

Preparing for the Future:

Utah's Science, Technology, Talent and Innovation Plan

**Prepared for: Governor's Office of
Economic Development
Utah System of Higher Education**

**Prepared by: Battelle Technology
Partnership Practice**

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GARY R. HERBERT
GOVERNOR

STATE OF UTAH
OFFICE OF THE GOVERNOR

GREG BELL
LIEUTENANT GOVERNOR

October 17, 2012

Dear Fellow Utahns,

Throughout my administration, my vision for Utah has remained clear: Utah will lead the nation as the best performing economy, and be recognized as a premier global business destination. I am thrilled to say our hard work is paying off.

Thanks to a robust public/private partnership, Utah continues to thrive. Our economy is being driven by innovation and spirited entrepreneurship, particularly in the arenas of science and technology. As a result, Utah is outpacing the nation in several key economic metrics.

We have long recognized that continued growth begins with education. By emphasizing Science, Technology, Engineering and Mathematics (STEM) education and working with the Utah System of Higher Education, and through our Utah Cluster Acceleration Project (UCAP), we can anticipate the workforce needed to meet the demands of an increasingly competitive global marketplace.

Utah's economic development plan recognizes the importance of creating an environment that fosters innovation and provides support to entrepreneurs and emerging companies.

But we can do more.

The *Science, Technology, Talent and Innovation (STI) Strategic Assessment and Growth Initiatives Plan* identifies opportunities to accelerate the state's technology-based industry clusters that have elevated Utah as a leader in today's global innovation economy. At its core, the *STI Plan* seeks to deepen the collaboration among higher education, industry, and government to help ensure that a coordinated strategy is in place to prepare our future workforce.

I encourage you to become familiar with, and use, the STI strategic plan to help focus our future investment so that we may all benefit from Utah's vibrant, growing, and sustainable economy.

Sincerely,

Gary R. Herbert.
Governor

Executive Summary

Utah has been hard at work to make economic development a top priority. As Governor Herbert stated in his State of the State address this past January:

“My vision for economic development is Utah will lead the nation as the best performing economy and be recognized as a premier global business location.”

While Utah is noted for its well-performing economy, it did decline along with the U.S. in the recent recession and continues to face the challenges of stiff global competition. Indeed, the U.S. as a whole faces challenges given the relentless advances being achieved in many developing countries in science, technology, education and innovation.

In response to this rapidly growing global economy and the need to accelerate Utah’s rebound from the deep recession of 2007–2009, Governor Herbert set out in 2010 a comprehensive plan for growing Utah’s economy in response to this rapidly growing global economy. It has four objectives:

- Strengthen and grow existing Utah businesses, both urban and rural
- Increase innovation, entrepreneurship and investment
- Increase national and international business
- Prioritize education to develop the workforce of the future.

Critical to achieving the four objectives of the Governor’s Economic Development Strategy is having in place an effective science, technology and innovation plan that ties closely to talent development, industry clusters and the demands of global competition. In particular, the Governor’s plan recognizes the importance of creating an environment that fosters innovation and provides support to entrepreneurs and emerging companies. The plan also called for connecting higher education, industry and government to identify industry workforce needs and ensure plans are in place that will deliver a trained and ready workforce for the future.

The Governor’s Strategy also recognized the importance of maintaining the state’s infrastructure, business climate and quality of life, all factors that influence business location decisions. In particular, Utah must continue to fund transportation infrastructure projects, expand broadband access, and maintain its business friendly regulatory environment. Given the state’s rapid growth, attention must be given to its natural resources, including air quality and the availability of water to meet the needs of both residences and businesses. Because it is critical to economic growth, this plan addresses water sustainability in addition to technology economic development.

This Science, Technology, Talent and Innovation (STI) Strategic Assessment and Growth Initiatives Plan was sponsored by the Governor’s Office of Economic Development (GOED) and the Utah System of Higher Education (USHE) to identify initiatives that may be taken to continue to grow the state’s technology-based industry clusters and make Utah a leader in today’s global innovation economy. Partial funding support for this effort came from a planning grant from the U.S. National Science Foundation EPSCoR program. To this end, this STI Strategic Plan:

- Evaluates the competitive position of Utah’s technology-based economy
- Identifies areas in which Utah has strengths that offer opportunities for future growth
- Identifies challenges that need to be addressed to continue to grow the state’s technology-based economy
- Assesses the state’s overall science, technology, talent and innovation infrastructure
- Proposes initiatives that could be undertaken to realize the full potential of Utah’s innovation economy
- Addresses the potential economic growth-limiting issue of water sustainability

To assist in this effort, the Battelle Technology Partnership Practice (TPP) was selected to conduct the analysis and to assist in crafting a strategic plan of action with concrete initiatives based on best practice lessons. Battelle TPP is the economic development consulting arm of the world’s largest independent non-profit research and development organization. Battelle TPP brings to this project a position as the national leader in advanced, technology-based and cluster-driven economic development practice with an established track record in developing and advising many of the most successful modern development programs in the U.S.

Key Findings on Utah’s Technology-based Industry Clusters Performance and Linkages with Core Technology Competencies Found in Utah

All states and regions of the nation need to foster globally competitive industry drivers given the economic forces shaping the 21st century. As the National Governor’s Association explains:

“U.S. economic strength depends on the ability of each state to “compete” successfully in the world marketplace. Each state must exploit the unique advantages it has relative to other states and build on the strengths found in its local “clusters of innovation”—distinct groups of competing and cooperating companies, suppliers, service providers and research institutions.”¹

Utah has been diligent in having its economic development efforts guided by a focus on advancing industry clusters around areas of strengths and to map both existing and emerging industry strengths to growth drivers of the national and global economy. Governor Herbert’s Economic Development Plan for Utah continues to embrace the importance of building upon Utah’s industry clusters: “The key is to bring industry, talent, government, universities, technology and capital together around industry sectors that possess the greatest opportunity for success. Their collective excellence allows all companies within the cluster to grow and thrive, resulting in increases in the standard of living within a region.”²

Among Utah’s identified industry clusters, several represent technology based industries, including:

- Aerospace & Defense
- Energy & Natural Resources
- Information Technology
- Life Sciences/Biomedical (not including hospitals)

¹ National Governor’s Association, “A Governor’s Guide to Trade and Global Competitiveness,” 2002

² Governor Herbert, Utah’s Economic Development Plan for Utah, 2010, page 13

The analysis of Utah’s technology industry clusters in the STI Plan takes a broad view of Utah’s technology-based industry clusters considering both their economic performance in recent years as well as the presence and alignment with core technology competencies found in Utah. From a state economic development perspective, core technology competencies can be identified where there is a “critical mass” of expertise and activities across product development and productivity in industry as well as research activities in universities, hospitals and non-profit research centers. By linking core competencies to industry clusters, it is possible for a state to identify how to position an existing industry cluster for future development and to identify the potential for advancing emerging industry clusters.

Overall, Utah’s Economic Cluster Initiative continues to reflect very well the specific technology-based industry strengths found in Utah. Of the nearly 117,000 jobs found in technology-based industries in Utah using the BLS definition of high technology industries, nearly 60 percent were found in the four existing industry clusters of Aerospace & Defense, Energy & Natural Resources, Information Technology and Life Sciences. The few significant technology-based industries not specifically included in the existing Utah Economic Cluster Initiative included broad-based activities in administrative services industries found in Utah which support both technology headquartered firms in Utah as well as non-technology headquartered firms, as well as technical services industries that largely support the Energy and Natural Resources Cluster.

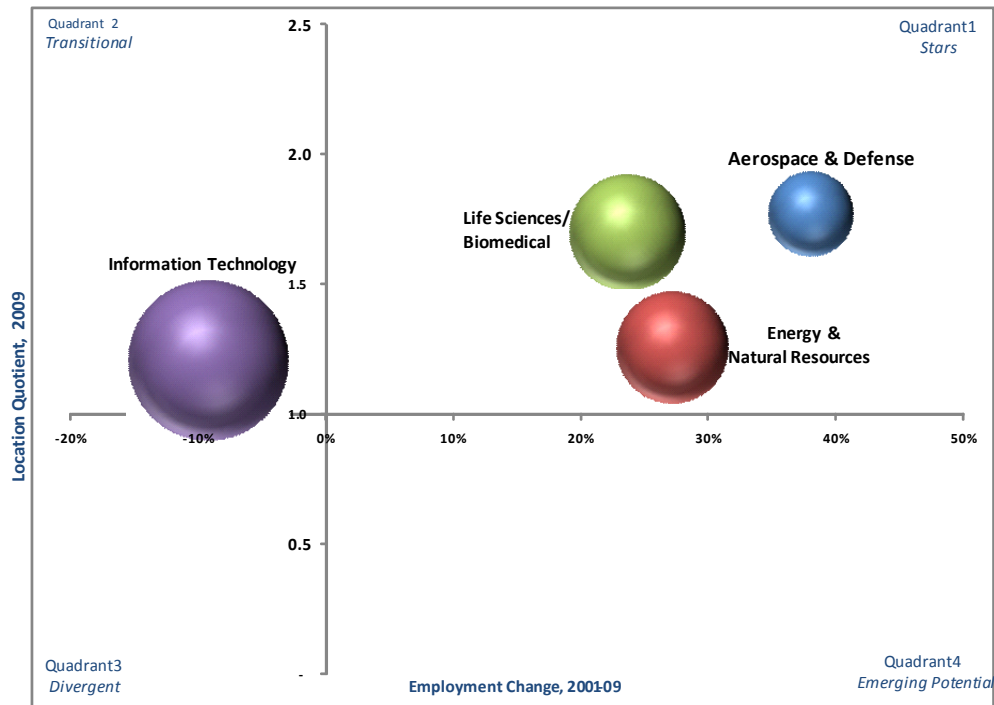
In economic performance, the four technology-based industry clusters found in Utah stand as either current or specialized industry strengths. Current strengths refer to those industry clusters that have a substantially higher relative level of concentration of employment than found at the national level (20 percent or higher) and are growing in jobs. Specialized industry clusters are those that are not growing in jobs, but remain substantially above the concentration of jobs found in the nation.

The results for Utah were very positive:

- Three industry clusters—Aerospace & Defense, Energy & Natural Resources and Life Sciences/Biomedical—stand as current strengths.
- One industry cluster—Information Technology—stands as a specialized strength.

A good way to visualize this economic performance is through the use of “bubble” charts that present in one graphic higher or lower concentration levels along the vertical axis, job growth or decline along the horizontal axis and size of employment in 2009 by the size of the bubble. See Figure ES-1.

Figure ES-1: Bubble Chart of the Economic Performance of Utah’s Technology-based Industry Clusters

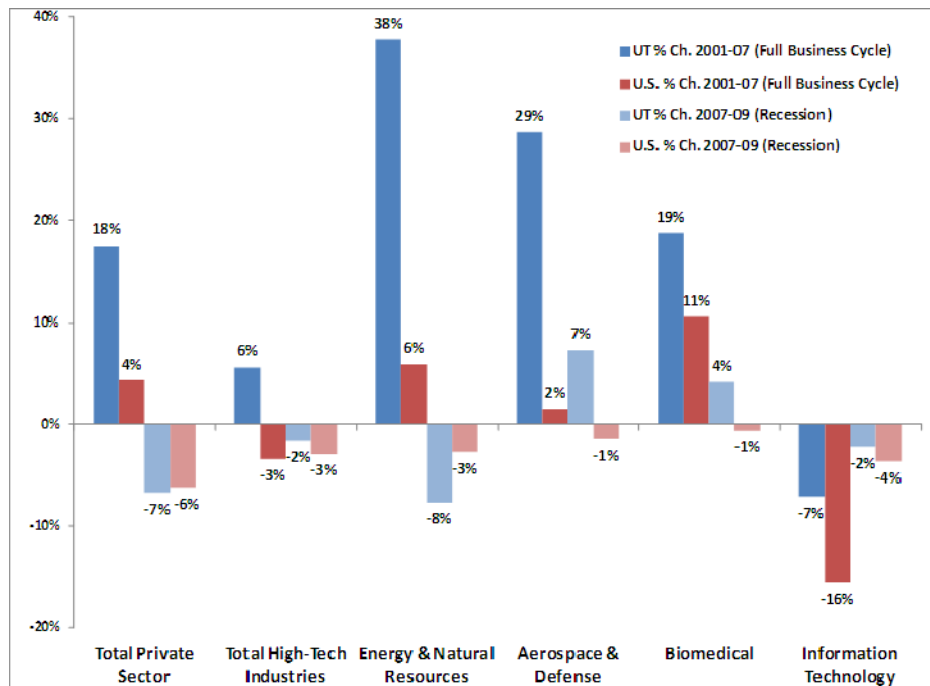


Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Utah has also been performing well in the growth of its technology-based industry clusters relative to the nation. This measure of regional trends examines whether a local industry cluster is gaining or losing competitive share compared to the nation. Figure ES-2 presents how well Utah’s technology-based industry clusters have performed compared to the nation over the last full business cycle from 2001 to 2007 and the recent recession years of 2007 to 2009. As a benchmark we also consider overall private sector employment in Utah and total technology-based industries. Three key findings emerge:

- Over the last full business cycle years of 2001 to 2007, each of the technology-based industry clusters in Utah outpaced the performance of similar U.S. industries.
- While Utah’s overall economy well outpaced the nation over the last full business cycle years of 2001 to 2007 in both total private sector employment and total technology-based industries, during the recent recession, Utah declined along with the nation at comparable levels.
- During the recession years, two technology-based industry clusters in Utah—Aerospace & Defense and Life Sciences/Biomedical—continued to make gains that outpaced the nation.

Figure ES-2 Recent Employment Trends for Utah’s Technology-based Industry Clusters, Total Private Sector and Total Technology Industries Compared to the U.S. for 2001 to 2007 Period and 2007 to 2009 Period



Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

There is a broad range of patent and publication cluster focus areas found across Utah’s industry and university base with a strong alignment to Utah’s technology-based industry clusters. A cluster analysis of the abstracts of over 20,000 patents and publications generated in Utah from 2006 through mid-year of 2011 identified 39 cluster focus areas. This cluster analysis uses a proprietary software tool to identify groupings based on the use of words in the text of the abstracts to identify logical groupings without an “*a priori*” bias, unlike standard analyses of publications, research trends, and reputational rankings for which the research field categories are predetermined by the entities collecting the data. Battelle then validated these patent and publication cluster focus areas through interviews with university officials, faculty leaders and corporate executives.

Battelle was able to map nearly all of these patent and publication cluster focus areas to the technology-based industry clusters found in Utah. Table ES-1 shows the mapping of the patent and publication cluster focus areas to the technology-based industry clusters in Utah. The only patent and publication cluster focus areas not mapped to technology-based industry clusters were in transportation vehicle components, manufacturing process engineering and polymer-based applications that spanned across many industry uses—together these three unmapped patent and publication cluster focus areas represented 976 patent and publication records, or less than 5 percent of the total.

Battelle then validated these patent and publication cluster focus areas from interviews with industry and university leadership and determined how they could best be grouped into broader core technology competencies reflecting further analysis on the presence of major research centers, leading publication fields, areas of strength in technology deployment and presence of innovative, emerging companies.

Battelle was able to identify a wide range of potential growth opportunities for Utah across its technology-based industry clusters using a line of sight analysis from detailed industry strengths to core technology competencies. This line of sight analysis to identifying potential growth opportunity areas for Utah was informed by interviews with industry executives and university leadership as well as incorporating the findings from many existing state level strategic reports developed in concert with industry, such as Utah Cluster Acceleration Strategies in Energy, Digital Media and Aerospace & Defense as well as Utah's 10 Year Strategic Energy Plan.

By linking core technology competencies to specific industry strengths within an overall industry cluster, it is possible to define not only where a state has demonstrated the ability to advance industry development but where it has the know how to continue to fuel innovation and further distinct areas of growth as set out in Figure ES-2.

Table ES-1: Mapping of Patent and Publication Cluster Focus Areas in Utah into Utah Technology-Based Industry Clusters

Aerospace & Defense	1236	<ul style="list-style-type: none"> ○ Automation & Control ○ Sensor and Sensor Systems ○ Aerospace-related Materials ○ Space Sciences
Energy & Natural Resources	3141	<ul style="list-style-type: none"> ○ Oil, Gas and Resource Mining Tools ○ Energy Conversion and Storage ○ Water and Soil Conservation ○ Atmospheric Sciences ○ Earth Science ○ Ecology ○ Range and Forest Sciences ○ Animal Health and Sustainability
Information Technology	3076	<ul style="list-style-type: none"> ○ Networking ○ Information and Data Systems Management ○ Semiconductor and Solid-State Devices ○ Image Processing ○ Optical Sciences ○ E-Commerce ○ Signal Processing ○ Information Security ○ Communications Processing Technologies ○ Data Storage and Memory
Life Sciences/ Biomedical	11,677	<ul style="list-style-type: none"> ○ Surgical Devices, Catheters, Instruments, and Equipment ○ Genomics and Biologics ○ Neurosciences ○ Cancer Research and Treatments ○ Musculoskeletal Implants and Devices ○ Psychology and Behavioral Research ○ Cardiovascular and Pulmonary Diseases and Conditions ○ Drug Development and Delivery ○ Infectious Diseases, Pathogens and Immunology ○ Reproductive Medicine ○ Molecular Genetics and Cell Biology ○ Medical Imaging ○ Diabetes ○ Transplantation and Stem Cell Therapies ○ Natural Products ○ Ophthalmology ○ Ion Channel Research

Figure ES-2: Summary Line of Sight for Technology Based Industry Clusters Aligning Core Technology Competencies to Detailed Industry Strengths to Possible Growth Opportunity Areas

Core Technology Competencies	Detailed Industries That Are Growing in Jobs and/or Specialized in Level of Employment Concentration	Possible Growth Opportunities for the Future
AEROSPACE & DEFENSE INDUSTRY CLUSTER		
Automation and Control Sensors and Sensor Systems Aerospace-related Materials Space Sciences	<ul style="list-style-type: none"> ▪ Guided Missile and Space Vehicle Propulsion Unit and Parts Manufacturing. ▪ Search, Detection, Navigation, Guidance, Aeronautical and Nautical System and Instrument Manufacturing. ▪ Aircraft Parts (not including engines) 	Unmanned Aerial Systems Advanced Aerospace Materials
ENERGY & NATURAL RESOURCES INDUSTRY CLUSTER		
Oil, Gas and Resource Mining Tools Energy Conversion and Storage Environment, Ecology, Water and Atmospheric Sciences	<ul style="list-style-type: none"> ▪ Support Activities for Oil and Gas Operations ▪ Bituminous Coal Underground Mining ▪ Petroleum Refineries ▪ Crude Petroleum and Natural Gas Extraction ▪ Fossil Fuel Electric Power Generation ▪ Water and Sewer Line and Related Structures Construction ▪ Hazardous Waste Treatment and Disposal ▪ Environmental Consulting Services ▪ Primary Smelting and Refining of Copper ▪ Copper Ore and Nickel Ore Mining ▪ Primary Smelting and Refining of Nonferrous Metal 	Clean Technologies for traditional and unconventional sources of fossil energy Energy storage and power delivery systems
INFORMATION TECHNOLOGY INDUSTRY CLUSTER		
Information Systems Electronics and Processing Technologies	<ul style="list-style-type: none"> ▪ Custom Computer Programming Services ▪ Data Processing, Hosting and Related Services ▪ Software Publishers ▪ Electronic Shopping ▪ Semiconductor and Related Device Manufacturing ▪ Internet Publishing, Broadcasting and Web Search Portals ▪ Computer Systems Design Services ▪ Other Electronic Component Manufacturing ▪ Other Computer Related Services ▪ Cable and Other Subscription Programming ▪ Bare Printed Circuit Board Manufacturing ▪ Audio and Video Equipment Manufacturing 	Networked information systems Digital gaming and other digital media
LIFE SCIENCES/BIOMEDICAL INDUSTRY CLUSTER		
Medical Device Disease Research, Drugs and Pharmaceutical Basic Biological Research Natural Products	<ul style="list-style-type: none"> ▪ Pharmaceutical Preparation Manufacturing ▪ Medical Laboratories ▪ Drugs Wholesalers ▪ Irradiation Apparatus Manufacturing ▪ Dental Laboratories ▪ Medicinal and Botanical Manufacturing ▪ Electromedical and Electrotherapeutic Apparatus Manufacturing ▪ Life Sciences Commercial Research & Development ▪ Medical, Dental and Hospital Equipment & Supplies Wholesalers ▪ Surgical Appliance and Supplies Manufacturing ▪ Surgical and Medical Instrument Manufacturing ▪ Dental Equipment and Supplies Manufacturing 	Molecular medicine, drug discovery, development and delivery Molecular diagnostics and personalized medicine Natural products and dietary supplements

One area of concern for Utah is the low value-added per employee compared to the U.S. average levels across all of Utah’s technology-based industry clusters. Industry technology competencies are more than just advancing new products and processes. Just as critical, if not as widely heralded, is the ability of industry to “put technology to work.” To assess Utah’s position in technology deployment an analysis of value added output per employee was undertaken to see how well the four technology-based clusters in Utah compare to the U.S. overall. Value added output measures output after subtracting out the cost of inputs to production. Higher value-added per employee suggests more effective deployment of technologies in production as well as an ability to produce more complex, higher-value products. Battelle calculated value added per employee from data on employment and value-added economic output reported for industries in Utah and the U.S. by IMPLAN.

While there are a few detailed industry sectors in which Utah exceeds the U.S. average, the consistency of Utah’s lower value-added per employee points to a more significant challenge of how to put technology to work to raise the value added of its industrial production. This can happen through the use of technology to develop more complex, higher valued products or to raise productivity of operations in Utah.

Table ES-3: Value Added Per Employee for Technology Based Industry Cluster: Utah Compared to U.S.

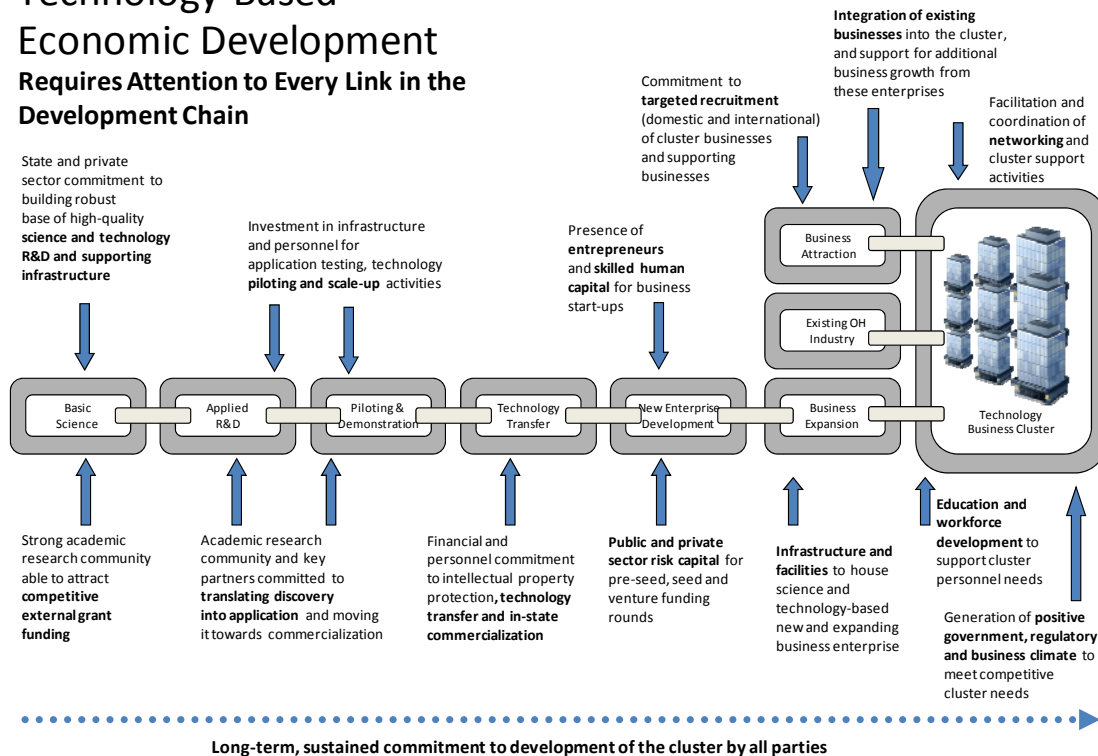
	Utah Value-Added Per Employee	U.S. Value-Added Per Employee	Utah Percentage of U.S. in Value-Added Per Employee
Aerospace & Defense	\$129,756	\$150,062	87%
Energy & Natural Resources	\$293,860	\$304,843	96%
Information Technology	\$99,458	\$147,845	67%
Life Sciences	\$106,379	\$120,313	88%

Source: Battelle calculations using IMPLAN data.

Recommended Strategic Initiatives to Realize the Full Potential of Utah's Innovation Economy

Economic development is not easy to achieve in general, while technology-based economic development is an even greater challenge. For economic development to occur, an entire interconnected sequence of positive factors has to be in place. For development of technology-based business sectors, the chain of factors is particularly complex and challenging to develop and manage. If any link in the chain is missing, a sustainable technology cluster is unlikely to develop. The graphic below presents an illustration of how to conceive of the linkages found in technology-based economic development.

Technology-Based Economic Development Requires Attention to Every Link in the Development Chain



The states and regions in the U.S. which have achieved success in growing robust technology industry clusters (places such as the San Francisco Bay region and Boston) have well-developed technology development chains in place. These technology-based economic development chains may form naturally over time (as occurred in Silicon Valley), or they may result from dedicated activities of states, regions and key stakeholders to connect and build links in the chain to assure such development happens. The figure above illustrates a basic technology-based economic development chain and the specific links that need to be in place to form and grow a technology cluster.

It is clear that Utah has policies and programs aimed at strengthening many of the links in the chain. A number of initiatives have been put in place to achieve the state's economic development objectives related to science, technology, talent and innovation. Through the Utah Science Technology and Research Initiative (USTAR), Utah has attracted more than 50 research teams to the University of Utah (U of U) and Utah State University (USU). These teams, which are led by world-class innovators, have attracted significant research dollars and initiated collaborations with both industry and other researchers. Utah's three research universities, the U of U, USU and Brigham Young University (BYU), have active and effective technology transfer and commercialization efforts that are creating new companies and bringing new products to the market.

Utah has developed robust technology-based industry clusters in aerospace and defense, energy and natural resources, life sciences, and information technology, among other areas. To continue to support the development of these clusters, the Utah University System of Higher Education (USHE), the Governor's Office of Economic Development (GOED) and the Division of Workforce Services (DWS) joined together to create the Utah Cluster Acceleration Partnerships (UCAP) initiative. The objective of UCAP is to explore ways in which Utah's educational and workforce development institutions can partner with Utah's industry clusters to accelerate their growth. UCAP strategies have been developed or are under development for the aerospace and defense industry cluster, the energy industry cluster, the life sciences industry cluster and the digital media industry cluster and more cluster acceleration strategies are anticipated.

Based on a comprehensive assessment of Utah's position in R&D and technology transfer, talent, capital availability and overall economic infrastructure, a number of specific gaps emerge that need to be addressed if Utah is to accelerate the growth of its technology clusters. These include:

- Insufficient linkages between Utah's industry clusters and its higher education institutions.
- Underdeveloped risk capital markets. Ways must be found to help Utah's large base of start-up companies to grow and succeed in Utah. In particular, Utah's capital markets must be developed to be able to meet companies' capital needs at every stage of their development, but particularly at the proof-of-concept and seed stages.
- Lack of talent to fill senior management and other skilled positions.
- Concern about the quality of STEM education. Utah must take steps to ensure that there is a talent pipeline sufficient to meet industry's need for skilled and educated workers.

