Opportunities for Advancing Job-Creating Research in Arkansas

A Strategic Assessment of Arkansas' University and Government Lab Research Base

Prepared for: Arkansas Research Alliance
Prepared by: Battelle Technology Partnership Practice
APRIL 2009

The **Arkansas Research Alliance** is a newly formed public-private partnership organization created to promote collaboration between Arkansas universities, businesses, and government in guiding the focus of research initiatives in Arkansas.

The Arkansas Research Alliance owes its vision to the leadership of *Accelerate*Arkansas, which identified supporting job-creating research as part of a broader set of initiatives to raise per capita income in Arkansas by creating the foundation for a stronger knowledge-based economy in the state.

Arkansas Research Alliance Board Members 2008–2009

Table of Contents

List of Figures

List of Tables

Preface

The Arkansas Research Alliance is a newly formed public-private partnership seeking to build a strong bridge to the 21st century global and knowledge-based economy. Our vision is to advance job-creating research in Arkansas by identifying those strategic areas in our universities where the combination of targeted funding and recognized recruited talent will lead to accelerated job creation and economic growth. While the realities of the pressing economic downturn calls for a priority on retaining and creating jobs across all industry sectors, it is well understand that in Arkansas we must do more to change our economic situation. In the face of a new global, knowledge-based economy, Arkansas confronts the even greater challenge of advancing higher value-added economic activities, utilizing and fostering technological innovation, to raise our state's persistently low per capita income.

Raising the per capita income is not a new challenge for Arkansas. In the 1950s, Arkansas confronted a particularly low per capital income of less than 60% of the national average. Five years later, Arkansas took a proactive approach to competing in an industrial economy by formalizing an economic development program to recruit manufacturing industries to Arkansas. The result was not only a growing base of jobs for Arkansas, but a significant rise in per capita income to a peak of 79% in 1978.

Since the late 1970s, Arkansas has not been able to gain new ground in our per capita income because the terms of competition changed. No longer do state and regional economies compete on the basis of costs alone, which underpinned Arkansas' prior successful economic development focus. Today, the driving factors in economic competition are the knowledge and skills of a state and region's workforce and the breadth and quality of its technology base. And this competition in the knowledge economy is not merely among U.S. states and other nations from the developed world. It increasingly is a global competition in which emerging economies, particularly India and China, are focused.

One critical ingredient to growing the high-end skills and technologies in Arkansas is a robust university research effort in the state. In light of a growing body of evidence, *The Economist* noted in a recent article, "Innovation in America: A Gathering Storm," that government-funded research done in university laboratories was one of the core aspects of America's competitiveness. Arkansas is behind other states in university research, receiving only $1 out of every $5,000 the federal government spends on research, ranking it 48th in the nation in 2000.

In the face of this new economic reality, Arkansas has no choice but to step up its efforts and once again focus on recruitment as a critical element of its economic development strategy. To address today's knowledge-based economy, the target for recruitment by Arkansas now needs to be ***world-class research talent.*** While we should also be focused on growing our own talent as part of a comprehensive strategy, we cannot move forward rapidly enough in Arkansas just by raising our educational system and the generation of a future highly skilled workforce.

It is critical to recognize that the seeds for Arkansas to thrive in research are already being planted. Arkansas does have an existing talent base of researchers helping to grow focused areas of research strengths in Arkansas. We can and should build on these efforts and, in doing so, recognize the talent we already have in Arkansas.

This first independent assessment of the core research strengths across Arkansas' universities and government labs and the identification of opportunities for advancing job-creating research will serve as a guide to the Arkansas Research Alliance and its partners. It demonstrates that the best way to increase the economic competitiveness of Arkansas is to understand where we have research competence, then add resources and recruit talent to accelerate economic formation … creating 21st century jobs for the citizens of Arkansas.

Hugh T. McDonald, Chairman of the Arkansas Research Alliance and President & CEO, Entergy

Jerry B. Adams, President and CEO, Arkansas Research Alliance

Key Findings

The first independent and comprehensive assessment of the core competencies and strategic focus areas across Arkansas' university research enterprise revealed significant opportunities within the state's growing base of research activities to advance job-creating research in Arkansas.

To analyze the position of the university research enterprise in Arkansas, and particular niches and opportunities upon which to build, the Arkansas Research Alliance engaged the Battelle Technology Partnership Practice to assist in assessing the following:

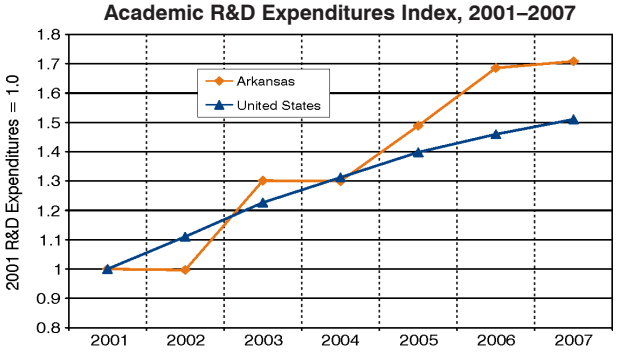
- Broad trends in the research enterprise in Arkansas
- Specific core research competencies found across research universities in Arkansas
- Potential strategic focus areas that represent broad, multidisciplinary areas of research that offer the potential to realize significant gains in economic development in a favorable timeframe and in multiple substantial, growing markets.

Arkansas Research Enterprise on a Strong Growth Trajectory, Yet Still Playing Catch-Up

The trends in research funding, publications in peer-reviewed journals, and generation of graduates in science, engineering, and math fields are all positive since the beginning of the new millennium. But, Arkansas still has far to come.

- Overall, university research funding in Arkansas made significant strides from 2001 to 2007, growing from $141 million to $240 million, a 70% gain. This is far in excess of the U.S. growth rate of 51% (figure at top right).

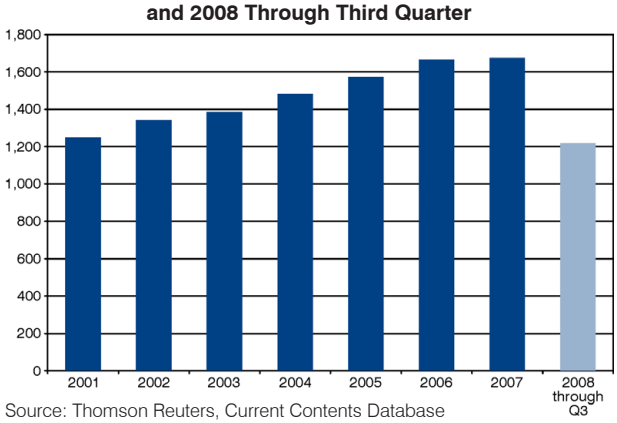
Academic R&D Expenditures Index, 2001–2007



Source: National Science Foundation, Calculations by Battelle.

- Publications activity is another key measure of scholarly activity. Arkansas has also raised its level of scholarly activity, as represented by publications, significantly in recent years. Publications in Arkansas across its universities and the National Center for Toxicology Research (NCTR) increased by roughly one-third, from 1,200 to 1,600, and are on course to continue that higher level of activity based on the results from the first three quarters of 2008 (figure below).

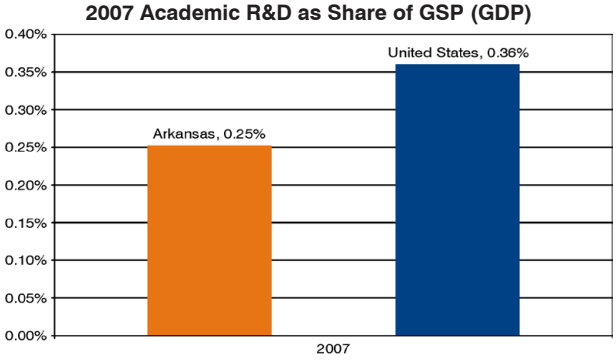
Arkansas Research Publications, 2001–2007 and 2008 Through Third Quarter



Source: Thomson Reuters, Current Contents Database for All Institutions in Arkansas.

- When compared with the overall size of the state's economy, Arkansas falls short on the level of university research. For the nation, university research comprised 0.36% of the gross domestic product (GDP) in 2007. In Arkansas, university research stands at just 0.25% of the gross state product (GSP). To reach the national average, Arkansas would have needed to increase its university research by $106 million or 44% to reach the national average in 2007 (figure below).

2007 Academic R&D as Share of GSP (GDP)



Source: National Science Foundation, U.S. Department of Commerce, Calculations by Battelle.

Across Arkansas' Research Enterprise a Wide Range of Core Research Competency Areas Identified

Core research competencies found across universities and government labs are those focused research areas where the state's university base can bring a critical mass of activity.

Based on both quantitative analysis and field interviews, the Battelle team identified 30 research competencies, reflecting the statewide nature of the study and the fact that research across Arkansas is still emerging and not highly distinguishable. Research competencies fell into two categories—18 broad research competencies based on their predominantly top- and middle-tier rankings in measures of publications, grants, talent, and institutional focus; and 12 niche research competencies that are more limited in breadth at this time (see table on next page).

The quantitative analysis included a rigorous cluster analysis to identify key research themes based on the abstracts of nearly 13,000 publications and grants. Not only was the focus of research activities examined through publications and grants, but also measures of excellence as reflected in citations per publication and presence of major grants.

Along with the quantitative analysis, the Battelle team conducted extensive qualitative interviews with university administrators and faculty. These interviews are essential in helping develop an understanding of how the data on publications and grant awards translate into on-the-ground focus areas in Arkansas.

This effort to assess core research competencies was facilitated and vetted by an Advisory Council to the Arkansas Research Alliance, composed of the senior administrators of research from the leading research universities and government labs in Arkansas.

Universities, just like industries, must nurture the development of specialized areas of expertise, or core competencies, where they can be national, if not world, leaders. According to Gary Hamel and C.K. Prahalad in their widely acclaimed business strategy book, *Competing for the Future,* "Core competencies are the gateways to future opportunities. Leadership in a core competence represents a potentiality that is released when imaginative new ways of exploiting that core competence are envisioned."

Listing of Broad and Niche Research Competencies in Arkansas

Research Competencies Identified in Arkansas	
Broad Research Competencies	**Niche Research Competencies**
Cancer Control, Detection, and Treatment	Obesity and Diabetes Research
Disease-Related Genomic and Cellular Processes	Animal Research
Plant Sciences	Nephrology Research
Metabolic Studies	Sleep, Auditory, and Memory Research
Infectious Disease Research and Treatment	Physics
Pediatric Research	Medical Technology and Non-Invasive Diagnosis
Nanotechnology	Electronics
Toxicology and Drug Development	Power Electronics and Alternative Energy
Mental Health and Behavior	Sensing and Sensor Networks
Food Science, Food Safety, and Nutrition	Logistics
Musculoskeletal Research	Radiation Biology
Water Quality and Resources	Bioenergy
Poultry Sciences	
Addiction Treatment and Management	
Optics	
Ecology and Environmental Sciences	
Aquaculture	
Informatics and Mathematical Research	

Nine Strategic Focus Area Opportunities Identified

Based on the findings from the quantitative and qualitative analyses of university research strengths found in Arkansas, it is important to consider how these research core competencies can be grouped into strategic focus areas to serve as investment targets for the Arkansas Research Alliance.

These strategic focus areas need to accomplish the following:

- Advance Arkansas in multidisciplinary fields of research, an essential feature of new innovations in technology in today's fast-paced knowledge economy, and enable Arkansas to leapfrog more traditional leading academic institutions that have built their strengths in narrow academic fields.

- Engage multiple Arkansas institutions so that the impact on Arkansas research capacities can be broad and not limited to individual institutions or areas of the state.

The following nine potential strategic focus areas were identified in consultation with the Arkansas Research Alliance Advisory Council:

- Enterprise Systems Computing
- Distributed Energy Network Systems
- Optics and Photonics
- Nano-Related Materials and Applications
- Sustainable Agriculture and Bioenergy Management
- Food Processing and Safety
- Personalized Health Research Sciences
- Behavioral Research for Chronic Disease Management
- Obesity and Nutrition.

The following table briefly describes these nine strategic focus areas.

Potential Strategic Focus Areas for Arkansas

Possible Strategic Focus Area	Core Competencies to Draw Upon	Arkansas Research Organizations to be Engaged	Rationale
Enterprise Systems Computing	Informatics and Mathematical Sciences Logistics Sensing and Sensor Networks	University of Arkansas-Fayetteville (UA-F) UA-Little Rock (UA-LR)	Existing base of informatics research is demonstrating growing excellence, and university officials suggest this is an area of significant industry demand. Arkansas' strength is in developing the applications and platforms for advancing industrial-strength computing that address real-world concerns of information quality; business intelligence; managing terabytes of data; and addressing large system architectures to integrate various devices, sensors, RFID, and information systems.
Distributed Energy Network Systems	Electric Power and Power Electronics Informatics and Mathematical Sciences	UA-F UA-LR	Become a national leader in smart energy grids and advance the integration of distributed energy sources. Develop the systems architecture for managing the future distributed energy system.
Optics and Photonics	Optics Sensing and Sensor Networks Electronics Physics	Arkansas State University (ASU) UA-F UA-LR	Arkansas has an existing base of optics research that uses lasers for materials development, processing and manufacturing; emerging areas of optics research in medical diagnostics, defense and security, and astronomy. Extensive lab facilities at the Arkansas Center for Laser Applications and Science (ArCLAS)—largest collection of lasers and support equipment in the U.S. mid-South region, but not well-known. UA-F brings strengths in optics and photonics from its physics department and its Microelectronics/ Photonics (microEP) program, which offers M.S. and Ph.D. degrees. And UA-LR has researchers working on optics as well.
Nano-Related Materials and Applications	Nanotechnology Sensing and Sensor Networks Medical Technology and Non-Invasive Diagnosis Cancer Control, Detection, and Treatment Water Quality and Resources Food Science, Food Safety, and Nutrition	UA-F UA-LR UA-Division of Agriculture (DA) University of Arkansas for Medical Sciences (UAMS)	Leverage the wide variety of nano-material developments and focus on applications from agriculture to food safety to biomedical.
Sustainable Agriculture and Bioenergy Management	Plant and Agricultural Sciences Water Quality and Resources Bioenergy Ecology and Environmental Sciences	UA-F UA-DA UA-Pine Bluff (UA-PB) ASU UA-LR	Address agriculture and bioenergy as an integrated system of growing, transporting, and processing feedstock and developing co-products. Strong interest from major Arkansas food-related companies in advancing sustainable agriculture and sustainable energy.
Food Processing and Safety	Food Science, Food Safety, and Nutrition Aquaculture	UA-DA UA-PB ASU NCTR	Leading position in food safety activities. Growing efforts in nutrition. Major connection to state's agriculture-related base.

