals. Arizona has had more companies, deals, and dollars going into health products and IT than the country as a whole.

Figure 21: Share of VC investments in the biosciences by stage for AZ and the U.S., 2002 through Q3, 2007

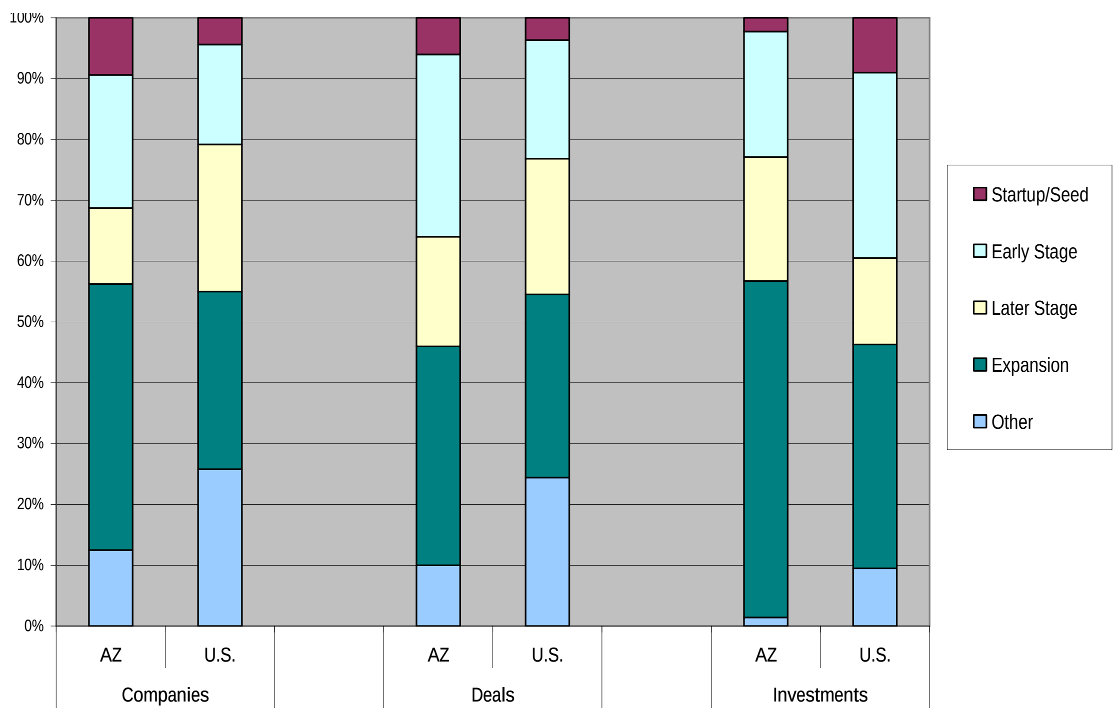


Figure 21 details at what stages the State's limited venture investments have been made. While Arizona exceeds the nation in more companies receiving startup/seed and early stage investments at these stages, in terms of dollars invested Arizona firms have received much less dollars in total than compared to the nation. Expansion stage investments exceed the nation in companies receiving investments and more deals were made as well as the total dollars of investments, at this stage. This demonstrates that while there appear to be companies and deals for venture capitalists to make in bioscience firms at the startup/seed stage in the State, the amount of the investments, in total, are much less than the country. No startup or seed investments were made in 2007 and the number has declined over the past three years. Even early stage deals are declining in Arizona. Arizona is not nurturing new young, small bioscience firms within its existing approach to risk capital.