Below is an overview of these gaps facing Utah and a set of proposed "initiative" options that the State of Utah can advance to address the gaps identified. Activities that could be undertaken under each initiative are suggested.

Knowledge Initiative – Encourage Greater Industry University Collaboration

Innovation, in and of itself, will not necessarily translate into economic activity. Rather it is the application of that technology and its introduction into the marketplace that results in economic

growth. Having a strong R&D base is necessary but not sufficient to grow a technology-based economy. An effective means of moving technology into the commercial marketplace is to encourage relationships between the researchers who are making the discoveries and the entrepreneurs and company CEOs that have the ability to commercialize them.

Utah has strong technology-based industry clusters and academic R&D strengths in areas that relate to these clusters. But Utah's research base has lagged and few companies report working collaboratively with academic researchers. In fact, a number of the interviewees suggested that it is difficult to work with technology transfer offices to either license technology or to conduct sponsored research. Issues often arise around IP ownership and expectations regarding the terms of licensing agreements. Such issues will need to be addressed to both grow its R&D base as well as to enable Utah to maximize the economic development benefits of its university R&D enterprise.

Utah has already taken steps to accelerate the growth of its R&D base. In addition to providing funding to allow the U of U and USU to recruit innovative faculty in key areas of importance to the state's industry clusters (an approach often referred to as Eminent Scholars programs in other states), USTAR has provided funds to build facilities to house these researchers, and awarded grants to fund proof of concept projects. USTAR also supports commercialization activities at a number of the state's colleges and universities. Utah should continue to fund USTAR to continue these activities and/or additional activities that could be undertaken to continue to grow the state's research and innovation base in its targeted technology areas.

The State of Utah should also consider undertaking activities directly aimed at creating industry/university partnerships. These could include

- Funding public-private partnerships that bring industry, academic researchers, institutions of higher education and state government together to pursue development of a particular technology area to further the growth of an industry cluster
- Providing funding to match industry research dollars
- Creating mechanisms that bring industry and academic researchers together.

Capital Initiative – Support the Creation and Growth of Innovative Companies by Ensuring Access to Capital

Utah has been very successful in creating start-up companies. Indeed, the state's universities lead the nation in forming companies around university-developed technologies. While new firm creation is a key prerequisite for growing a knowledge-based economy, it is not sufficient. It is equally important that a state or region provide an environment in which such companies can succeed and grow.

Firms need to be able to access the resources they need when they need them. The most critical of these is capital. Business development requires not only R&D dollars but also substantial funds necessary to bring a new product or service to market. Capital is required to conduct market

assessments, develop prototypes, scale up production and establish distribution and sales outlets. Sufficient capital is necessary to grow a business through each major stage and milestone.

Interviews with entrepreneurs, faculty inventors, CEOs of companies, economic developers and venture capitalists suggest that it is very difficult to access risk capital in Utah. The gap is particularly severe at the proof of concept and seed stage but it can also be difficult to obtain later stage capital as well. This is due in part to the fact that there are few Utah-based venture capital funds to serve as lead investor.

The Utah Fund of Funds was created to attract out of state venture capital investment in Utah-based companies. The Fund has invested \$120 million in 28 venture funds, seven of which are Utah-based. Despite the Fund of Funds initiative, however, it remains difficult to obtain early-stage financing and certain types of companies, especially life science companies, have difficulty obtaining capital. There are a number of approaches that states have taken to increase the availability of risk capital. They include:

- Providing commercialization grants
- Directly investing in a seed or venture fund
- Using tax incentives to encourage venture investments
- Providing comprehensive in-depth support to entrepreneurs to enable them to obtain private capital.

Talent Initiative– Meeting the Need for an Innovation Workforce

Utah's employers report that the state's workforce is well educated and hard working and that in general companies have little trouble finding workers to fill technician, production and assembly positions.

Still industry is concerned about finding the high skilled workers that they need. As Utah's industry clusters have grown, demand for skilled workers has increased and firms find that they must recruit from out-of-state (which is expensive and can be difficult to accomplish), train workers internally or recruit workers from other Utah employers. To address this issue, Utah is challenged to:

- Better link education and training programs and their students to Utah's industry clusters
- Continue efforts to improve STEM education
- Promote an image of Utah as a welcoming place that provides a wealth of opportunities for workers and businesses.

Introduction

Utah has been hard at work to make economic development a top priority. As Governor Herbert stated in his State of the State address this past January: “My vision for economic development is Utah will lead the nation as the best performing economy and be recognized as a premier global business location.”

While Utah is noted for its well-performing economy, it did decline along with the U.S. in the recent recession and continues to face the challenges of stiff global competition. Indeed, the U.S. as a whole faces challenges given the relentless advances being achieved in many developing countries in science, technology, education and innovation. As the September 2010 update by the members of the highly influential 2005 report from the National Academies, *Rising Above the Gathering Storm*, explained, the U.S. outlook in global competitiveness has worsened in recent years:

*In the five years that have passed since Rising Above the Gathering Storm was issued, much has changed in our nation and world...America’s competitive position in the world now faces even greater challenges, exacerbated by the economic turmoil of the last few years and by the rapid and persistent worldwide advance of education, knowledge, innovation, investment and industrial infrastructure.*¹

The rise of a more integrated global economy seems to be unabated even in the aftermath of the recent severe global economic recession. McKinsey & Company in its 2010 survey of business executives reports that “an ongoing shift in global economic activity from developed to developing economies, accompanied by growth in the number of consumers in emerging markets, are the global developments that executives around the world view as the most important for business and the most positive for their own companies’ profits over the next five years.”²

In 2010, Governor Herbert set out a comprehensive plan for growing Utah’s economy in response to this rapidly growing global economy. It has four objectives:

- Strengthen and grow existing Utah businesses, both urban and rural
- Increase innovation, entrepreneurship and investment
- Increase national and international business
- Prioritize education to develop the workforce of the future.

Critical to achieving the four objectives of the Governor’s Economic Development Strategy is having in place an effective science, technology and innovation plan that ties closely to talent development, industry clusters and the demands of global competition. In particular, the Governor’s plan recognizes the importance of creating an environment that fosters innovation and provides support to

My vision for economic development is Utah will lead the nation as the best performing economy and be recognized as a premier global business location.”

Governor Gary R. Herbert
State of the State Address
01/26/2011

“In the long run, standards of living can be expanded only with innovation...This requires an environment that is conducive to innovative activity, supported by both the public and the private sectors. In particular, this means sufficient investment in research and development especially by the private sector, the presence of high-quality scientific research institutions, extensive collaboration in research between universities and industry, and the protection of intellectual property.”

World Economic Forum, The Global Competitiveness Report 2010-2011, page 8

entrepreneurs and emerging companies. The plan also called for connecting higher education, industry and government to identify industry workforce needs and ensure plans are in place that will deliver a trained and ready workforce for the future.

The Governor's Strategy also recognized the importance of maintaining the state's infrastructure, business climate and quality of life, all factors that influence business location decisions. In particular, Utah must continue to fund transportation infrastructure projects, expand broadband access, and maintain its business friendly regulatory environment. Given the state's rapid growth, attention must be given to its natural resources, including air quality and the availability of water to meet the needs of both residences and businesses.

A number of initiatives have been put in place to achieve the state's economic development objectives related to science, technology, talent and innovation. Through the Utah Science Technology and Research Initiative (USTAR), Utah has attracted more than 50 research teams to the University of Utah (U of U) and Utah State University (USU). These teams, which are led by world-class innovators, have attracted significant research dollars and initiated collaborations with both industry and other researchers. Utah's three research universities, the U of U, USU and Brigham Young University (BYU), have active and effective technology transfer and commercialization efforts that are creating new companies and bringing new products to the market.

Utah has developed robust technology-based industry clusters in aerospace and defense, energy and natural resources, life sciences, and information technology, among other areas. To continue to support the development of these clusters, the Utah University System of Higher Education (USHE), the Governor's Office of Economic Development (GOED) and the Division of Workforce Services (DWS) joined together to create the Utah Cluster Acceleration Partnerships (UCAP) initiative. The objective of UCAP is to explore ways in which Utah's educational and workforce development institutions can partner with Utah's industry clusters to accelerate their growth. UCAP strategies have been developed or are under development for the aerospace and defense industry cluster, the energy industry cluster, the life sciences industry cluster and the digital media industry cluster and more cluster acceleration strategies are anticipated.

The question remains how should Utah continue to move forward to build on its strengths and successful initiatives in science, technology, talent and innovation in the aftermath of the recent recession and presence of stiff global competition. The ability of a state to lead in technology innovation in particular industry sectors (including both existing and emerging industries) is generally recognized as a critical determinant of a state's economic competitiveness. But to tailor initiatives for a specific state and its regions, it is critical to have in place an up-to-date assessment coming out of the recent recession of its technology industry developments and a situational assessment of its position in talent, technology, innovation, venture capital and overall economic development infrastructure.

This Science, Technology, Talent and Innovation (STI) Strategic Assessment and Growth Initiatives Plan was sponsored by GOED and USHE through the NSF EPSCoR Planning Grant to identify initiatives that could be taken to continue to grow the state's technology-based industry clusters and make Utah a leader in today's global innovation economy. To this end, this STI Strategic Plan:

- Evaluates the competitive position of Utah’s technology-based economy
- Identifies areas in which Utah has strengths that offer opportunities for future growth
- Identifies challenges that need to be addressed to continue to grow the state’s technology-based economy
- Assesses the state’s overall science, technology, talent and innovation infrastructure
- Proposes initiatives that could be undertaken to realize the full potential of Utah’s innovation economy.

To assist in this effort, the Battelle Technology Partnership Practice (TPP) was selected to conduct the analysis and to assist in crafting a strategic plan of action with concrete initiatives based on best practice lessons. Battelle TPP is the economic development consulting arm of the world’s largest independent non-profit research and development organization. Battelle TPP brings to this project a position as the national leader in advanced, technology-based and cluster-driven economic development practice with an established track record in developing and advising many of the most successful modern development programs in the U.S.

Utah’s Technology-based Economy’s Performance and Position for Growth

All states and regions of the nation need to foster strong technology industry drivers given the economic forces shaping the 21st century. Increasing globalization, the fast pace of technological change, and the growing strength of developing nations in generating highly educated and skilled talent are threatening the economic competitiveness of all regions of the nation.

Technology industry development is already well recognized as the driver of regional economic growth. A study by the Milken Institute, a private, nonprofit research organization, evaluated economic growth across 315 regions in the United States during the 1975 to 1998 time period. The Milken Institute found that the growth and presence of high-technology industries accounted for 65 percent of the difference in economic success for regions. The Milken Institute concludes: “Because of the growing role of high-tech industries in the national economy, regions that do not achieve some level of attainment in these critical industries will likely experience substandard economic growth in the future.”³

“U.S. economic strength depends on the ability of each state to “compete” successfully in the world marketplace. Each state must exploit the unique advantages it has relative to other states and build on the strengths found in its local “clusters of innovation”—distinct groups of competing and cooperating companies, suppliers, service providers and research institutions.”

National Governor’s Association,
“A Governor’s Guide to Trade and Global
Competitiveness,” 2002

It is important to recognize that technology development drives not only emerging industries but also more mature and established industries. Consider that roughly six of every 10 information technology workers are employed outside of computer and telecommunications industries, with high concentrations found in finance, insurance, logistics, and manufacturing. Moreover, established products such as energy, industrial machinery, plastics, and measuring and control devices have growing high-technology content embedded in them and their production processes. Many of these more mature and established industries are defined as high technology by the U.S. Bureau of

Labor Statistics because they have twice the number of workers in scientific, engineering, and computing occupations than is found in all industries at the national level.

To sustain economic growth in the 21st century, best practice in economic development recognizes that each state in the nation has a set of target industry sectors or “regional industry clusters” in which it can differentiate itself and build specialized areas of expertise where it can be a world leader.

From an economic development perspective, it is particularly important to focus on those industry sectors that address the “wealth-creating” sectors of the state’s economy, or what are often referred to as “economic base” or “primary” industries. These primary industries address needs beyond local residents and businesses, and so either are involved in exports or substitute for importing goods and services from outside of the state. Other non-primary industries are often referred to as local or sheltered economic activity. While they do not generate new economic wealth for the state, these non-primary industries are important for addressing local needs and ensuring a high quality of life in the state.

What is different today is the emphasis placed on technology-based development to support future industry cluster development. The ability of a region to lead in technology innovation and deployment in particular areas of industry is becoming a critical and defining driver of economic competitiveness. It is the intersection between industry cluster development and the advancement of specialized areas of technology know-how where competitive advantage is defined to fuel future growth. As Michael Best, a leading scholar chronicling the growth and development of industries across states and broader regions, explains in *The New Competitive Advantage*:

“[Each state and regional economy] can be thought of as developing specialized and distinctive technology capabilities, which give them unique global market opportunities. The successful pursuit of these market opportunities in turn reinforces and advances their unique regional technological capabilities. Regional specialization results from cumulative technological capability development and the unique combinations and patterns of intra- and inter-firm dynamics that underlie enterprise and regional specialization.”⁴

To identify areas where a state has strengths in technology innovation and deployment requires augmenting traditional regional economic analysis to look more closely at the “core technology competencies” found across the region’s industry, university, and federal laboratory base from a technology perspective. From a state economic development perspective, specialized know-how can be identified where there is a “critical mass” of expertise and activities across product development and productivity in industry as well as research activities in universities, hospitals and non-profit research centers. As defined by Gary Hamel and C.K. Prahalad in *Competing for the Future*,⁵ a “competence is a bundle of skills and technologies representing the sum of learning across individual skill sets and organizational units.”

By linking core technology competencies to industry clusters, it is possible for a state to identify how to position an existing industry cluster for future development and to identify the potential for advancing emerging industry clusters. In fact, core technology competencies represent a unifying thread for economic development efforts. It is the same core technology competencies that inform and guide both a

state's efforts in more home-grown development strategies to retain and grow emerging industries and its outreach marketing to attract industries to locate in the region. By being guided by core technology competencies, state efforts between home-grown and business attraction efforts are highly compatible and reinforce each other.

This analysis of Utah's technology industry clusters takes a broad view of Utah's technology-based industry clusters considering both their economic performance in recent years as well as the presence and alignment with core technology competencies found in Utah.

But to gain a detailed view of how Utah is positioned for technology-based growth, it is best to examine each of the specific technology-based industry clusters to gain the depth of analysis needed to inform Utah's Science, Technology, Talent and Innovation strategy.

Setting the Stage: Utah's Existing Industry Clusters Overall Economic Performance and Core Technology Competencies

Utah has been diligent in having its economic development efforts guided by a focus on advancing industry clusters to identify focus areas of strengths and to map both existing and emerging industry strengths to growth drivers of the national and global economy. Governor Herbert's Economic Development Plan for Utah continues to embrace the importance of building upon Utah's industry clusters: "The key is to bring industry, talent, government, universities, technology and capital together around industry sectors that possess the greatest opportunity for success. Their collective excellence allows all companies within the cluster to grow and thrive, resulting in increases in the standard of living within a region."⁶

Currently five of the seven industry clusters identified by the Utah Governor's Office of Economic Development in its Economic Cluster Initiative have a significant base of technology-based industries, as defined by the U.S. Bureau of Labor Statistics, or a strong R&D presence in industry patents or university research activities.⁷ They include:

- ***Life Sciences/Biomedical***
- ***Information Technology***
- ***Aviation & Aerospace***
- ***Defense and Homeland Security***
- ***Energy and Natural Resources.***

As Battelle considered these industries, the Aviation & Aerospace Cluster and Defense & Homeland Security were combined into a single Aerospace and Defense Cluster. This was done because of the close connections between aerospace and defense activities in Utah and the fact that the significant detailed industries found in Utah are overlapping between aerospace and defense, including the Guided Missile and Space Vehicle Propulsion industry and Search, Detection, Navigation, Guidance, Aeronautical and Nautical System and Instrument industry.

The two other industry clusters identified by the Utah Governor's Office of Economic Development are Financial Systems and Outdoor Products and Recreation, which deploy technology, but are not extensively technology-based industries.

Reviewing the Inclusiveness of Utah's Economic Cluster Initiative Definitions

The first step in Battelle's analysis of Utah's technology-based economy was to examine the range of technology-based industry activities taking place in Utah and to ensure that in light of recent economic trends the set of industry clusters set out by Utah's Economic Cluster Initiative reflect the breadth of technology-based activities taking place as of 2009, the latest year for which data are available.

Overall, Utah's Economic Cluster Initiative continues to reflect very well the specific technology-based industry strengths found in Utah. Of the nearly 117,000 jobs found in technology-based industries in Utah using the BLS definition of high technology industries, more than 58 percent were found in the four existing industry clusters.

The few significant technology-based industries not specifically included in the existing Utah Economic Cluster Initiative were found to be closely tied to the existing clusters, including:

- *Broad-based activities in administrative services industries found in Utah which support both technology headquartered firms in Utah as well as non-technology headquartered firms.*
 - In 2009, there were 17,062 jobs found in Corporate, Subsidiary and Regional Managing Offices industry in Utah, which is a separate industry classification now maintained under the North American Industry Classification System. This reflects the extensive base of headquarter and administrative operations found in Utah across both technology and non-technology firms. While a large number of jobs, it has fallen a sharp 13.8 percent in Utah since 2001, and is not highly specialized in its concentration.
 - Closely related are 2,347 jobs found in Utah in 2009 in Administrative Management and General Management Consulting Services, which again supports both technology and non-technology firms. This industry, which reflects outsourcing of administrative operations and the demand for strategic operating advice, has grown sharply in Utah since 2001, increasing employment by 164 percent through 2009, but is not very specialized, standing well below the national level of employment and suggests that the market for strategic administrative and management consulting in Utah is still maturing.
- *Technical services industries that largely support the Energy and Natural Resources Cluster.*
 - Engineering services, with 7,993 jobs in 2009 in Utah, has been growing strongly with employment gains of 38 percent from 2001 to 2009. An examination of the firms involved in this industry reveals the focus of activities is largely in supporting energy and environmental sectors. Examples of such firms include Energy Solutions in Salt Lake City and FLSmith CEntry Engineering in Midvale.

- Similarly, non-life sciences testing laboratories, stand at 1,630 jobs in 2009 and grew a hefty 34 percent from 2001 to 2009, while Non-life sciences Commercial Research and Development stood at 1,527 jobs in 2009, with healthy growth of nearly 20 percent. Most of the employment found in these non-life science testing laboratories and commercial research and development are focused on supporting the energy and environmental industries. Examples of such firms include Ceramatec and TerraTek (Schlumberger), both in Salt Lake City.
- *The remaining significant technology-based industries, employing over 1,000 workers in 2009 in Utah, represent no consistent themes:*
 - Marketing consulting services employed 2,066 workers in 2009.
 - Computer and Computer Peripheral Equipment and Software Merchant Wholesalers, which may be linked to Utah’s Information Technology Cluster, employed 1,834 workers in 2009.
 - Architectural Services employed 1,632 workers in 2009.

Economic Performance of Utah’s Industry Clusters

In economic performance, the four technology-based industry clusters found in Utah stand as either current industry strengths or specialized industry strengths. Current strengths refer to those industry clusters that have a substantially higher relative level of concentration of employment than found at the national level (20 percent or higher) and are growing in jobs. Specialized industry clusters are those that are not growing in jobs, but remain substantially above the concentration of jobs found in the nation.

The concept of relative concentration is an important measure in regional economic analysis. It measures how specialized an industry cluster is in a specific geographic area relative to the nation, and so gauges “competitive advantage” of that industry cluster relative to the nation. The specific measurement of relative concentration is known as a location quotient. A location quotient is the share of a local area’s employment found in a particular industry cluster divided by the share of total industry employment in that industry cluster for the nation. A location quotient greater than 1.0 indicates a higher relative concentration, whereas a location quotient of less than 1.0 signifies a relative underrepresentation. A location quotient greater than 1.20 denotes employment concentration significantly above the national average, and therefore is considered specialized.

Employment growth, meanwhile, offers a straightforward measure of whether an industry cluster is gaining or losing jobs in the geographic area. It is best to examine changes in employment over an entire business cycle (peak to peak) to ensure an “apples to apples” comparison. The last business cycle occurred over the 2001 to 2007 period. Since we also have data through the recent recession years of 2007 to 2009, it is helpful to also include that period. So, the period of employment change considered is from 2001 to 2009 incorporating both a full business cycle and the following recessionary period.

The results for Utah were very positive:

- **Three industry clusters—Aerospace & Defense, Energy & Natural Resources and Life Sciences—stand as current strengths.**
- **One industry cluster—Information Technology—stands as a specialized strength.**

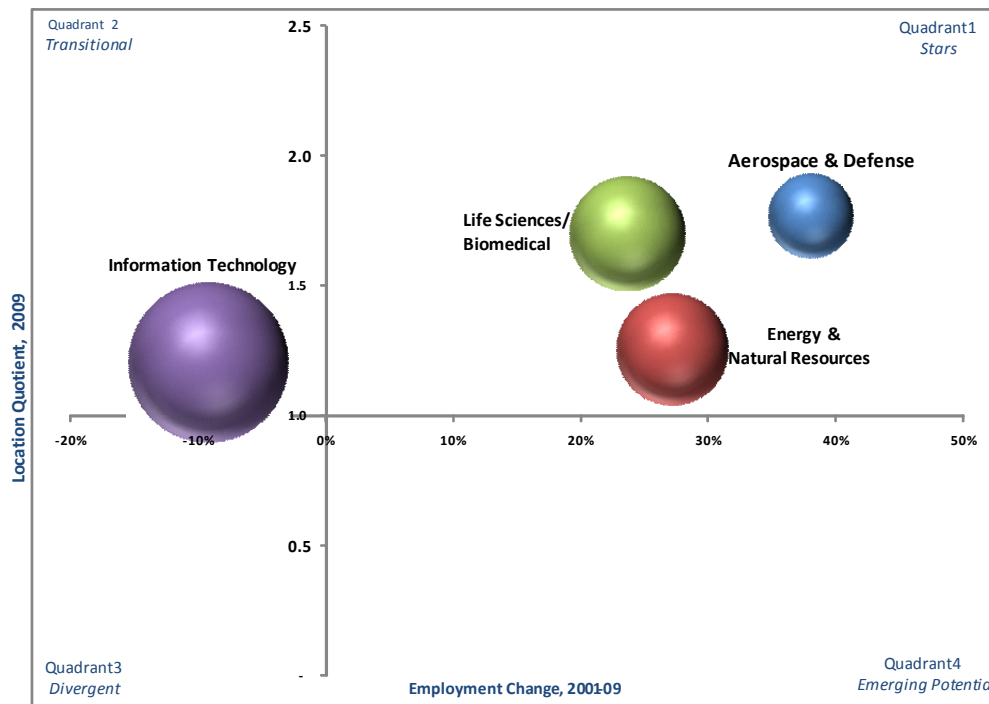
Table 1 presents the level of 2009 employment, the level of concentration and the employment changes over the 2001 to 2009 period. A good way to visualize this economic performance is through the use of “bubble” charts that present in one graphic higher or lower concentration levels along the vertical axis, job growth or decline along the horizontal axis and size of employment in 2009 by the size of the bubble. See Figure 1.

Table 1: Economic Performance of Utah’s Technology-based Industry Clusters

INDUSTRY CLUSTER	UT Employment, 2009	UT Location Quotient, 2009	UT Employment Change, 2001–09
Information Technology	46,897	1.21	-9.2%
Life Sciences/Biomedical	24,132	1.70	23.6%
Energy & Natural Resources	22,853	1.26	27.1%
Aerospace & Defense	13,034	1.77	38.0%

Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Figure 1: Bubble Chart of the Economic Performance of Utah’s Technology-based Industry Clusters

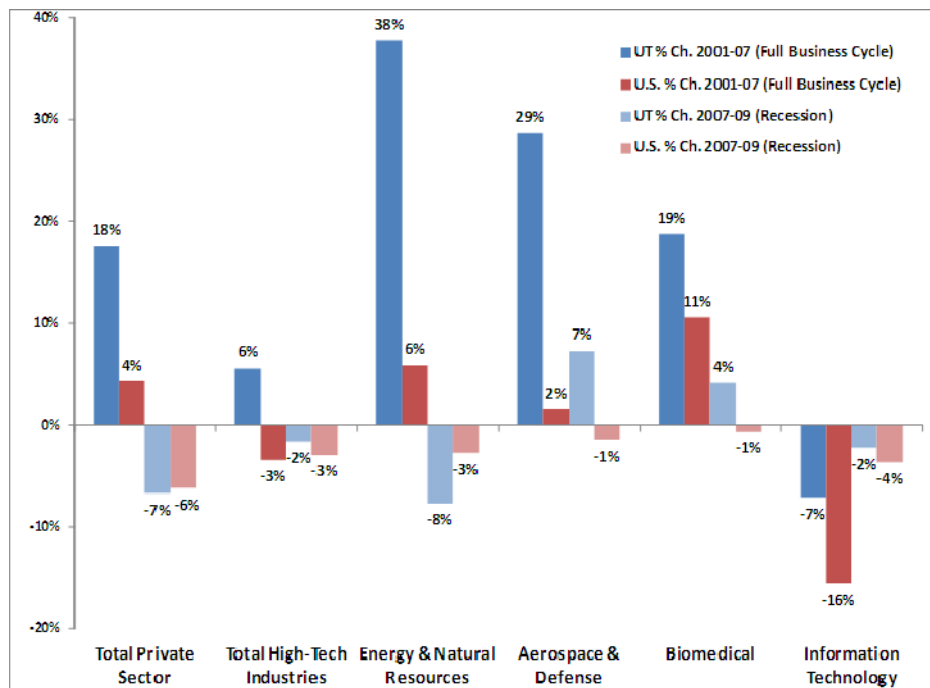


It is also important in standard regional economic analysis to consider the relative growth of an industry cluster. This third measure of regional trends examines whether a local industry cluster is gaining or

losing competitive share compared to the nation. It is measured as the difference between the percentage change in employment in an industry cluster at the local geographic level minus the percentage change in employment in that same industry cluster for the nation.

Figure 2 presents how well Utah’s technology-based industry clusters have performed compared to the nation over the last full business cycle from 2001 to 2007 and the recent recession years of 2007 to 2009. As a benchmark we also consider overall private sector employment in Utah and total technology-based industries.

Figure 2: Recent Employment Trends for Utah’s Technology-based Industry Clusters, Total Private Sector and Total Technology Industries Compared to the U.S. for 2001 to 2007 Period and 2007 to 2009 Period



Source: Battelle analysis of Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

The results generally show a positive pattern for Utah and its technology-based industries:

- **Over the last full business cycle years of 2001 to 2007, each of the technology-based industry clusters in Utah outpaced the performance of similar U.S. industries.** These higher growth levels were extraordinary for Energy & Natural Resources and Aerospace & Defense. Even, Information Technology which declined by 7 percent in Utah, did much better than the nation, which declined by 16 percent in Information Technology industries.
- **While Utah’s overall economy well outpaced the nation over the last full business cycle years of 2001 to 2007 in both total private sector employment and total technology-based industries, during the recent recession Utah declined along with the nation at comparable levels.** Utah’s private sector rose a healthy 18 percent during the 2001 to 2007 period, compared to a very modest gain of 4 percent for the nation. Total high technology industries in Utah also rose, though at a lower 6 percent level, but this level stood out compared to the

national decline of 3 percent due to the continued fall out nationally in Information Technology in the aftermath of the dot.com bust and the continued employment losses in more mature technology industries.