Potential Strategic Focus Areas for Arkansas (continued)

Possible Strategic Focus Area	Core Competencies to Draw Upon	Arkansas Research Organizations to be Engaged	Rationale
Personalized Health Research Sciences	Cancer Control, Detection, and Treatment Food Science, Food Safety, and Nutrition Toxicology and Drug Development Obesity and Diabetes Addiction Treatment and Management Mental Health and Behavior	UAMS NCTR UA-F UA-DA ASU Arkansas Children's Hospital Research Institute (ACHRI)	Arkansas has strengths in pharmacogenomics research on how genetic variations or differences in gene expression affect people's responses to drugs, due to its strengths in toxicology and drug development and the focus of its cancer research efforts. But, since Arkansas also brings growing strengths in food safety, nutritional analysis, and health behaviors, along with broader public health and health services perspectives, an opportunity exists to move into "personalized health," which looks at the impact of bringing more systematic predictive and preventive approaches to health-care delivery.
Behavioral Research for Chronic Disease Management	Cancer Control, Detection, and Treatment Obesity and Diabetes Addiction Treatment and Management Mental Health and Behavior	UAMS (various colleges) ACHRI	Build upon growing interest in disease prevention and control by using behavioral change approaches as a focus of intervention. Target cancer control and obesity/diabetes. Arkansas' nationally recognized Addiction Treatment and Management experience can be broadened to address broader chronic diseases by seeking to improve "executive function" of targeted populations.
Obesity and Nutrition	Obesity and Diabetes Food Science, Food Safety, and Nutrition	UAMS (various colleges) ACHRI NCTR ASU	Ongoing funded research in type 2 diabetes. Major U.S. Department of Agriculture (USDA) funded research center in nutrition with a focus on children. Recent establishment of Robert Wood Johnson Foundation Center to Prevent Childhood Obesity in Arkansas.

Strategic Focus Areas Evaluated

The assessment of strategic focus areas required the consideration of several criteria:

- **Opportunities drawing upon multiple core competencies and organizations.** A strategic focus area should address opportunities that transcend multiple core competencies and organizations, ensuring that Arkansas' research base is a fertile, multidisciplinary, cross-cutting, and collaborative research environment rather than a collection of stand-alone research strengths.
- **Opportunity for external research funding.** A strategic focus area should relate to pressing issues or needs and thus be likely to attract major external research and development (R&D) funding and investment. It is also important to consider the level of competition from research institutions in other states.
- **Market potential.** A strategic focus area should align institutional research strengths with emerging and growing market opportunities.
- **Economic linkages with Arkansas.** A strategic focus area should offer existing linkages to Arkansas industries or offer an opportunity for generating new start-up firms.

The following table presents the evaluation from Battelle on these criteria.

Overall Evaluation of the Strategic Focus Areas

Strategic Focus Area	**Breadth of Competencies and Institutions** **Established** based on extensive depth of core research competencies **Emerging** based on more limited depth of core competencies	**Opportunity for External Research Funding** **Significant** = ≥$500 million in federal funding **Moderate** = $250 to $500 million in related federal funding **Limited** = <$250 million in federal funding	**Market Potential** **Extensive** = More than $10 billion **Moderate** = $1 billion to $10 billion **Limited** = <$1 billion **Immediate** = Established market today **Near term** = Expect market to unfold in next 3–5 years **Long term** = Expect market to unfold in more than 5 years	**Existing or Emerging Industry Connections** **Extensive** = Significant presence of industry **Moderate** = Some presence of industry **Limited** = Minimal presence of industry
Enterprise Systems Computing	Emerging	Moderate	Extensive (immediate)	Extensive
Distributed Energy Network Systems	Emerging	Limited	Extensive (near term)	Extensive
Optics and Photonics	Emerging	Limited	Moderate (immediate)	Limited
Nano-Related Materials and Applications	Established	Significant	Extensive (long term)	Moderate
Sustainable Agriculture and Bioenergy Management	Established	Limited	Moderate (near term)	Moderate
Food Processing and Safety	Established	Moderate	Moderate (immediate)	Extensive
Personalized Health Research Sciences	Emerging	Moderate	Extensive (longer term)	Limited—addresses major public health issues
Behavioral Research for Chronic Disease Management	Emerging	Significant	Limited (immediate)	Limited—addresses major public health issues
Obesity and Nutrition	Emerging	Significant	Extensive	Limited—addresses major public health issues

Why Research Matters

World-class research is a passport to success in the global economy. Industry can no longer compete by selling standard products made with standard processes and that could be produced anywhere in the world at lower cost. Businesses must constantly innovate to raise the quality of production, introduce new product lines or services, and add greater value to their outputs. For this reason, states must create an environment that supports continuous innovation. This requires investment in cutting-edge research, facilities, and equipment.[1]

These are the words of the National Governors Association in its guidance to governors entitled "A Governor's Guide to Building State Science and Technology Capacity." And, the evidence on the importance of research universities to advance technology-based economic development is overwhelming:

- The Milken Institute noted that research centers and institutes are "indisputably the most important factors in incubating high-tech industries" in a widely cited study, which found that 65% of the difference in economic success for regions from 1975 to 1998 is accounted for by the presence and growth of high-technology industries.[2]

- According to a study prepared for the U.S. Small Business Administration, "Research universities and investment in research universities are major factors contributing to economic growth in the labor market areas in which the universities are situated."[3]

- Studies by the Office of Technology Policy and others have found that all areas of technology-based economic development in the United States have strong concentrations of both university and private research.[4]

- On its Web site (www.indiana.edu/about/economic.shtml), Indiana University states that each $1 million in competitively won grants and contracts generates 41.4 jobs.

An excellent example of how a sustained statewide effort to build research can grow an economy is the Georgia Research Alliance (GRA). Launched in 1990, GRA has focused its efforts on recruiting Eminent Scholars to Georgia research universities who not only excel in scholarship but also have an orientation toward commercialization and entrepreneurship. To date, 60 scholars have been recruited. The return on the state of Georgia's investment has been substantial—$467 million in state investment since 1990 has garnered $2.1 billion in new funding, more than 5,200 jobs, and 142 new companies as well as more than 100 partnerships with Georgia companies.[5]

Today's university research activities are about more than just advancing knowledge for knowledge's sake. Research universities across the nation are becoming anchors and contributors to economic development in several important ways:

- **Commercialization of New Technologies:** Universities are empowered to turn their discoveries into commercialization through technology transfer, which is becoming a major direct contribution. In 2007, research universities generated 17,415 disclosures, 3,256 patents, 4,316 licenses, and 502 new company spin-offs.

- **Applied Research and Development (R&D):** Harder to quantify but no less substantial is that research universities offer industry a means to work out thorny problems and make use of leading scientific equipment and laboratories to address specific needs. Through collaborative and multidisciplinary research centers, many companies open up their research enterprise to work with industry. In 2007, industry funded $2.97 billion in university-based R&D.

[1] National Governors Association, "A Governor's Guide to Building State Science and Technology Capacity," 2002, page 15.
[2] Milken Institute, *America's High-Tech Economy*, 1999.
[3] Bruce Kirchhoff, "The Influence of R&D Expenditures on New Firm Formation and Economic Growth," Maplewood, N.J.: BJK Associates, 2002.
[4] U.S. Department of Commerce, Office of Technology Policy, *The Dynamics of Technology-based Economic Development: State Science and Technology Indicators,* Washington, D.C., 2000.
[5] Michael Cassidy, Georgia Research Alliance Presentation to the Arkansas Research Alliance Board on October 10, 2009.

- **Quality of Life:** Increasingly, regions are learning that factors driving location decisions are rapidly shifting in today's global, knowledge-based economy. Companies want to be in dynamic, technology-centric environments that university life can generate. The Jones Lang LaSalle and LaSalle Investment Management in studying the drivers of rising urban stars in their World Winning Cities research program, an effort to identify the essence of contemporary city competitiveness with a view to predicting the potential winning cities of the future, suggest that one key theme to development is: "**Being Technology Rich:** Technology hubs—whether Raleigh-Durham or Austin, Texas or Helsinki, Finland—are seen as key to having high value knowledge intensive industry linked to a strong research and educational infrastructure, and offering a high quality of life to retain and attract highly educated knowledge workers."[6]

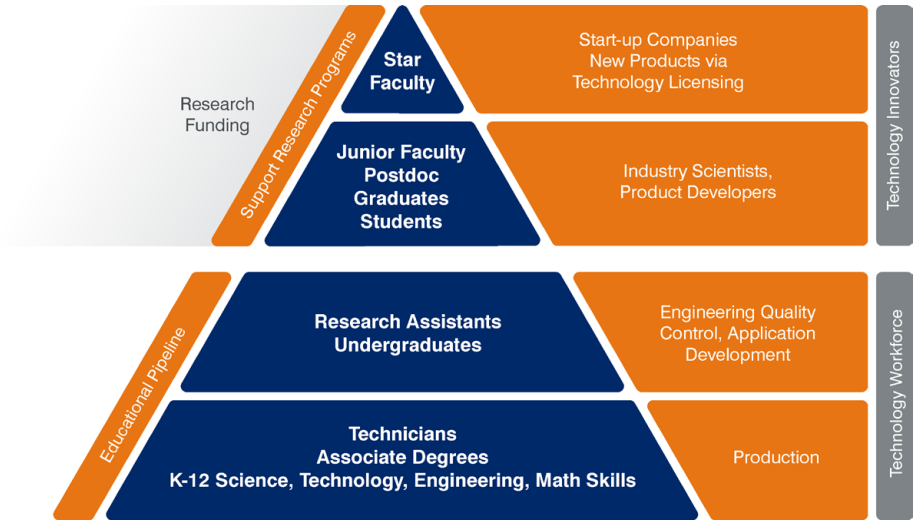
But, the most important contribution that university research makes toward economic development is in talent generation. Perhaps the most important economic value from universities is the specialized technical workforce and future entrepreneurs who in turn strengthen existing industries and advance emerging technology sectors. As the National Governors Association explains: "CEOs report that the availability of technically trained talent is their top priority—one that often determines where they locate high-value investments."[7]

According to the 2004 Massachusetts Technology Road Map, "These talent pools do not begin with educating students, but with the research faculty advancing university research excellence. States must be able to recruit and retain the best and brightest faculty if they are to be world-class leaders in science and technology development. In turn, top faculties are able to recruit top students at both the undergraduate and graduate level."[8]

Figure 1, adapted from the Technology Road Map, suggests the relationship that star faculty members have across the talent pipeline in advancing technology leadership, which in turn results in broad economic activity that offers jobs across the spectrum of skills.

In the past, a region's natural resources and proximity to markets were critical factors to economic success. Today, however, with the rising importance of knowledge workers and innovation, a state's competitiveness for technology-based growth is highly intertwined with the presence of a robust university research base.

Figure 1. Connection of Talent Generation to Economic Development



[6] Jones Lang Lasalle and LaSalle Investment Management, "Rising Urban Stars – Uncovering Future Winners," May 2003.
[7] National Governors Association, "A Governor's Guide to Building State Science Technology Capacity," 2002, page 8.
[8] Mass Insight, *Choosing to Lead: The Race for National R&D Leadership and New Economy Jobs, Case Statement & Core Technology Audit, The Massachusetts Technology Road Map and Strategic Alliances Study,* 2004, page 28.

A Research Enterprise in Development

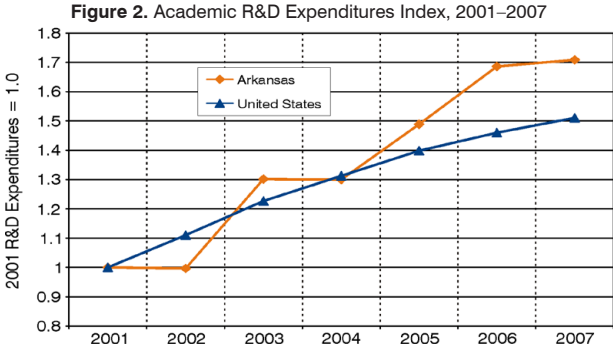
An important input for understanding the job-creating research potential of universities in Arkansas is to analyze the overall standing and trends in the university research enterprise found in Arkansas. The trends in research funding, publications in peer-reviewed journals, and generation of graduates in science, engineering, and math fields are all positive since the beginning of the new millennium. But, Arkansas still has far to go.

Research Funding Levels and Trends

All universities in Arkansas and across the nation report annually to the National Science Foundation (NSF) the funding of research across detailed fields of study and from all sources, whether federal, state, industry, foundation, or internal.

There is very positive news for Arkansas in the trends in university research. Overall, university research funding in Arkansas made significant strides from 2001 to 2007, growing from $141 million to $240 million, a 70% gain. This is far in excess of the U.S. growth rate of 51% (Figure 2).

Figure 2. Academic R&D Expenditures Index, 2001–2007



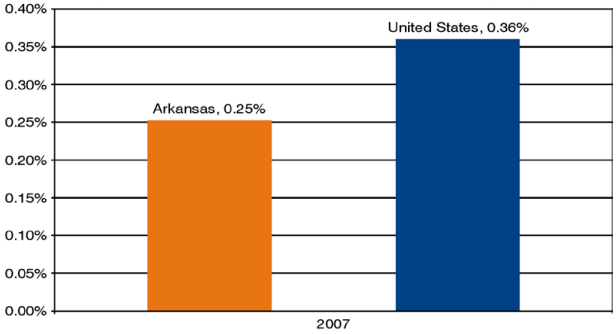
Source: NSF, Calculations by Battelle.

The growth in Arkansas' university research base is widely shared across several research fields. In all, Arkansas outpaced the national growth rate in 2007 in the following six research fields in which the state has a measurable presence of at least $5 million in research funding:

- **Medical Sciences**—which reached $62.5 million and outgrew the nation 83% vs. 62%.
- **Biological Sciences**—which reached $49 million and outgrew the nation 133% vs. 55%.
- **Chemistry**—which reached $11 million and outgrew the nation 205% vs. 44%.
- **Physics**—which reached $7.6 million and outgrew the nation 94% vs. 31%.
- **Other Engineering** (systems, biomedical, etc.)—which reached $7.4 million and outgrew the nation 105% vs. 28%.
- **Other Life Sciences** (pharmacy, nursing, public health)—which reached $5.3 million and outgrew the nation 443% vs. 50.5%.