Figure 22: Share of Arizona VC investments for all industries 2002 through Q3 2007

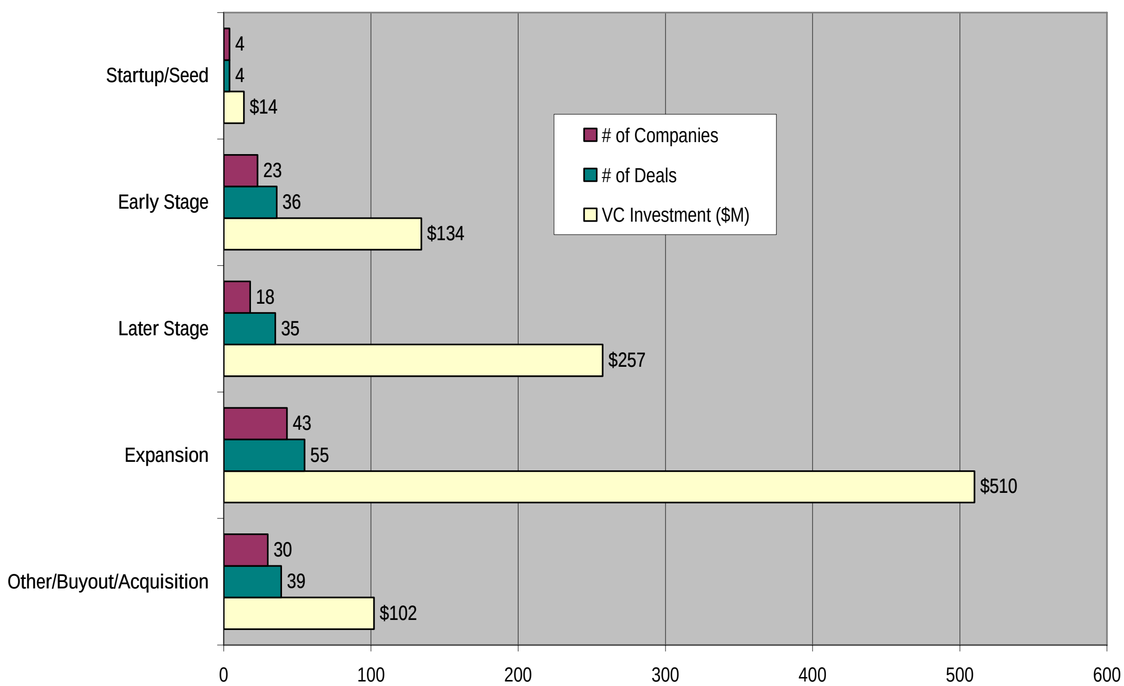


Figure 22 shows these earliest stages of financing—startup/seed and early stage are difficult to obtain funding for in Arizona in other technology areas, not just in the biosciences in Arizona. And, as is the case for the biosciences, dollars are more likely to go to the expansion stage.

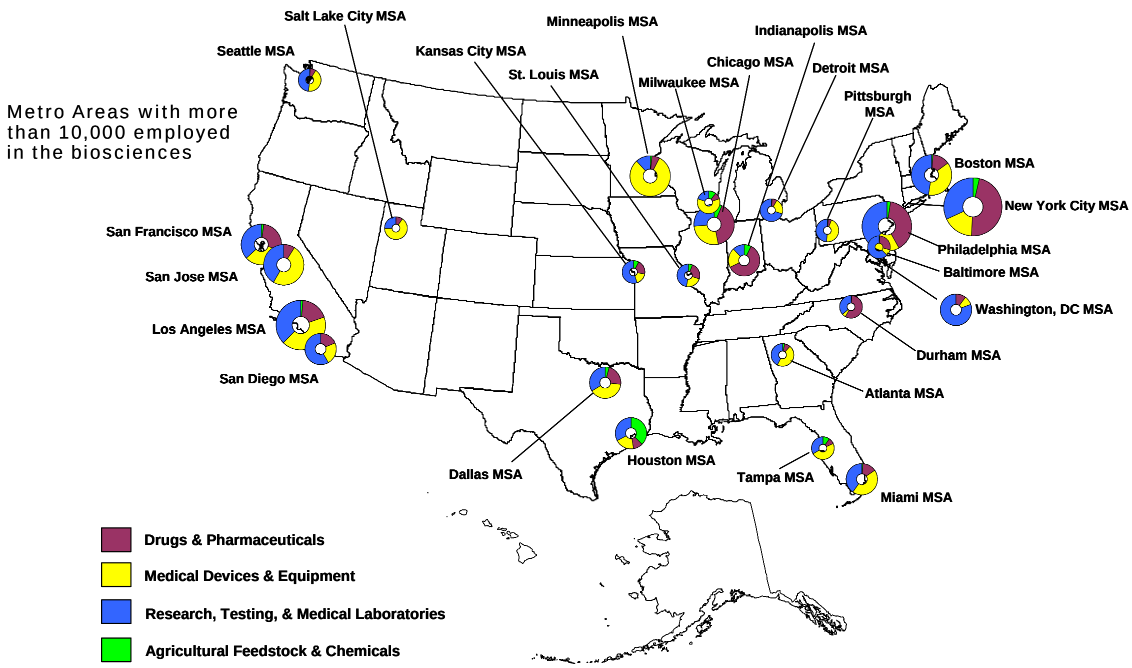
Table 13: Risk Capital Situation: Bioscience Accounts for a Larger Share of Deals, Companies, and Investments in AZ