- **During the recession years, two technology-based industry clusters in Utah—Aerospace & Defense and Life Sciences/Biomedical—continued to make gains that outpaced the nation.** For Aerospace & Defense, the gain of 7 percent in jobs in Utah particularly stood out since the nation declined overall by 1 percent. Similarly for Life Sciences, Utah’s firms added 4 percent to their employment base while the national sector declined by 1 percent. Again, Information Technology declined in Utah by another 2 percent in the recession years, but at a much lower level than the nation. Only Energy & Natural Resources fell in Utah during the recession years at a steeper rate than the nation, 8 percent decline in Utah compared to 3 percent decline for the nation.

Assessing Core Technology Competencies Found in Utah and Their Alignment with Utah’s Technology-based Industry Clusters

Battelle used a rigorous and well-proven methodology to assess Utah’s core technology competencies or “know how” in focused technology areas. The Battelle core technology competency methodology is based on an in-depth analysis of documented activities in patent and publications activities in Utah, coupled with intelligence gathered through interviews with university officials, faculty leaders and corporate executives and further analysis of research and innovation activities in Utah.

A key starting point for identifying Utah’s core technology competencies is the use of a proprietary software tool to examine the relationships found across the abstracts of peer-reviewed publications and patents issued or applied for by Utah inventors and companies. This text analysis of the abstracts from publications and patents allows for a high-level understanding of the possible technology focus areas across higher education and industry in Utah with no “*a priori*” bias, unlike standard analyses of publications, research trends, and reputational rankings for which the research field categories are predetermined by the entities collecting the data.

Altogether, 20,106 publications and patents covering the January 2006 through June 2011 time period fell into specific identified clusters that were analyzed by Battelle. Two separate cluster analysis runs were undertaken that separately considered life sciences from non-life sciences activities since the coverage, especially in publications, is much deeper in life sciences. There were 11,677 records of publications and patents in the life sciences that grouped into distinct clusters and 8,429 records of publications and patents in the non-life sciences.

One key finding is that there is a broad range of patent and publication cluster focus areas found across Utah’s industry and university base with a strong alignment to Utah’s technology-based industry cluster. The results from the cluster analysis of patent and publication activities in Utah from 2006 through mid-year of 2011 identified 39 cluster focus areas. Battelle was able to map nearly all of these patent and publication cluster focus areas to the technology-based industry clusters found in Utah. The only patent and publication cluster focus areas not mapped to technology-based industry clusters were in transportation vehicle components, manufacturing process engineering and polymer-

based applications that spanned across many industry uses—together these three unmapped cluster focus areas represented 976 patent and publication records, or less than 5 percent of the total. Table 2 below shows the mapping of cluster themes to the technology-based industry clusters in Utah.

Table 2: Mapping of Patent and Publication Cluster Focus Areas in Utah into Utah Technology-Based Industry Clusters

Technology-based Industry Cluster	Number of Patents and Publications	Patent and Publication Cluster Focus Areas
Aerospace & Defense	1236	<ul style="list-style-type: none"> ○ Automation & Control ○ Sensor and Sensor Systems ○ Aerospace-related Materials ○ Space Sciences
Energy & Natural Resources	3141	<ul style="list-style-type: none"> ○ Oil, Gas and Resource Mining Tools ○ Energy Conversion and Storage ○ Water and Soil Conservation ○ Atmospheric Sciences ○ Earth Science ○ Ecology ○ Range and Forest Sciences ○ Animal Health and Sustainability
Information Technology	3076	<ul style="list-style-type: none"> ○ Networking ○ Information and Data Systems Management ○ Semiconductor and Solid-State Devices ○ Image Processing ○ Optical Sciences ○ E-Commerce ○ Signal Processing ○ Information Security ○ Communications Processing Technologies ○ Data Storage and Memory
Life Sciences	11,677	<ul style="list-style-type: none"> ○ Surgical Instruments, Equipment and Devices ○ Genomics and Biologics ○ Neurosciences ○ Cancer Research and Treatments ○ Musculoskeletal Implants and Devices ○ Psychology and Behavioral Research ○ Cardiovascular and Pulmonary Diseases and Conditions ○ Drug Development and Delivery ○ Infectious Diseases, Pathogens and Immunology ○ Reproductive Medicine ○ Molecular Genetics and Cell Biology ○ Medical Imaging ○ Diabetes ○ Transplantation and Stem Cell Therapies ○ Natural Products ○ Ophthalmology ○ Ion Channel Research

The Battelle team then examined several other technology-related factors to shed light on Utah’s core technology competency areas. These included:

- Industry Cluster Value-Added Per Employee:** Industry technology competencies are more than just advancing new products and processes. Just as critical, if not as widely heralded, is the ability of industry to “put technology to work.” To assess Utah’s position in technology deployment an analysis of value added output per employee was undertaken to see how well the four technology-based clusters in Utah compare to the U.S. overall. Value added output measures output after subtracting out the cost of inputs to production. Higher value-added per employee suggests more effective deployment of technologies in production as well as an ability to produce more complex, higher-value products. Battelle calculated value added per employee from data on employment and value-added economic output reported for industries in Utah and the U.S. by IMPLAN.

Across all of the technology-based industry clusters, Utah stands below the U.S. levels of value-added per employee. While there are a few detailed industry sectors in which Utah exceeds the U.S. average, the consistency of Utah’s lower value-added per employee points to a more significant challenge of how to put technology to work to raise the value added of its industrial production. This can happen through the use of technology to develop more complex, higher valued products or to raise productivity of operations in Utah.

Table 3: Value Added Per Employee for Technology Based Industry Cluster: Utah Compared to U.S.

	Utah Value-Added Per Employee	U.S. Value-Added Per Employee	Utah Percentage of U.S. in Value-Added Per Employee
Aerospace & Defense	\$129,756	\$150,062	87%
Energy & Natural Resources	\$293,860	\$304,843	96%
Information Technology	\$99,458	\$147,845	67%
Life Sciences	\$106,379	\$120,313	88%

Source: Battelle calculations using IMPLAN data.

- Publications activity:** Publications in peer-reviewed journals is a key indicator of scholarly activity, typically led by universities and non-profit research organizations in a state. Two measures of publications activity capture how specific fields of research stand out within the universities of a state. One is the share of U.S. publications, which measures level of activity, and the other is the state’s level of citations per publication compared to the U.S. average for that field, which offers a perspective on the quality of publications generated. Both of these measures are provided by Thomson Reuters’ University Science Indicators database that tracks major university and medical center publications activity across well over 200 discrete research fields associated with specific peer-reviewed journals.

A breadth of scholarly excellence is found in Utah. Battelle identified 64 publication fields of note in Utah falling into one of three categories:

- High Share/High Quality Publication Fields – This includes 26 fields that had at least a 1.5 percent share or greater of all U.S. publications from 2005 to 2009 and a citations per publication level at least 40 percent higher than for the U.S. average.
- High Share Only Publication Fields – This includes 26 fields that had at least a 2 percent share or greater of all U.S. publications from 2005 to 2009.
- High Quality Only Publication Fields – This included 12 fields that a citation per publication level at least twice the U.S. average with at least 50 publications from 2005 to 2009.

Table 4 below presents the listing of these fields, which crosswalk well to Utah’s technology-based industry clusters.

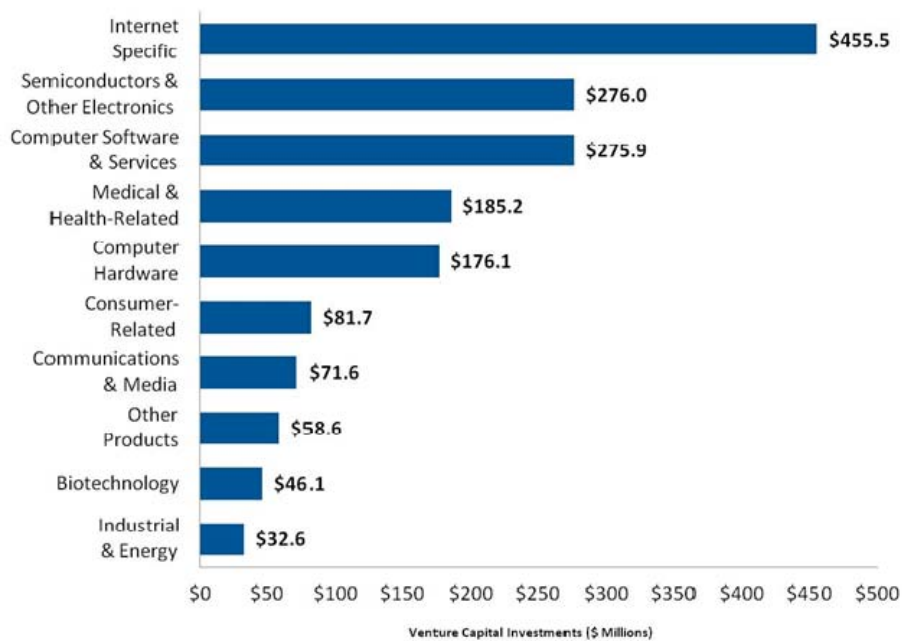
Table 4: Utah Publications and Citations, 2005 –2009

	High Share/High Quality: Publication Fields with High Citations Per Publication (> 40 percent) and High Share of U.S. (> 1.5 percent)	High Share Only: Publication Fields with High Share of U.S. (> 2 percent)	High Quality Only: Publication Fields with High Citations Per Publication (Twice Nat’l. Level) and >50 Publications
Aerospace & Defense	<ul style="list-style-type: none"> • Automation & Control Systems 		
Energy & Natural Resources	<ul style="list-style-type: none"> • Geochemistry & Geophysics • Meteorology/Atmospheric Sci. • Soil Sciences 	<ul style="list-style-type: none"> • Biodiversity Conservation • Ecology • Energy & Fuels • Mineralogy • Mining/Mineral Processing 	<ul style="list-style-type: none"> • Environmental Eng • Environmental Science
Information Technology		<ul style="list-style-type: none"> • Software Engineering • Applied Math 	<ul style="list-style-type: none"> • Telecommunications
Life Sciences	<ul style="list-style-type: none"> • Anatomy & Morphology • Biomaterials • Biophysics • Cardiovascular Systems • Critical Care Medicine • Developmental Biology • Evolutionary Biology • Genetics & Heredity • Hematology • Med Lab Technology • Pharmacology/Pharmacy • Psychology • Rehabilitation • Toxicology • Transplantation • Urology & Nephrology 	<ul style="list-style-type: none"> • Ag Dairy/Animal Sciences • Biochemistry & Mol Biology • Biomedical Engineering • Clinical Neurology • Clinical Psychology • Nursing • Neurosciences • Obstetrics & Gynecology • Ophthalmology • Orthopedics • Otorhinolaryngology • Physiology 	<ul style="list-style-type: none"> • Cell Biology • Endocrinology & Metabolism • Geriatrics • Neuroimaging • Nutrition & Dietetics • Peripheral Vascular Disease • Rheumatology
Other Fields and/or Crosscutting	<ul style="list-style-type: none"> • Analytical Chemistry • Imaging Sciences • Metals and Metal Eng • Organic Chemistry • Physical Chemistry • Thermodynamics 	<ul style="list-style-type: none"> • Civil Engineering • Composites • Manufacturing Engineering • Plant Sciences • Robotics • Transportation • Zoology 	<ul style="list-style-type: none"> • Nanosciences • Particle Physics

Source Battelle analysis of Thomson Reuters University Science Indicators database.

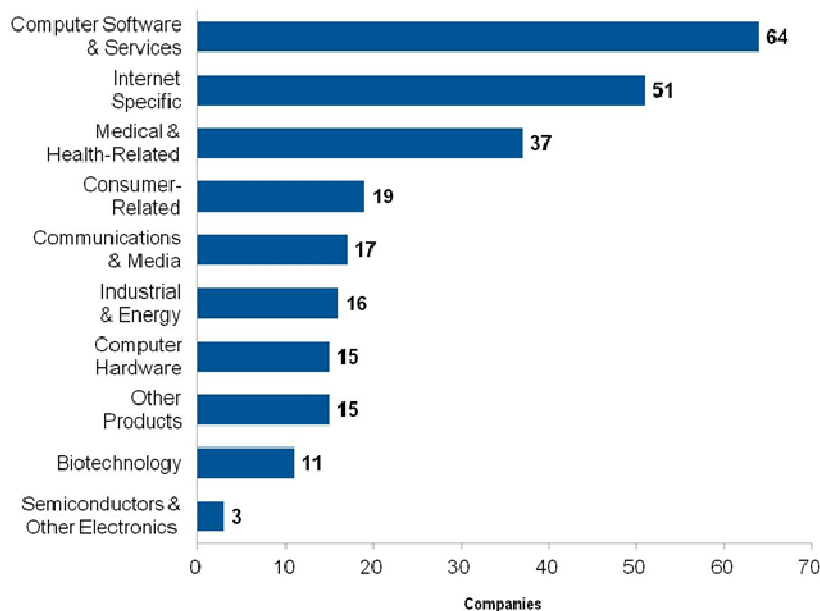
- Presence of innovative emerging venture-backed companies:** Innovation is often brought forward through emerging high growth potential companies. A good way to understand whether an industry sector possesses such companies is to examine the extent of emerging companies that have received venture financing in recent years. Battelle used venture financing reported by VentureOne.
 - Information technology dominates in terms of generating venture capital funding, receiving nearly 66 percent of all venture capital funding over the 2006 to 2nd quarter 2011 period. This includes 27.5 percent of all Utah venture capital investment going to Internet-specific companies, 16.6 percent of the investment going to Semiconductors and Other Electronics, another 16.6 percent in Computer Software and Services companies and 5.1 percent to Communications companies. Another major sector receiving venture capital funding over the 2006 to 2nd quarter 2011 period was the biomedical sector with 13 percent going to medical therapeutics and devices and 3 percent going to biotechnology-related ventures. See Figure 3 and 4.

Figure 3: Key Sectors Receiving Venture Financing in Utah, 2006 through 2011, 2nd Quarter



Source: Battelle analysis of Thomson Reuters, Thomson One database.

Figure 4: Companies in Key Sectors Receiving Venture Financing in Utah, 2006 through 2011, 2nd Quarter



Source: Battelle analysis of Thomson Reuters, Thomson One database.

Detailed Analysis of the Line of Sight to Growth Opportunities for Each of Utah's Technology-based Industry Clusters

It is important to consider each technology-based industry cluster in more depth to examine how it is positioned for technology-based growth. In today's globally-based economy, the key to success for states is to identify those growth opportunities within its leading industry sectors for which it is best positioned to differentiate itself and become a world leader. This is a critical best practice lesson in economic development for states in the 21st century global economy.

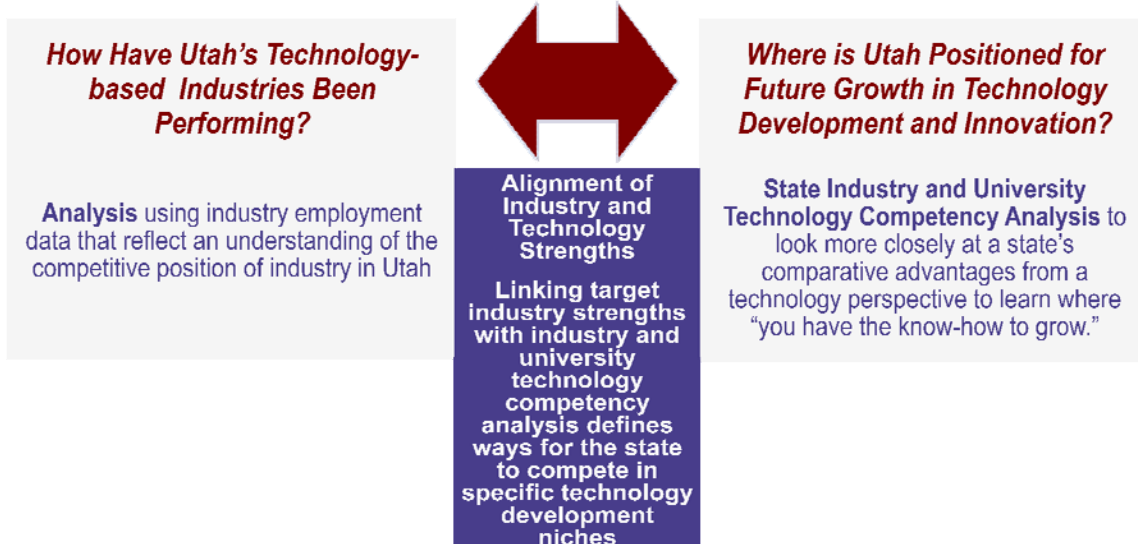
The approach taken to identify growth opportunities within each technology-based industry cluster is to consider the alignment of two key factors:

- Detailed industry-level analysis of specific product and service focus areas found in Utah to identify the drivers of major technology industry sector growth in Utah.⁸
- Technology competencies found within each of the technology-based industry clusters in Utah. As mentioned earlier, technology competencies represent focused areas of "know how" where there is demonstrated critical mass in Utah. The starting point for defining these technology competencies is the patent and publication cluster focus areas.
- Battelle then validated these patent and publication cluster focus areas from interviews with industry and university leadership and determined how they could best be grouped into broader core technology competencies reflecting further analysis of key measures of industry and scholarly activities, including:
 - Focus of scholarly excellence in Utah based on performance of research universities in peer-reviewed publications analysis.

- Identified research centers and major research activities found across Utah’s research universities, based on Battelle’s interviews and review of major grants and web sites.
- Level of technology deployment as suggested by value-added per employee for detailed industry segments.
- Presence of innovative, emerging technology firms, based on firms receiving venture capital funding between 2006 and 2011 (2nd quarter).

By linking core technology competencies to specific industry strengths within an overall industry cluster, it is possible to define not only where a state has demonstrated the ability to advance industry development but where it has the know how to continue to fuel innovation and further distinguish areas of growth. This approach is depicted in Figure 5.

Figure 5: Alignment of Detailed Industry Strengths and the Presence of Core Technology Competencies



A detailed description of the methodology and findings for each technology-based industry cluster is contained in Appendix A.

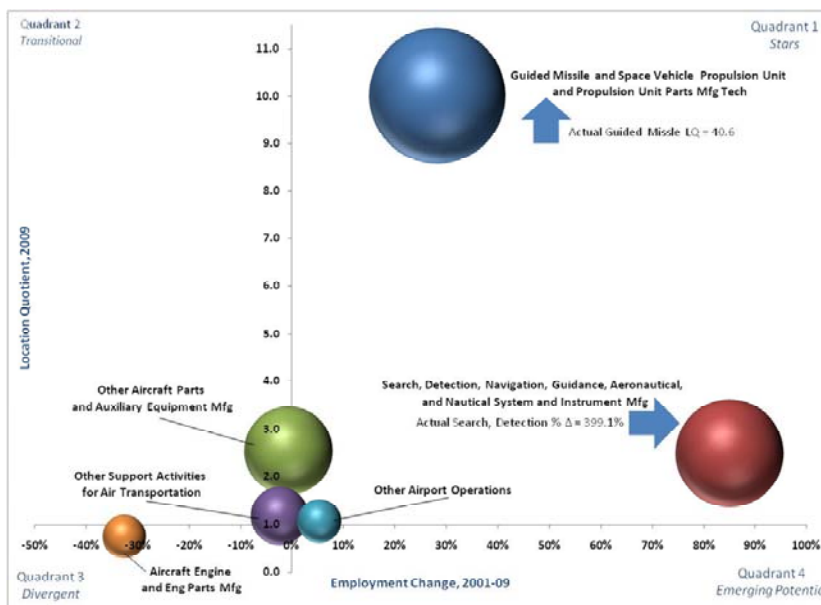
Aerospace & Defense

The Aerospace & Defense industry cluster grew rapidly over the 2001 to 2009 period, increasing its employment base in Utah by 38 percent, while the national Aerospace & Defense industry cluster remained flat in employment. By 2009, Utah's Aerospace & Defense cluster reached 13,034 jobs in 2009, and it stands as a highly specialized industry with a 77 percent higher level of employment concentration in Utah than nationally.

Detailed Industry Strengths

Six detailed industries comprise the Aerospace and Defense industry cluster, and Utah stands out in three out of the six as set out in the bubble chart in Figure 6.

Figure 6: Economic Performance of Utah's Aerospace and Defense Industries, 2009



Two detailed industries stand as current strengths, being both specialized in industry concentration in 2009 and growing in employment from 2001 to 2009, including:

- Guided Missile and Space Vehicle Propulsion Unit and Parts Manufacturing.
- Search, Detection, Navigation, Guidance, Aeronautical and Nautical System and Instrument Manufacturing.

One detailed industry stands as specialized in its level of industry specialization:

- Aircraft Parts (not including engines).

Linkage to Core Technology Competencies

Four core technology competencies, aligned with the patent and publication cluster focus areas related to Utah’s Aerospace & Defense Industry Cluster, were validated from the interviews and further analysis of industry and scholarly activities, including:

- Automation and Control
- Sensors and Sensor Systems
- Aerospace-related Materials
- Space Sciences.

Table 5: Core Technology Competencies Within the Aerospace and Defense Industry Cluster

Core Technology Competencies	Breadth of Patent and Publications Clusters	Productivity	Publications	Presence of Detailed Industry Strengths	Presence of Venture-backed Companies
	<ul style="list-style-type: none"> ●●● Clusters with 750 or more records ●● Clusters with 250-749 records ○ Clusters with less than 250 records 	<ul style="list-style-type: none"> ●●● Industry sectors with 106% or higher than U.S. average ●● Industry sectors 95% to 105% of U.S. average ○ Industry sectors Less than 95% of U.S. average 	<ul style="list-style-type: none"> ●●● Fields that are both high impact and high share ●● Fields with either high share or high impact ○ No fields with high share and/or high impact 	<ul style="list-style-type: none"> ●●● Detailed industry with current strength ●● Detailed industry that is either emerging or specialized strength ○ No detailed industry either current, emerging or specialized strength 	<ul style="list-style-type: none"> ●●● 5 or more ●● 1-4 ○ None
Automation & Control	○	N/A	●●●	●●●	○
Sensors & Sensor Systems	●●	N/A	●●●	●●●	○
Aerospace Related Materials	●●	○	●●	●●	○
Space Sciences	●●	●●	○	●●●	○

Possible Opportunities for Future Growth

From discussions with industry executives and university leadership as well as guidance from the recent Aerospace & Defense cluster acceleration strategy supported by the Utah Higher Education System, Battelle suggests two specific niches stand out for Utah:

- **Unmanned Aerial Systems** – Unmanned aerial systems (UAS), often referred to as drones, are aircraft systems that operate without a flight crew on-board either by remote control or autonomously. UAS are being used extensively by the military either for surveillance or attack missions. But the applications of UAS can be quite extensive from transportation, homeland security

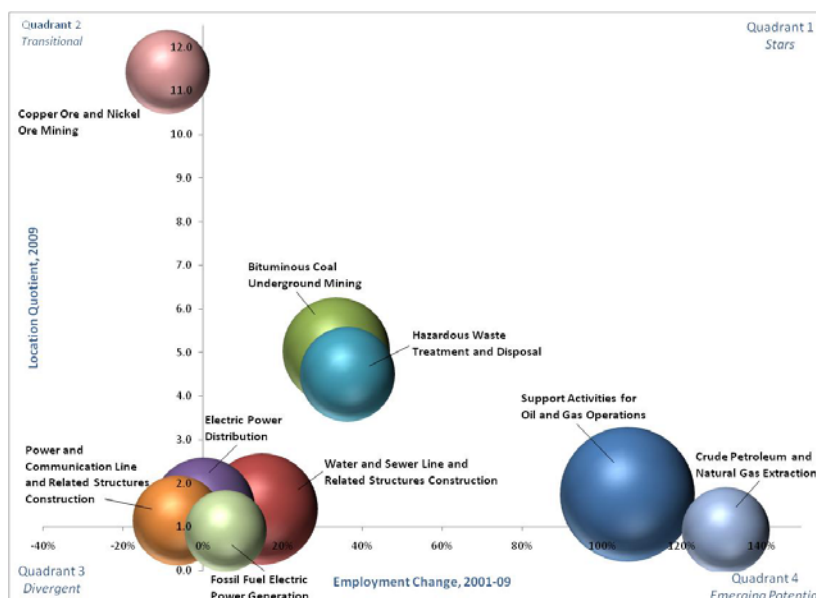
and law enforcement surveillance, performing geophysical surveys for oil, gas and mineral exploration, and hunting hurricanes, among other uses. UAS are highly advanced inter-disciplinary technology systems calling for advances in automation and control, remote sensing, sensing data management systems, power and propulsion and aircraft materials and design. While there are other states with opportunities in unmanned aerial systems, particularly those with a strong presence of military bases and/or defense contractors, such as Ohio and Arizona, it is an opportunity area that Utah is well positioned due to the activities of Hill Air Force Base as well as its defense contractors and universities.

- Advanced Aerospace Materials** – The need for advanced composites that provide light weight, with greater strength and durability is critical for advancing airframes, and particularly extending the life of existing aircraft. The ability to easily fabricate composites into nearly any shape will also increase applications advanced composites in the aerospace market. Among the key new applications is the use of carbon fiber made from a continuous matrix reinforced with dispersed fibers along with an interfacial region. Titanium alloys are another key material used in modern airframes. Titanium is relatively inexpensive, widely available and provides favorable properties including a high strength-to-weight ratio and superior corrosion resistance. In addition, advanced coatings are critical to protect from heat and corrosion, as well as to offer smart functionality to identify structural defects and self-repairing properties.

Energy & Natural Resources

The Energy & Natural Resources industry cluster in Utah grew at a healthy rate of 27.1 percent from 2001 to 2009, compared to fewer than 3 percent nationally. While it did decline by 8 percent during the recession years of 2007 to 2009, it still employed 22,853 workers in 2009, which represents a 26 percent higher employment concentration in Utah than the nation, and so has reached the level of industry specialization.

Figure 7: Bubble Chart of the Performance of Utah’s Energy and Natural Resources Industry Cluster



Detailed Industry Strengths

The Energy & Natural Resources industry cluster is very broad involving 16 detailed industries employing over 500 workers in Utah as of 2009. Three distinct detailed industry groupings emerge: two that are fast growing and a third that is highly specialized but not growing in jobs:

Fossil-based energy industries offer a mix of sizable and growing industries, many of which are specialized, including:

- Support Activities for Oil and Gas Operations – Both specialized and gaining jobs from 2001 to 2009
- Bituminous Coal Underground Mining – Both specialized and gaining jobs from 2001 to 2009
- Petroleum Refineries – Both specialized and gaining jobs from 2001 to 2009
- Crude Petroleum and Natural Gas Extraction – Both specialized and gaining jobs from 2001 to 2009
- Fossil Fuel Electric Power Generation – Gaining jobs from 2001 to 2009, but not yet specialized.

Environmental technologies and services also offer a mix of sizable and growing industries, many of which are specialized.

- Water and Sewer Line and Related Structures Construction – Both specialized and gaining jobs from 2001 to 2009
- Hazardous Waste Treatment and Disposal – Both specialized and gaining jobs from 2001 to 2009
- Environmental Consulting Services – Gaining jobs from 2001 to 2009, but not yet specialized.