Still, the overall base of university research in Arkansas is relatively small at $240 million. Arkansas is not highly ranked in any field of research, except agricultural sciences where it ranks 19th in the nation. More typical top rankings for Arkansas—even in more detailed fields—are in the high 20s and low 30s. When compared with the overall size of the state's economy, Arkansas falls short on the level of university research. For the nation, university research comprises 0.36% of total national economic output in 2007. In Arkansas, university research stands at just 0.25% (Figure 3). To reach the national average, Arkansas would have needed to increase its university research by $106 million or 44% to reach the national average in 2007.

Figure 3. 2007 Academic R&D as Share of GSP (GDP)

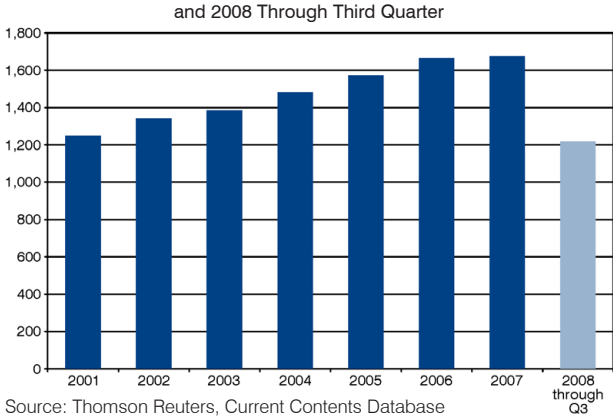


Source: NSF, U.S. Department of Commerce, Calculations by Battelle.

Publications Activity

Publications activity is another key measure of scholarly activity. While publications are a common means in which researchers report on the findings from their grant activities, it is also true that publications, when based on more theoretical work or pilot studies, can be critical to demonstrate a body of work to win research grants. Thomas Reuters tracks publications and associated citations in peer-reviewed journals for universities in 106 fields involving basic, applied, and clinical research. Arkansas has also raised its level of scholarly activity, as represented by publications, significantly in recent years. Publications in Arkansas across its universities and the National Center for Toxicology Research (NCTR) increased by roughly one-third, from 1,200 to 1,600, and are on course to continue that higher level of activity based on the results from the first three quarters of 2008 (Figure 4).

Figure 4. Arkansas Research Publications, 2001–2007 and 2008 Through Third Quarter



Source: Thomson Reuters, Current Contents Database for All Institutions in Arkansas.

Looking within specific publication fields, it is important to consider both the share of research publications in a field to identify areas of focus as well as the quality of publications as measured by citations per publication. When examining publication activity by specific fields, it is best to look at a period of at least 5 years to allow for year-to-year variations.

Arkansas stands out in particular fields in the level or volume of research publications. While Arkansas in total publications reaches 0.5% share of all U.S. publications over 2003 to 2007, Table 1 lists 18 fields where the state has 1.0% or more of the U.S. total—of which 12 are primarily found in agricultural sciences.

Table 2 shows that Arkansas has 21 publication fields with at least 40 publications and a 10% higher rate of citation per publication than the national average over 2003 to 2007. In this measure of publication quality, broader research strengths emerge, particularly in biomedical and material sciences research.

Table 1. Arkansas' Share of National Publications, by Publication Field, 2003–2007

Publication Field	Arkansas' Share of National Publications (>1%)
Agricultural Diary and Animal Sciences	4.0%
Agricultural Engineering	2.8%
Toxicology	2.6%
Agronomy	2.5%
Food Sciences and Technology	2.2%
Agricultural Multidisciplinary Sciences	1.8%
Horticulture	1.7%
Fisheries	1.6%
Mycology (study of fungi)	1.6%
Agricultural Soil Sciences	1.4%
Applied Chemistry	1.3%
Nutrition	1.2%
Pathology	1.1%
Geriatrics and Gerontology	1.1%
Ornithology (study of wild birds)	1.0%
Biotechnology and Applied Microbiology	1.0%
Plant Sciences	1.0%
Entomology	1.0%

Source: Thomson Reuters, University Science Indicators.

Table 2. Arkansas' Rate of Citation per Publication, by Publication Field and Number, 2003–2007

Publication Field	Arkansas' Rate of Citation per Publication ≥10% of National Average for That Field	Number of Publications (≥40)
Nuclear Physics	168%	42
Information Systems (Computer Sciences)	168%	41
Software Engineering (Computer Sciences)	112%	52
Internal Medicine	106%	80
Physical Chemistry	94%	74
Agricultural Multidisciplinary	61%	55
Material Sciences Multidisciplinary	55%	138
Infectious Disease	49%	63
Dermatology	34%	68
Agricultural Soil Sciences	33%	57
Sports Sciences	30%	45
Entomology	26%	96
Applied Chemistry	26%	92
Health-Care Sciences and Services	26%	159
Medicinal Chemistry	24%	45
Nanoscience	22%	67
Zoology	18%	110
Physiology	15%	145
Agricultural Engineering	14%	62
Toxicology	12%	325
Veterinary	11%	80

Source: Thomson Reuters, University Science Indicators.

Table 3. Arkansas' Talent Deficit

Measure of Talent Generated	At or Above Proficient: Arkansas	At or Above Proficient: United States
Elementary and Secondary Education Assessment (National Assessment of Education Progress)		
4th Grade Math (2007)	37%	39%
8th Grade Math (2007)	24%	32%
4th Grade Science (2005)	24%	29%
8th Grade Science (2005)	23%	29%
Higher Education		
Bachelor's Degrees Conferred per 1,000 Individuals 18–24 Years Old	41.4	48.4
Bachelor's Degrees in Science and Engineering per 1,000 Individuals 18–24 Years Old	6.0	7.9
Science and Engineering Graduate Students per 1,000 Individuals 25–34 Years Old	6.5	11.7
Workforce		
Bachelor's Degree Holders Potentially in the Workforce	22.5%	31.7%
Engineers as Share of Workforce	0.56%	1.06%
Life and Physical Scientists as Share of Workforce	0.22%	0.40%
Computer Specialists as Share of Workforce	1.03%	2.05%

Source: NSF, *Science and Engineering Indicators, 2008*; except National Centers for Educational Statistics for elementary and secondary educational assessment.

Talent Generation

Another critical aspect of the research enterprise is the talent being generated. For Arkansas, the importance of talent generation in considering the progress of its research enterprise is particularly pressing because of the significant "talent deficit" the state faces (see Table 3 for an overview of Arkansas' lagging in the national average in its talent base).

In recent years, Arkansas has been making steady gains in the level of graduates from its universities. Overall, awarding of university degrees—bachelor's, master's, and doctorate—has grown from 12,153 in 2001 to 15,262 in 2007, a gain of nearly 26%.

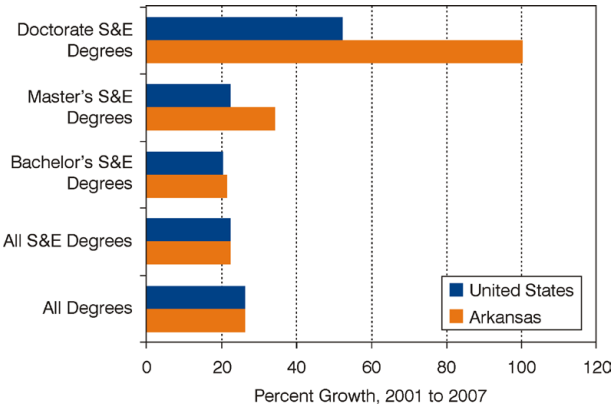
A lower but still significant gain in degrees awarded has occurred in fields related to science, math, and engineering, which rose from 3,548 in 2001 to 4,341 in 2007, a gain of 22%. This growth was realized in all levels of education as bachelor's, master's and doctorate degrees rose.

Still, the most impressive gain has been the near doubling of doctorate degrees in Arkansas in science, math, and engineering fields—suggesting its strong growth in research funding is translating into top-level talent creation in the state. Health and clinical sciences led the strong growth in degrees, but substantial gains were also made in engineering and agricultural/food sciences.

Table 4 presents the detailed information on growth of degrees granted between 2001 and 2007 in Arkansas by major science, engineering, and math fields at the bachelor's, master's and doctorate levels.

In comparison with the nation, Arkansas tracks well with overall national trends in total degrees and science, math, and engineering degrees (Figure 5). Where Arkansas stands out is the gains in doctorate degrees, which far outpaced the nation but started at a small base.

Figure 5. Arkansas and U.S. Growth in Degrees, 2001–2007



Source: National Center for Educational Statistics.

The Arkansas Research Challenge: Building Excellence Within a Growing Research Enterprise

The trends across research funding, publications, and talent generation for Arkansas' universities is generally very positive, but the overall research enterprise in Arkansas remains undersized; much more is needed to reach national levels of excellence. The challenge for Arkansas' research enterprise is how to build upon the momentum of the past few years to identify specific areas where Arkansas can reach national excellence.

The Arkansas Research Alliance is committed to advancing world-class excellence in university research in Arkansas. Building upon those areas where a critical mass of research activities exist—what is termed "core research competencies"—can guide the Arkansas Research Alliance in identifying strategic focus areas in which Arkansas is positioned for world-class excellence and for job-creating research. The next section presents specifics about the research enterprise in Arkansas.

Table 4. Details of University Degree Generation Across Arkansas Universities and Colleges

Arkansas Colleges and Universities	2001				2007			
Key S&E Fields	Doctorate Degrees	Master's Degrees	Bachelor's Degrees	Total	Doctorate Degrees	Master's Degrees	Bachelor's Degrees	Total
Engineering	7	86	269	362	15	74	341	430
Engineering Technologies			78	78			112	112
Chemistry	2	6	115	123	4	12	117	133
Physics	4	3	32	39	1	9	44	54
Mathematics and Statistics	2	29	88	119	2	27	127	156
Computer Science	0	34	370	404	1	68	269	338
Earth Sciences	1	10	18	29	4	12	23	39
Agriculture and Food Sciences	12	39	108	159	20	26	89	135
Biological Sciences	22	27	462	511	20	58	506	584
Psychology	9	56	451	516	6	46	547	599
Health and Related Clinical Sciences	6	289	913	1,208	55	358	1,303	1,716
Total, Key S&E Fields	65	519	2,904	3,548	130	697	3,514	4,341
Total, All Fields	144	2,232	9,777	12,153	218	3,257	11,787	15,262

Source: National Center for Education Statistics.

Assessing Arkansas' Core Research Competencies

In pursuing future activities, states are learning that universities, just like regions of their states, must nurture the development of specialized areas of expertise, or core competencies, where they can be national, if not world, leaders. As defined by Gary Hamel and C.K. Prahalad in *Competing for the Future*,[9] a "competence" is a bundle of skills and technologies representing the sum of learning across individual skill sets and organizational units. From a state perspective, core competencies across universities are those focused areas where the state's university base can bring a critical mass of activity—as measured by research, talent generation, and unique facilities and resources—along with an identified measure of excellence.

Using both quantitative and qualitative methods, Battelle has developed a rigorous approach for assessing the core competencies of research institutions (Figure 6). Three key steps were taken to identify potential research competencies:

- Step One: A cluster analysis of peer-reviewed publications and grant awards to identify key research themes.

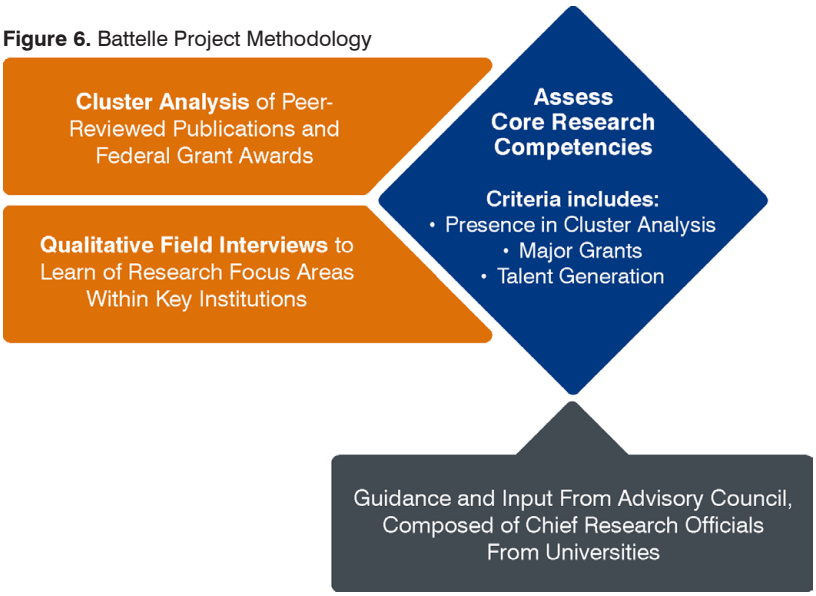
> "Core competencies are the gateways to future opportunities. Leadership in a core competence represents a potentiality that is released when imaginative new ways of exploiting that core competence are envisioned."
>
> Gary Hamel and C.K. Prahalad, *Competing for the Future*

- Step Two: Field interviews to gain a more hands-on understanding of research focus areas within each of the research institutions in Arkansas.

- Step Three: Assessment of core competencies considering key criteria in addition to cluster analysis and field interviews, including publications analysis, major grants, and talent generation.

This core competency assessment was facilitated and vetted by the Advisory Council to the Arkansas Research Alliance, composed of Vice Presidents/Vice Provosts of Research from the leading research universities and government labs in Arkansas.

Figure 6. Battelle Project Methodology



[9] Gary Hamel and C.K. Prahalad, *Competing for the Future*, Harvard Business Press, 1994, pages 90 and 217.

Step One: Cluster Analysis

With regard to the relationships and key themes found across publications and federal research grant awards to organizations, cluster analysis performs the following:

- Examines how publications and grants relate to one another based on the actual research activities underway in each grant and publication.

- Identifies, through the use of proprietary data mining software, clusters of activity based on the connections of words in sentences from the abstracts and titles of grants.

Altogether, 12,946 publications and grants from 2003 to 2007 were analyzed, including the following:

- 11,772 publications across all Arkansas institutions, including NCTR

- 718 National Institutes of Health (NIH) awards to Arkansas institutions

- 348 NSF awards to Arkansas institutions

- 110 U.S. Department of Agriculture (USDA) awards to Arkansas institutions.

Twenty-six cluster themes were identified from the analysis of these nearly 13,000 publications and grants. Appendix B sets out the size and key focus areas found within the cluster themes.