Total VC Investments in Arizona and the U.S., 2002–Q3, 2007						
	Arizona			U.S.		
Metric	Biosciences	All Industries	Bioscience share of Total VC	Biosciences	All Industries	Bioscience share of Total VC
Number of Deals	50	169	30%	5,816	23,228	25%
Number of Companies Invested In	22	87	25%	2,452	10,348	24%
Investment in $Millions	$344	$1,019	33%	$50,069	$175,276	29%

Table 13 shows that Arizona no longer mimics the nation in the share of deals and dollars biosciences represents of all venture investments. Arizona has reversed course and now biosciences accounts for a larger share of deals, companies invested in, and receives a greater share of total venture capital investments, compared to national trends. This must be considered within the constraint that Arizona has insufficient venture capital invested in the State overall, so while biosciences is now accounting for greater share, it's a small consolation given the limited amount of venture capital available and invested.

Arizona does not yet show up on the national map of major bio centers, because it does not yet have a critical mass of firms (Figure 23). However, Flagstaff is a center in the medical device industry and Tucson is rapidly growing as an emerging research and testing center.

Figure 23: Metropolitan areas with largest total employment (greater than 10,000) in biosciences by major subsector, 2004, Battelle



The consensus of experts and observers are that several approaches are needed to address the gaps in the risk capital continuum over the next several years. Addressing risk capital gaps is a key element of technology commercialization that must be addressed if the State's investments in its research enterprises are going to turn into successful business enterprises offering both jobs and access to early stage medical treatment in the State.

Proposal

Five specific actions are suggested:

1. **Create a stronger resident venture capital industry with a stronger set of funds to attract outside the state dollars and the sources of capital to Arizona entrepreneurs**
2. **Explore an accelerator model addressing issues of risk capital, space, and serial entrepreneurial management talent concurrently**
3. **Increase support to entrepreneurs to seek and win more SBIR/STTR awards**
4. **Recruit and educate venture and other risk capital investors outside of Arizona about the State's biosciences base**
5. **Encourage an increased base of capital formation for Arizona individual and institutional investments in risk capital including an Arizona BioSeed Fund**

Each of these actions is discussed below:

1. Create a stronger resident venture capital industry with a stronger set of funds to attract outside the state dollars and sources of capital to Arizona entrepreneurs.

Arizona needs to not only to "replenish" its existing resident base of venture funds and managers but find ways to increase their number. Ideally, Arizona should have several different funds whose focus will vary depending upon the stage of firm being financed, what industries and technology applications they focus on, e.g., genomics, devices, bioinformatics, as well as their geographical focus.

Arizona has a many wealthy individuals, some of whom have made their money in the biosciences and others who, while making their money in other sectors, are very interested in the biosciences because of its impact on medical and health care. Building a coalition of individual, philanthropic, business, and civic leadership around addressing the need to replenish and grow the State's venture industry base is required if this risk capital deficit in Arizona is to be overcome.