Metals mining offers more modest sized industries that are not growing, but are highly specialized due to the unique presence of metal resources in Utah.

- Primary Smelting and Refining of Copper – Both specialized and gaining jobs from 2001 to 2009
- Copper Ore and Nickel Ore Mining – Specialized, but not growing in jobs from 2001 to 2009
- Primary Smelting and Refining of Nonferrous Metal – Specialized, but not growing in jobs from 2001 to 2009.

Linkage to Core Technology Competencies

Similar to the breakout of detailed industry strengths, there emerge two distinct areas of core technology competencies related to the Energy and Natural Resources industry cluster from the patent and publication cluster analysis, interviews with university and industry leaders and further analysis of industry and scholarly activities.

One distinct area is in energy with two core technology competencies that track well to the patent and publication cluster focus areas:

- Oil, Gas and Resource Mining Tools
- Energy Conversion and Storage.

Another distinct area is in the environmental area where Utah has a core technology competency in Environment, Ecology, Water and Atmospheric Sciences, which encompasses a rich base of patent and publication cluster focus areas, including

- Ecology
- Water and Soil Conservation
- Atmospheric Sciences
- Range and Forest Sciences
- Earth Science
- Animal Health & Sustainability.

Table 6: Core Technology Competencies Within the Energy and Natural Resources Industry Cluster

Core Technology Competencies	Breadth of Patent and Publications Clusters ●●● Clusters with 750 or more records ●● Clusters with 250–749 records ○ Clusters with less than 250 records	Productivity ●●● Industry sectors with 106 percent or higher than U.S. average ●● Industry sectors 95 percent to 105 percent of U.S. average ○ Industry sectors Less than 95 percent of U.S. average	Publications ●●● Fields that are both high impact and high share ●● Fields with either high share or high impact ○ No fields with high share and/or high impact	Presence of Detailed Industry Strengths ●●● Detailed industry with current strength ●● Detailed industry that is either emerging or specialized strength ○ No detailed industry either current, emerging or specialized strength	Presence of Venture-backed Companies ●●● 5 or more ●● 1–4 ○ None
Oil, Gas and Resource Mining Tools	●●	●●●	●●●	●●●	●●
Energy Conversion and Storage	●●	N/A	●●●	○	○
Environment, Ecology, Water and Atmospheric Sciences	●●●	○	●●●	●●●	●●

Possible Opportunities for Future Growth

From interviews with industry executives and university leadership as well as guidance from the Governor’s 10 year Energy Plan, the Energy cluster acceleration strategy supported by the Utah Higher Education System, and a focus group discussion with environmental organizations, Battelle suggests three specific niches stand out for Utah in Energy and Natural Resources:

- Clean Technologies for Traditional and Unconventional Sources of Fossil Energy:** With continued global development, the demands for increased energy generation will continue to mount. Despite the rising interest in renewable energy sources, the U.S. Energy Information Agency estimates that fossil based sources of energy will remain quite significant with liquid fuels, largely comprising petroleum-based fuels, meeting 31.8 percent of global demand by 2030, coal 28 percent and natural gas 23 percent. Since we cannot in the near- to mid-term displace fossil fuels with renewable energy technologies, the importance of mitigating environmental impacts of fossil based energy sources through clean energy technologies is important. One important focus of clean energy technologies is clean coal technology. Clean coal technologies have a long history starting with the earliest techniques that were aimed at cleaning or pre-combustion “washing” of coal. The Department of Energy’s CO₂ program is pursuing evolutionary improvements in existing CO₂ capture systems and also exploring revolutionary new capture and sequestration concepts. Another focus area of clean energy technologies is addressing the environmental impacts from extracting black wax and shale oil and gas reserves. As the extraction of black wax and shale reserves in states such as Utah grows, so

do environmental issues and opportunities related to the use and reprocessing of water resources through advanced current methods.

Both Utah's 2011 Strategic Energy Plan and the Energy UCAP call for more focused research into clean energy technologies. The 2011 Strategic Energy Plan sets out the need for a "research triangle" of Utah's three research universities placing an "emphasis on clean technology for fossil fuels (i.e., gasification, carbon capture and sequestration, unconventional fuel, etc.) and the interface with other energy forms" (Page 7). The Energy UCAP identifies as among the growth accelerators for Utah "innovate clean coal technologies for increased coal production" and enable oil shale/oil sands/shale gas production" (Page 19).

- **Energy Storage and Power Delivery Systems** – Energy storage is an enabling technology that allows us to power personal electronics and use energy more efficiently and responsibly through plug-in electric hybrid vehicles and renewable energy sources. Efficient energy storage systems can make electronics last longer with less frequent charging, start or power vehicles, and ensure that energy derived from solar or wind power is available for use long after sunset or when the wind stops blowing. Batteries are an important solution to energy storage needs, and new technological innovations are enabling them to have longer running time, produce higher voltage, reduce emissions, reduce recharge time, and increase the number of recharges while increasing safety. Batteries store energy in the form of chemical energy; when connected in a circuit the battery can produce electricity.

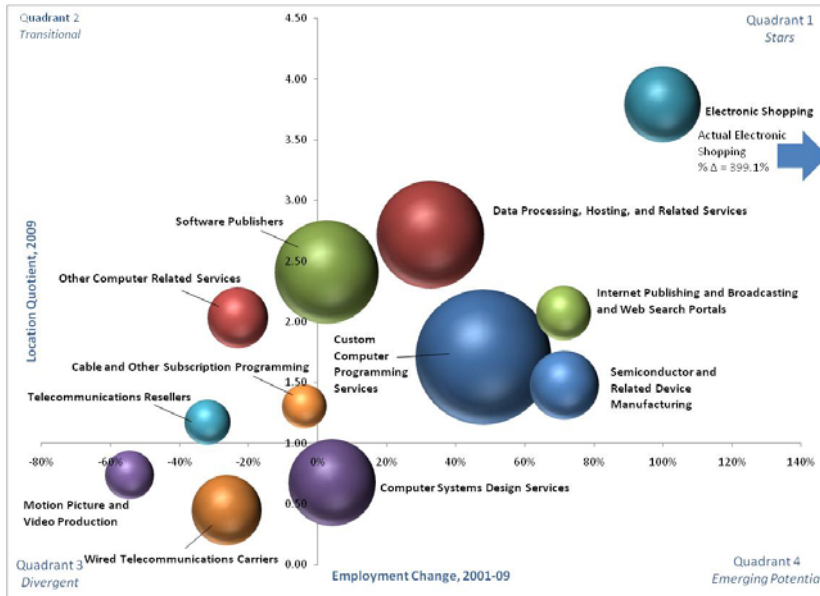
Information Technology

The Information Technology cluster in Utah is the largest among the technology-based clusters in the state, with 46,897 jobs in 2009. It just crosses the threshold of being a specialized industry cluster having a 21 percent higher level of concentration in Utah than found in the nation. Along with the nation, the Information Technology cluster fell in employment from 2001 to 2009, though at a lower level of 15.2 percent compared to the national decline of 25.2 percent. This reflects both the sharp fall-off from the heights of the dot.com boom and the continued pressure from global information technology outsourcing.

Detailed Industry Strengths

The Information Technology cluster is far-ranging covering detailed industries involved in software development, digital media, Internet, telecommunications and electronics. There are 19 detailed industries in Information Technology that employ more than 500 workers in Utah. Of these 19 detailed industries, six detailed industries stand as specialized and growing, two stand as growing but not yet specialized and four stand as specialized but declining in employment. One negative finding was that productivity was consistently lower across the information technology industries in Utah than for the U.S. This suggests that Utah's information technology sector is likely generating less valued products and undertaking more labor intensive activities in the Information Technology sector. This is an issue that exists across the technology sectors in Utah.

Figure 8: Bubble Chart of the Performance of Utah's Information Technology Industry Cluster



The six detailed industries in Information Technology that are current strengths, being both specialized in industry concentration in 2009 and growing in employment from 2001 to 2009, include:

- Custom Computer Programming Services
- Data Processing, Hosting and Related Services
- Software Publishers
- Electronic Shopping
- Semiconductor and Related Device Manufacturing
- Internet Publishing, Broadcasting and Web Search Portals.

Two detailed industries in Information Technology are emerging strengths, growing in jobs but not yet specialized, including:

- Computer Systems Design Services
- Other Electronic Component Manufacturing.

There are four detailed industries in Information Technology that stand as specialized strengths, with higher levels of industry concentration than found in the nation, but not growing in jobs over the 2001 to 2009 period, including:

- Other Computer Related Services
- Cable and Other Subscription Programming

- Bare Printed Circuit Board Manufacturing
- Audio and Video Equipment Manufacturing.

Linkage to Core Technology Competencies

Two core technology competencies relating to the Information Technology industry cluster were identified from the patent and publication cluster analysis, interviews with university and industry leaders and further analysis of industry and scholarly activities – one in information systems and the other in electronics & processing technologies. Each of these two technology competencies group together a set of patent and publication cluster focus areas.

The **Information Systems** technology competency encompasses the following patent and publication cluster focus areas:

- Networking
- Information and Data Systems Management
- E-commerce
- Information Security.

The **Electronics and Processing Technologies** technology competency encompasses the following patent and publication cluster focus areas:

- Semiconductor and Solid-State Devices
- Image Processing
- Optical Sciences
- Signal Processing
- Communications Processing Technologies
- Data Storage & Memory.

Table 7: Core Technology Competencies Within the Information Technology Industry Cluster

Core Technology Competencies	Breadth of Patent and Publications Clusters ●●● Clusters with 750 or more records ●● Clusters with 250-749 records ○ Clusters with less than 250 records	Productivity ●●● Industry sectors with 106 percent or higher than U.S. average ●● Industry sectors 95 percent to 105 percent of U.S. average ○ Industry sectors Less than 95 percent of U.S. average	Publications ●●● Fields that are both high impact and high share ●● Fields with either high share or high impact ○ No fields with high share and/or high impact	Presence of Detailed Industry Strengths ●●● Detailed industry with current strength ●● Detailed industry that is either emerging or specialized strength ○ No detailed industry either current, emerging or specialized strength	Presence of Venture-backed Companies ●●● 5 or more ●● 1-4 ○ None
Information Systems	●●●	○	●●	●●●	●●●
Electronics and Processing Technologies	●●	●●	●●	●●	●●●

Possible Opportunities for Future Growth

From interviews with industry executives and university leadership as well as the guidance from Digital Media cluster acceleration strategy supported by the Utah Higher Education System, Battelle suggests two specific niches stand out for Utah in Information Technology:

- Networked Information Systems:** The use of computer software and networks to advance business operations has been underway for more than a generation. Today, advanced information systems has been dramatically changing with the rapid deployment of the Internet, which is leading a new era some have called “ubiquitous networking” where computing and communications technologies are converging. With the advent of ubiquitous networks, businesses no longer will be bound by physical locations and their interactions with customers will profoundly change as the use of computer/network-driven technology becomes pervasive. Related to this advancement of Networked Information Systems are key activities including:

 - Cloud computing which refers to both the applications delivered over the internet and the hardware and systems software at datacenters that enable the services to be delivered. Cloud computing may be best understood as “computing as a utility”; a technological shift similar to the change from on-site electrical generation to plugging into the electrical grid at the turn of the 20th century.
 - Information security, which in the context of the highly networked enterprise goes well beyond placing data behind a firewall as information attacks today are aimed at entire processes. Identity management, intrusion detection systems/antivirus, and security management are among the most active approaches to addressing information security needs.

- Business analytics and Knowledge Management providing organizations with timely access to relevant data reporting and analysis, including online analytical processing (OLAP) tools providing multi-dimensional data management environment to model business problems and analyze data, data mining technologies such as neural networks, rule induction and clustering to discover relationships in data and make predictions, and packaged data mart/warehouse products that are preconfigured software that combine data transformation, management and access in a single package, usually with modeling software included.
- **Video Gaming and Other Digital Media:** Digital media has emerged as a high value and broad economic driver. Digital media technologies are leading the convergence of information technology, communications and content. As Gartner, a leading market research firm, explains the “convergence of technologies is allowing users to access and exchange information and content in ways that were not possible before. Industries such as media and communications that once had clearly defined boundaries are seeing business models converge and perhaps collide as technologies change the possibilities.”⁹ The primary digital media industries today include not only the traditional industries of movie, video and television production, but newly emerging industries involved in video gaming and digital rendering software. It is not only in the emergence of video gaming and video rendering software that digital media stands out, but in how pervasive digital media technologies are becoming across industries today to make it possible to access digital content virtually anywhere and at anytime. A broader definition of digital media certainly needs to incorporate advertising, marketing, e-commerce and Internet publishing and portals.

Life Sciences/Biomedical

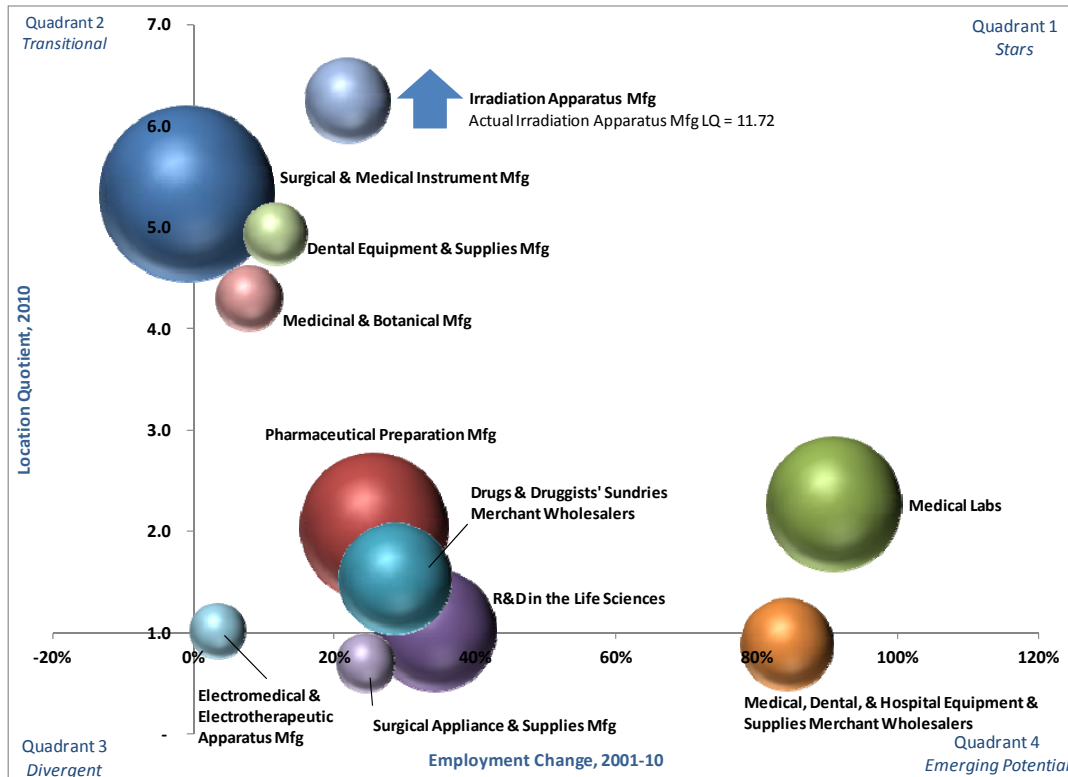
The life sciences industry cluster is both specialized and growing in Utah. In 2010, it stood at 22,983 jobs, which translates into an 82 percent higher employment concentration in Utah than the nation. Employment in the life sciences industry also grew a healthy 25.8 percent over the 2001 to 2010 period, which included a 9.2 percent increase in jobs from 2007 to 2010, a period which includes the deep recession years of 2008 and 2009 and the nascent recovery that began in 2010.

The life sciences industry is composed of four subsectors including Medical Devices and Equipment; Drugs and Pharmaceuticals; Research, Testing, and Medical Labs; and Biomedical Distribution. It is important to note that the life sciences industry is closely related to but not the same as healthcare industry, which provides direct clinical services. The breadth of Utah’s life sciences industry cluster comes across, since all of these subsectors of the life sciences are specialized and growing rapidly in Utah.

Detailed Industry Strengths

At the detailed industry level, there are 11 industries within the life sciences industry cluster with 500 or more jobs in 2010—all are either specialized and/or growing in employment.

Figure 9: Economic Performance of Utah's Life Science Industries, 2010



Six of the 11 detailed life sciences industries are both specialized and growing, including:

- Pharmaceutical Preparation Manufacturing
- Medical Laboratories
- Drugs Wholesalers
- Irradiation Apparatus Manufacturing
- Medicinal and Botanical Manufacturing
- Dental Equipment and Supplies Manufacturing.

Four of the 11 detailed life sciences industries are growing in jobs, but not yet specialized in the concentration of industry employment in Utah.

- Life Sciences Commercial Research & Development
- Medical, Dental, and Hospital Equipment and Supplies Wholesalers
- Surgical Appliance and Supplies Manufacturing
- Electromedical and Electrotherapeutic Apparatus Manufacturing.

One of the 11 detailed life sciences industries is highly specialized, but not growing in jobs:

- Surgical and Medical Instrument Manufacturing.

It is important to note that natural products and dietary supplement firms fall in various industry classifications including pharmaceuticals, biomedical distribution industries, and other food and beverage categories.

Linkage to Core Technology Competencies

Four core technology competencies were identified and validated from the patent and publication cluster analysis, interviews with university and industry leaders and further analysis of industry and scholarly activities.

The Medical Device core technology competency encompasses five patent and publication cluster focus areas, including:

- Surgical Devices, Catheters, Instruments, and Equipment
- Cardiovascular & Pulmonary Diseases and Conditions
- Medical Imaging
- Musculoskeletal Implants and Devices
- Ion Channel Research.

The Disease Research, Drugs and Pharmaceutical core technology competency encompasses eight patent and publication cluster focus areas, including:

- Drug Development & Discovery
- Cancer Research and Treatments
- Neurosciences
- Infectious Diseases, Pathogens and Immunology
- Reproductive Medicine
- Diabetes
- Transplantation and Stem Cell Therapies
- Ophthalmology.

The Basic Biological Research core technology competency encompasses two patent and publication cluster focus areas:

- Genomics and Biologics:
- Molecular Genetics and Cell Biology.

The Natural Products core technology competency aligns with the natural products patent and publication cluster focus area.

Table 8: Core Technology Competencies Within the Life Science Industry Cluster

Core Technology Competencies	Breadth of Patent and Publications Clusters	Productivity	Publications	Presence of Detailed Industry Strengths	Presence of Venture-backed Companies
Medical Device Related	●●● Clusters with 750 or more records ●● Clusters with 250-749 records ○ Clusters with less than 250 records	●●● Industry sectors with 106 percent or higher than U.S. average ●● Industry sectors 95 percent to 105 percent of U.S. average ○ Industry sectors Less than 95 percent of U.S. average	●●● Fields that are both high impact and high share ●● Fields with either high share or high impact ○ No fields with high share and/or high impact	●●● Detailed industry with current strength ●● Detailed industry that is either emerging or specialized strength ○ No detailed industry either current, emerging or specialized strength	●●● 5 or more ●● 1-4 ○ None
Disease Research, Drugs and Pharmaceutical Related	●●●	○	●●●	●●●	●●
Basic Biological Research Related	●●●	○	●●●	●●●	●●●
Natural Products	○	N/A	●●	N/A	○

Possible Opportunities for Future Growth

From interviews with industry executives and university leadership as well as ongoing input from the Life Sciences cluster acceleration strategy steering committee, Battelle suggests several specific niches stand out for Utah in Life Sciences set out below. These opportunities for future growth not only relate to growing market areas, but offer a means to bring an increased level of innovation to the overall life sciences/biomedical industry sector, which is critical to raising the low value added per worker found in Utah.

- **Novel Medical Devices:** A medical device is a product involved in diagnosis, therapy or surgery for medical purposes. It involves a wide range of products from imaging to monitoring to implants to surgical instruments and equipment. A major revolution is taking place in advanced medical devices involving the introduction of advanced technologies to improve tools for diagnosis and treatment and the development of biological substitutes to restore, maintain, and improve tissue, bone, and organs. Some of the leading technologies being adapted for use in innovative medical treatments

and diagnostics include: microelectronics, imaging, nanotechnology-related biosensors, robotics, and biopolymer materials.

- **Molecular Diagnostics and Personalized Medicine:** The growing knowledge of genomic and proteomic data linked to specific disease states or predisposition is fueling the rise of molecular diagnostics. Molecular diagnostics is not only a new tool for medical diagnosis, it is a gateway to personalized medicine. As we near the end of the first decade of the 21st century, the promise of personalized medicine remains largely ahead of us. Molecular diagnostics are integrally linked with the personalized medicine approach of pharmacogenomics, which considers how genetic variations or differences in gene expression affect the ways in which people respond to drugs. In fact, these personalized medicine approaches to understanding of how genetic variations affect reactions to different drugs can enable diagnostic tests to be established that can guide doctors to make more informed and cost-effective medication decisions for their patients.
- **Molecular Medicine, Drug Discovery, Development & Delivery:** With the recent advances in genomics and biotechnology, a new era of molecular medicine is revolutionizing the development of drugs from the traditional trial and error approach to a more predictive and systematic use of detailed information about the operations of cells and molecules to pursue more focused interventions on disease processes. In particular, the use of advances in genomics and proteomics combined with improved disease model systems and computerized or “in silico” high throughput screening is transforming our understanding of the structure and function of genes and proteins and leading to improved ability to identify new potential targets of intervention for diseases. An important use of in silico drug development is assisting in the pharmacological study of drugs to improve drug design for absorption, distribution, metabolism, excretion and toxicity.
- Drug delivery is also being advanced through the use of polymer-based drug delivery systems and nanotechnology. Advances in polymer science have led to the development of several novel drug-delivery systems, including biodegradable polymers that can degrade into non-toxic forms in the body, highly absorbent and responsive hydrogels that can be used as biosensors as well as in wound healing and tissue scaffolding, and novel supramolecular structures able to deliver biologics. Often involved in novel polymers, but also other materials for drug delivery, are advances in nanomaterials. Nanomaterials have a number of functions in drug delivery such as encapsulation to protect the drug and prevent it from reacting with non-targeted tissues during transport, and as functional drug carriers in targeted delivery systems. These applications of advanced drug delivery systems are often distinct from more device like approaches to drug delivery. **Natural Products and Dietary Supplements:** According to the Dietary Supplement Health and Education Act of 1994, a dietary or nutritional supplement is any product that contains one or more dietary ingredients such as a vitamin, mineral, herb or other botanical, amino acid or other ingredient used to supplement the diet. Dietary supplements come in a variety of forms: traditional tablets, capsules, and powders, as well as drinks and energy bars. Popular supplements include vitamins D and E; minerals like calcium and iron; herbs such as Echinacea and garlic; and specialty products like glucosamine, probiotics, and fish oils. Dietary supplements are not food additives (such as saccharin) or drugs. It is

estimated by the NIH Office of Dietary Supplements that Americans spend about \$25 billion a year on dietary supplements and at least 50,000 products are available that contain dietary supplements.

There is an active effort at the National Institutes of Health to investigate the potential roles of dietary supplements in promoting health and reducing the risk of chronic disease. Much of this work is done in concert with other NIH institutes and centers, the Office of Dietary Supplements also engages its federal partners in activities to fill essential needs that would not otherwise be addressed. In 2010, 89 NIH supported projects focused on the health impacts of dietary supplements for conditions such as age-related disease, anti-cancer activity, bone health, inflammatory disease prevention, asthma, cardiovascular disease, heart failure, sickle cell disease, malaria, maternal and child health, obesity and diabetes, among other health conditions.

Summary

The analysis of Utah's Technology-based Economy's Performance and Position for Growth reinforces the importance of the four technology-based industry clusters identified for Utah, including:

- Aerospace & Defense
- Energy & Natural Resources
- Information Technology
- Life Sciences.

These four technology-based industry clusters are also well aligned with the core technology competencies found across Utah's patent, publication and broader innovation activities.

There is also a strong line of sight to growth opportunities linking the detailed industry strengths and core technology competencies found in each industry cluster. Together the detailed industry strengths and core technology competencies offer a way to identify, along with the input of recent UCAP and other strategic studies and interviews with university and industry leadership, possible focus areas for growth opportunities in which Utah can further its global leadership.

These inter-connections between technology-based industry clusters, core technology competencies, detailed industry strengths and possible growth opportunities are presented in Figure 10.

But there are also areas of concern for Utah. One that stands out is the low level of value-added per employee across the technology-based industry clusters. This suggests that Utah still has a way to go in advancing more innovative, complex technology products and services that generate high economic value, along with improved productivity.

Another area of concern is that Utah's venture capital is highly concentrated in Information Technology. While Life Sciences is served, it is not clear whether there is sufficient follow-on financing, and other technology areas are generally lacking in venture-backed companies.

Figure 10: Summary Line of Sight for Technology Based Industry Clusters Aligning Core Technology Competencies to Detailed Industry Strengths to Possible Growth Opportunity Areas

Core Technology Competencies	Detailed Industries That Are Growing in Jobs and/or Specialized in Level of Employment Concentration	Possible Growth Opportunities for the Future
AEROSPACE & DEFENSE		
Automation and Control Sensors and Sensor Systems Aerospace-related Materials Space Sciences	<ul style="list-style-type: none"> ▪ Guided Missile and Space Vehicle Propulsion Unit and Parts Manufacturing. ▪ Search, Detection, Navigation, Guidance, Aeronautical and Nautical System and Instrument Manufacturing. ▪ Aircraft Parts (not including engines) 	Unmanned Aerial Systems Advanced Aerospace Materials
ENERGY & NATURAL RESOURCES		
Oil, Gas and Resource Mining Tools Energy Conversion and Storage Environmental (Ecology, Water and Soil Conservation, Atmospheric Sciences, Range and Forest Sciences, Earth Science, and Animal Health & Sustainability)	<ul style="list-style-type: none"> ▪ Support Activities for Oil and Gas Operations ▪ Bituminous Coal Underground Mining ▪ Petroleum Refineries ▪ Crude Petroleum and Natural Gas Extraction ▪ Fossil Fuel Electric Power Generation ▪ Water and Sewer Line and Related Structures Construction ▪ Hazardous Waste Treatment and Disposal ▪ Environmental Consulting Services ▪ Primary Smelting and Refining of Copper ▪ Copper Ore and Nickel Ore Mining ▪ Primary Smelting and Refining of Nonferrous Metal 	Clean Technologies for traditional and unconventional sources of fossil energy Energy storage and power delivery systems Water and ecosystem sustainability
INFORMATION TECHNOLOGY		
Information Systems Electronics and Processing Technologies	<ul style="list-style-type: none"> ▪ Custom Computer Programming Services ▪ Data Processing, Hosting and Related Services ▪ Software Publishers ▪ Electronic Shopping ▪ Semiconductor and Related Device Manufacturing ▪ Internet Publishing, Broadcasting and Web Search Portals ▪ Computer Systems Design Services ▪ Other Electronic Component Manufacturing ▪ Other Computer Related Services ▪ Cable and Other Subscription Programming ▪ Bare Printed Circuit Board Manufacturing ▪ Audio and Video Equipment Manufacturing 	Networked information systems Digital gaming and other digital media
LIFE SCIENCES		
Medical Device Disease Research, Drugs and Pharmaceutical Basic Biological Research Nutritional Products and Functional Foods	<ul style="list-style-type: none"> ▪ Pharmaceutical Preparation Manufacturing ▪ Medical Laboratories ▪ Drugs Wholesalers ▪ Irradiation Apparatus Manufacturing ▪ Dental Laboratories ▪ Medicinal and Botanical Manufacturing ▪ Electromedical and Electrotherapeutic Apparatus Manufacturing ▪ Life Sciences Commercial Research & Development ▪ Medical, Dental and Hospital Equipment & Supplies Wholesalers ▪ Surgical Appliance and Supplies Manufacturing ▪ Surgical and Medical Instrument Manufacturing ▪ Dental Equipment and Supplies Manufacturing 	Molecular medicine, drug discovery, development and delivery Molecular diagnostics and personalized medicine Nutritional supplements and functional foods Novel medical devices

Utah's Technology and Innovation Infrastructure

Utah has R&D strengths that align well with the state's robust and growing technology industry clusters. Indeed the state is well positioned to capitalize on rapidly expanding markets in aerospace and defense, energy and natural resources, life sciences and digital media. But realizing the opportunities described above will require that Utah maintain a competitive position and address any gaps in its technology and innovation infrastructure. To maintain its competitive position, Utah must ensure that the state has a robust R&D and economic development infrastructure, a significant pool of talent, and capital markets able to support companies through all stages of their development. Additionally, as discussed in Appendix B, Utah must address the critical, quality of life issues facing the state including water, transportation, air quality and recreation.