Not all cluster themes are of equal depth. Three levels of cluster themes emerged: large, with over 500 records; mid-sized, with between 200 and 500 records; and niche, with fewer than 200 records.

26 Cluster Themes Identified From Analysis of Publications and Grants

Large cluster themes include:

- Cancer Control, Detection, and Treatment with 1,105 records
- Disease-Related Genomic and Cellular Processes with 850 records
- Metabolic Studies with 650 records
- Infectious Disease Research and Treatment with 642 records
- Pediatric Research with 604 records
- Plant Sciences with 600 records
- Food Science, Food Safety, and Nutrition with 539 records
- Nanotechnology with 517 records.

Mid-sized cluster themes include:

- Mental Health and Behavior with 468 records
- Water Quality and Resource Studies with 443 records
- Musculoskeletal Research with 408 records
- Poultry Sciences with 290 records
- Addiction Treatment and Management with 268 records
- Optics with 240 records
- Ecology and Environmental Sciences with 228 records
- Aquaculture with 201 records.

Niche cluster themes include:

- Obesity and Diabetes Research with 189 records
- Animal Sciences with 188 records
- Nephrology Research with 188 records
- Pain Research with 138 records
- Informatics and Mathematical Research with 134 records
- Sleep, Auditory, and Memory Research with 126 records
- Physics with 98 records
- Medical Technology and Non-Invasive Diagnosis with 95 records
- Electronics with 72 records
- Medical Implants and Prosthetics with 28 records

Step Two: Qualitative Field Interviews

Along with the quantitative analysis, the Battelle team conducted extensive qualitative interviews with university administrators and faculty. These interviews were essential in helping develop an understanding of how the data on publications and grant awards translate into on-the-ground focus areas in Arkansas.

There is strong overlap between the core competency strengths identified from the cluster analysis of publications and grant awards and those identified in the interviews. However, several core competency areas emerged that were not identified by the cluster analysis of publications and grant awards, including the following:

- Electric Power and Power Electronics
- Sensing and Sensor Networks
- Logistics
- Bioenergy
- Radiation Biology and Health
- Toxicology and Drug Development.

Step Three: Assessment of Research Competencies Identified From Cluster Analysis and Field Interviews

To further define the research core competencies in Arkansas identified from the cluster analysis and qualitative field interviews, Battelle considered a number of key variables to assess the presence and overall strength of the research core competency areas, including the following:

- **Presence in the cluster analysis** of grants and publications across Arkansas' universities and government labs. A higher number of grants and publications found in a particular research area suggest that it is a more significant focus of research activity in Arkansas, though emerging areas may not be fully captured because of inherent time lags from research efforts to publications and winning grant awards.

- **Publications and citation analysis** across research institutions in Arkansas using data from Thomson Reuters University Scientific Indicators. This analysis enables a comparison of Arkansas to the nation, both in the volume of publications in particular fields and the quality of publications as measured by citations per publication for a particular field. The publication fields are predetermined by USI and may not fully reflect all of the particular areas of research strength found in Arkansas.

- **Major grants** relating to each research core competency area. This provides another measure of the depth and quality of the research focus areas. Unfortunately, the grants of every federal agency are not available for review, and this effort focuses on the grants of NSF, NIH, and USDA—which do span much of the research activities in academia.

- **Presence of graduate-level degree programs** in a research core competency area. This factor suggests the ability for Arkansas to generate top talent in a research field and to have the infrastructure to attract more research-oriented faculty.

- **Institutional focus as identified from field interviews.** This provides the context of where individual institutions are growing their research infrastructure and recruiting faculty that will lead to future research activities.

For each of these criteria, Battelle established ratings of Top Tier, Middle Tier, Lower Tier, and Bottom or No Presence in Table 5. In some cases, there are cross-cutting fields or no data available.

Altogether, Battelle identified 30 research competencies in part reflecting the statewide nature of the study and in part the fact that research across Arkansas is still emerging and not highly distinguishable These research competencies fell into the following two categories, as noted in Table 6:

- 18 broad research competencies based on having predominantly top- and middle-tier rankings in measures of publications, grants, talent, and institutional focus

- 12 niche research competencies that are more limited in breadth at this time.

The rankings for each core competency by the criteria are detailed in Tables 7 and 8.

Table 5. Key to 2008 Quantitative Assessment of Arkansas' Research Core Competencies

Presence in Cluster Analysis of Grant Awards and Publications: Measures activity within Arkansas

- Top Tier: Related meta-clusters contain 500 or more records
- Middle Tier: Related meta-clusters contain 200 to 500 records
- Lower Tier: Related meta-clusters contain less than 200 records
- No Presence: No related meta-clusters
- Cross-Cutting: Presence across more than several meta-clusters

Position in USI Publications and Citations Analysis: Analyzes Arkansas' share of all U.S. publications per field and degree of citations per publication

- Top Tier: At least 40 publications in relevant fields of research with relative impact at least 20% higher than the national average for the field or more than 1.0% of U.S. share of publications
- Middle Tier: At least 40 publications in relevant fields of research with relative impact between 10% and 20% higher than the national average for the field; or share of U.S. publications above state average and relative impact of between 0% and 10% higher than the national average
- Lower Tier: At least 40 publications with lower relative impact between 1% and 10% higher than the national average for the field or a relative impact below the national average for the field and a share of U.S. papers above the statewide average
- Bottom Tier: At least 40 publications with lower relative impact than the national average for the field and a lower share of U.S. papers than the statewide average
- Not Available: No field listed in USI that covers research focus area

Presence of Major Competitively Funded Grants: Reviews active major grant awards for programs or centers in excess of $250,000.

- Top Tier: Ten or more competitively funded grants
- Middle Tier: Seven to nine competitively funded grants
- Lower Tier: Four to six competitively funded grants
- Bottom Tier: Less than three competitively funded grants above $250,000

Talent Generation:

- Top Tier: Offer three or more Ph.D. options
- Middle Tier: Offer one or two Ph.D. programs
- Lower Tier: Offer only Master's-level degree
- No Presence: No Ph.D. or Master's-level degree offered

Institutional Focus:

- Top Tier: Well-established strength with a cluster of faculty researchers funded in the area
- Middle Tier: Growing strength with an existing presence and key plans to advance
- Lower Tier: Emerging strength still at a nascent level
- No Presence

Table 6. Listing of Broad and Niche Research Competencies in Arkansas

Research Competencies Identified in Arkansas	
Broad Research Competencies	**Niche Research Competencies**
Cancer Control, Detection, and Treatment	Obesity and Diabetes Research
Disease-Related Genomic and Cellular Processes	Animal Research
Plant Sciences	Nephrology Research
Metabolic Studies	Sleep, Auditory, and Memory Research
Infectious Disease Research and Treatment	Physics
Pediatric Research	Medical Technology and Non-Invasive Diagnosis
Nanotechnology	Electronics
Toxicology and Drug Development	Power Electronics and Alternative Energy
Mental Health and Behavior	Sensing and Sensor Networks
Food Science, Food Safety, and Nutrition	Logistics
Musculoskeletal Research	Radiation Biology
Water Quality and Resources	Bioenergy
Poultry Sciences	
Addiction Treatment and Management	
Optics	
Ecology and Environmental Sciences	
Aquaculture	
Informatics and Mathematical Research	

Table 7. Details of Core Competency Assessment Criteria: Broad Research Competencies

Core Competency Area	**Presence in Cluster Analysis** ●●●● = >500 records ●●● = 200–500 records ●● = <200 records	**Position in Publication and Citation Analysis** At least 40 publications in the area and relative impact is: ●●●● = Citation per publication >20% greater than nat'l avg. ●●● = Citation per publication 10–20% greater than nat'l avg.; or citation per publication 1–10% greater than nat'l avg. with above avg. share of U.S. papers ●● = Citation per publication 1–10% greater than nat'l avg.; or citation per publication below the nat'l avg. with above avg. share of U.S. papers ○ = Citation per publication below nat'l avg. and below avg. share of U.S. papers	**Major Grants in Excess of $250,000** ●●●● = ≥10 grants ●●● = 7–9 grants ●● = 4–6 grants ○ = 1–3 grants	**Talent Generation Programs Offered** ●●●● = ≥3 Ph.D. degrees ●●● = 1–2 Ph.D. degrees ●● = Master's only ○ = No graduate degree	**Institutional Focus** ●●●● = Established strength with cluster of faculty ●●● = Growing strength with some faculty ●● = Emerging strength with minimal faculty ○ = No Presence
Cancer Control, Detection, and Treatment	●●●● (1105 records)	●●	●●●	●●●	●●●●
Disease-Related Genomic and Cellular Processes	●●●● (850 records)	●●	●●●●	●●●●	●●●
Metabolic Studies	●●●● (650 records)	●●●	●●	●●●	●●●
Infectious Disease Research and Treatment	●●●● (642 records)	●●●●	●●●●	●●●	●●●
Pediatric Research	●●●● (604 records)	●●	●●	●●●	●●●
Plant Sciences	●●●● (600 records)	●●●●	●●	●●●●	●●●●
Nanotechnology	●●●● (517 records)	●●●●	●●●	●●●● (for offerings in related degree areas)	●●●
Toxicology and Drug Development	Cross-cutting—key term in many clusters	●●●●	○	●●●●	●●●●
Mental Health and Behavior	●●● (468 records)	○	●●	●●●●	●●●
Food Science, Food Safety, and Nutrition	●●● (539 records)	●●	●●	●●●	●●●●
Musculoskeletal Research	●●● (408 records)	●●	●●●	●●●	●●●●
Water Quality and Resources	●●● (443 records)	●●●●	●●	●●●	●●●●
Poultry Sciences	●●● (290 records)	●●	●●	●●●	●●●●
Addiction Treatment and Management	●●● (268 records)	●●	●●●●	●●●●	●●●●
Optics	●●● (240 records)	○	●●	●●●	●●●
Ecology and Environmental Sciences	●●● (228 records)	●●	●●●	●●●	●●●
Aquaculture	●●● (201 records)	●●	○	●●	●●●
Informatics and Mathematical Research	●● (134 records)	●●●●	●●●●	●●●●	●●

Table 8. Details of Core Competency Assessment Criteria: Niche Research Competencies

Core Competency Area	**Presence in Cluster Analysis** ●●●● = >500 records ●●● = 200–500 records ●● = <200 records	**Position in Publication and Citation Analysis** At least 40 publications in the area and relative impact is: ●●●● = Citation per publication >20% greater than nat'l avg. ●●● = Citation per publication 10–20% greater than nat'l avg.; or citation per publication 1–10% greater than nat'l avg. with above avg. share of U.S. papers ●● = Citation per publication 1–10% greater than nat'l avg.; or citation per publication below the nat'l avg. with above avg. share of U.S. papers ○ = Citation per publication below nat'l avg. and below avg. share of U.S. papers	**Major Grants in Excess of $250,000** ●●●● = ≥10 grants ●●● = 7–9 grants ●● = 4–6 grants ○ = 1–3 grants	**Talent Generation Programs Offered** ●●●● = ≥3 Ph.D. degrees ●●● = 1–2 Ph.D. degrees ●● = Master's only ○ = No graduate degree	**Institutional Focus** ●●●● = Established strength with cluster of faculty ●●● = Growing strength with some faculty ●● = Emerging strength with minimal faculty ○ = No Presence
Obesity and Diabetes Research	●● (189 records)	●●	●●	○	●●●
Animal Research	●● (188 records)	●●	○	●●●	●●●
Nephrology Research	●● (188 records)	●●●	○	●●●	●●
Sleep, Auditory, and Memory Research	●● (126 records)	●●	●●	●●●	●●
Physics	●● (98 records)	●●●●	○	●●●	●●
Medical Technology and Non-Invasive Diagnosis	●● (95 records)	○	●●	●●●	●●
Electronics	●● (72 records)	○	○	●●●●	●●●
Power Electronics and Alternative Energy	○	○	●●	●●●	●●
Sensing and Sensor Networks	○	○	●●●	●●●	●●●
Logistics	○	—	○	●●●	●●●
Radiation Biology	○	—	●●	○	●●
Bioenergy	○	—	○	○	●●

Identifying Strategic Focus Areas for Investment

Arkansas' core competencies in university basic and applied research are the foundations on which the Arkansas Research Alliance can promote job-creating research from the state's universities. Core competencies by themselves do not generate "signature" areas of focus. Instead, they 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 7).

In the future, it is not just deep strengths in single disciplines that will matter, but interdisciplinary fields that can apply technology convergence to addressing key research problems and applications development. As the *Chronicle of Higher Education* notes, "[interdisciplinary] partnerships are proliferating in academe—and slowly changing the face of science—because they offer the best hope for answering some of the thorniest research subjects including climate change, biodiversity and cancer."[10]

Strategic focus areas should be broad, multidisciplinary areas of research that offer the potential to realize significant gains in economic development in a favorable timeframe and in multiple substantial, growing markets. Focusing on them can accelerate technology development, foster effective collaboration and partnerships, raise public awareness of the global issues they address, and stimulate investment in R&D. And, in the long term, implementation of a strategic focus area can produce sustainable competitiveness for the region by stimulating innovation, overcoming the barriers to the deployment of new technologies, and generating economic growth and expansion.

Identification of strategic focus areas requires the consideration of several criteria:

Figure 7. Relationships Among Core Competencies and Development and Market Opportunities

[10] Jeffrey Brainard, "U.S. Agencies Look to Interdisciplinary Science," *Chronicle of Higher Education*, June 14, 2002.

- **Opportunities drawing upon multiple core competencies and organizations.** A strategic focus area should address opportunities that transcend multiple core competencies and organizations, ensuring that Arkansas' research base is a fertile, multidisciplinary, cross-cutting, and collaborative research environment rather than a collection of stand-alone research strengths.

- **Opportunity for external funding.** A strategic focus area should relate to pressing issues or needs and thus be likely to attract major external R&D funding and investment. It is also important to consider the level of competition from research institutions in other states.

- **Market potential.** A strategic focus area should align institutional research strengths with emerging and growing market opportunities.

- **Economic linkages with Arkansas.** A strategic focus area should offer existing linkages to Arkansas' industries or offer an opportunity for generating new start-up firms.

The following nine potential strategic focus areas were identified in consultation with the Arkansas Research Alliance Advisory Council, composed of senior university executives responsible for their universities' research activities:

- Enterprise Systems Computing
- Distributed Energy Network Systems
- Optics and Photonics
- Nano-Related Materials and Applications
- Sustainable Agriculture and Bioenergy Management
- Food Processing and Safety
- Personalized Health Research Sciences
- Behavioral Research for Chronic Disease Management
- Obesity and Nutrition.