The most effective way to mobilize and capture this support is the creation of a Fund of Funds, which would enable several funds to become established. A Fund of Funds could help deepen the residential venture manager base within the state, and enable not only biosciences but information technology, sustainable systems, and advanced manufacturing focus to show up as investments in some funds, building on the State's industry and university base in these areas. And it could help take advantage of the technology convergence of biosciences with materials and information technology. Such a Fund is likely to need at least $50 million and ideally $150–200 million in support. However, it may take too much time, require too many additional resources, and otherwise delay solving the impending crisis in venture financing to focus on a Fund of Funds immediately.

A quicker alternative may be simply to replenish the funding of existing Arizona-based venture funds so there continues to be a flow of capital to technology entrepreneurs. This still requires building a private-public coalition but at less total cost.

2. Explore the development of an accelerator model, addressing issues of risk capital, space, and serial entrepreneurial management talent concurrently

Because of inter-related issues—sufficient startup and growth space for bioscience firms in some places in Arizona, lack of sufficient early stage risk capital for bioscience entrepreneurs to start and grow their firms, and lack of sufficient experienced serial entrepreneurial managers to jump start efforts—consideration should be given to development of an Arizona version of the "Accelerator," associated with the Institute for Systems Biology, in Seattle, Washington.

Key Elements: Seattle Accelerator

- Anchor institution – Institute for Systems Biology
- Top-tier venture firms
- Experienced management
- Talent entrepreneurs

Founded in 2003, the Seattle "accelerator" has secured nearly $22 million in funds from six venture capital firms; developed a shared management team to run the Accelerator companies whom are physically co-located in the same complex as the Institute; and hired Alexandria LLC, whom, along with the associated venture capital firms, concurrently fund and support these startup firms with risk capital, space, and a shared or common management team. A total of 18,000 sq. ft. of space is available for "accelerator" firms with wet labs making up nearly half the space and are fully fitted to commercial biotech standards. All six venture capital partners invest on a pooled basis with capital committed in advance and these venture firms together establish investment milestones as startup firms go about doing proof of concept. Scientists focus on what they do well and the management team does not need to spend an inordinate amount of time looking for capital. Investments have been made in six emerging bioscience firms, two of which have graduated; having receiving second rounds of financing of over $84 million and hiring their own management teams in separate, secured private space.

3. Increase support to biosciences entrepreneurs to seek and win more SBIR/STTR awards

The Federal SBIR/STTR program offers millions of dollars in grants to small, young growing firms to undertake applied research and development around new products and treatments. NIH alone in its Phase II awards under SBIR can provide several millions of dollars to a startup, without requiring the startup to give up any equity. Indeed, in places such as Maryland, San Diego, Boston, and Seattle, the growth of their bioscience industry and achievement of a critical mass or technology cluster came about in part due to the success of their bioscience entrepreneurs in seeking and winning Federal SBIR awards.

The State of Arizona has a small grant program to entrepreneurs seeking Federal SBIR awards to help them get started, including limited funding support for technology and market assessment, and related services. Technopolis at ASU offers an extensive course on SBIR and other groups and organizations offer ad hoc support. But other states offer much deeper services from technical assistance consultants to matching grants. To “jump start” and build Arizona’s bioscience base, a $1-million-a-year program should be offered. Increasingly SBIR recipients collaborate in their work with universities and medical centers, and the SBIR has a good track record of commercial success.

4. **Recruit and educate venture and other risk capital investors outside of Arizona about the State’s biosciences base**

Because of the close proximity of California to Arizona and a history of California venture funds making investments in Arizona enterprises, it may be fruitful for the state and regional economic development groups and organizations along with AZBio and BIO-SA to focus efforts to educate and inform such venture firms on Arizona bioscience opportunities. Other neighboring states with resident venture funds that this effort could be broadened to include Utah, Washington, and New Mexico. However, this communication and education needs to be undertaken concurrent with addressing the lack of sufficient seed and venture funding sources within the State.