Research and Commercialization Infrastructure

Research has shown that over the long-term the majority of newly created jobs are the direct or indirect result of advances in science and technology. For example, it was the emergence of information technology in the early to mid 1990's that led to broad-based economic development as a result not only of jobs created in the IT sector but the additional jobs created in supporting industries. In the 21st century, advances in the biosciences are driving growth of numerous industries including biopharmaceuticals, medical devices, energy and other bio-based products.

Characteristics of Universities and other Research institutions that Contribute to Growing Innovation Economies

- World-class research
- Nationally prominent faculty
- Leadership committed to working with industry
- State-of-the-art labs and facilities
- Aggressive technology transfer and commercialization

An examination of states and regions that are home to robust innovation-driven economies reveals that they have a strong research and development (R&D) enterprise. They have both research institutions, including universities, academic medical centers, national laboratories and nonprofit research institutions, and industry that are conducting world-class R&D and moving discoveries into new products and processes.

The presence and productivity of research institutions with recognized areas of research excellence is critical for regions and states seeking to grow technology-based knowledge economies. First, the research conducted at these institutions generates new knowledge and technology forming the basis for creating new firms and introducing new products in the marketplace. Second, these organizations both attract and produce highly-trained personnel who provide the skilled workforce needed by technologically advanced companies. Third, the presence of such a workforce, in turn, attracts technology companies to locate in proximity to these centers of excellence.

The universities that have been most effective in launching and supporting knowledge economies display the following characteristics:

- They are performing world class research in areas that correspond to the science and technology drivers of the regional and national knowledge sectors.

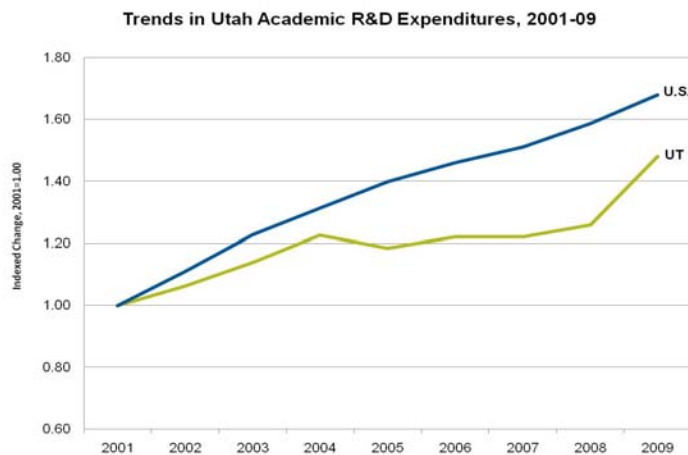
- They have a cadre of nationally prominent faculty. Numerous studies have found that “the presence of star scientists and engineers affect university spin-off activity as they have leading-edge knowledge and the ability to create radical innovations suitable for commercial exploitation.”¹⁰
- They have leadership who views the university as a key partner with industry and government in creating and growing a knowledge economy.
- They have the physical infrastructure needed to support research and technology development.
- They have mechanisms in place, including financing programs, to facilitate the translation of research findings into commercial products and processes.

Successful states and regions depend on institutional excellence in pertinent areas of science and engineering research to drive the economy. They also recognize that to achieve the requisite level of quality and critical mass within its research base requires public investment. However, academic stature is not sufficient by itself to drive a technology-based economy. Strong technology communities continue to feature top institutional leadership fully committed to engaging with industry and institutional cultures comfortable participating in the conversion of intellectual capital into economic activity. It is important to note, however, programmatic incentives are often required to assure these goals of public purpose lead to institutional action.

Utah’s Situation

Utah’s academic R&D expenditures reached \$500 million in 2009, an increase of 48 percent since 2001. This growth was, however, below the national growth in academic R&D of 68 percent nationally. See Figure 11.

Figure 11: Growth Trends in Academic R&D Expenditures, Utah and U.S., 2001–2009



Source: National Science Foundation

More than half of Utah’s academic R&D (56 percent) was in the life sciences in 2009. Another 27 percent was in engineering sciences. The areas that grew faster in R&D expenditures in Utah as compared to the nation include civil engineering, chemistry, mathematical sciences and agricultural sciences. Environmental sciences R&D expenditures declined by 3.1 percent in Utah between 2001 and 2009

while growing 61 percent nationally. See Table 9. Overall, Utah’s academic R&D expenditures have not kept pace with national growth in R&D expenditures.

Table 9: Academic R&D Expenditures, Utah and U.S. 2001 and 2009

	Utah Academic R&D Expenditures 2001 (millions \$)	Utah Academic R&D Expenditures 2009 (millions \$)	Change 2001–2009, Utah	Change 2001–2009, U.S.
Engineering Sciences	\$92.0	\$133.7	45.3%	73.0%
Physical Sciences	\$21.8	\$35.0	60.5%	53.4%
Environmental Sciences	\$13.7	\$13.3	-3.1%	61.0%
Math & computer Sciences	\$20.1	\$24.8	23.1%	63.6%
Life Sciences	\$168.6	\$279.4	65.7%	70.9%
Total	\$338.1	\$500.4	48.0%	67.9%

Utah has taken action to bolster its academic R&D enterprise. In March 2006, the Utah State Legislature passed Senate Bill 75 creating USTAR. This measure provided funding to enable U of U and USU to recruit world-class researchers and build state-of-the-art interdisciplinary research and development facilities and to form science, innovation, and commercialization teams across the state. A total of \$201 million, \$161 million from USTAR matched with \$40 million from the U of U and USU, has been used to construct a Molecular Biotechnology Building at the U of U that opened in April of 2012 and a Bioinnovations Building at USU, which opened in late 2010 and houses advanced nutrition, veterinary and other life science researchers.

While these steps are positive, it remains to be seen as to the extent to which they will result in increased academic R&D expenditures. Utah will have to continue to invest in growing its R&D enterprise in order to remain competitive.

But having a sizable, cutting edge research enterprise is just the first step. To leverage that base for economic development, discoveries in the lab have to translate into commercial products and services. Utah’s research universities have taken steps in the past five years to restructure their technology transfer and commercialization activities and to encourage and support faculty seeking to commercialize their research findings.

- The U of U has placed a strong emphasis on commercialization of university technology dating back to 2005. Since that time, the U of U has spun off 132 start-up companies and in 2009 became the number one university in the country in terms of university-based start-up companies.
- USU created an Office of Commercialization and Regional Development, which brings together all of the university’s commercialization activities including outreach to regional campuses. The office includes Commercial Enterprises, a one-stop shop for industry partnerships and IP development.
- BYU’s Technology Transfer Office’s mission is to commercialize technology and technical software developed at the university. BYU also has a separate Creative Works Office that seeks to take advantage of commercial applications in areas of instructional materials, software and creative works such as art, music and other media.

All of Utah’s research universities perform much better than the national average for universities in terms of their technology transfer metrics, particularly when the size of their research budgets are taken into account. As shown in Table 10, Utah universities generally exceed the U.S. average across the technology transfer pipeline of disclosures to patents to licenses to start-ups, except is slightly below in patent applications though higher in patents issued. What particularly stands out is Utah universities higher level of disclosures, licenses executed and start-ups, normalized for level of research expenditures.

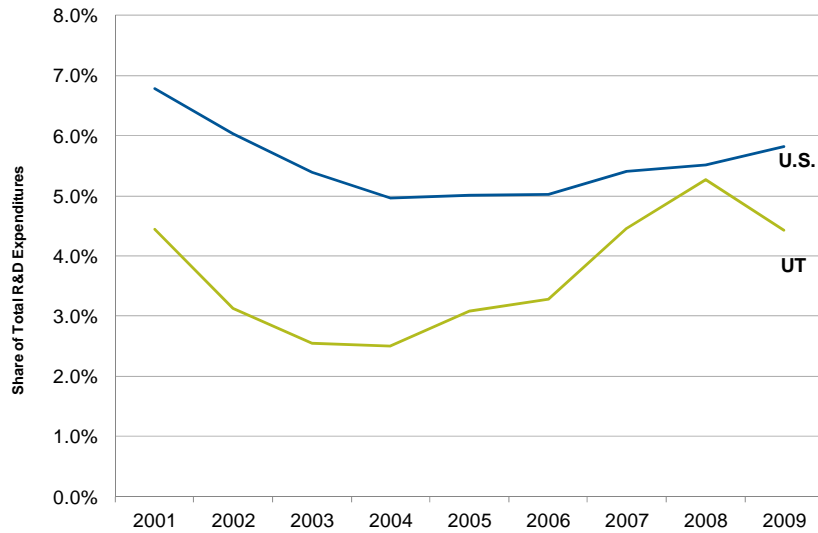
Table 10: University Technology Transfer Metrics, Utah and U.S. Average, 2010

University	Metrics per \$10M in Research Expenditures					
	2010 Invention Disclosures	2010 New Patent Applications	2010 U.S. Patents Issued	2010 Licenses & Options Executed	2010 License Income	2010 Start-ups
Utah Total	5.00	1.98	0.95	1.45	\$ 638,313	0.38
U.S. Total	3.50	2.12	0.76	0.89	\$ 368,914	0.12

Source: Association of University Technology Managers, 2010

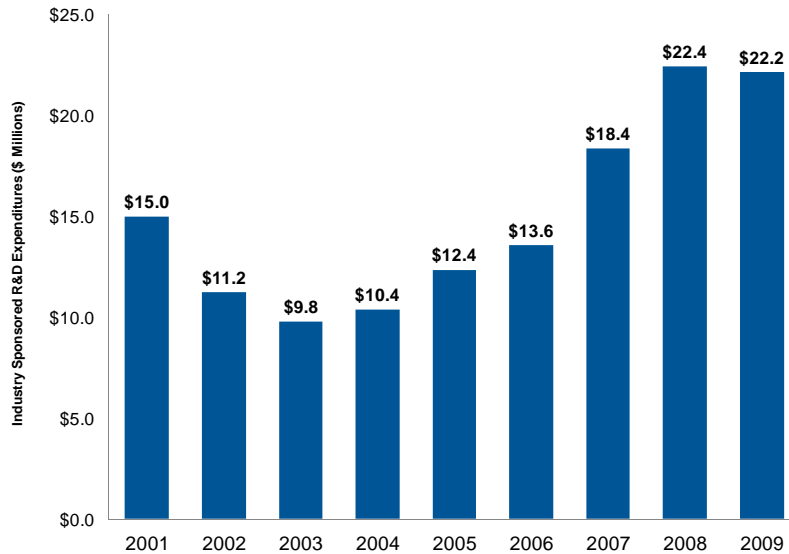
Another metric used to measure the extent to which academic research is focused on areas with commercial potential is to look at the level of industry- supported research being conducted by universities. On this metric, Utah lags the U.S. At the national level, 5.8 percent of academic R&D was supported by industry in 2009. In Utah only 4.4 percent of academic R&D was supported by industry in 2009. Utah’s industry share, however, increased from 2004 until 2008 and was approaching the national average but the share dropped in 2009. Data for additional years will be required to determine if 2009 was an anomaly. See Figures 12 and 13.

Figure 12: Industry Share of R&D Utah and U.S., 2009



Source: National Science Foundation/Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges

Figure 13: Industry-sponsored R&D at Utah Colleges and Universities, 2001–2009



Source: National Science Foundation/Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges

While interviewees usually listed Utah’s universities as among the key competitive advantages of the state, few reported being engaged in collaborative research projects with university partners. In part, this was reported to be due to difficulties in resolving issues of intellectual property. State and regions that have robust technology-based industry clusters also have engaged universities willing to partner with industry and each other. Given that the universities are engaged in R&D that is relevant to Utah’s industry clusters, this is an area of opportunity. Increasing university/industry collaboration likely would be an effective means of helping to raise the value added of the industry clusters and offers a vehicle for commercializing new technologies.

Talent

In the 21st Century, human capital is the key differentiator between winning regions and losing ones. Without skilled people, technology innovation cannot occur and advanced technologies cannot be deployed. Without skilled technical and managerial personnel, capital is extremely difficult, if not impossible, to secure. Natural resources have ceased to be important sources of economic advancement. It is the talent of people that drives economic success and is the fuel of the innovation and knowledge economy. It is the nations, regions, communities, and individual firms that have the most highly skilled workforce that will be the most productive. They will dominate markets by delivering the best products and services at the lowest costs and, as a result, will earn the highest profits.

Among all the riches a nation may possess, its people—its human resources, its human capital—is the most important. The value of this human resource depends not on size, however, but on the occupational and intellectual skills its members possess.

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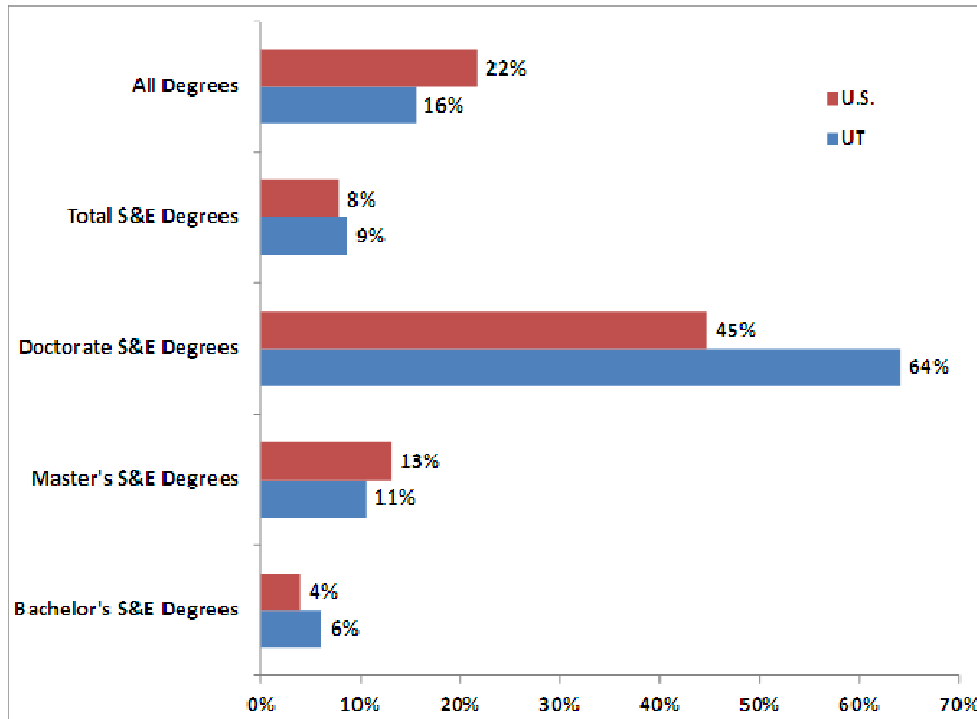
A supply of qualified, technology-trained workers is critical to the development and sustainability of a technology-based/innovation economy. Any knowledge-based industry requires a supply of qualified, trained workers at all levels. Successful states and regions maintain an adequate supply of doctoral-level researchers, technicians with two-year degrees, and managerial talent ranging from entrepreneurs themselves through mid- to senior-level executives who are comfortable in high-technology settings. States that lack a deep, natural pool of talent use a variety of tools, including formal university curricula, marketing programs aimed at worker retention, and peer-support for entrepreneurs, to attract and retain talent.

Utah's Situation

Utah's universities generate a high level of bachelor degrees in the sciences and engineering fields. The National Science Foundation reports that Utah exceeds the U.S. in the level of bachelor degrees per population aged 18 to 24 years old, with Utah standing at 10.1 per 1,000 aged 18 to 24 year old and the U.S. at 8.1 per 1,000 aged 18 to 24 years old. Utah, however, seems to confer fewer graduate degrees than the U.S., with 11.2 per 1,000 aged 25 to 34 in Utah compared to 12.3 per 1,000 aged 25 to 34.

In terms of recent trends in science and engineering postsecondary graduates, Utah has been keeping pace in the growth of science and engineering (S&E) degrees across its colleges and universities to that of the U.S., despite having slower overall growth than the U.S. in all postsecondary degrees awarded. As shown in Figure 14, Utah increased its level of postsecondary degrees in sciences and engineering fields by 9 percent from 2003 to 2009 compared to 8 percent for the U.S. The largest gain in science and engineering degrees in Utah was at the doctorate level, which rose 64 percent in Utah from 2003 to 2009 compared to 45 percent for the U.S. In bachelor's and master's degrees in science and engineering fields, Utah was generally on pace with the U.S., slightly ahead at the bachelor's level (6 percent vs. 4 percent) and slightly below at the master's level (11 percent vs. 13 percent). Graduate degrees in S&E fields have risen substantially in both Utah and the U.S. particularly in Utah's generation of graduates with doctoral degrees. See Figure 14.

Figure 14: Utah and U.S. Change in Postsecondary Degrees, 2003–2009



Source: Battelle analysis of Postsecondary Degree data from National Center for Education Statistics, IPEDS database.

The generally positive trends in science and engineering graduates in Utah reflect the significant activities in Utah to bolster its engineering and computer science workforce through the Utah Engineering Initiative. Begun in 2001 as a means to generate more high paying jobs in Utah by ensuring a supply of engineering students, the Utah Engineering Initiative has involved:

- Providing funds for equipment purchases to improve quality of instruction in engineering, computer science and related technology.
- Establishing a student loan forgiveness program and increasing student scholarships.
- Assisting the Utah System for Higher Education in attracting and retaining highly qualified faculty to teach in initiative programs.
- Increased physical capacity by funding new and remodeled capital facilities.
- Creating an industry-led Technology Initiative Advisory Board to make recommendations to Regents in administration of the initiative.

In more recent years, the Utah Engineering Initiative has been involved in strengthening articulation and improving educational efficiency via remote delivery, distance learning and creative partnerships among institutions.

Despite these gains in STEM degrees at the higher education level, industry has expressed concerns about the quality of science and math education at the K-12 level both in terms of finding future workers but also because it impacts firm's ability to attract highly skilled workers who may be unwilling to relocate to Utah if they think there are deficiencies in public education. An analysis conducted by the

Utah Foundation examined Utah's performance on National Assessment of Educational Progress (NAEP) math, science and reading tests from 1992 to 2009.¹¹ They found that:

- Utah is underperforming compared to states with similar demographics in terms of its math, science and reading scores. When compared to a number of peer states, Utah most often ranks last in these tests.
- In addition to persistently low peer-state rankings over the past two decades, Utah's national ranking on these exams has fallen significantly.
- Utah's math scores have increased over the years, but other states' scores have risen faster, leading to a lower ranking for Utah. Reading scores have been flat for Utah during this period. Utah's science scores are higher than the national average but at the bottom of peer states.

Overall, Utah's employers report that the state's workforce is well educated and hard working. Still industry is concerned about finding the high skilled workers that they need. As Utah's industry clusters have grown, demand for skilled workers has increased and firms find that they must recruit from out-of-state (which is expensive and can be difficult to accomplish), train workers internally or recruit workers from other Utah employers.

This suggests that continued efforts to expand the generation of postsecondary science and engineering graduates in Utah is needed, and that focused efforts on the STEM talent pipeline from K-12 must be an area of attention in Utah.

Capital

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

Yet, few sources of funding bridge the gap between the point at which a discovery has been identified and demonstrated and the point at which a business case has been validated and venture capital or debt capital can be obtained. Research conducted by Lewis Branscomb and Philip Auerswald for the U.S. Department of Commerce's National Institute of Standards and Technology found that "efficient markets do not exist for allocating risk capital to early-stage technology ventures."¹² The sources typically tapped to address this gap include angel investors, venture funds that invest at the seed and early stage, and publicly and privately supported university and non-university programs specifically created for this purpose.

In the past, angel investors played an important role in bridging the gap between funding from friends and family and funding from formal venture capital funds. In fact, data developed by the Center for

Venture Research (CVR) at the University of New Hampshire revealed that angels are the largest source of seed and start-up capital. After experiencing a significant contraction in angel investments in 2008 and 2009, the angel investment market began to rebound in 2010. Total investment in 2010 was \$20.1 million, an increase of 14 percent over 2009 according to CVR. Over time there has been an increase, however, in angel investment in post-seed and later-stage investments. In 2005, 55 percent of angel investment was at the seed and start-up stage, by 2010 only 31 percent was invested at the seed and early-stage.¹³¹⁴ CVR attributes this trend to changes in market conditions, i.e., the fact that formal venture capital funds are making later-stage investments, thus creating a gap at the post-seed stage, and the preferences of larger, more formal angel alliances.

Another factor makes it difficult to obtain seed and early-stage financing: as formal venture capital funds have become larger—in 2010 the average fund size was \$149 million—the amount invested per deal has increased to a minimum of several million dollars initially. This means that the stage of investment has tended to move downstream to larger, later-stage deals. As a result, it has become increasingly difficult to obtain small amounts of seed capital in the \$1 million to \$2 million range or less.

Figure 15 shows the amounts and types of capital needed by technology companies at various stages of their development.

Figure 15: Technology Commercialization Financing Needs

	R&D	Translational Research and Commercialization	Pre-seed/Seed	Start-up	Expansion
ACTIVITIES	Conduct R&D Identify discoveries with possible commercial potential	Assess potential of technology Identify market Demonstrate proof of concept at lab scale Protect IP Engineering optimization Licensing or business formation	Develop prototype Testing and validation Prepare business strategy Establish business function Secure initial financing	Put management team in place Secure follow-on financing Staff up for sales and marketing Initial sales and marketing	Full scale production
FINANCING SOURCES	Conventional peer reviewed federal grant support	<ul style="list-style-type: none"> • Within university: Grants funded with university, state or industry dollars • Non-University: Grants funded by public and philanthropic support • SBIR I 	<ul style="list-style-type: none"> • Friends and Family • Pre-Seed/Seed funds • Angel investors • SBIR Ph II 	<ul style="list-style-type: none"> • Early-seed stage venture capital • Publicly supported investment funds 	<ul style="list-style-type: none"> • Venture funds • Equity • Commercial debt • Industry (strategic alliances, mergers and acquisitions)
LEVEL OF INVESTMENT	Varies	\$25,000 to \$250,000	\$250,000 - \$1 million	\$1 – \$2 million	> \$2million

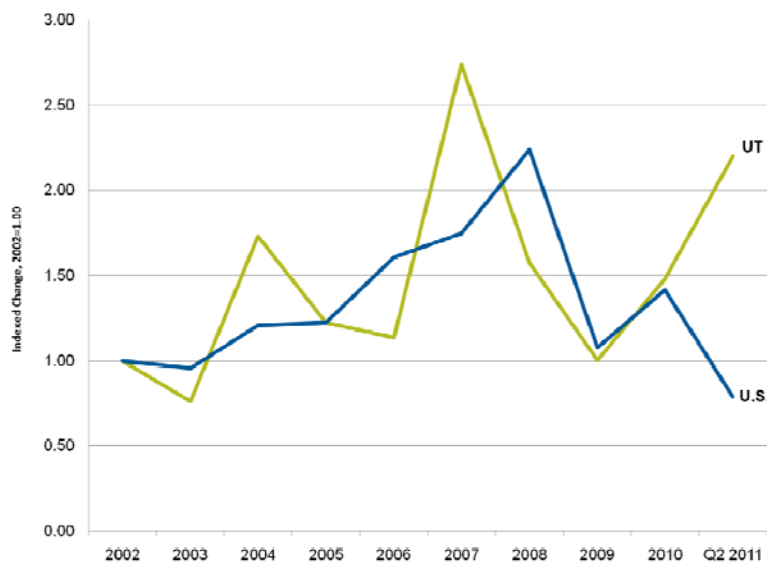
Utah's Situation

Venture capital funds invested approximately \$1.4 billion in Utah-based companies between 2004 and 2008 and \$776 million between 2009 and the 2nd Quarter of 2011. Utah's level of venture capital investment generally followed national trends until the 2009–2011 time period when venture investment increased significantly in Utah while total investment declined at the national level. The

large increase between 2009 and the 2nd Quarter of 2011 is due, in part, to a single company that received a \$275 million investment (Pinnacle Security) and two other companies (Schiff Nutrition and Fusion-IO) that together received more than \$90 million during that time period.

While many of Utah’s emerging information technology and digital media companies are able to bootstrap their operation until they reach the revenue stage and therefore do not necessarily have to tap into the venture capital market, this is not the case with most life science companies. A majority of the life science entrepreneurs and CEOs of start-up companies reported that it is very difficult to obtain venture capital in Utah. There are few locally-based venture funds and it is difficult to attract capital from out of state without a local partner.

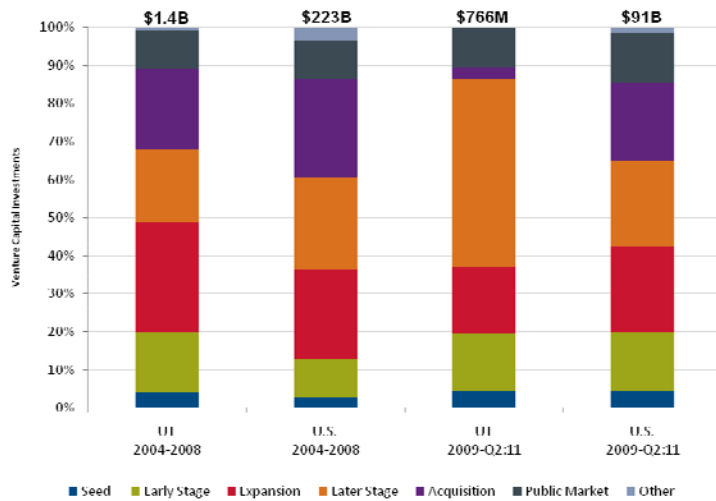
Figure 16: Venture Capital Investments, Utah and U.S., 2002–2Q 2011



Source: Battelle analysis of Thomson Reuters, Thomson One database.

In terms of stage of investment, almost half of the venture capital invested in Utah companies during the 2009–2011 time period were later-stage investments. Investment at the seed and early stage are similar to the levels seen nationally. See Figure 17.