Table 9 presents the evaluation from Battelle on these criteria.

Table 9. Overall Evaluation of the Strategic Focus Areas

Strategic Focus Area	**Breadth of Competencies and Institutions** **Established** based on extensive depth of core research competencies **Emerging** based on more limited depth of core competencies	**Opportunity for External Research Funding** **Significant** = ≥$500 million in federal funding **Moderate** = $250 to $500 million in related federal funding **Limited** = <$250 million in federal funding	**Market Potential** **Extensive** = More than $10 billion **Moderate** = $1 billion to $10 billion **Limited** = <$1 billion **Immediate** = Established market today **Near term** = Expect market to unfold in next 3–5 years **Long term** = Expect market to unfold in more than 5 years	**Existing or Emerging Industry Connections** **Extensive** = Significant presence of industry **Moderate** = Some presence of industry **Limited** = Minimal presence of industry
Enterprise Systems Computing	Emerging	Moderate	Extensive (immediate)	Extensive
Distributed Energy Network Systems	Emerging	Limited	Extensive (near term)	Extensive
Optics and Photonics	Emerging	Limited	Moderate (immediate)	Limited
Nano-Related Materials and Applications	Established	Significant	Extensive (longer term)	Moderate
Sustainable Agriculture and Bioenergy Management	Established	Limited	Moderate (near term)	Moderate
Food Processing and Safety	Established	Moderate	Moderate (immediate)	Extensive
Personalized Health Research Sciences	Emerging	Moderate	Extensive (longer term)	Limited—addresses major public health issues
Behavioral Research for Chronic Disease Management	Emerging	Significant	Limited (immediate)	Limited—addresses major public health issues
Obesity and Nutrition	Emerging	Significant	Extensive	Limited—addresses major public health issues

Enterprise Systems Computing

Opportunity:

Today's advanced information systems have been dramatically changing with the rapid deployment of the Internet, which is leading a new era of enterprise systems computing. The following are among the emerging technology trends in this new era in enterprise systems computing:

- "Web Services," the new model for enterprise-wide information technology (IT) solutions, is changing the business-to-business scenario, much in the same way a universal server-client model supported by industry-wide standards revolutionized business-to-consumer interaction.
- The seamless integration of an enterprise with its requirement and has led to more integrated logistics including the planning, implementation, and control of the flow and storage of raw materials, in-process inventory, finished goods, services, related information, and payments among suppliers and consumers.
- Broad uses of sensors, wireless networks, and multimedia data are changing the demands on enterprise systems computing.
- Demands are growing for information management, quality assurance, and knowledge management to address the enormous volumes of data being generated.
- The "On Demand" model of service delivery is enabling greater levels of resource optimization and has brought solutions such as grid computing and utility computing into the mainstream IT solutions market. Leading vendors such as HP, IBM, Sun, and communication systems providers such as AT&T have all announced ambitious plans.

This era is different from the rise of dot-coms and the technology boom of the late 1990s because it reaches far beyond just a handful of companies and industry niches. Many industries are being affected by this change in technology. UPS uses the Internet to help customers track their shipments. Wal-Mart, well-known for its advanced computerized supply chain and inventory management systems, is requiring its suppliers to use radio-frequency identification (RFID) tags to track all of their products. Delta Airlines enables cell phone and personal digital assistant users to access arrival and departure information through mobile communications.

Multiple competencies and institutions: Emerging

Across the University of Arkansas (UA) campuses at Fayetteville, Little Rock, and Pine Bluff, the following core competencies exist:

- Informatics and mathematical sciences, including information assurance, grid computing, middleware development, and object-oriented software development.
- Sensing and sensor networks with an emphasis on RFID, wireless networking, and smart sensor development.
- Logistics involving an emphasis on supply chain management and transportation logistics using modeling, analysis, and intelligence systems technologies.

Opportunity for external research funding: Moderate

Enterprise systems computing is not a particular focus of federal funding, but niche areas such as cluster computing, information assurance, data mining and knowledge management, and wireless sensor networking are opportunity areas.

The NSF is a major funding agency for IT. The Directorate for Computer and Information Science and Engineering provides roughly $538 million a year in grant funding.

The Department of Defense (DoD) is another funding agency for funding related to enterprise systems computing, with an emphasis on more command and control systems, particularly adaptive systems able to recognize new entities.

In the area of information assurance and security, the Department of Homeland Security (DHS) is a funding source, but more limited.

Interestingly, there is significant funding from NIH for information systems development, with a focus on biological systems.

Market potential: Extensive (immediate)

Enterprise computing systems represent a broad set of markets serving the needs for "industrial-strength" computing. Particular market segments relating to strengths found in Arkansas include the following:

- **Information Assurance and Quality**—The overall information quality market involving software, professional services, and data enhancement will pass the $1 billion mark in 2008, according to Forrester Research Inc. More and more information assurance and quality are being addressed, not only at the level of data warehouse environments but also from the peripheries of enterprises in which they interact with suppliers and customers. Also, a growing aspect of information assurance and quality reaches beyond customer infor mation, such as product information, inventory, pricing, order management, and business administration.

- **Wireless and Sensor Networks**—Over the next 5 years, industrial use of wireless sensor networks is expected to explode from under 1 million endpoints to more than 40 million endpoints and an estimated market value of $5.3 billion, according to ON World Inc. The advantages of wireless sensor networks are that they allow users monitoring capabilities in places where they could not before and perform measurements that would be prohibitively expensive with hardwiring. The ON World study found that wireless promises to allow faster reconfiguration of plant-floor networks as applications change. It also states that many potential sensor ap plications are not possible today because of remote and/or hazardous environments.

- **Logistics IT**—Worldwide spending on logistics software and services nearly doubled from 2001 to 2006, reaching close to $3 billion in 2006, according to market research firm ARC Advisory Group Inc.

Still, markets of enterprise computing systems are sensitive to overall economic conditions. An IDC study completed in the spring 2008 already identified that IT budgets were being cut across companies. IDC's interviews with 27 chief information officers and senior IT leaders found that there is a "significant shift towards cost reduction rather than revenue generation as a driver for IT investment. Being able to deliver IT services more efficiently, as a response to the economic downturn and to recent mergers and acquisitions, is setting today's IT agenda."[11] In particular, infrastructure improvement, including data center consolidation and virtualization, application consolidation, and data consolidation, was most frequently mentioned as a priority aimed at achieving lower-cost, higher-performance IT. Almost all of the interviewees (25 of 27) are engaged in some form of application modernization, citing a large remaining core of aging applications. Many of these applications are industry specific. Complicating factors include legacy client/server architectures and hard-to-support languages, including COBOL and Visual Basic.

Existing or emerging Arkansas industry connections: Extensive

- Industries in Arkansas related to enterprise systems computing employ more than 35,000 workers in more than 1,700 establishments. The two largest industries, computer facility management services (5,404 jobs) and corporate management offices (24,171 jobs), are key economic specializations.

- Arkansas' strength in enterprise systems computing is also embedded within other industry sectors. This embedded strength is more fully understood by consider ing the demand for computer-related occupations.

  – All computer-related occupations are expected to grow by more than twice the projected growth rate for all occupations in Arkansas through 2016; 35.6% versus 15.1%, respectively. Annual State job openings in these IT occupations are projected at 1,000 per year—about 600 per year in new jobs and the remaining 400 as replacements.

  – Projected growth in computer-related jobs in Arkansas is expected to be faster than that for the United States as a whole (36% through 2016 vs. 25%).

- Many of Arkansas' innovative companies are found within enterprise systems computing.

  – Two large Arkansas firms identified in the Corptech database of technology firms are Acxiom and IntelliMark.

[11] IDG Press Release, "IDC Study Finds U.S. IT Executives Cutting Budgets and Consolidating Assets in 2008," April 28, 2008.

– In Arkansas, seven companies with Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) grant awards from 2002 to 2008 performed research in areas related to enterprise systems computing:

  - AriseTek, LLC
  - ArkLight
  - Green Technologies, Inc.
  - Invotek
  - JAECO Orthopedic, Inc.
  - Parallel Quantum Solutions
  - Space Photonics, Inc.

– Twelve of the 51 emerging technology companies served by Innovate Arkansas are found in computer software and services.

– Three companies in Arkansas were identified with two or more U.S. patents in the classes related to enterprise computing systems:

  - Wal-Mart Stores, Inc.
  - Acxiom Corporation
  - Munro & Company, Inc.

Distributed Energy Network Systems

Opportunity:

Electric power is essential to modern society, but generating electricity is only part of the solution. Transmitting and distributing electricity are often overlooked, yet critical requirements to ensure meeting the growing demand for electricity.

The network of transmission lines that carries power from facilities generating electricity is called the grid. To enhance the transmission of electricity over longer distances, system interconnections were formed to link the nation's electric utilities to the grid. The benefits of system interconnections to the grid include increased reliability by electric utilities providing alternative paths to route the electricity and lower costs by allowing the utilities to buy and sell power from each other and other power suppliers. In the United States, the grids are primarily interconnected through three major networks: (1) Eastern Interconnection, connecting the Eastern seaboard, the Plains states, and Eastern and Central Canadian provinces; (2) the Western Systems Coordinating Council, including the Pacific Coast, Mountain states, and Western Canadian provinces; and (3) the Electric Reliability Council of Texas, which operates in Texas.

The United States is currently facing an aging grid consisting of equipment at or near the end of its design life. This aging grid not only poses problems of outages, but also is highly inefficient, losing up to 20% of the electricity it is attempting to transmit and distribute. There is also a need to respond to rapidly changing customer needs for electricity. Having the ability to monitor and influence each customer's usage, in real time, could enable distribution operators to better match supply with demand, thus boosting asset utilization, improving service quality, and lowering costs.

Of particular importance for renewable energy generation is the concept of "distributed generation" to allow small, renewable energy producers to supply surplus power to the grid. There are a wide variety of opportunities for "connecting" renewable energy sources to the grid, from solar to wind to geothermal to ocean power.

Multiple competencies and institutions: Emerging

There is an emerging core research competency in power electronics and alternative energy in Arkansas, particularly at UA campuses at Fayetteville and Little Rock. The efforts in power electronics build off of the strengths in microelectronics and include a unique power transmission and distribution test facility at UA-Fayetteville that ties directly to the grid. UA-Little Rock has a broad array of alternative energy development and deployment activities, including solar power and energy efficiency.

Complementing these efforts are (1) the niche core research competency in informatics and mathematical research that includes grid computing and middleware development and (2) the emerging core research competency in sensing and sensor networks that can support technologies developed for smart energy grids.

Opportunity for external research funding: Limited

An aging transmission grid infrastructure and the need to modernize it to easily connect to alternative and renewable power sources are creating potential research funding opportunities.

The Department of Energy (DOE) is a major funding agency for distributed energy network systems. The DOE through its Office of Electricity Delivery and Energy Reliability received $110 million in fiscal year (FY) 2008 for research focused on high-temperature superconductivity (HTS), visualization and controls, energy storage and power electronics, and renewable and distributed systems integration. The HTS program is currently the largest funded program, receiving about $28 million in FY 2008; but, it has continued to decrease in the past few years. The Visualization and Controls and the Renewable and Distributed Systems Integration research funding have remained flat in recent years, with each area receiving roughly $25 million in FY 2008. Energy Storage and Power Electronics is the smallest research area, with about $6.7 million in FY 2008; but, it is has continued to grow in recent years, with research funding expected to be $13 million (i.e., almost double the previous year's funding) in FY 2009.

The DHS is another agency that provides some funding in the distributed energy network area. It also collaborates with DOE to protect the grid and assists with restoration when major interruptions occur on the grid. In May 2007, DHS announced that it expects to invest as much as $25 million to develop technology to enable secure super grids in the United States. Such grids will use customized HTS wires, HTS power cables, and ancillary controls to deliver more power through the grid while also being able to suppress power surges that can disrupt service.

Market potential: Extensive (near term)

Experts predict that more than 75% of current network assets must be replaced over the next decade at a cost of $50 billion. The assets include transformers, transmission lines, and control equipment used to monitor grid status and initiate repair and maintenance operations.

Given that U.S. electric power demand is expected to rise by 32% over the next decade, a more complex energy grid will be needed as distributed power emerges as a new way of producing electric power, enabling alternative energy generation to be linked into a broader energy-delivery system.

North American utilities are already spending nearly $10 billion annually on smart technologies including automated meters that are helping to transform the grid.

A key portion of the recently enacted federal stimulus funding will go toward upgrading the electric power grid.

Existing or emerging Arkansas industry connections: Extensive

Industries related to distributed energy network systems in Arkansas employ more than 14,000 and are 23% more concentrated in Arkansas than the nation, thus representing an economic specialization. Leading industries include the following:

- Motor and generator manufacturing with 4,010 jobs and a 9 times higher level of concentration than the nation
- Electric bulk power transmission and control with 2,726 jobs and an 11 times higher level of concentration than the nation
- Electric power distribution with 1,279 jobs and 10% higher level of concentration than the nation
- Power and communication system construction with 1,909 jobs and a 58% higher level of concentration than the nation.

Arkansas is also home to the **Southwest Power Pool**, which is one of nine independent System Operators/ Regional Transmission Organizations whose job is to operate the power grid, serving as the equivalent of "air traffic controllers" of the electric power grid. Southwest Power Pool is mandated by the Federal Energy Regulatory Commission to ensure reliable supplies of power, adequate transmission infrastructure, and competitive wholesale prices of electricity.

A broad range of Arkansas' innovative companies are found within distributed energy network systems:

- Leading Arkansas firms identified in the Corptech database include Baldor Electric Motors, Basler Electric Company, and Milibank Manufacturing (meters).

- In Arkansas, four companies with SBIR/STTR grant awards from 2002 to 2008 performed research in areas related to distributed energy network systems:
  - Arkansas Power Electronics International Inc. (APEI)
  - Integral Wave Technologies (formerly Arkansas Microelectronics Development Company)
  - Moducell
  - Power Electronics Leveling Solutions LLC.
- APEI, a developer of electric power systems, is one of the emerging technology companies served by Innovate Arkansas.
- Three companies in Arkansas were identified with two or more U.S. patents in the classes related to distributed energy network systems:
  - Scroll Technologies
  - Central Moloney, Inc.
  - WeighTech, Inc.

Optics and Photonics

Opportunity:

One of the major applications from the area of optics and photonics is the laser or "Light Amplification by Stimulated Emission of Radiation." Lasers and laser systems are used in a variety of industry applications, from the processing of materials to the storage of data in high-technology devices, because it's a highly efficient and intense source of light that can be tailored for its planned use.