5. Encourage an increased base of capital formation for Arizona individual and institutional investments in risk capital including an Arizona BioSeed Fund

There is a clear need to increase individual and institutional investments in all areas of risk capital mentioned in this section, from the earliest angel and pre-seed to seed and venture capital. Arizona lags the nation and its research output will not likely result in new firms, new jobs, or new industries in the State unless individuals and institutions step to the table and make private commitments. The State has provided an angel tax credit to incentivize individuals to do so, but much more progress is needed in the State.

An Arizona BioSeed Fund was an important action item included in Arizona’s Bioscience Roadmap but it has yet to be implemented. A State BioSeed Fund will have to be supported by philanthropic, private, and public sources with the recognition that it will not have the same return on investment as a purely private for-profit fund. Investors in the BioSeed Fund have to have an economic development and community good will orientation—to fund firms at the “farm team” level to the point where they are mature and robust enough to be funded from private venture and other sources. Otherwise firms either will never get beyond the idea stage or leave the state. The Massachusetts Technology Development Corporation is an example of a one-time State government investment to an organization that provides the earliest stages of risk capital prior to formal venture capital being committed and is recognized by the New England venture community as key to the ability to grow firms through the entire continuum for idea to prototype to firm formation and growth in Massachusetts.

Potential Impact

Implementation of these actions could have several potential benefits:

- Encourages an increase in the amount of private investment made to technology enterprises in the state
- Accelerates the time that technology companies will be ready to for later stage funding to help commercialize their products
- Increases opportunities for investment in early to later stage technology firms in Arizona
- The amount of capital invested in Arizona technology companies from VCs outside of the area will increase by having Arizona-based venture partners and an Arizona venture industry

6: ARIZONA'S BIOSCIENCE ROADMAP to 2012:
An Updated Vision and Strategies for Arizona in the Biosciences

Arizona's maturing research base enables the state to more closely focus on signature opportunities that bring together collaborators from the research and clinical settings; from academe, industry and non profits; from diverse fields of expertise and study. Because of this maturity Arizona is now in a better position than five years ago to make serious efforts to grow the critical mass of focused biomedical research and of bioscience firms. The State has recognized bio stars in firms such as W.L.Gore, Medtronic, Ventana, and Sanofi-aventis—already located here—but it is clear that an increased rate of bio business opportunities can emerge if the State can enhance its technology commercialization infrastructure. This suggests some refinement in the goals, objectives and actions for Roadmap implementation over the next five years.

Battelle's revised goal for Arizona is to:

Develop Arizona as a global biomedical research and bioscience commercial center over the next 20 years

- **OBJECTIVES**
  - Leapfrog research opportunities
  - Catalyze bioscience commercialization
- **ACTIONS**
  - Make strategic investments in research infrastructure
  - Make strategic investments in commercialization
  - Recruit intellectual capital
  - Provide guidance, support and information on the biosciences

Going forward, research and technology commercialization become the twin focal points for the Bioscience Roadmap. This requires focusing on "signature opportunities" and continuing to build Arizona's translational research capacity. Strong efforts are required to advance bioscience commercialization, bringing together the many participants from developers and builders to venture capitalists, higher education institutions, medical centers, and private research institutes.

SUMMARY

Arizona is at a critical juncture in its quest to become the major Southwest bioscience center and by 2012 a major national and international center. Significant progress has been made; resources have been secured; and there has been a considerable alignment across medical institutions, research institutes, higher education institutions, and others. While it continues to be important to focus strategically on the research base around competencies, research does not by itself create the technologies and innovations in the marketplace, create jobs, introduce products, or impact health care treatment and prevention.

Arizona's private and public sectors must jointly address gaps and deficiencies in "technology commercialization" to gain the economic and health benefits that might be derived from this research. The dollars required to create new cutting edge enterprises are not huge—indeed they are less than is needed to build a strong "research engine"—but they are critically important. Without sufficient investment in building its technology commercialization enterprise, Arizona will be challenged to create a sufficient and critical mass of firms and products and it will not fully realize its potential to improve the quality of health care and diversify Arizona's economy.