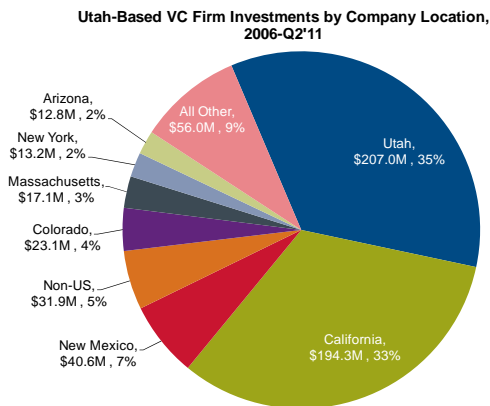
Figure 17: Utah Venture Capital Investments by Stage of Investment, 2004–2Q 2011



Source: Battelle analysis of Thomson Reuters, Thomson One database

An examination of the venture investments made in Utah companies from 2006 until the 2nd Quarter of 2011 shows that 35 percent of the total invested was invested by Utah-based funds, another 33 percent came from California with the remaining capital coming from a variety of other states or international sources. See Figure 18.

Figure 18: Venture Capital Firms with Investment in Utah Companies



Source: Battelle analysis of Thomson Reuters, Thomson One database

Utah-based venture capital funds invested \$595.5 million between 2006 and 2Q 2011, \$207 million of which was invested in Utah-based firms. Slightly more than \$100 million of the \$207 million was invested by one firm, vSpring Ventures.

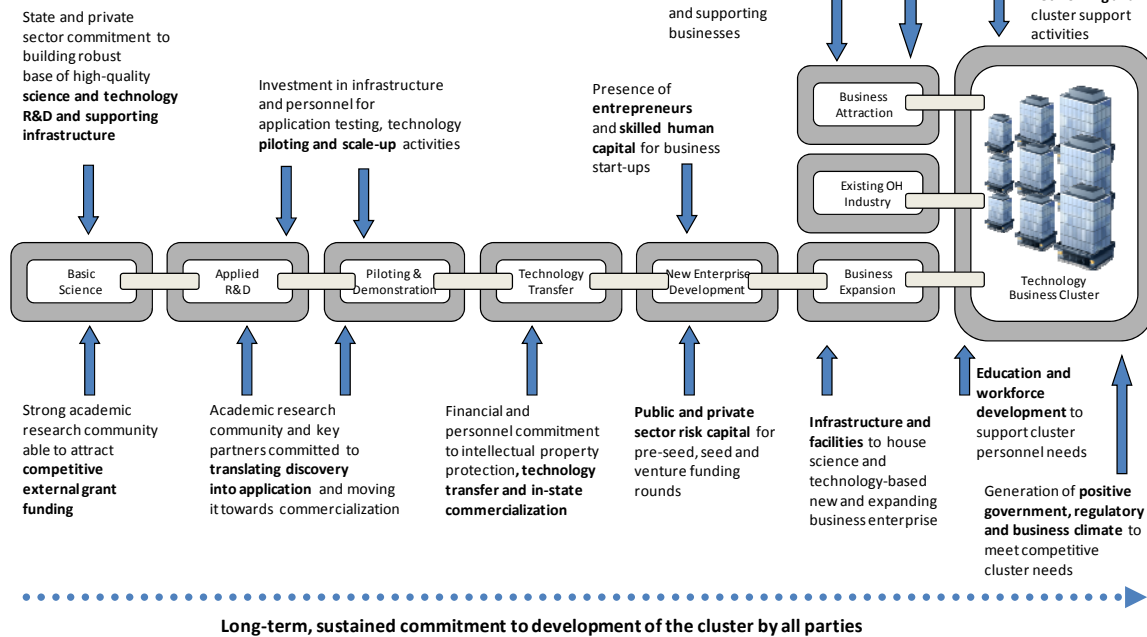
In 2003 Utah passed legislation creating the Utah Fund of Funds (UFOF). The UFOF was charged with investing in venture capital and private equity funds. Rather than appropriate funds, the legislation created \$300 million in contingent tax credits. These credits could be used by the UFOF to raise private capital. A first tranche of \$100 million was raised from Deutsche Bank. As of 2011, \$120 million had been committed in 28 venture funds, eight of which are Utah-based.

Despite the investments made by the fund of funds, risk capital still appears to be limited in Utah.

Summary

Economic development is not easy to achieve in general, while technology-based economic development is an even greater challenge. For economic development to occur an entire interconnected sequence of positive factors have to be in place. For development of technology-based business sectors the chain of factors is particularly complex and challenging to develop and manage. If any link in the chain is missing, a sustainable technology cluster is unlikely to develop. The graphic below presents an illustration of how to conceive of the linkages found in technology-based economic development.

Technology-Based Economic Development Requires Attention to Every Link in the Development Chain



The states and regions in the U.S. which have achieved success in growing robust technology industry clusters (places such as the San Francisco Bay region and Boston) have well-developed technology development chains in place. These technology-based economic development chains may form naturally over time (as occurred in Silicon Valley), or they may result from dedicated activities of states, regions and key stakeholders to connect and build links in the chain to assure such development happens. The figure below illustrates a basic technology-based economic development chain and the specific links that need to be in place to form and grow a technology cluster. It is clear that Utah has policies and programs aimed at strengthening many of the links in the chain. There are, however, a few gaps that need to be addressed if Utah is to accelerate the growth of its technology clusters. These include:

- Insufficient linkages between Utah’s industry clusters and its higher education institutions.
- Underdeveloped risk capital markets. Ways must be found to help Utah’s large base of start-up companies to grow and succeed in Utah. In particular, Utah’s capital markets must be developed to be able to meet companies’ capital needs at every stage of their development, but particularly at the proof-of-concept and seed stages.
- Lack of talent to fill senior management and other skilled positions and concern about the quality of STEM education. Utah must take steps to ensure that there is a talent pipeline sufficient to meet industry’s need for skilled and educated workers.

Recommended Strategic Initiatives to Realize the Full Potential of Utah's Innovation Economy

Utah's Economic Development Strategy proposes a number of specific actions to achieve its objectives of increasing innovation, entrepreneurship and investment and prioritizing education to develop the workforce of the future. This STI plan identifies a number of key gaps in the state's technology infrastructure that could hinder the state's effort to achieve its economic development objectives. This section of the report proposes that the State of Utah develop several initiatives to address the gaps identified. Activities that could be undertaken under each initiative are suggested along with examples of activities that have been effective in other states and regions. Please note that many of the potential activities described may already be underway in some form in Utah but may need to be scaled up or expanded.

At the same time, it is important to recognize that Utah's growing economy and population is placing strains on the state's environmental infrastructure and in the future key issues such as water sustainability and air quality are likely to be top concerns related to advancing economic development. For instance, Utah is the third driest state in the nation, yet it is estimated that by 2050 Utah's population will double to five million people yet. As a result, the state faces a serious long-term challenge: how to meet future demand for water. With 85 percent of Utah's citizens currently living in the Wasatch Range and most future growth expected to occur in this area, this places real constraints on Utah's quality of life and ability to ensure a key resource for industry activities—water. Further complicating the situation is that approximately 70 percent of surrounding land is federally-owned which constrains where and how economic development can occur.

Knowledge Initiative – Encourage Greater Industry University Collaboration

Innovation, in and of itself, will not necessarily translate into economic activity. Rather it is the application of that technology and its introduction into the marketplace that results in economic growth. Having a strong R&D base is necessary but not sufficient to grow a technology-based economy. An effective means of moving technology into the commercial marketplace is to encourage relationships between the researchers who are making the discoveries and the entrepreneurs and company CEOs that have the ability to commercialize them.

As discussed previously, Utah has strong technology-based industry clusters and academic R&D strengths in areas that relate to these clusters. In talent development, there has been close ties between industry and universities in Utah, particularly through the Utah Engineering Initiative that has bolstered engineering degree generation to meet the demand by industry as well as created new degree programs in response to industry demand, such as in systems engineering, power engineering and the development of a distance-learning master's program. But Utah's research base has lagged and industry support for university research is well below the U.S. Among the industry interviews conducted by Battelle, few companies report working collaboratively with academic researchers, and a number of the industry executives interviewed suggest that it is difficult to work with universities through their sponsored research and technology transfer offices. Issues often arise around IP ownership and expectations regarding the terms of licensing agreements. Such issues will need to be addressed to both

grow its R&D base as well as to enable Utah to maximize the economic development benefits of its university R&D enterprise.

Utah has already taken steps to accelerate the growth of its R&D base. USTAR has provided funding to allow the U of U and USU to recruit innovative faculty in key areas of importance to the state's industry clusters (an approach often referred to as Eminent Scholars programs in other states), provided funds to build facilities to house these researchers, and awarded grants to fund proof of concept projects. USTAR also supports commercialization activities at a number of the state's colleges and universities. Utah should continue to fund USTAR to continue these activities and/or additional activities that could be undertaken to continue to grow the state's research and innovation base in its targeted technology areas.

The State of Utah should also consider undertaking activities directly aimed at creating industry/university partnerships. These could include the following types of actions:

- Funding public-private partnerships that bring industry, academic researchers, institutions of higher education and state government together to pursue development of a particular technology area to further the growth of an industry cluster
- Providing funding to match industry research dollars
- Creating mechanisms that bring industry and academic researchers together.
- Convening an industry-university panel to conduct a review of policies and practices that affect university/private sector collaborations.

Facilitating public-private partnerships

New global realities are reshaping the landscape in which U.S. regions and states must compete. International competition, the increasing pace of development and rapid diffusion of technologies, the growing convergence of technologies, along with a new focus on "open innovation," continue to reshape the competitive technology landscape. A new paradigm has emerged in which leading technology companies are looking to universities and innovative emerging companies for new technologies, rather than investing as many resources in internal high-risk R&D work as in the past. As a result, more and more companies are looking for opportunities to partner with research universities. Universities are looking to corporations and entrepreneurs to provide an avenue to move their discoveries into applications.

But, the academic and corporate worlds differ in many ways. Intellectual property protection, differences in time horizons, and other issues often present challenges to industry-university partnerships. States have developed various mechanisms, such as providing matching grants for research partnerships and creating centers where industry and academic researchers can work together on collaborative projects, to encourage and facilitate such partnerships. Not surprisingly, given the changing landscape for innovation, states are increasingly focusing on the industry-university interface. In 2008, 28 states reported specific initiatives to encourage industry-university partnerships. This included Utah's Centers of Excellence Program, reorganized in 2010 to become the Technology Commercialization and Innovation Program (TCIP).

Public-private partnerships to promote economic development are not a new phenomenon but the nature of these relationships have changed dramatically. Today's programs focus on fostering relationships and communications across and between universities who generate new discoveries, emerging technology companies focused on new product development and larger companies seeking to meet the needs of existing and emerging markets.

Experience has shown that it often requires creating an entity, such as an Institute or Center, to bring together industry and academic researchers with similar interests. State governments have encouraged the creation of such mechanisms by providing both operational and capital funding that then seeks to leverage the state funds to attract additional private and federal funding.

The **Oregon Nanoscience and Microtechnologies Institute (ONAMI)** is an example of a public/private partnership that was seeded with state dollars. ONAMI is a collaboration of four Oregon's universities (Oregon Health and Science University, University of Oregon, Oregon State University (OSU) and Portland State University), a national laboratory (Pacific Northwest National Laboratory – PNNL), industry and the investment community. It is one of three "Signature Research Centers" created by the State of Oregon. ONAMI's mission is to accelerate research and commercialization of materials science and related device and system technology in Oregon.

ONAMI seeks to achieve its mission by

- **Providing matching funds for federal and private collaborative research projects** undertaken by ONAMI principal investigators
- **Providing industry with access to a collection of university-based shared/open user facilities** on a user friendly, fee for service basis. These are world-class materials characterization and fabrication laboratories. Not only do the firms have access to sophisticated equipment but they also have access to people with the expertise to run the equipment.
- **Providing commercialization funding and business development services.** ONAMI provides proof-of-concept grants that enable university researchers to conduct commercialization ***activities and helps link entrepreneurs to sources of private capital. Efforts are underway to*** create a nanoscience and microtechnology-focused early-stage fund that would be similar to Seattle's Biotechnology Accelerator.
- **Holding periodic conferences and seminars** and providing opportunities for networking among industry and academic researchers. The ONAMI network includes 150 research affiliates at four universities and PNNL.

ONAMI received both capital and operating support from the State of Oregon. Between March 2006 and April 2011, ONAMI distributed \$14.75 million in grants to Oregon universities, helping to attract more than \$100 million in federal and industry R&D funding. Between 2004 and 2008, awards to Oregon's universities for nanotechnology and microtechnology R&D tripled and seven new companies were created based on nanotechnology and microtechnology discoveries.¹⁵ Companies working with ONAMI have raised more than \$70 million for research projects to help dramatically grow research revenue in

Oregon and accelerate commercialization of resulting technology.¹⁶ ONAMI is housed in Corvallis on Hewlett-Packard's campus, and has provided many research and employment opportunities for OSU students and graduates.

Additional examples of programs that seek to facilitate collaborations between academia and industry are **Science Foundation Arizona's (SFAz) Strategic Research Groups (SRG)** program and **Small Business Catalytic Fund**. The former provides up to \$10 million to facilitate collaborations between nonprofit research laboratories, hospitals and academic institutions and industry. Seed funding of \$2 million a year for up to 4 years is provided to each SRG and another \$2 million is provided to recruit and fund a start-up package for a director. The Small Business Catalytic Fund supports R&D partnerships between a principal investigator and an Arizona company to ensure a product's success and to accelerate time to market. To date, SFAz has awarded nearly \$120 million across more than 140 individual grants. Over \$80 million has been funded across 101 research grants and \$37 million has been funded for 41 education grants. For every \$1.00 that SFAz has awarded toward university and nonprofit research funding initiatives, an additional \$3.06 was committed from industry matching and non-state research funding including venture capital attracted, federal grant awards, and nonprofit funding.

SFAz grantees are generating impressive results with significant statewide research, innovation, and economic impacts. The most current impacts and returns on investments were recorded in June 2010 and track cumulative grant outcomes that span three fiscal years, 2007 through 2009. The cumulative results from grants to research-performing institutions are substantial:

- 1,151 jobs created related to the grants
- 84 patents filed and/or issued
- 11 technology licenses in place
- 16 technology company formations in Arizona.

In addition, SFAz is upgrading K-12 science, technology, engineering and math (STEM) education and addressing Arizona's talent deficit in science and engineering fields.

Providing funding to match industry research dollars

The most common and, in Battelle's experience, one of the most effective means of fostering greater university and industry interaction is to provide matching grants for research partnerships. Such programs help build relationships between

Maryland Industrial Partnerships Program

The Maryland Industrial Partnerships Program (MIPS) has a proven track record of working with industry to accelerate the commercialization of technology by funding collaborative university-industry product R&D projects. Originally started as an outreach effort by the University of Maryland College Park Engineering School, MIPS has grown to encompass all campuses of the University of Maryland System across all fields. MIPS projects are conducted by university faculty and graduate students in conjunction with company researchers. More than 400 companies have participated in project awards worth more than \$160 million since 1987. MIPS-supported products have generated more than \$19.5 billion in sales, added jobs to Maryland, and exported state-of-the-art Maryland-originated technology into the global marketplace. MIPS, for example, jointly funded six different research projects with Medimmune, including three directly related to their drug Synagis, the first monoclonal antibody approved for the prevention of an infectious disease. Total sales of Synagis© since 1998 exceed \$6.4 billion.

academic researchers and companies and provide support for activities that may lead to investments of private capital and commercialization of new technologies.

As of 2008, 28 states had matching grant programs that provide an incentive for firms to support research projects at local research institutions.¹⁷ Most of these programs solicit applications on a competitive basis and make awards to projects that are both technically sound and likely to have a positive economic development impact. All of the programs require that the company shares the cost of the research project, which is conducted by faculty and students on behalf of the company. The level of cost share can vary. Some programs vary the matching requirement based on the size of the company.

Maryland has a long established matching grant program, the **Maryland Industrial Partnerships Program (MIPs)**. All 13 campuses of the University of Maryland system participate in the program. MIPS grants, which are used to fund research projects conducted by faculty or students, can be up to \$100,000 for large companies and up to \$90,000 for start-up companies. The level of match depends on the size of the company with large firms required to provide 50 percent match and start-ups required to provide 10 percent cash match. The MIPS program has no payback provision.

Creating networks around the targeted technology focus areas

Battelle's analysis identified a number of strategic technology opportunity areas for each of the state's technology-based industry clusters. To capitalize on these opportunities and realize the economic development potential of developing these areas, researchers from Utah's colleges and universities, medical centers, and industry should get to know one another and begin to find ways to collaborate. Interviews with researchers and industry CEOs suggested that Utah would benefit from increased communication across disciplines and institutions, as well as between universities and industry. One mechanism that can be used to foster such relationships is the development of technical networks or scientific interest groups composed of industry, academia, and resource providers.

Utah has already brought such groups together to serve on steering committees to develop UCAP strategies. Creating technical networks would be a way of continuing the dialogue between higher education, industry and state government.

North Carolina's Intellectual Exchange Networks

The North Carolina Biotechnology Center (NCBC) supports intellectual exchange networks that are designed to foster a research and information-sharing environment for industry and academic partnerships, and professional networking opportunities in the state of North Carolina. Intellectual Exchange Groups (IEGs) are initiated by interested individuals or groups within the life science communities; and participants might be drawn from universities, the business community, or other constituencies. NCBC provides funding to the IECs to cover the cost of meeting expenses. IEGs are expected to meet at least four times a year. Current IEGs supported by NCBC include the following:

- Atlantic Coast Chromatin Conference
- Bioprocessing/Process Development Group
- Laser Technologies Applications Group
- Next Generation Sequencing Group
- One Health Group
- Plant Molecular Biology Consortium
- RNA Society of North Carolina
- Smaller Eukaryotes Group
- Triangle Chromatography Discussion Group
- Triangle Immunology Interest Group

Convening an industry university panel to conduct a review of policies and practices that affect university/private sector collaborations

As noted previously, in interviews, companies reported that it is often difficult to work with universities on sponsored research projects and to license technologies due to the terms and conditions imposed by the universities. To explore this issue, it is recommended that the Utah System of Higher Education convene a committee composed of researchers, individuals who have started companies based on university-developed technologies, attorneys familiar with intellectual property protection, representatives of the financial capital and economic development communities and staff of the university technology transfer offices to review current policies and practices and recommend actions that could be taken to streamline the contracting and licensing process thereby removing any barriers that exist to firms wishing to work in partnership with the universities.

Carolina Express License Agreement

The University of North Carolina at Chapel Hill has created a standardized license agreement to be used with any start-up company. The Carolina Express License Agreement was developed by a university committee that included faculty members, participants from the Office of Technology Development (OTD), venture capitalists, and attorneys from firms that have represented university startups.

The standardized agreement was developed to address perceived policies that make it difficult for start-up companies to license university technologies, including:

- Demand for excessive equity for IP
- Required royalties that can exceed cash flow
- Expecting external financing
- Imposing unpredictable or unreasonable financing terms.

Key provisions in the agreement include a one percent royalty on products requiring FDA approval based upon human clinical trials, a two percent royalty on all other products, and cash payout equal to 0.75 percent of the company's fair market value in the event that the company is involved in a merger, stock sale, asset sale, or IPO. The license includes provisions that encourage broad commercialization of the licensed technology, including making products available for

Capital Initiative – Support the Creation and Growth of Innovative Companies by Ensuring Access to Capital

Utah has been very successful in creating start-up companies. Indeed, the state's universities lead the nation in forming companies around university-developed technologies. While new firm creation is a key prerequisite for growing a knowledge-based economy, it is not sufficient. It is equally important that a state or region provide an environment in which such companies can succeed and grow.

Firms need to be able to access the resources they need when they need them. The most critical of these is capital. Business development requires not only R&D dollars but also substantial funds necessary to bring a new product or service to market. Capital is required to conduct market assessments, develop prototypes, scale up production and establish distribution and sales outlets. Sufficient capital is necessary to grow a business through each major stage and milestone.

Interviews with entrepreneurs, faculty inventors, CEOs of companies, economic developers and venture capitalists suggest accessing risk capital in Utah can be improved. The gap is particularly severe at the proof of concept and seed stage but it can also be difficult to obtain later stage capital as well. This is due in part to the fact that there are few Utah-based venture capital funds to serve as lead investor.

The Utah Fund of Funds was created to attract out of state venture capital investment in Utah-based companies. The Fund has invested \$120 million in 28 venture funds, only 7 of which are Utah-based. Despite the Fund of Funds initiative, however, it remains difficult to obtain early-stage financing and certain types of companies, especially life science companies, have difficulty obtaining capital. There are a number of approaches that states have taken to increase the availability of risk capital. They include:

- Providing commercialization grants
- Directly investing in a seed or venture fund
- Using tax incentives to encourage venture investments
- Providing comprehensive in-depth support to entrepreneurs to enable them to obtain private capital.

Each of these approaches is discussed below.

Providing commercialization grants

It has become increasingly common for states and/or universities to provide funding for activities needed to determine the commercial potential of a discovery and to advance the technology to the point at which a commercial partner can be found. Commercialization funds support prototype development, testing and validation, and marketing research and is usually provided in the form of a grant that does not require any repayment. Such funding is often needed to commercialize university-owned IP at the highest value—and sometimes to license it at all—as such technology usually is at an early stage of development and requires additional studies or a working prototype before it can be shown to have commercial value. It also is necessary to surround the original discovery with additional patents and protections. Such activities are almost never fundable through conventional peer-reviewed federal programs and, if they are to take place at all, must be separately funded under a different set of criteria focused mainly on economic development. Companies seeking to develop a product or process also often require funding for proof-of-concept activities.

Thirty-three states reported offering proof-of-concept funding in 2008.¹⁸ About half of these programs fund university principal investigators and/or for-profit companies. Ten or slightly less than a third of the programs fund university principal investigators only in an active university/industry partnership, and eight fund for-profit companies only in an active industry/university partnership. Seven of the programs provide funding to university technology transfer programs.

In 2010, USTAR used funding obtained through the American Recovery and Reconstruction Act (stimulus funds) to support proof-of-concept projects at Utah universities. In 2011, GOED administers a Technology Commercialization and Innovation Program, which provides matching grants of \$40,000 that can be used to support commercialization activities. The grants are awarded on a competitive basis to university researchers and/or companies that have licensed technology from a Utah university that they plan to commercialize.

Utah may want to consider expanding this program to allow for follow-on and/or larger awards along the lines of the Georgia Research Alliance's VentureLab program which is described in the text box. Utah may also consider making this funding available for technologies developed outside of the universities.

Georgia Research Alliance's VentureLab Program

GRA's VentureLab was created to move university technologies out of the lab and into the marketplace and to grow university-based start-up companies in Georgia. To accomplish these goals, GRA awards the following:

- Phase I grants (up to **\$50,000**) to university researchers to answer the question, "Is it commercially feasible to build a company around this technology?"
- Phase II grants (up to **\$100,000**) to university researchers to continue prototype development and formulate a company.
- Phase III loans (up to **\$250,000**) to eligible VentureLab companies that have a fully executed license from the university. These companies must also have Georgia-based management. The noncollateralized loan has favorable repayment terms and conditions.

Since 2002, GRA has evaluated the commercial potential of more than 300 inventions or discoveries at universities. The most promising of these were awarded VentureLab grants to help fund the technology research necessary to further develop the invention or discovery. This process has led to the formation of more than 80 early-stage companies that employ more than 450 people and have attracted \$300 million in private equity investment.

Utah has many such technology companies which are based on R&D not originally associated with research universities and should incent those as well.

Directly investing in a seed or venture fund

Seed funds make equity or near-equity investments in early-stage companies, usually up to approximately \$2 million. A number of states have used state dollars to create such investment funds. The Oklahoma Seed Capital Fund (OSCF), for example, is a state-appropriated investment fund that makes concept, seed and start-up equity investments in Oklahoma businesses. The fund makes concept investments, typically in the range of \$50,000 to \$200,000 and seed investments, typically less than \$500,000. Co-investors are required for both types of financing. The funds can be used to develop intellectual property, complete market assessments, implement business operations, and recruit key members of the management team. The OSCF is administered by i2E, Oklahoma's statewide technology commercialization organization. In addition to making investments, i2E provides comprehensive in-depth support to entrepreneurs, including helping them to become investment grade.

Utah has a constitutional prohibition against investing directly in a private company. A constitutional change would likely be required to allow the state to create a publicly-funded seed fund. This is a change that might be considered in light of Utah's desire to grow its technology clusters. An alternative would be to use a portion of the funds available to the Utah Fund of Funds to create a seed fund or to encourage private investment in seed or venture funds or in companies directly by offering a tax incentive.

Using tax incentives to encourage private investment in early-stage companies and/or seed and venture funds

As of 2010, 20 states offered tax credits to angel investors who invest in technology companies and 12 states provide tax credits to individuals who invest in early-stage venture funds. Utah has several angel investor groups including Salt Lake Life Science Angels, SLC Angels (formerly Olympus Angels), Park City Angels, Dixie Angels and Utah Valley Angels. These angel groups are making investments in Utah's information technology and digital media companies but they are less of a source for life science companies, particularly given the large capital requirements and long time line for the development of biomedical products. Another approach is one that Utah has taken by creating the Utah Fund of Funds.

Wisconsin enacted a major package of venture investment tax credits under Act 255 in 2004, under which, qualifying angel—both individuals and angel networks (An angel investment network is a group of accredited investors organized for the sole purpose of investing in a single Qualified New Business Venture)—and venture capital investors in Qualified Small Business Ventures (as certified by the Department of Commerce) may receive tax credits of 25 percent. The annual statewide pool of credits was tripled to \$18.25 million for the angel credit and \$18.75 million for the venture credit in 2009.

The credit appears to be having an impact. In 2003, the average Wisconsin angel investment was \$158,000 in 11 deals; in 2008, the average Wisconsin angel investment was \$283,000 in 53 deals. Wisconsin angel investors invested \$15 million in 2008 and \$22.1 million in 2009 in Wisconsin companies. Wisconsin had 6 angel networks in 2003; this number had grown to 22 angel groups in 2009, 14 of which made investments in 2009.

The Wisconsin legislature is currently considering legislation that would make its early-stage, seed and angel tax credits refundable (AB20).

Utah could consider enacting legislation to create an angel investor tax credit and/or a tax credit that could be provided to investors in early-stage venture funds.

Providing a comprehensive set of services for entrepreneurs and start-up companies to better position them to obtain private investment capital.

Utah has a strong history of entrepreneurship and many successful entrepreneurs that can and do serve as role models and mentors to aspiring entrepreneurs. But Utah's statewide entrepreneurial support infrastructure is in an early stage of development. The state's institutions of higher education are putting programs in place to assist faculty seeking to start a company and the state's entrepreneurship educational programs are being recognized for their excellence. In addition, USTAR's Technology Outreach and Innovation Program assists faculty and businesses that are licensing university-developed technologies. The outreach program can assist entrepreneurs with business plan development, market studies, product development and testing and patent research, among other services. Resources for this program are very limited, however, and the services are not available to entrepreneurs and start-up companies that are not licensing a university-developed technology.

At the same time, it should be recognized that entrepreneurial firms need many resources, including management talent, technology, capital, and professional expertise. They often need assistance in determining economic feasibility and identifying markets and distribution channels. They may also need access to specialized equipment and laboratories and to expertise to solve technical issues that arise during product development. They must be able to recruit key personnel and have access to small amounts of pre-seed capital.