Three major drivers of laser systems have led to increased end use over the past 5 years—demand by consumers for miniaturized electronic devices (e.g. , cell phones, smart cards, and optical storage), material processing applications in manufacturing (such as semiconductor wafer and industrial materials processing), and defense and security applications. In 2008, these three areas were 82% of the overall revenue for the world laser market. Some of the specialized areas for laser systems are medical therapy and diagnostics and basic research, which comprise 10% of the overall sales for the laser market.[12]

Multiple competencies and institutions: Emerging

In Arkansas, several institutions contribute to the state's competencies in optics. At UA-Fayetteville, optics research and education is a key component of its physics department and its Microelectronics/Photonics (microEP) program, which offers M.S. and Ph.D. degrees. At Arkansas State University (ASU), the Arkansas Center for Laser Applications and Science (ArCLAS) is another primary contributor to the state's optics competencies, including a large collection of lasers and support equipment. UA-Little Rock has researchers focusing in optics through its applied science Ph.D. program in physics.

The primary efforts in optics at these institutions build off of the strengths in using lasers for material development, processing, and manufacturing. These efforts are complemented by niche core competencies in sensing and sensor networks, electronics, and physics. Included in these niche core competencies are optical laser systems developed for applications in medical diagnostics, defense and security, and astronomy.

Opportunity for external research funding: Limited

Optics and photonics is not a particular area of focus for NIH funding; but, it is cross-cutting across the disease areas at the NIH.

The NSF through its Electronic and Photonic Materials program in its Directorate for Mathematical and Physical Science's Division of Materials Research (DMR) provides a range of annual grant awards averaging from $130,000 to $135,000 for projects focused on optics and photonics. The NSF's DMR will provide $273 million in grant funding in FY 2008.

Market potential: Moderate (immediate)

In 2008, the global laser systems market experienced a 3.7% increase over 2007, with sales growing from $6.87 billion to $7.12 billion. With laser systems employed in many end-user applications that are experiencing slowing sales as a result of the global economic crisis, the world laser market in 2009 is forecasted to experience an 11% decline in sales, from an estimated $7.1 billion in 2008 to $6.3 billion. This will be the first annual decline since 2000 to 2002.

[12] Laser Focus World, available at http://www.laserfocusworld.com/display_article/349353/12/none/none/Feat/LASER-MARKETPLACE-2009:-Photonics-enters-a-period-of-high-anxiet.

Existing or emerging Arkansas industry connections: Limited

There is no existing significant industry base in optics or lasers in Arkansas. There are few innovative companies in Arkansas in the area of optics and photonics:

- No large companies were identified in the CorpTech database of technology firms for this area.
- In Arkansas, four companies with SBIR/STTR grant awards from 2002 to 2008 performed research in areas related to optics and photonics:
  - Invotek
  - Mesolight LLC
  - Minotaur Technologies, LLC
  - Space Photonics, Inc.
- Two of the 51 small technology businesses served by Innovate Arkansas are involved in this area—Inovtek and Mesolight LLC.

Nanotechnology-Related Materials and Applications

Opportunity:

Nanotechnology, the understanding and control of matter at dimensions of roughly one to 100 nanometers, is an emerging field of technology viewed by many as leading the next industrial revolution. At the nanometer level, the physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of individual atoms and molecules or bulk matter. Indeed, recent progress in the measurement, modeling, and manipulation of matter at the nanoscale suggests vast advances in materials, data storage and processing, sensors, power generation, environment, and medicine.

Nanoscale materials such as zeolites have been manufactured for several decades, and nanoscale chips have been a reality since the introduction of the 100-nm-scale Pentium 4 by Intel. There are many well-established applications of nanoscale coatings and particulate materials today. The 2004 Chevy Impala used body moldings made of a clay nanocomposite to reduce body weight by 7%. Apparel with nanocoatings that repel water and grime is already available. Nanocoating-based medical products such as wound dressings from Smith and Nephew and hard tissue coatings and fillers are in use today. In all of these cases, the original material has almost become a commodity and much of the added value from using nanotechnology has benefited manufacturers of the nano-enabled end product.

While the estimated market of nanotechnology is roughly $12 billion, the revenues from end products that use established nanoscale materials today are on the order of $150 billion. This revenue figure includes zeolites, disk drives using 40-nm-film–based heads, as well as the currently available nanoscale chip–based electronics and a host of other applications, such as nanocoatings, that have small markets less than $100 million. Emerging nanomaterials including new biomaterials, carbon nanotubes, and dendrimers are expected to drive the market for nanomaterial applications over the next decade.

Of particular importance to Arkansas are the emerging applications of nanotechnology involving microfabrication and micromanipulation technologies to create nanoscale medical devices. 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 (MEMS) for biomedical uses (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.

Multiple competencies and institutions: Established

The following core competencies underpin the strategic focus area in nanotechnology-related materials and applications:

- Nanotechnology is a well-established core research competency across Arkansas research universities with broad efforts underway, such as making well-defined nanoparticles; processing nanostructures; developing thin films for MEMS smart materials; and focusing on commercial applications of carbon nanotube synthesis, tissue engineering, and cancer treatment.

- As an enabling technology, nanotechnology activities across Arkansas' research universities are found within many other core research competencies, including the following:

  – Sensing and sensor networks, an emerging strength with efforts in biosensors and smart sensors for water quality monitoring, food safety, and neurostimulators

  – Cancer control, detection, and treatment, including use of nanoparticles for cancer diagnostics and treatment.

Opportunity for external research funding: Significant

Spurred by the increasing number of uses for nanotechnology-related materials and applications, nanotechnology is an emerging area where there is a great deal of research funding support by the federal agencies. Through the National Nanotechnology Initiative, the U.S. government coordinates nanotechnology research efforts among the 25 federal agencies. Of these, 13 agencies have dedicated budgets for nanotechnology research and invested an estimated $1.49 billion in FY 2008. The federal agencies providing the most research funding in this area are the DoD, NSF, DOE, and NIH.

In FY 2008, the federal agency that invested the most in nanotechnology research was the DoD, with $487 million in research funding. The DoD is focusing its research efforts primary on fundamental nanotechnology research and the development of nanotechnology devices and systems to advance its defense capabilities, with about $260 million and $120 million, respectively, granted for research in these two areas in FY 2008.

The NSF provided $389 million in funding in FY 2008 for nanotechnology research. The Civil, Mechanical and Manufacturing Innovation (CMMI) Division and the Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET) in the NSF's Directorate of Engineering offer grant funding programs for fundamental nanotechnology research. The NSF's CMMI Division will provide $159 million in grant funding in FY 2008 and has provided annual grant awards ranging from $95,000 to $100,000 for programs focused on nanomanufacturing in its advanced manufacturing. The NSF's CBET Division supplies $133 million in grant funding in FY 2008 and offers annual grant awards ranging from $100,000 to $250,000 for programs focused on the properties of nanomaterials and nanoparticles in its Mechanics and Engineering Materials cluster.

In funding nanotechnology research, the DOE ranks third among leading federal agencies, providing $251 million in FY 2008. The DOE is focusing on fundamental research where nanomaterials can be used to foster energy conversion and transmission in applications such as solid-state lighting, electric generators, and combustion of transportation fuels through major program grants from its Office of Science. Additionally, the DOE is also looking at manufacturing these nanomaterials for energy technologies through its Office of Energy Efficiency and Renewable Energy (EERE).

NIH grant funding research is fundamental and applied in the nanotechnology area. Most of the applied research for nanotechnology by the NIH is fostered through their SBIR/STTR program. Estimates from the NIH indicate that nanotechnology research funding reached $225 million in FY 2008 and has slightly increased in the past few years.

Market potential: Extensive (longer term)

The global market for nanotechnology was worth $11.6 billion in 2007. This is expected to increase to $12.7 billion in 2008 and $27.0 billion by the end of 2013, a compound annual growth rate (CAGR) of 16.3 percent, according to BCC Research. The market is broken down into applications of nanomaterials, nanotools, and nanodevices.

- Nanomaterials dominated in 2007, accounting for 87% of the market. Worth an estimated $10.8 billion in 2008, this segment should reach $18.7 billion in 2013, for a CAGR of 11.7%.

- Nanotools accounted for 12.8% of the market in 2007. Worth an estimated $1.9 billion in 2008, the segment will reach almost $8.0 billion by the end of 2013, for a CAGR of 33.3%. Nanotools, which include the nanolithographic tools used to produce the next generation of semiconductors, are projected to grow at a much faster rate than nanomaterials.

- Nanodevices, a segment that is expected to increase from $26.2 million in 2008 to $366.2 million by the end of 2013, will enjoy a CAGR of 69.5%.

According to BCC Research, the largest end-user markets for nanotechnology in 2007 were environmental remediation (56% of the total market), electronics (20.8%), and energy (14.1%). Biomedical and consumer applications and electronics have much higher projected growth rates than other applications over the next 5 years (i.e., 56.2%, 45.9%, and 30.3%, respectively). In contrast, energy applications are projected to grow at a CAGR of only 12.6% and environmental applications are projected to actually decline by an average of 1.5% per year.

A closer look at the global medical market for nanotechnology applications by BCC Research reveals a market size of $1.7 billion in 2007 that is expected to reach $3.8 billion in 2013, for a CAGR of 14.9%. Pharmaceutical applications currently dominate the market, accounting for nearly 90% of revenue in 2007, and this trend is expected to continue through 2008. Nanotechnology applications for medical research and medical devices are both expected to significantly gain in market share, each potentially reaching 20% by 2018.

Existing or emerging Arkansas industry connections: Moderate

- Industries related to nanotechnology in Arkansas—such as carbon black manufacturing, carbon and graphite product manufacturing, and semiconductors—are relatively small, with under 500 employees.

- Seven emerging nanotechnology firms are clients of Innovate Arkansas—each a university-related spin-out: GuardIN Fresh, Mesolight, NN-Labs, NanoMech, Duralor, Synanomet, and Orlumet.

- Six companies in Arkansas were SBIR/STTR grant awardees from 2002 to 2008 that performed research in areas related to nanotechnology-related materials and applications:

  – Mesolight LLC
  – NanoMech
  – NN-Labs
  – Ocean NanoTech, LLC
  – Omnipak, LLC
  – Sysconn Corporation.

- There were no companies in Arkansas that were identified with two or more U.S. patents in the classes (i.e., class 977) related to nanotechnology-related materials and applications.

Sustainable Agriculture and Bioenergy Management

Opportunity:

There is a strong movement to advance more sustainable agricultural activities in order to reduce greenhouse gas emissions, promote energy independence, and establish another market for agricultural products. Bioenergy, which results from transforming plant matter or other biodegradable materials into fuel or electricity, is most recognized as the leading component of this sustainable agricultural approach. But, for bioenergy to be successful as an agricultural activity, it needs to be part of an integrated system from the growing of feedstock, transporting of feedstock, pretreatment and processing, management of water resources, and development of co-products. In particular, at this level of farming, there must be a focus on developing the management approaches and decision tools to inform the mix of activities between food production and bioenergy production.

Currently, corn-based ethanol is the largest source of biofuel; but, other biological sources of bioenergy are of particular interest to Arkansas.

One area closely linked to the idea of agricultural sustainability is the growing use of co-products from crop processing as well as animal fat and waste as sources of bioenergy. The development of co-products is of particular importance to Arkansas given its sizable agricultural sector.

Another highly touted area is cellulosic materials, which make up the majority of most plants. This area offers greater energy potential and is less controversial than using food crops to meet energy needs. It holds promise for Arkansas, which, with its strong forest industry, has a high capacity to grow cellulosic materials. However, the use of cellulosic materials for bioenergy is still at the R&D, not the production, stage.

A third promising area for Arkansas is the use of algae for the production of biodiesel and even biobased jet fuel. Algae have much faster growth rates and higher oil yields than crops. They can also grow in installations placed on subprime land, whereas crops require arable land. The major barriers in efficient algae-based biodiesel production include identifying the best algal strains, designing the best equipment to grow the algae in large quantities, and developing optimized cultivation systems (photobioreactors).

Other technology challenges in sustainable agriculture and bioenergy management include the following:

- **Conversion**—More efficient conversion techniques could be mediated by genetically modified microorganisms or newly identified microorganisms that can withstand extremely high temperatures or acidic conditions.

- **Separations**—Novel, cost-efficient separation procedures are needed that isolate high-value chemicals from feedstocks while separating/recovering the ethanol. These procedures are likely to involve new membrane technologies.

- **Consolidated bioprocessing (CBP) and related biopower technologies**—CBP is a relatively new process that involves directly fermenting biomass using cellulolytic microorganisms without adding enzymes. Although CBP may take a few years to attain commercial viability, it could become one of the most commercially competitive processing technologies. Other technologies related to the production of bioenergy include co-firing (jointly burning biofeedstock with fossil fuel), gasification (converting biomass into synthetic gas or syngas, a biofuel), pyrolysis (conversion of biomass into liquid biofuel through rapid heating and cooling), and anaerobic digestion (microorganism-mediated breakdown of biomass into biofuel and biogas). Enhancing any of these technologies to make them more cost efficient is a major goal of bioenergy production.

- **Biorefinery byproducts**—Biorefineries can generate multiple products in addition to bioenergy by maximizing the value derived from the original feedstock. Such by-products may include high-value chemicals, amino acids, feed, nutraceuticals, or materials that would otherwise be made from petroleum.

Multiple competencies and institutions: Established

Led by the UA Division of Agriculture, with active programs across campuses at Fayetteville, ASU, and Monticello, several core research competencies support this strategic focus area:

- Plant and agricultural sciences, one of the most pronounced core research competencies in Arkansas, provides the backbone for ongoing work in feedstock assessment and development.

- Water quality and resource studies, a well-established core research competency, offers a capacity for broader integration of biomass production with environmental sustainability.

- Ecology and environmental sciences, a niche strength, include a focus on forest resources and broader efforts on climate change.

- Bioenergy is an emerging research competency that includes co-product development from rice and sweet sorghum as well as research efforts in algae-based microbes for photosynthesis.

Opportunity for external research funding: Limited

Increased prices for energy and food are contributing to an increase in the number of federal opportunities in the strategic focus area of sustainable agriculture and bioenergy management as well as the specialized areas of sustainable development and biomass.