In 2008, the Utah Business Resource Centers (BRC) Act was signed into law. BRCs, which are established by GOED, are certified one-stop resource centers providing coordination of business support, education, tracking of clients, access to sources of funding, training, technical expertise, talent, and networking for new and existing businesses. They are usually located at institutions of higher education with a focus on small business assistance. It is not clear to what extent the BRCs are able to meet the needs of technology-based start-up companies. Often such firms require assistance that is not normally able to be provided by organizations focused on small business assistance.

Another entrepreneurial development and networking activity has been through Grow Utah Ventures, a private non-profit organization. In the past Grow Utah involved direct investing in promising ventures and support to community efforts in entrepreneurial development, but now is more involved in facilitating entrepreneurial competitions and forums, helping entrepreneurs to learn how to advance their ideas and networking with angel investors. This includes CrowdPitch Events in which entrepreneurs pitch to investors, while the audience can watch and learn from investor feedback. In addition, Concept to Company Contests are held to identify entrepreneurs to bring to CrowdPitch Events.

Going forward, Utah should consider developing a more direct service approach to working directly with technology-based entrepreneurs to help them commercialize their technologies, launch and grow new businesses and access needed capital through a one-stop commercialization and venture development center. Among the services to be considered to advance to technology-based entrepreneurs would be:

- Providing organizational documentation, preliminary technology and market assessments, and start-up strategic planning
- Providing management and in-depth business planning support to technology entrepreneurs and start-up companies
- Linking companies to mentors
- Conducting due diligence
- Providing consultation and ongoing entrepreneurial education
- Preparing companies to seek venture financing
- Linking companies to sources of capital
- Supporting development of angel networks.

Alternatively, the BRCs, the Technology Outreach and Innovation Program, or another organization could be given additional funding to provide these services. Also for such centers to be successful, they usually require access to small amounts of capital that can be used to help companies reach the point at which they can obtain private capital.

Another way of providing these services is through incubators such as Bioinnovations Gateway. Started as a replicable model, Bioinnovations Gateway provides business and commercialization services to its client companies as well as access to state-of-the-art facilities, laboratories, equipment, resources and talent. It was started in part with USTAR and federal funding. Bioinnovations Gateway is focused on life science companies but this approach could be used to provide the same types of services to firms in Utah's other technology industry clusters.

Talent Initiative – Meeting the Need for an Innovation Workforce

The greatest challenge industry faces in Utah is being able to find the skilled workers they need. As Utah's industry clusters have grown, demand for skilled workers has increased and firms find that they must recruit from out-of-state (which is expensive and can be difficult to accomplish), train workers internally or recruit workers from other Utah employers. To address this issue, Utah is challenged to

- Improve the links of education and training programs and their students to Utah's industry clusters
- Continue efforts to improve STEM education
- Promote an image of Utah as a welcoming place that provides a wealth of opportunities for workers and businesses.

Improving the links of education and training programs and their students to Utah's industry clusters.

A key element of the UCAP process is to identify future talent needs. UCAP strategies have been developed thus far for the Aerospace and Defense cluster, the Energy cluster and the Digital Media cluster and the Life Science Cluster was recently released. Each of the UCAP strategies have identified specific talent needs.

- The **Aerospace and Defense** industry UCAP calls for creating some very specific new programs, such as establishing an aerospace defense program manager curriculum and implementing an aerospace emphasis in an MBA program, and also calls for increasing the number of students studying electronics engineering, software engineering and composite structural engineering.
- The **Energy** UCAP calls for providing training and workforce skill development to train electrical linemen, grid technicians, technicians in oil, gas, and coal extraction, and people knowledgeable about energy efficiency, energy management, carbon management automation, energy trades and green construction methods.
- The **Digital Media** UCAP strategy identifies a set of skills that will be needed and calls for establishing university-based creative institutes that promote cross discipline curricula to produce creative thinkers.
- The **Life Science** cluster has identified the need for quality engineers, people trained in quality assurance, regulatory affairs and good manufacturing practices.

Going forward, the UCAP effort provides an excellent platform for developing more intensive mechanisms to link education and training programs and their students to the needs of Utah's industry clusters. Among the suggested mechanisms are:

- ***Promoting postsecondary student internships across the state with businesses in Utah's targeted industry clusters.*** Student internships with employers can serve to establish relationships of benefit to both employers and students. For students, the internships can provide the opportunity for enriched, real-world problem-solving. Companies can benefit by not only raising their profiles on college campuses, but also by receiving new ideas and energy from students through various mechanisms. A 2010 survey of the 884 industry members of the National Association of Colleges and Employers revealed that 82.5 percent of employers surveyed have an internship or co-op program. Furthermore, more than 50 percent of interns accept full-time employment with the company for which they interned.

Other states are turning to more extensive use of internships. Nebraska recently enacted InternNE internship grants providing a 40 percent match, up to \$3,500 per internship, for up to 10 interns per year (5 at a single location). Up to \$1.5 million is allocated for the Nebraska program and it is targeted to certain set of eligible businesses. Ohio's Third Frontier Program has an internship program that reimburses up to 50 percent of the intern's wages, or no more than \$3,000 for a 12 month period. Ohio targets its internships to a set of high growth technology industries such as biosciences, information technology, instruments and controls, advanced materials and advanced energy, among others. Since 2002, more than 3,000 students have participated.

- ***Dedicated funding for new curriculum, certificate and degree programs for skill shortage areas.*** It is important that UCAP have a systematic means for acting promptly on documented needs for new curriculum, certificate or degree programs to fill skill shortage areas. It is often very difficult for colleges and universities to have readily available start-up funding for such new efforts, including funding and equipping labs, developing curriculum, training faculty and recruiting students. An example of another state's efforts is the University of Georgia System's

Intellectual Capital Partnership Program (ICAPP) Advantage that meets company and groups of companies hiring needs through expedited curriculum and degree development that is designed at a college or university. An ICAPP Advantage project requires at least 10 new knowledge jobs being created with a documented shortage. Examples of ICAPP projects include a new graduate Certificate in Computer Modeling and Simulation around the expansion of Fort Benning, as well as new aviation management courses and an accelerated bachelor's degree in aviation management for a group of companies led by Delta Airlines.

- **Targeted jobs incentives for hiring recent graduates and workers from outside of Utah in high skilled shortage areas.** For persistent skill shortage areas in high growth oriented focus areas of Utah's industry clusters, another key tool may be providing for targeted job incentives for recent graduates and workers outside of Utah. An excellent example of such an approach was Oklahoma's Aerospace Engineering Tax Credits which, until its recent suspension due to budget constraints, provided tax credits of \$5,000 a year for up to five years to engineers who were hired after Jan. 1, 2009. The companies hiring the engineers received a tax credit equal to 10 percent of the compensation paid to an engineer of at least \$50,000 during the first five years of his or her employment if the engineer graduated from an Oklahoma college or university. If the engineer graduated from a college outside Oklahoma, the employer received a tax credit equal to 5 percent of the compensation paid to the employee during the first five years. In

addition, the law granted Oklahoma aerospace companies a tax credit in the amount of 50 percent of the tuition reimbursed to a new engineer graduate for the first four years of his or

Iowa Mathematics and Science Education Partnership

The Board of Regents, State of Iowa and the Iowa Legislature established the Iowa Mathematics and Science Education Partnership (IMSEP) in early 2007. UNI leads the initiative in collaboration with the UI and ISU. IMSEP has four core programs:

- Math and science teacher real world internships — Summer-long paid internships for current science and math teachers in business and industry to update skills while modernizing the curriculum. In 2010, 33 teachers participated in the program; it is proposed that the program be expanded to include 50 participants in 2011.
- Project Lead The Way® (PLTW) expansion — A national pre-engineering curriculum package for middle and high school students to learn science and math through engineering is being implemented in more than 100 Iowa high schools. This effort should be expanded to include the biotechnology engineering curriculum. UNI is also offering a curriculum that will allow teachers to graduate with PLTW certification.
- A special STEM community college teaching certificate program is being offered at ISU to address the shortage of math and science instructors at community colleges.
- I-Teach project: to recruit more talented and diverse candidates to math and science teaching. Offers tuition-waived courses exploring teaching, followed by paid internships in educational settings with mentors.

In addition to coordinating these core programs, the IMSEP promotes and coordinates business-school partnerships, studies and reports on state science and math education trends, and promotes science and technology careers through multimedia assets for schools and other educational entities.

her employment. The tax credit was limited to 50 percent of the average annual tuition paid by an engineer at a public university in Oklahoma.

With these added mechanisms UCAP can translate its strategic focus on talent generation into specific actions that address skill shortage requirements.

Continuing efforts to improve STEM education

As discussed previously, while Utah students perform at about the national average in terms of achievement in math and science, a closer examination by the Utah Foundation of Utah's performance on National Assessment of Educational Progress (NAEP) math, science and reading tests from 1992 to 2009 found that Utah is underperforming compared to states with similar demographics in terms of its math, science and reading scores. Therefore, improving STEM education is a critical imperative for Utah.

Utah has in place a number of efforts to improve STEM education.

The **Utah Science and Mathematics Education Consortium** is a coalition of the science deans from all the colleges and universities in the state, teamed with representatives from public education and from industry. The goal of this group is to promote programmatic cooperation among the state's institutions of higher education, as well as to develop a better dialog between higher education and K-12 schools.

The **Center for Science and Mathematics Education (CSME)** was established in fall, 2009 at the University of Utah within the College of Science and the College of Education. The mission of CSME is to facilitate, coordinate and implement collaboration between the two Colleges as well as with Utah school districts. The Center was created to address the need for employees with highly developed mathematics science and engineering knowledge and skills, as well as, to satisfy the critical need for more qualified teachers of mathematics and science.

Utah State University is in the process of creating a **STEM Education Center** which will conduct R&D on STEM education, offer professional development opportunities for STEM teachers, and perform outreach activities aimed at interesting students in STEM.

The University Educational Network has created a **STEM (Science, Technology, Engineering, and Mathematics) website**, which connects students, teachers, counselors, parents and others to the many programs, opportunities, and services available to students who wish to participate in math and science programs. Many opportunities are embedded in the State's colleges and universities. Others are offered by the network of museums, libraries and similar organizations that provide programs that complement formal studies in math, science, and engineering.

The Utah Technology Council (UTC) has been active in advancing STEM programs and policies in Utah. Through the efforts of UTC staff and member companies, strong industry support has been mobilized to advance major STEM initiatives in Utah, including enhancing the state's graduation requirements in math and science, establishing Utah's Engineering Initiative and support for funding of these and other STEM initiatives.

What is needed going forward is a coordinating effort to maximize the reach and effectiveness of ongoing STEM activities. It is particularly important to create a single place where input and guidance from industry can be shared across programs, and industry awareness and engagement can be promoted. It is also important to have a statewide, sustained outreach and marketing effort of the state's many STEM related programs to students and their parents. This is especially important for the emerging efforts to educate and train students in career opportunities in the life sciences.

At the same time, these efforts in STEM education are critical to advancing the attractiveness of Utah in recruiting high skilled workers and their families to the state. A particular concern expressed in the industry interviews is that as K-12 education in Utah is slipping, Utah becomes less competitive for attracting high skilled workers, especially compared to other fast growing technology-based states.

In response to the imperative of STEM education for Utah's future, a unique partnership between Utah leaders in education, business and industry to improve education outcomes—Prosperity 2020 Business Promise—was formed under the leadership of Governor Herbert and his Education Excellence Commission. The goal of Prosperity 2020 is that two-thirds of Utahans earn post-secondary degrees or certificates by 2020, and 90 percent of elementary students are proficient in reading and math. Prosperity 2020 will advance these goals through school partnerships and volunteers from the business community serving as tutors and mentors, involving 20,200 volunteers by 2020 to help students achieve success.³

A more systematic approach recommended for Utah's consideration is to advance an integrated Career and Technical Education curriculum which links Science, Technology, Engineering, and Mathematics (STEM) education with problem-solving, team building and experiential learning activities in defined areas of technology and industry. With the 2006 changes in the federal Carl D. Perkins Career and Technical Education Improvement Act, which provides federal funding for career technical education (CTE) to states for high school programs, Utah has an unprecedented opportunity to connect CTE efforts with broader school reform. For the first time, federal legislation requires that career-oriented courses teach essential academic skills, while also requiring greater collaboration between high schools and postsecondary education and an increased focus on the needs of business and industry in identifying specific career clusters for CTE to emphasize.

One way to accomplish this is to create more enriched CTE courses to build off of the basic courses in STEM (such as biology, math and other sciences) and demonstrate their relevancy to students, linking to mastering critical thinking, problem-solving and experiential learning. This type of effort would involve combining experiential learning together with CTE courses and offering a team-building challenge in which student teams, along with their teachers, interact with each other and with business mentors along with college student mentors from local colleges.

An example of this is Connecticut Career Choices (CCC), an initiative of the Connecticut Office for Workforce Competitiveness to engage pre-kindergarten through post-secondary education students in technology-related career development. Since its inception, CCC has accomplished the following:

³ For more details, see www.p2020businesspromise.com

- Core curriculum developed and implemented, including E-Commerce, Biotech R&D, Foundations in Health, Digital Media and Film Making, Innovation (IT) Research & Development and Science Research Seminar;
- Fifty high schools offering one or more CCC courses involving nearly 6,000 students and 125 teachers;
- Almost 100 experiential learning activities reaching over 400 students and 130 student teams at the HS Innovation Challenge; and,
- Providing on-line content and tools over the Connecticut Education Network.

Most notably, in July of 2007, Education Connection—CCC curriculum and education delivery partner—was successful in winning a prestigious three-year grant from the National Science Foundation (NSF) for the “Connecticut Pathways to Innovation (CPI) Project.” The CPI project will enable Education Connection to articulate CCC courses into post-secondary education programs in partnership with Connecticut’s College of Technology. The project will place an emphasis on serving underserved and underrepresented students and will focus on equipping students with skill sets to enter the workforce of our 21st century knowledge economy. This new NSF grant will complement and augment CCC activities and enable it to spur the focus on talent pipeline development in a more concrete manner.

Then in 2010, the education provider for Connecticut Career Choices—Education Connection’s Center for 21st Century Skills—was awarded \$4.5 million from the U.S. Department of Education to advance a STEM high school academy, known as STEM21. This effort partners with the Connecticut College of Technology, Southern Connecticut State University, Connecticut Pre-Engineering Program, the Connecticut Office for Workforce Competitiveness and industry partners, such as IBM and AT&T. The STEM Academy builds on Connecticut Career Choices courses, delivering in the same blended learning environment, engaging students in a progression of innovative online coursework guided by teachers in classrooms and augmented by experiential learning. To foster STEM21 participation, high-need middle school students will be involved in STEM preparatory programs. STEM21 students will be eligible to earn up to 15 college credits prior to graduation.

Utah can bring this same type of systematic effort to high schools across the state linking STEM and Career & Technical Education together in defined focus areas targeted by the state’s industry clusters. Consideration could also be given to allowing certain CTE courses to be used to meet math and science requirements for graduation.

Promoting an image of Utah as a welcoming place

A key concern expressed by industry leaders is that it is often difficult to recruit senior-level workers to relocate to Utah if they have never been a resident. This is due, in part, to the fact that some of Utah’s technology industry clusters, such as in the life sciences, are not of a sufficient size that a worker would feel that there would be additional options for employment if he or she wanted to leave the job for which they were recruited. But interviewees also attributed this to misperceptions about Utah’s culture and the dominance of the Church of Jesus Christ of Latter Day Saints.

Utah has done a very good job of marketing the state as a recreational destination. The State of Utah needs to develop a brand around the fact that Utah is a good place to work and play and is home to world-class, globally competitive, technology-intensive companies. Utah should communicate that companies and individuals coming to Utah will find a supportive environment in which they can thrive in finding the talent, research, and commercial relationships that are critical to growing a successful business.

Utah's science and technology community should develop a common theme that can be incorporated in state marketing materials as well as those of the various organizations that are committed to growing the state's innovation economy. The Utah Technology Council currently has a campaign underway called "Why Utah" that seeks to address misperceptions about what it is like to live in Utah. An active earned media campaign could be undertaken following the release of the industry UCAP strategies. Having articles appear in newspapers and magazines nationwide describing Utah as a very desirable place to live can play a key role in changing the state's image. The placement of such articles, however, will require an active public relations outreach to key publications and the active development of news stories.

Utah should also seek to attract national and international conferences that would bring industry leaders to the state. Such conferences can be important not only in that they bring people to see the available assets and resources but they can also focus attention on areas of key strengths.

Appendix A: Detailed Industry Cluster Profiles

It is important to consider each technology-based industry cluster in more depth to examine how it is positioned for technology-based growth. In today's globally-based economy, the key to success for states is to identify those growth opportunities within its leading industry sectors for which it is best positioned to differentiate itself and become a world leader. This is a critical best practice lesson in economic development for states in the 21st century global economy.

The approach taken to identify growth opportunities within each technology-based industry cluster is to consider the alignment of two key factors:

The approach taken to identify growth opportunities within each technology-based industry cluster is to consider the alignment of two key factors:

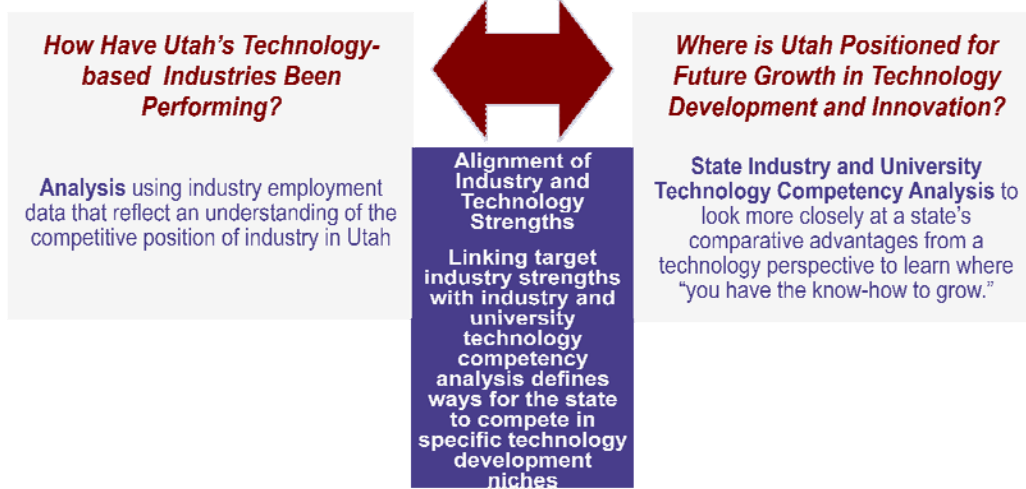
- Detailed industry-level analysis of specific product and service focus areas found in Utah to identify the drivers of major technology industry sector growth in Utah.¹⁹
- Technology competencies found within each of the technology-based industry clusters in Utah. As mentioned earlier, technology competencies represent focused areas of “know how” where there is demonstrated critical mass in Utah.

The starting point for defining these technology competencies is through a cluster analysis of patents and publications in Utah from 2006 through June of 2011. Battelle then validated the extent of these patent and publication cluster focus areas based on both industry and scholarly activities by considering:

- Focus of scholarly excellence in Utah based on performance of research universities in peer-reviewed publications analysis.
- Identified research centers and major research activities found across Utah's research universities, based on Battelle's interviews and review of major grants and web sites.
- Level of technology deployment as suggested by value-added per employee for detailed industry segments.
- Presence of innovative, emerging technology firms, based on firms receiving venture capital funding between 2006 and 2011 (2nd quarter).

By linking core technology competencies to specific industry strengths within an overall industry clusters, it is possible to define not only where a state has demonstrated the ability to advance industry development but where it has the know how to continue to fuel innovation and further distinct areas of growth. This approach is depicted in Figure A1 below.

Figure A1: Alignment of Detailed Industry Strengths and the Presence of Core Technology Competencies



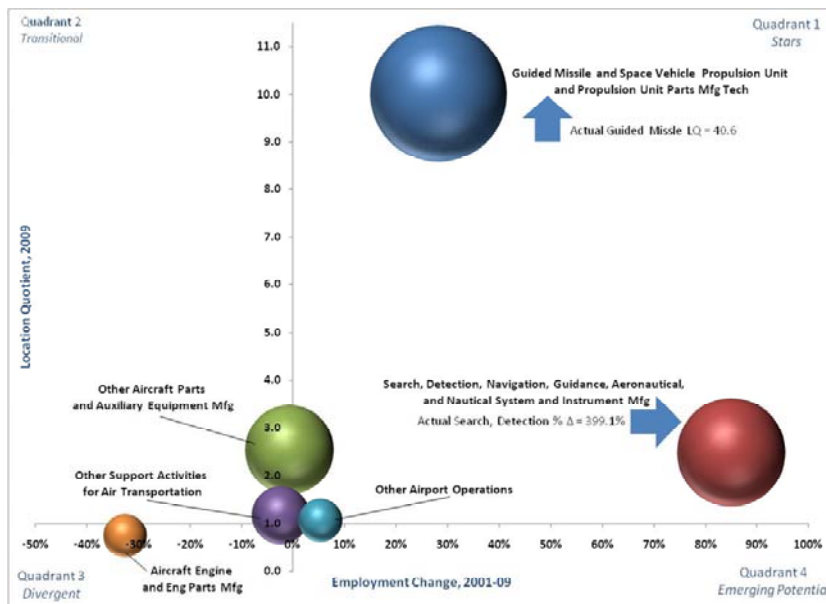
Aerospace & Defense

The Aerospace & Defense industry cluster grew rapidly over the 2001 to 2009 period, increasing its employment base in Utah by 38 percent, while the national Aerospace & Defense industry cluster remained flat in employment. By 2009, Utah’s Aerospace & Defense cluster reached 13,034 jobs in 2009, and it stands as a highly specialized industry with a 77 percent higher level of employment concentration in Utah than nationally.

Detailed Industry Strengths

Six detailed industries comprise the Aerospace and Defense industry cluster, and Utah stands out in three out of the six as set out in the bubble chart in Figure A2.

Figure A-2: Aerospace and Defense Industry Cluster



- The largest and most specialized detailed Aerospace & Defense industry in Utah is **Guided Missile and Space Vehicle Propulsion Unit and Parts Manufacturing** with 5,309 jobs in 2009. This detailed industry is extraordinarily specialized in Utah, with a higher relative concentration that stands 41 times higher than in the nation. Utah has one out of every three jobs in this detailed industry nationally. This detailed industry grew by 28.3 percent in Utah from 2001 to 2009, and well outpaced the national growth rate.
- The fastest growing detailed industry in Aerospace & Defense in Utah is **Search, Detection, Navigation, Guidance, Aeronautical and Nautical System and Instrument Manufacturing**. This detailed industry grew by 399 percent in Utah from 2001 to 2009, while nationally this industry grew a miserly 1 percent. It is also highly specialized, with a 148 percent higher level of employment concentration in Utah than in the nation.
- Another highly specialized detailed industry, but slightly declining in employment in Utah over the 2001 to 2009 period is **Aircraft Parts** (not including engines). This detailed industry has a 154 percent higher level of employment concentration in Utah compared to the nation, with 2,228 jobs in 2009. This detailed industry had a modest employment decline of 0.7 percent over the 2001 to 2009 period, so has been relatively flat.

Linkage to Core Technology Competencies

Four core technology competencies, aligned with the patent and publication cluster focus areas related to Utah's Aerospace & Defense Industry Cluster, were validated from the interviews and further analysis of industry and scholarly activities, including:

- Automation and Control
- Sensors and Sensor Systems
- Aerospace-related Materials
- Space Sciences.

The patent and publication cluster focus areas included:

- **Automation and Control encompassing 96 patents and publications from 2006 to 2011.** Illustrative applications include: analysis of fractional order dynamic systems; tuning methods for fractional order controllers; methods for solving fractional differential equations; various types of actuators such as mechanical, hydraulic, pneumatics, and robotic for sensing and control.
- **Sensors and Sensor Systems with 405 patents and publications from 2006 to 2011.** Illustrative applications include: multi-gas sensors; sonar sensor; thermal sensors; nanobased sensors; detecting targets; immersion detection; in-line inspection systems; sensor arrays for determining position; multi-sensor systems for navigation; miniature air vehicle visual odometry systems; detecting and identifying rapidly moving objects; sensors to locate faults in live aircraft

wires; sensing systems for field robots; optical fiber sensors for embedded instrumentation systems; high precision motion control systems.

- **Aerospace-related Materials with 340 patents and publications from 2006 to 2011.** Illustrative applications include composite structures for airplanes and spacecrafts; nanocomposites; composites for adhesives; fiber/glass/epoxy composites development and fabrication; micromechanical studies of material properties; material coating methods (chemical vapor deposition, spraying, metal powder application, seal coating) for jet engines and gas turbines.
- **Space Sciences with 395 patents and publications from 2006 to 2011.** Illustrative applications include: space science (i.e., hot stars, gravitational waves, black holes, dark matter); methods for detecting planets and stars; high energy detection in objects (such as gamma rays, cosmic rays); earth/space science (detection of plasma in the earth ionosphere and analyzing ionospheric/plasosphere models).

Below is a chart that presents the further analysis of these four core technology competencies, including an examination of fields of publications excellence, institutional research activities, productivity, and presence of detailed industry strengths, though there were no recorded venture-backed companies in Aerospace & Defense in Utah over the 2006 to 2011 (2nd Q) period.

Table A-1: Core Technology Competencies Within the Aerospace and Defense Industry Cluster

Breadth of Patent and Publications in Cluster Focus Area Number of patent and publication records in cluster groupings from 2006 to 2011	Presence of Institutional Research Centers and Other Specialized Strengths	Publications <i>High Share/High Quality:</i> Greater than 1.5% of U.S. pubs and greater than 40% higher citation impact than U.S. average <i>High Share Only:</i> Greater than 2% of U.S. pubs <i>High Quality Only:</i> Greater than 50% higher citation impact than U.S. average	Productivity Relative level of 2009 value added per employee for detailed industry sector in Utah compared to U.S. average	Presence of Detailed Industry Strengths <i>Current Industry Strength:</i> both specialized (greater than 20% higher industry employment concentration in 2009) and growing in jobs from 2001 to 2009) <i>Emerging Industry Strength:</i> Growing in jobs from 2001 to 2009, but not specialized <i>Specialized Industry Strength:</i> Specialized, but lost jobs from 2001 to 2009	Presence of Venture-backed Companies Number of companies receiving venture funding from 2006 to 2011
AUTOMATION & CONTROL					
96	Unmanned aerial vehicles (USU, BYU) – MAGICC – Multiple Agent Intelligent Coordination & Control Lab (BYU); Center for Self-Organizing & Intelligent Systems (USU)	<i>High Share/High Quality:</i> Automation & Control Systems:	None applicable		None
SENSORS & SENSOR SYSTEMS					
405	Upper Atmosphere & Space Measurements – Center for Advanced Imagery and Space Dynamics Lab (USU) Hill Air Force Base growing base of MRO activities call for expertise in sensor and sensor systems.	<i>High Share/High Quality:</i> Imaging Sciences	Search, detection and navigation instruments: 88%	<i>Current Industry Strengths:</i> Search, detection and navigation instruments	None
AEROSPACE RELATED MATERIALS					
340	Center for Space Engineering (USU) Friction Stir Welding (BYU) Hill Air Force Base growing base of MRO activities position Utah as a leader in extending the life of aging Air Force planes where upgrades require new composite structural materials, along with other components.	<i>High Share Only:</i> Composites	Aircraft mfg.: 67%	<i>Specialized Industry Strengths:</i> Aircraft Parts	None
SPACE SCIENCES					
395	Space Dynamics Lab and Experimental Flow Research Lab (USU) Space Weather: – Center for Atmospheric & Space Sciences (USU)	None	Guided missile and space vehicle mfg.: 102% Propulsion units and parts for space vehicles: 100%	<i>Current Industry Strengths:</i> Guided Missile and Space Vehicle Propulsion Unit and Parts Manufacturing	None

Possible Opportunities for Future Growth

From discussions with industry executives and university leadership as well as guidance from the recent Aerospace & Defense cluster acceleration strategy supported by the Utah Higher Education System, Battelle suggests two specific niches stand out for Utah:

- **Unmanned Aerial Systems** – Unmanned aerial systems (UAS), often referred to as drones, are aircraft systems that operate without a flight crew on-board either by remote control or autonomously. UAS are being used extensively by the military either for surveillance or attack missions. But the applications of UAS can be quite extensive from transportation, homeland security and law enforcement surveillance, performing geophysical surveys for oil, gas and mineral exploration, and hunting hurricanes, among other uses. UAS are highly advanced inter-disciplinary technology systems calling for advances in automation and control, remote sensing, sensing data management systems, power and propulsion and aircraft materials and design.