The USDA is a major funding agency for sustainable agriculture through its Cooperative State Research, Education, and Extension Service (CSREES) that is appropriated $6.6 million a year to help improve the agricultural systems from farm to consumer. The USDA's Sustainable Agriculture Research and Education (SARE)

Program supported by CSREES offers competitive grant funding ranging from $500 to $200,000 for basic and applied research in the area of sustainable agriculture and development.

As the need for energy independence has become more urgent in recent years, the DOE through its EERE has become a major funder of bioenergy efforts by fostering the development of cost-competitive transportation fuel (primarily ethanol) from cellulosic biomass by 2012, with the DoD and the USDA also providing limited funding to complement efforts this area. The DOE EERE biomass program provides funding for basic and applied research for small- to large-scale projects ranging from $50,000 to $3 million that involve the conversion of biomass into bioproducts. In addition, the DOE and the USDA offer joint grant-funding opportunities in the range of $250,000 to $26 million as part of the Biomass Research and Development Initiative (BRDI) to help accelerate development of bioproducts from bioenergy R&D.

The NSF through its Biotechnology, Biochemical, and Biomass Engineering and Energy for Sustainability programs in its Directorate for Engineering's CBET Division also provide a range of annual grant awards averaging $80,000 to $100,000.

The Environmental Protection Agency (EPA) and the NSF are more limited funders of sustainable development efforts with a focus on environmental sustainability. The NSF's Directorate for Engineering provides approximately $133 million a year in grant funding through its CBET Division for environmental sustainability programs, with average award amounts ranging from $90,000 to $100,000. The EPA also offers grants in the area of sustainable development, with award funding ranging from $10,000 to $1.5 million focused on environmental, air, and water quality through a number of its offices.

Market potential: Moderate (near term)

Bioenergy today—primarily ethanol and biodiesel—are gaining popularity nationally and worldwide. Bioenergy ranks second (to hydropower) in renewable U.S. primary energy production and currently accounts for 3% of the primary energy production in the United States. Worldwide ethanol production has increased roughly 15% a year since 2000, led largely by the United States where ethanol production from corn is growing at more than 7% annually. Worldwide biodiesel production has largely outpaced that of ethanol, with an 85% annual increase in production in recent years. In the United States, biodiesel production is expected to grow from 75 million gallons in 2005 to 816 million gallons by 2011, worth an estimated $2.9 billion.

A senior vice president of Shell Global Solutions recently predicted that the global market for cellulosic biofuels could exceed $10 billion by 2012.

Existing or emerging Arkansas industry connections: Moderate

- Six biodiesel refineries have come on line in Arkansas since 2005—Batesville, Stuttgart, DeWitt, Helena, Crossett, and Arkansas City.
- Several emerging technology companies that are clients of Innovate Arkansas are involved in sustainable agriculture and bioenergy, including AgRobotics for soil sampling, Hyphenated Solutions for environmental and bioanalytical testing, International Silica Technologies for producing silica from rice hulls as a by-product of power generation, and Izon AMS for agricultural remote monitoring.
- In Arkansas, four companies with SBIR/STTR grant awards from 2002 to 2008 performed research in areas related to sustainable agriculture and bioenergy management:
  - Agricultural Research Initiatives
  - BlueInGreen, LLC
  - Bioengineering Resources, Inc.
  - Vegrandis LLC.

Food Processing and Safety

Opportunity:

This strategic focus area concerns the application of technologies to agricultural commodities after harvest for the purpose of loss prevention, preservation, food safety, and quality control or enhancement. The technologies involved relate to on-farm handling, food processing (such as drying or shelling), food packaging, storage, and distribution. Environmental control and temperature management are critical issues at each step. The development of new, efficient technologies and processes that maintain high food quality and/or destroy harmful pathogens now frequently requires the use of computer-aided simulations, robotics, sensors, and controls.

Multiple competencies and institutions: Established

This strategic focus area comprises three well-established core research competencies:

- Food science, food safety, and nutrition, which involves major grants in animal science food safety and food science engineering. A major focus of these efforts is on controlling salmonella through antimicrobial treatments. There is a particularly strong emphasis on sensing and detection technologies in Arkansas.
- Poultry sciences, in which Arkansas is clearly a national leader, with a broad-based program involving food safety and thermal processing and validation.
- Aquaculture, in which UA-Pine Bluff has a leading program that involves new production systems for growing fish and designer fish products.

Opportunity for external research funding: Moderate

Strong gains in the food safety industry will be driven by increased federal efforts to eliminate foodborne illness outbreaks led by the Food and Drug Administration (FDA) and USDA. For FY 2008, the proposed funding for the USDA's Food Safety and Inspection Service (FSIS) is $930 million, while the funding for the FDA's food safety program is only $467 million, despite the fact that the FDA oversees about 80% of the food supply. Approximately $840 million of the USDA's FSIS funding is focused on meat, egg, and poultry inspection, while the majority of the FDA funding is for seafood and poultry inspections.

In recent years, the FDA has received increased funding for its food safety program, which will support research to prevent food contamination and to develop rapid pathogen detection methods. The FDA awards grants to fund research pertaining to food and agricultural feed safety, food screening capabilities, food security monitoring, and the development of rapid responses to food hazards.

The USDA's Agriculture and Food Research Initiative (AFRI) is a competitive grants program that offers annual awards up to $4 million to support fundamental and applied research and extension on a number of priority areas including food safety, nutrition, and health. The overarching objectives center on the reduction of foodborne illness. SBIR funding may be available for advanced food packaging R&D. The USDA is also developing a National Animal Identification System (NAIS), a disease response network that will allow the government to trace the origin of any meat product within 48 hours.

The NSF in its Directorate for Engineering's CBET Division offers grant funding through its Biotechnology, Biochemical, and Biomass Engineering and Energy for Sustainability programs in the area of food processing with a focus on safety of the nation's food supply with annual award of $120,000.

Market potential: Moderate (immediate)

Foodborne illness is a serious food safety problem worldwide. The Centers for Disease Control and Prevention (CDC) have estimated that foodborne pathogens cause 76 million illnesses and 5,000 deaths annually in the United States.

The U.S. food safety products industry is currently valued at $2.3 billion according to the Freedonia Group. The market is projected to grow 6.5% annually through 2012, driven by rising food safety concerns and new rules and regulations. Diagnostics for toxins and contaminants will increase from $78 million in 2007 to $135 million in 2012, a CAGR of 11.6% according to BCC Research. Disinfection products will remain the largest segment and benefit from relatively new technologies such as ultraviolet and ozone equipment; smart labels and tags are another fast-growing segment and should experience double-digit annual growth rates. An example of a smart label is the SensorQ™ that verifies freshness in uncooked meat and poultry packages by measuring foodborne bacteria levels inside packages, changing the color of the label from bright orange (fresh) to tan (spoiled).

Market opportunities within this strategic focus area include the following:

- **New food processing and preservation technologies**—Development of new food processing methods or improvement of existing methods include vacuum-steam-vacuum (VSV) pasteurization, infrared surface heating, high-pressure microfluidization, pulsed electric field processing, light technologies, and cold plasma. Also, technologies such as magnetic resonance imaging are being used to observe changes

in foods during processing. New technologies are also needed to prevent, detect, or eliminate harmful abiotic compounds such as acrylamide and melamine.

- **Advanced food packaging**—Packaging trends include increases in package flexibility, advanced films (such as antimicrobial) that prevent produce spoilage, new package shapes that fit better in car holders or refrigerator doors, biodegradable or "green" packaging, and even edible packaging. Engineered nanoscale materials are also being developed for food packaging with enhanced mechanical and thermal properties to ensure better protection of foods from exterior effects.

- **Food safety biosensors and rapid foodborne pathogen detection**—Biosensors can be used to improve food safety by detecting and quantifying foodborne pathogens. Biosensor platforms employ techniques such as chemiluminescence and bioconjugated nanomaterials, and devices are often portable for on-site detection. Other detection platforms may involve molecular diagnostics such as immunochemical or nucleic acid technologies for screening food samples. The overall biosensors market has expanded over the past decade, projected to value $8.2 billion in 2009. Although this figure represents three major industrial sectors—pharmaceutical, medical, and food—the food testing market should only increase in response to growing global concerns over food and water security.

Existing or emerging Arkansas industry connections: Extensive

Processing activities in Arkansas generate $5 billion in value-added output and represent approximately 6% of the state's total value-added output (a measure comparable to GDP).

Total food manufacturing employment in Arkansas stood at 49,522 workers in 2007. Leading food manufacturing industries include the following:

- Animal slaughtering and processing—32,899 jobs
- Fruit and vegetable processing—6,835 jobs
- Grain and oilseed milling—2,361 jobs.

In Arkansas, there are a minimal number of innovative companies found in the area of food processing and safety:

- One large company was identified in the CorpTech database of large firms for this area—Tyson Foods, Inc.

- Eight companies in Arkansas were SBIR/STTR grant awardees from 2002 to 2008 that worked in areas related to food processing and safety:

  – A&A Laboratories
  – Baxter Land Company, Inc.
  – BioDetection Instruments
  – BioKinetic Controls LLC
  – Biostrategies, LLC
  – Nutraceutical Innovations, LLC
  – Soy Pectin, Inc.
  – White River Bioscience, Inc.

- Two of the 51 small technology businesses served by Innovate Arkansas are involved in this area—BioDetection Instruments and Soy Pectin.

Personalized Health Research Sciences

Opportunity:

Medicine in the 21st century is being radically transformed from an inexact science of detection and treatment to one of prediction, prevention, and strategic intervention—or what is more popularly known as "personalized or individualized" medicine. As Steve Burrill in his annual reviews of biotechnology explains, "In healthcare, there is no doubt that we are moving to a more personalized, predictive and preventive medicine world that embraces not only the possibility of using a person's genetic information to identify their risks for disease, but also individualized strategies for prevention or treatment."[13]

A key area of focus in personalized medicine is pharmacogenomics, which addresses how genetic variations or differences in gene expression affect people's responses to drugs. Understanding how genetics affect drug response is so important because many common diseases are actually syndromes, i.e., a collection of different diseases with similar appearance. This is true, for instance, for breast cancer, which has already been identified to involve at least three disease states related to different genetic variations. Comprehending the genetic causes of disease for an individual is critical to identifying effective treatment. Moreover, genomic variations across individuals lead to different ways in which drugs are metabolized. Individuals are already known to have different abilities to absorb drugs, resulting in

[13] Steve Burrill, *Life Sciences: A 20/20 Vision to 2020*, 2008, page 94.

normal doses leading to unexpectedly low or high drug concentrations in the blood, causing ineffective therapy or severe toxicity.

It is becoming more apparent that personalized medicine will shape not only drug development approaches and use of advanced molecular diagnostics, but also approaches to overall health-care delivery. Health research will be needed to understand how best to bring a more systematic predictive and preventive approach to health-care delivery, addressing issues such as how best to structure and utilize patient genetic information, which health-care professional can best advise patients, and how reimbursement can be most effectively structured.

Multiple competencies and institutions: Emerging

Two well-established core research competencies in Arkansas position the state to play a significant role in personalized medicine:

- Toxicology and drug development in Arkansas is quite advanced because of the presence of the NCTR, a leading center for identifying biochemical and molecular markers of safety and toxicity.

- Cancer control, detection, and treatment in Arkansas brings an emphasis on population-based studies needed to inform how genetic differences matter in cancer prevention and treatment.

Opportunity for external research funding: Moderate

The NIH is a major funding agency focusing on pharmcogenomics in the area of personalized medicine. There are currently 20 NIH research grant opportunities ranging widely in funding amounts (consisting of 7-R01, 6-R21, 3-R03, 1-R33, 2-U01, and 1-U10) and seeking to advance basic, clinical, and translational pharmcogenomics research in a broad range of disease-related areas such as cancer, HIV/AIDS, and autism. The NIH Pharmacogenetics Research Network (PGRN) is another area that provides funding in the area of pharmacogenomics. The PGRN comprises 12 independently funded, multidisciplinary research groups studying the effects of genes on human responses to a wide variety of medicines; they also populate the Pharmacogenetics and Pharmacogenomics Knowledge Base (PharmGKB). The NIH National Human Genome Research Institute (NHGRI) is a $488 million research center that conducts studies aimed at understanding the structure and the function of the human genome and its role in health and disease. In FY 2009, NHGRI plans to award $150 million in funding for 280 research project grants in the area of genomics. Of the 280 grants awarded by NHGRI, 62 will be competing research project grant awards, while 26 will be SBIR/STTR program grants.

The FDA is another agency that provides funding focused on pharmacogenomics. The FDA's Center for Drug Evaluation and Research (CDER) will be provided with $25 million in funding for FY 2009 to educate the research community and regulate pharmacogenomic drugs and tests. Through the NCTR, the FDA will be supplied with $45 million in research funding for FY 2009 focused in the areas of personalized nutrition and medicine, food protection, and product safety enhancement.

Market potential: Extensive (longer term)

The market for personalized medicine is becoming sizable. BCC Research reports that the overall pharmacogenomics market—which applies genomics information and technologies to better target drugs to an individual's genetic makeup and to better identify drug targets based on genetic variations among individuals—reached $1.24 billion in 2004 and is projected to rise at an average annual growth rate of 24.5% to reach $3.7 billion by 2009. Molecular-based diagnostics composed 39% of the total market in pharmacogenomics and is expected to account for 45% in 2009. Market opportunities also exist for development of genomic and pharmacogenomic tools and technologies for use in drug discovery and development. The worldwide market for genomic technologies used in the processes of drug target screening, identification, and validation is expected to reach $13.6 billion by 2007, according to BCC Research.

There is still substantial concern that personalized medicine is slow to be realized. Patricia Danzon, Chair of Health Care Systems at the University of Pennsylvania Wharton School, concludes: "Back at the time of the mapping of the human genome, people were talking about developing pharmacogenomic tests and really personalized drugs. That has not come to fruition…Where we are right now is that there are a very small number of drugs on the market for which there is some sort of test as to whether or not that drug is appropriate for that patient."[14]

[14] FDABeat Report on "Getting Personal: FDA's Plan to Save the Drug Industry," September 2006.

There are various reasons why personalized medicine has been slow to grow in the marketplace:

- Pharmaceutical companies are concerned about their markets being constricted in size by the narrowing of the definition of a disease or its indication.
- Cost reimbursement remains a major stumbling block.
- Intellectual property for diagnostics is complex.
- Many physicians lack the science background and confidence that pharmacogenomics can be of benefit to their patients.
- The public has concerns surrounding genetic testing.
- The regulatory environment for pharmacogenomics is still evolving.
- A health information infrastructure providing the level of detail and information required to conduct research and make pharmacogenomic-based treatment decisions is lacking.

Existing or emerging Arkansas industry connections: Limited (but addresses major public health issues)

Minimal presence in industries related to personalized health research sciences in Arkansas includes the following:

- R&D in biotechnology—22 establishments with 241 jobs
- *In-vitro* diagnostic substance manufacturing—One establishment with 13 employees.

In Arkansas, there are a minimal number of inventive companies found in the area of personalized health research sciences:

- No large companies were identified in the CorpTech database of technology firms for this area.
- Eight companies in Arkansas were SBIR/STTR grant awardees from 2002 to 2008 that worked in areas related to personalized health research sciences:
  - 3D Imaging, Inc.
  - Acetaminophen Toxicity Diagnostics, LLC
  - BioDefense Technologies, Inc.
  - DCV Technologies
  - Minotaur Technologies, LLC
  - Multimedia Technology Developers
  - SFC Fluidics, LLC
  - Xenocept, Inc.
- Two of the 51 small technology businesses served by Innovate Arkansas are involved in this area—Biostrategies and Ezra Pharma.
- Four companies in Arkansas were identified with two or more U.S. patents in the classes related to personalized health research sciences:
  - Bioengineering Resources, Inc.
  - Celanese International Corporation
  - Medical Merchandising, Inc.
  - Shiva Biomedical, LLC.

From a public health perspective, it is expected that cancer will be the primary focus of advancing personalized health research sciences in Arkansas and around the United States. In 2003, health-care expenditures attributable to all cancers were estimated at $48.05 billion for the United States and $0.48 billion for Arkansas. During the same year, lost productivity due to the presence of any cancer cost the United States and Arkansas $271 billion and $3.21 billion, respectively. Projections place the health-care expenditures due to all forms of cancer as high as $146.26 billion for the United States and $1.48 billion for Arkansas by the year 2023.

Behavioral Research for Chronic Disease Management

Opportunity:

Often overlooked in disease research is the value that behavioral research can play in disease prevention, control, and management. Behavior contributes significantly to health, well-being, and longevity. Indeed, clinical and epidemiological research supports numerous behavioral guidelines for the prevention of disease. Among persons who suffer from disease, behavior also is often critical to achieving treatment objectives, including compliance with complex and lengthy treatment regimens.

Behavior's role in health and disease encompasses both promise and challenge—the promise of a reduced risk for illness and better disease management, and the challenge of promoting actions that will contribute significantly to this goal.

Behavioral research seeks to accomplish the following:

- Elucidate the nature, origins, and effects of health-related behaviors.
- Apply behavioral principles to modify individuals' health-impairing behaviors and lifestyles.[15]

With advances in cognitive sciences and applications of technologies ranging from imaging to the use of IT, there are powerful ways to advance behavioral research and interventions for addiction and chronic disease management.

Multiple competencies and institutions: Emerging

Behavioral research is found across many of the leading disease and disorder core research competencies in Arkansas:

- In addiction treatment and management, behavioral research approaches are the centerpiece of the state's research strength, including the role of impulse management, use of incentives, and neurological-based executive function. In particular, the success of the Center for Addiction Research at UAMS opens the door for broader research programs into behavioral change involving a wider set of chronic disease issues.
- In cancer control, detection, and treatment, behavioral research is applied as part of its population-based studies on cancer control, involving how to increase the use of cancer screening services and improved lifestyles.
- In obesity and diabetes research, there is a strong focus on obesity prevention through cognitive improvement in decision-making in community settings.
- In mental health and behavior, there is a focus on behavioral research on cognitive impairment of the elderly.

Opportunity for external research funding: Significant

Behavioral research is a cross-cutting area of disease-based basic and clinical research focus of the NIH. Estimates of funding from the NIH reveal that basic behavioral and social science research has reached slightly over $1 billion in FY 2008 and has been flat for several years. Clinical behavioral and social science research, meanwhile, stood at over $3 billion in FY 2008 and also has been flat in funding in recent years.

Market potential: Limited (immediate)

The market potential for behavioral research needs to focus on its use in chronic disease prevention, control, and management. The number of people in the United States with chronic conditions is rapidly rising, with projections of 141 million in 2010 and 171 million (i.e., half of the U.S. population) by 2030. Chronic illness accounts for roughly 80% of all health-care spending in the United States. The seven most common chronic diseases—cancer, diabetes, hypertension, stroke, heart disease, pulmonary conditions, and mental illness—have a total impact on the economy of $1.3 trillion annually.

With staggering numbers and growth rates only increasing, there is widespread need for programs and services to prevent and/or manage the onset and effects of chronic diseases. Chronic disease management programs entail behavioral modification techniques, reminders and checklists, online support tools and resources, actionable clinical practice guidelines, and automated clinical decision support.

[15] This discussion draws from *Behavioral Research in Cardiovascular, Lung, and Blood Health and Disease;* National Heart, Lung, and Blood Institute; U.S. Department of Health and Human Services; February 1998; page 1.

In 2002, $600 million was spent on disease management in the United States, and the CAGR of revenues for disease management organizations such as Inflexxion and HealthMedia Inc. was 28%. The market potential for chronic disease management is more than $30 billion, largely attributed to the avoidance of hospital and emergency room costs.

Existing or emerging Arkansas industry connections: Limited (but addresses major public health issues)

Very few of the innovative companies found in Arkansas are focused in the area of behaviorial research for chronic disease management:

- None of the large Arkansas firms in the CorpTech database of technology were identified as focusing in this area.
- Two companies in Arkansas were SBIR/STTR grant awardees from 2002 to 2008 that worked in areas related to behavioral research for chronic disease management:
  - InterveXion Therapeutics, LLC (formerly Inflexion Therapeutics, LLC)
  - Psychiatric Assessment Systems.
- Four of the 51 small technology businesses served by Innovate Arkansas are involved in this area: HealthSpan Solutions, InterveXion Therapeutics, Accupal, and MedBox.
- One company in Arkansas was identified with two or more U.S. patents in the classes related to behavioral research—Medical Merchandising, Inc.

From a public health perspective, many chronic diseases of considerable incidence and economic burden call for more behavioral interventions, including the following:

- Diabetes: Arkansas has higher reported rates of diabetes than the country as a whole. The prevalence of diabetes has consistently been equal to, or higher than, the national average for over a decade. Nearly a third of those with diabetes in Arkansas are undiagnosed. In 2003, diabetes ranked sixth among all causes of death in Arkansas. In 2006, more than 5,800 community hospital visits were principally because of diabetes mellitus; the majority of these visits resulted from diabetes with complications. This follows the pattern seen in the nation as a whole. In both cases, Arkansas and the United States, diabetes with complications is also associated with the greatest mean cost, with the mean cost of discharges with a principal diagnosis of diabetes with complications over twice as high as the mean cost of discharges diagnosed as diabetes without complications.
- Addiction: From 2004 to 2006, Arkansas was one of only six states that experienced a significant increase in the number of persons 12 or older reporting past-month alcohol use (39.6% to 42.6%). During the same period, Arkansas also experienced a significant increase in underage binge drinking. Arkansas ranks among the top fifth of states in past-month tobacco use and 12-month use of pain relievers for nonmedical purposes among persons of all ages. Alcohol and substance dependence create a significant burden for the community hospitals of Arkansas. In 2006, nearly 2,000 community hospital visits were principally because of an alcohol- or substance-related mental disorder. Among those visits, the median cost of a hospital stay with a principal diagnosis of an alcohol-related disorder was $6,651. During the same year, more than 61,000 discharges from community hospitals included a diagnosis of an alcohol or substance-related mental disorder.
- Cardiovascular Disease: Arkansas has higher reported rates of heart attack, coronary heart disease, and stroke than the country as a whole. Cardiovascular events create a significant burden for the community hospitals of Arkansas. In 2006, nearly 15,274 community hospital visits were principally because of heart attack, stroke, mini-stroke, or effects of stroke. Among those visits, the mean cost of a hospital stay due to stroke was nearly $20,000.

Obesity and Nutrition

Opportunity:

Obesity is reaching enormous proportions and is a looming public health crisis. Two-thirds of American adults are now overweight and half of them are clinically obese, according to the CDC. In the past 30 years, the prevalence of obesity has more than doubled. In 1985, there were only eight states where more than 10% of adult residents were obese; by 2001, there was not a single state with obesity prevalence below 15%.[16]

Obesity, in turn, brings vulnerability to diabetes, a debilitating metabolic dysfunction that results in heart disease, loss of limbs, and blindness. The cost of caring for diabetes accounts for $1 in every $12 of health-care spending in the United States, and the overall health-related costs of obesity have surpassed those of smoking.

The links to obesity have to do with poor diet, too little exercise, and unhealthy lifestyles. But, scientists are finding genetic connections that suggest not only who is prone to obesity, but also the types of diets that work for some individuals and not for others. In regards to diet, there is a debate on whether simply too much food or the wrong types of food promote diabetes.

Multiple competencies and institutions: Emerging

Led by UAMS, ACHRI, ASU, and NCTR, Arkansas has a niche, but identifiable, core research competency in obesity and diabetes research. This competency includes research funding on the genetics of type 2 diabetes and on the mechanisms underlying metabolic syndrome in obesity. There is also a particular strength in childhood obesity with the presence of the USDA Arkansas Children's Nutrition Center (ACNC) and the recent award of the Robert Wood Johnson Foundation Center to Prevent Childhood Obesity to Arkansas. ASU College of Nursing and Health Professions has been involved in efforts to measure childhood obesity rates and family health-related behaviors in regional school districts, which has resulted in established collaborative efforts between ASU, the NEA/Delta region, and the regional school districts that focus on developing an effective, sustainable model for obesity prevention that can be applied nationally.

Complementing this focus on obesity and diabetes is a more established core research competency in food science, food safety, and nutrition that includes a growing emphasis on metabolism and improving nutritional content of foods. NCTR has started a new Division of Personalized Nutrition and Medicine that will be advancing new capacities to study nutrigenomics, including gene-nutrient interactions.

In addition, Arkansas has become a leader in monitoring and combating childhood and adolescent obesity. Policy-level efforts have included the legislation of mandatory body mass index measurement and reporting in Arkansas schools and the mandated inclusion of 150 minutes of physical activity per week for grades K-12. Arkansas is also participating in national initiatives to reduce obesity and increase physical activity, including the 5-year CDC Nutrition, Physical Activity and Obesity Program (NPAO).

Opportunity for external research funding: Significant

Despite an increasing number of adults as well as children in the United States becoming obese, the amount of research funding for obesity and diabetes as well as the area of nutrition has continued to remain flat because of the lack of growth in the overall NIH research budget. Estimates from the NIH indicated that in FY 2008 obesity research was $660 million, diabetes research was $1.035 billion, and research in the area of nutrition was $1.073 billion; funding has remained constant at these respective amounts in recent years.

The USDA is another agency that provides funding opportunities in the area of nutrition. Through support by the USDA's Agricultural Research Service, the ACNC is one of six centers in the National Human Nutrition Research Centers (HNRCs) Program and one of only two pediatric HNRCs in the United States. ACNC's focus is pediatric nutrition with programs funding the following areas: brain development and function, dietary factors (nontraditional nutrients or functional foods), bone development and remodeling, childhood obesity, and enhancement of immune function. With annual awards ranging from $70,000 to $80,000, the USDA SBIR Food Science and Nutrition Program supports applied research that focuses on developing new and improved processes, technologies, or services that increase the understanding

[16] Elizabeth Gudrais, "Decoding Diabetes: New Discoveries About a Growing Disease Threat," *Harvard Magazine*, November-December 2008.

of food safety issues and the nutritional characteristics of foods. The USDA Agriculture and Food Research Initiative (AFRI) Competitive Grants Program provides fundamental, applied, and multidisciplinary support in the area food safety, nutrition, and health and has about $190 million allocated in FY 2009 for annual grant awards up to $250,000.

Market potential: Extensive

There is a significant market for addressing diabetes. The global diabetes market is slated to become one of the largest health-care markets over the next 5 years. The 205 million people worldwide estimated at the end of 2007 to be afflicted with diabetes demand health-care products and services to manage this multifactored and heterogeneous condition and its complications, and the next 5 years promise to be a dynamic time for the global diabetes market. According to BCC Research, the global market for diabetes therapeutics and diagnostics will be worth $213.8 billion in 2008. This is expected to increase to more than $241.9 billion by 2013, a CAGR of 2.5%.

Existing or emerging Arkansas industry connections: Limited (but addresses major public health issues)

A minimal number of innovative companies in Arkansas are working in the area of obesity and nutrition:

- No large companies were identified in the CorpTech database of technology firms for this area.
- One company in Arkansas was an SBIR/STTR grant awardee from 2002 to 2008 that worked in the area related to obesity and nutrition—Nephropathology Associates.
- None of the 51 small technology businesses served by Innovate Arkansas are involved in this area.

From a public health perspective, obesity is of significant economic impact. Arkansas has consistently reported a higher rate of obesity than the nation as a whole. Nearly two-thirds (65.6%) of Arkansans are overweight or obese, compared with 63% of U.S. citizens. Due to its relationship with a wide range of chronic and acute disease states, obesity conveys a major financial burden both on the United States and the state of Arkansas. A recent conservative estimate indicates that obesity-attributable medical costs accounted for 6% ($661 million) of the total health-care expenditures in Arkansas from 1998 to 2000. Among more vulnerable populations in Arkansas, obesity-attributable medical expenditures account for an even higher proportion of medical costs. For example, among Medicaid and Medicare recipients, obesity-attributable medical costs account for 11.5% and 7% of total medical expenditures, respectively. However, nearly half of the costs associated with obesity are indirect. Nearly a decade ago, the combined direct and indirect costs of obesity totaled $100 million for the nation as a whole.

Next Steps

The results from this first ever comprehensive assessment of the core competencies and strategic focus areas found across Arkansas' university research enterprise offers a strong roadmap for the Arkansas Research Alliance to move forward. It demonstrates that Arkansas does have a growing base of research across its universities and government labs and particular areas of established and emerging research strengths.

The Arkansas Research Alliance will now be using these results to act to advance job-creating research in Arkansas, primarily through the recruitment, retention, and recognition of world-class talent. In the coming months, the Arkansas Research Alliance will be considering which of the strategic focus areas to designate as priority areas to advance first. In those selected strategic focus areas, the Arkansas Research Alliance will be considering the key expertise needed for Arkansas to succeed in advancing job-creating research and building a nationally recognized program of excellence.

These efforts will take time to demonstrate results; but, Arkansas is in a marathon, not a sprint. The state's economic well-being and competitiveness for the next generation are at stake.