How It Builds on Utah Strengths

- The Aerospace & Defense UCAP steering committee identified Unmanned Aerial Systems as a strategic area for the continued development of Utah’s aerospace and defense cluster. It notes that Utah firms already servicing this expanding market, such as Procerus and IMSar, are well positioned to capitalize on this growth. General Atomics, the maker of the Predator and Reaper UAS is likely increasing its presence in the state. Other firms serving traditional aerospace and defense markets may be able to leverage skills into the UAS market. For example, L-3 Communications technologies are a critical component for air to ground data transfer and controls. This industry strength is found in Search, Detection, Navigation Guidance System and Instruments, which is closely aligned to unmanned aerial systems and its components.
- It builds upon Utah’s core technology competencies in Automation and Control as well as in Sensor and Sensor Systems, along with publications excellence found in Robotics, Automation and Control Systems and Aerospace Engineering across Utah’s research universities.
- Both BYU and Utah State University have active programs that offer key technologies to advance unmanned aerial systems:
 - BYU has an active research team working in miniature air vehicles (MAVs), a class of unmanned aircraft with wingspans ranging from 1 to 6 feet. MAV research at BYU has been directed towards the precise control of small aircraft and developing enhanced autonomous capabilities—including cooperative control, path planning trajectory generation, image directed control, autonomous vehicles. BYU in collaboration with the University of Colorado has received a planning grant from the National Science Foundation to form a University-Industry Collaboration Research Center.

- At Utah State University, the Space Dynamics Lab is actively involved in remote sensing and reconnaissance systems, while the Center for Self-Organizing and Intelligent Systems (CSOIS) focuses on the design, development, and implementation of intelligent, autonomous mechatronic systems.
- **Advanced Aerospace Materials** – The need for advanced composites that provide light weight, with greater strength and durability is critical for advancing airframes, and particularly extending the life of existing aircraft. The ability to easily fabricate composites into nearly any shape will also increase applications advanced composites in the aerospace market. Among the key new applications is the use of carbon fiber made from a continuous matrix reinforced with dispersed fibers along with an interfacial region. Titanium alloys are another key material used in modern airframes. Titanium is relatively inexpensive, widely available and provides favorable properties including a high strength-to-weight ratio and superior corrosion resistance. In addition, advanced coatings are critical to protect from heat and corrosion, as well as to offer smart functionality to identify structural defects and self-repairing properties.

How It Builds on Utah Strengths

- In industry development, aircraft parts is already a strength for Utah. Discussions with the leadership of the Aerospace Utah Cluster Acceleration strategy identified this as a growing area for employment gains in Utah’s aerospace industry in 2010 and 2011.
- Hill Air Force Base has an expanding MRO (maintenance, repair and overhaul) mission involving more sophisticated aircraft requiring new skills involved in composite know-how, along with challenges of maintaining the air frames and embedded systems of aging aircraft.
- An identified patent and publication cluster focus area, with publication excellence found in composites.
- While there are research centers involved in materials sciences, they are not broad or extensively focused on aerospace materials. And the research expenditures across Utah’s research university in materials engineering in Utah overall stands at only \$5.5 million, which is just 0.8 percent of all materials engineering research nationally.

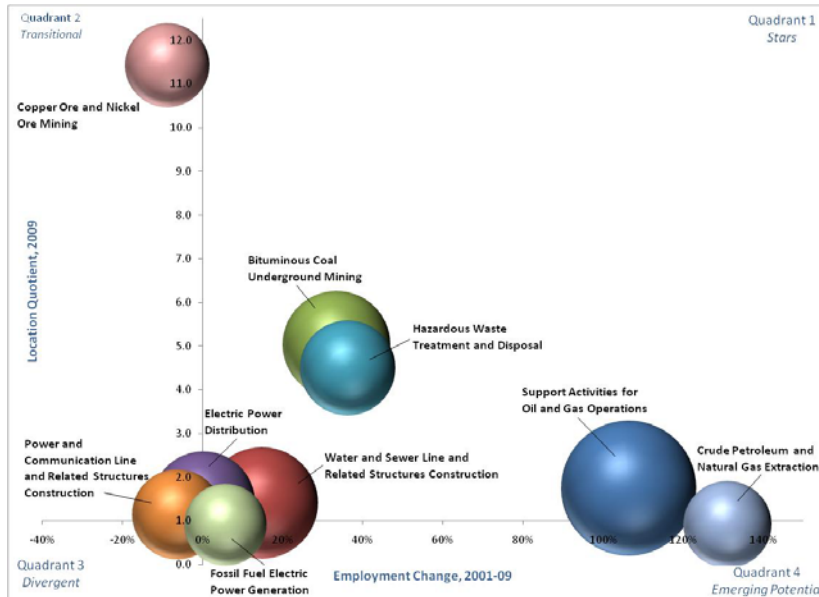
Energy & Natural Resources

The Energy & Natural Resources industry cluster in Utah grew at a healthy rate of 27.1 percent from 2001 to 2009, compared to fewer than 3 percent nationally. While it did decline by 8 percent during the recession years of 2007 to 2009, it still employed 22,853 workers in 2009, which represents a 26 percent higher employment concentration in Utah than the nation, and so has reached the level of industry specialization.

Detailed Industry Strengths

The Energy & Natural Resources industry cluster is very broad involving 16 detailed industries employing over 500 workers in Utah as of 2009. Three distinct detailed industry groupings emerge—two that are fast growing and a third that is highly specialized but not growing in jobs:

Figure A-3: Energy & Natural Resources Industry Cluster



- **Fossil-based energy industries offer a mix of sizable and growing industries, many of which are specialized, including:**

- **Support Activities for Oil and Gas Operations**, with 3,008 jobs in 2009, a 74 percent higher relative concentration than the nation and job growth of 107 percent from 2001 to 2009.

- **Bituminous Coal Underground Mining**, with 1,902 jobs in 2009, a

502 percent higher relative concentration than the nation and job growth of 33.6 percent from 2001 to 2009.

- **Petroleum Refineries**, with 987 jobs in 2009, a 46 percent higher relative concentration than the nation and job growth of 32.8 percent from 2001 to 2009.
- **Crude Petroleum and Natural Gas Extraction** with 1,260 jobs in 2009 and employment growth of 131 percent from 2001 to 2009—but not yet specialized in employment concentration.
- **Fossil Fuel Electric Power Generation** with 1,101 jobs in 2009 and employment growth of 5.8 percent from 2001 to 2009—but not yet specialized in employment concentration.
- **Environmental technologies and services also offer a mix of sizable and growing industries, many of which are specialized.**
 - **Water and Sewer Line and Related Structures Construction** with 2,054 jobs in 2009, a 40 percent higher relative concentration than the nation and job growth of 14.9 percent from 2001 to 2009.

- **Hazardous Waste Treatment and Disposal**, with 1,483 jobs in 2009, a 450 percent higher relative concentration than the nation and job growth of 36.3 percent from 2001 to 2009.
- **Environmental Consulting Services** with 563 jobs in 2009 and employment growth of 84.6 percent from 2001 to 2009—but not yet specialized in employment concentration.
- **Metals mining offers more modest sized industries that are not growing, but are highly specialized due to the unique presence of metal resources in Utah.**
 - **Primary Smelting and Refining of Copper**, with 610 jobs in 2009, a 36 times higher relative concentration than the nation and job growth of 13.7 percent from 2001 to 2009.
 - **Copper Ore and Nickel Ore Mining** with 1,173 jobs in 2009 and an industry specialization 11 times higher in employment concentration in Utah than the nation, but lost jobs at a rate of 8.7 percent from 2001 to 2009.
 - **Primary Smelting and Refining of Nonferrous Metal** with 512 jobs and an industry specialization 786 percent higher in employment concentration in Utah than the nation, but lost jobs at a rate of 3.8 percent from 2001 to 2009.

Another important implication of environmental issues for Utah’s economic development that is not reflected in detailed industry analysis is that the delivery of freshwater resources in Utah is facing both immediate and long-term challenges that impact the sustainability of urban and natural ecosystems. Utah today is the 3rd driest state in the nation and its population is expected to double over the next three decades. With 85 percent of Utah’s citizens currently living in, and most future growth expected to occur, along the Wasatch Range Megapolitan area, this places real constraints on Utah’s quality of life and ability to ensure a key resource for industry activities—water. Further complicating the situation is that approximately 70 percent of surrounding land is federally-owned which constrains where and how economic development can occur.

Linkage to Core Technology Competencies

Similar to the breakout of detailed industry strengths, there emerge two distinct areas of core technology competencies related to the Energy and Natural Resources industry cluster from the patent and publication cluster analysis, interviews with university and industry leaders and further analysis of industry and scholarly activities.

One distinct area is in energy with two core technology competencies that track well to the patent and publication cluster focus areas:

- **Oil, Gas and Resource Mining Tools**, with 501 patents and publications from 2006 to 2011. Illustrative applications include: drilling tools (i.e., drill bits, down the hole assembly, core barrel assembly) for various earth boring applications (such as oil/other hydrocarbons, paving material,

underground mines, subsea line drilling); methods for manufacturing cutting and drilling tools (e.g., polycrystalline abrasive layers, superabrasive insert, axially-tapered waterways, fibers); bearings and bearing assemblies for earth boring; machining processes (for milling, turning, and drilling); polycrystalline diamond materials for various applications (including bearings, cutting tools, rotary drill bits, wire drawing dies, and other elements).

- **Energy Conversion and Storage**, with 587 patents and publications from 2006 to 2011. Illustrative applications include: combustion processes; analysis of combustion processes (particulate emissions, lower flammability limit); power conversion (e.g., internal combustion engines, heat exchangers, electrochemical cell); fuel cell development; catalysis of fuel cells and emission control systems; advanced battery development; nanopore and nanoparticle based electrodes; polymer based electrolytes; rechargeable batteries; thin film batteries.

Another distinct area is in the environmental area where Utah has a core technology competency in Environment, Ecology, Water and Atmospheric Sciences, which encompasses a rich base of patent and publication cluster focus areas, including.

- **Ecology**, with 815 patents and publications from 2006 to 2011. Illustrative applications include: habitat analysis, complexities, development; impacts of human interactions on species development and habitats, including development projects, pollution; endangered species assessments; global diversity of species; diet impacts on habitats; genomic analysis of species development and biological diversity; microsatellite mapping of species genomic development.
- **Water and Soil Conservation**, with 526 patents and publications from 2006 to 2011. Illustrative applications include: water conservation; aquatic plant survival; impact of nutrients on lakes and streams; Groundwater flow movements; Analysis of lake/river sediment deposits and material; soil erodability; nutrient cycling management; salt affected soils; soil-sediment analysis.
- **Atmospheric Sciences**, with 255 patents and publications from 2006 to 2011. Illustrative applications include: climate analysis and modeling; analysis of cloud properties, formation; land-ocean interactions; rainfall analysis and projections; Utah tropical rainfall measuring mission; weather modeling systems and assessment; analysis of storms; river level forecasting; snow forecasting; snow density analysis; impact of climate change on snow cover.
- **Range and Forest Sciences**, with 235 patents and publications from 2006 to 2011. Illustrative applications include: plant and grassland analysis; identification of plant and grassland pathogens; rangeland restoration; plant and grassland differentiation and development; plant and grassland seed development and viability; forest development and sustainability; tree protection systems; mapping land cover; genomic analysis of tree species.
- **Earth Science**, with 139 patents and publications from 2006 to 2011. Illustrative applications include: seismic analysis and mapping (for earthquakes and tsunamis); fault structure and

zones; deformation modeling; sediment and fossil deposits in various earth formations (such as basins, geothermal fields, quarries).

- **Animal Health & Sustainability**, with 83 patents and publications from 2006 to 2011. Illustrative applications include: various studies of animal health and survival from rattlesnakes to wild dogs to June suckers to honeybee to seabirds; analysis of pathogens and infections with impact on animal populations; climate and species interactions; sheep related genomics, diet, and environmental impacts.

Below is a chart that presents the further analysis of these three core technology competencies, including an examination of fields of publications excellence, institutional research activities, productivity, presence of detailed industry strengths, and presence of venture-backed companies:

Table A-2: Core Technology Competencies Within the Energy and Natural Resources Industry Cluster

Breadth of Patent and Publications Cluster Focus Areas Number of patent and publication records in cluster groupings from 2006 to 2011	Presence of Institutional Research Centers and Other Specialized Strengths	Publications <i>High Share/High Quality:</i> Greater than 1.5% of U.S. pubs and greater than 40% higher citation impact than U.S. average <i>High Share Only:</i> Greater than 2% of U.S. pubs <i>High Quality Only:</i> Greater than 50% higher citation impact than U.S. average	Productivity Relative level of 2009 value added per employee for detailed industry sector in Utah compared to U.S. average	Presence of Detailed Industry Strengths <i>Current Industry Strength:</i> both specialized (greater than 20% higher industry employment concentration in 2009) and growing in jobs from 2001 to 2009) <i>Emerging Industry Strength:</i> Growing in jobs from 2001 to 2009, but not specialized <i>Specialized Industry Strength:</i> Specialized, but lost jobs from 2001 to 2009	Presence of Venture-backed Companies Number of companies receiving venture funding from 2006 to 2011
ENERGY-RELATED					
Oil, Gas and Resource Mining Tools: 501	Energy & Geoscience Institute (U of U)	High Share and High Quality: Geochemistry & Geophysics High Share Only: Mineralogy Mining/Mineral Processing Energy & Fuels	Petroleum Refineries: 104% Mining and Oil & Gas Field Machinery: 89% Support Activities for Oil and Gas Operations: 85% Mining Coal: 83% Extraction of Oil and Gas: 77%	Current Strengths: Support Activities for Oil and Gas Operations Bituminous Coal Underground Mining Petroleum Refineries Crude Petroleum and Natural Gas Extraction Emerging Strengths: Fossil Fuel Electric Power Generation	1 Oil and Gas Exploration 1 Chemicals for Mining
Energy Conversion and Storage: 587	Electrochemical systems found at both U of U, BYU & Energy Dynamics Lab at USU Combustion: Adv. Combustion Engineering Research Center (BYU); ICSE, Institute of Clean & Secure Energy (U of U); Catalysts at BYU		Power Distribution and Specialty Transformer Mfg.: 158%	None	1 Carbon Capture 1 Energy Management Company
ENVIRONMENT, ECOLOGY, WATER AND ATMOSPHERIC SCIENCES					
Ecology: 815	Ecology Center (USU)				
Water & Soil Conservation: 526	Utah Water Research Laboratory (USU) and Environmental Modeling Research Lab (BYU)				
Atmospheric Sciences: 255					
Range & Forest Sciences: 235	Various research efforts at USU, U of U, and BYU	High Share Only: Biodiversity Conservation: High Quality Only: Environmental Sciences:	Environmental Control Mfg: 91% Environmental Consulting Services: 83%	Current Strengths: Water and Sewer Line and Related Structures Construction Hazardous Waste Treatment and Disposal Emerging Strengths: Environmental Consulting Services	1 Pollution and Recycling
Earth :139	Earth Science: Microwave Earth Remote Sensing Lab (BYU)				
Animal Health & Sustainability: 83	Animal Science: Utah State Veterinary Diagnostic Lab (USU)				

Possible Opportunities for Future Growth

From interviews with industry executives and university leadership as well as guidance from the Governor's 10 year Energy Plan, the Energy cluster acceleration strategy supported by the Utah Higher Education System, and a focus group discussion with Environmental organizations, Battelle suggests three specific niches stand out for Utah in Energy and Natural Resources:

- Clean Technologies for traditional and unconventional sources of fossil energy
- Energy storage and power delivery systems
- Water and ecosystem sustainability.

Each is discussed below.

Clean Technologies for Traditional and Unconventional Sources of Fossil Energy

With continued global development, the demands for increased energy generation will continue to mount. Despite the rising interest in renewable energy sources, the U.S. Energy Information Agency estimates that renewable sources of energy are only expected to meet 10.9% of global demand by 2030. By comparison, fossil based sources of energy will remain quite significant with liquid fuels, largely comprising petroleum-based fuels, meeting 31.8 percent of global demand by 2030, coal 28 percent and natural gas 23 percent. Since we cannot in the near- to mid-term displace fossil fuels with renewable energy technologies, the importance of mitigating environmental impacts of fossil based energy sources through clean energy technologies is important.

One important focus of clean energy technologies is clean coal technology. Clean coal technologies have a long history starting with the earliest techniques that were aimed at cleaning or pre-combustion "washing" of coal. The Department of Energy's CO₂ program is pursuing evolutionary improvements in existing CO₂ capture systems and also exploring revolutionary new capture and sequestration concepts.

Another focus area of clean energy technologies is addressing the environmental impacts from extracting black wax and shale oil and gas reserves. As the extraction of black wax and shale reserves in states such as Utah grows, so do environmental issues and opportunities related to the use and reprocessing of water resources through advanced current methods.

Both Utah's 2011 Strategic Energy Plan and the Energy UCAP call for more focused research into clean energy technologies. The 2011 Strategic Energy Plan sets out the need for a "research triangle" of Utah's three research universities placing an "emphasis on clean technology for fossil fuels (i.e., gasification, carbon capture and sequestration, unconventional fuel, etc.) and the interface with other energy forms" (Page 7). The Energy UCAP identifies as among the growth accelerators for Utah "innovate clean coal technologies for increased coal production" and enable oil shale/oil sands/shale gas production" (Page 19).

How It Builds on Utah Strengths

- In industry development, Utah stands out in having energy industries with strong jobs growth and levels of specialization, including: support activities for oil and gas operations, coal mining, crude petroleum and natural gas extraction and petroleum refineries. Utah's 2011 Strategic Energy Plan notes that Utah stands out in its fossil energy sources standing as: the 13th highest state in coal production in 2009 with coal reserves standing at 202.5 million tons in 2009; the 8th largest state in onshore natural gas production; and one of the leading states in oil shale and oil sands reserves.
- An identified core technology competency in oil, gas and resource mining tools, with publication excellence found in Utah's universities in several fields related to clean energy technologies, including: Energy and Fuels, Mineralogy, Mining and Mineral Processing and Water Resources.
- Each of the universities is identified to have strengths that can be applied to clean energy technologies:
 - University of Utah with the Energy & Geoscience Institute, a leader in fossil fuel, geothermal and carbon sequestration research, and the Institute for Clean and Secure Energy focused on fossil fuel combustion, gasification and computer modeling research.
 - Utah State University brings key strengths in environmental and water quality including watershed research at the College of Natural Resources and hydrology/hydraulic engineering, water resource planning and management and environmental and natural systems engineering at the Utah Water Research Laboratory.
 - BYU's Department of Dept. of Chemical Engineering has faculty involved in cryogenic carbon capture, with a start-up company, and oxy-fuel combustion patented process to capture CO₂ from coal combustion.

Energy Storage and Power Delivery Systems – Energy storage is an enabling technology that allows us to power personal electronics and use energy more efficiently and responsibly through plug-in electric hybrid vehicles and renewable energy sources. Efficient energy storage systems can make electronics last longer with less frequent charging, start or power vehicles, and ensure that energy derived from solar or wind power is available for use long after sunset or when the wind stops blowing. Batteries are an important solution to energy storage needs, and new technological innovations are enabling them to have longer running time, produce higher voltage, reduce emissions, reduce recharge time, and increase the number of recharges while increasing safety. Batteries store energy in the form of chemical energy; when connected in a circuit the battery can produce electricity.

How It Builds on Utah Strengths

- In industry development, the energy storage industry is an emerging sector, with few commercially available solutions. Utah currently does not have a strong industry presence, but a number of companies are focused in this area including Ceramtec and Power Innovations International.

- Builds upon an identified core technology competency in Energy Conversion and Storage, with publication excellence found in Utah’s universities in the fields of Electrochemistry and Chemical engineering.
- Each of the universities is identified to have strengths that can be applied to energy storage and power delivery systems:
 - The University of Utah Energy Dynamics Laboratory has a focused research program on vehicle and roadway electrification. This involves wireless power transfer based on electrical induction which allows the transfer of power to a rechargeable battery up to 10.5 inches away. Not only does technology have application for powering vehicles, it has other applications for medical devices and consumer electronics.
 - The University of Utah has a number of several senior level faculty in its Chemistry Department that bring key strengths in catalysis and electrochemistry, with an emphasis on microscale and nanoscale domains. This includes research into understanding the factors that control chemical reactions, use of nanoparticles for catalysts that includes the development of catalysts at the nanoscale out of less expensive base metals by tuning their chemical properties, and reconfiguring the electrode materials into 3-D architectures for use in batteries.
 - Brigham Young University has a faculty team working on lithium-ion batteries, micro- and nano-sized batteries, fuel cells, electrodeposition, nanocircuits, and molecular simulations.

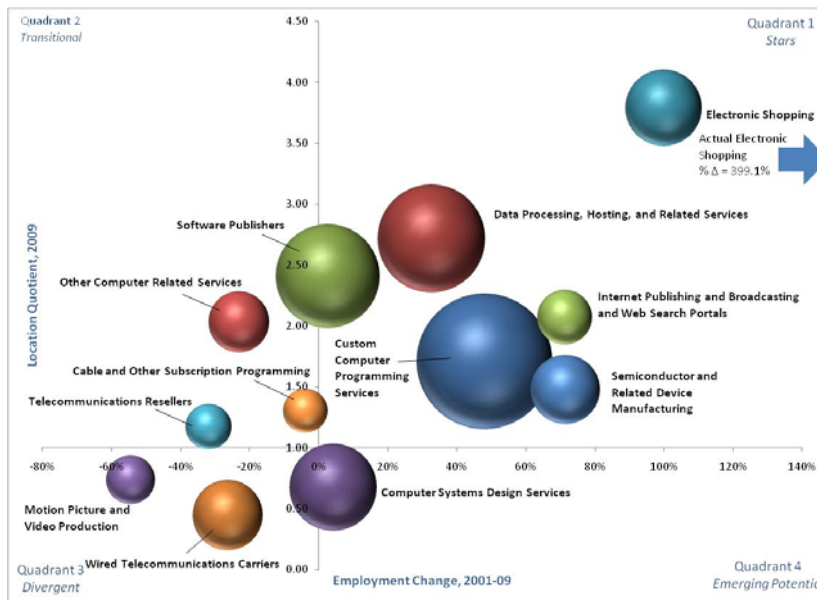
Information Technology

The Information Technology cluster in Utah is the largest among the technology-based clusters in the state, with 46,897 jobs in 2009. It just crosses the threshold of being a specialized industry cluster having a 21 percent higher level of concentration in Utah than found in the nation. Along with the nation, the Information Technology cluster fell in employment from 2001 to 2009, though at a lower level of 15.2 percent compared to the national decline of 25.2 percent. This reflects both the sharp fall-off from the heights of the dot.com boom and the continued pressure from global information technology outsourcing.

Detailed Industry Strengths

The Information Technology cluster is far-ranging covering detailed industries involved in software development, digital media, Internet, telecommunications and electronics. There are 19 detailed industries in Information Technology that employ more than 500 workers in Utah. Of these 19 detailed industries, six detailed industries stand as specialized and growing, two stand as growing but not yet specialized and four stand as specialized but declining in employment.

Figure A-4: Information Technology Cluster



The six detailed industries in Information Technology that are specialized and growing are:

- **Custom Computer Programming Services** with 9,359 jobs in 2009, a 71 percent higher level of concentration in Utah than the nation and a 48 percent growth rate in jobs from 2001 to 2009.

- **Data Processing, Hosting and Related Services** with 5,958 jobs in 2009, a 171 percent higher level of

concentration in Utah than the nation and a 32.8 percent growth rate in jobs from 2001 to 2009.

- **Software Publishers** with 5,496 jobs in 2009, a 141 percent higher level of concentration in Utah than the nation and a 2.7 percent growth rate in jobs from 2001 to 2009.
- **Electronic Shopping** with 2,966 jobs in 2009, a 279 percent higher level of concentration in Utah than the nation and a staggering growth rate of 948 percent (9.5 times increase) in jobs from 2001 to 2009.
- **Semiconductor and Related Device Manufacturing** with 2,438 jobs in 2009, a 48 percent higher level of concentration in Utah than the nation and a 71.6 percent increase in jobs from 2001 to 2009.
- **Internet Publishing, Broadcasting and Web Search Portals** with 1,516 jobs, a 107 percent higher level of concentration in Utah than the nation and a 71.3 percent increase in jobs from 2001 to 2009.

The two growing but not yet specialized detailed industries in Information Technology are:

- **Computer Systems Design Services** with 3,858 jobs in 2009 which increased in jobs by 4.3 percent from 2001 to 2009.
- **Other Electronic Component Manufacturing** with 571 jobs in 2009, which increased in jobs by 6.1 percent from 2001 to 2009.

The four specialized but not growing detailed industries in Information Technology are:

- **Other Computer Related Services** with 1,874 jobs in 2009, a 103 percent higher level of concentration in Utah than the nation, but a 22.9 percent loss in jobs from 2001 to 2009.

- **Cable and Other Subscription Programming** with 1,000 jobs in 2009, a 30 percent higher level of concentration in Utah than the nation, but a 3.8 percent fall off in jobs from 2001 to 2009.
- **Bare Printed Circuit Board Manufacturing** with 620 jobs in 2009, a 71 percent higher level of concentration in Utah than the nation, but a 57.9 percent decline in jobs from 2001 to 2009.
- **Audio and Video Equipment Manufacturing** with 526 jobs in 2009, a 162 percent higher level of concentration in Utah than the nation, but a slight 0.9 percent decline in jobs from 2001 to 2009.

Linkage to Core Technology Competencies

Two core technology competencies relating to the Information Technology industry cluster were identified from the patent and publication cluster analysis, interviews with university and industry leaders and further analysis of industry and scholarly activities—one in information systems and the other in electronics & processing technologies. Each of these two technology competencies group together a set of patent and publication cluster focus areas.

The **Information Systems** technology competency encompasses the following patent and publication cluster focus areas:

- **Networking** with 856 patents and publications from 2006 to 2011. Illustrative applications include: network communication software and methods (IP protocol, token packet exchange); computing network devices (routers, servers, bridges, switches); information networks for various applications (such as real estate, traffic, financial, health care); information network management; data exchange and transfer on networks using nodes and node processing; communication networks/nodes (e.g., mesh network, content distribution network); wireless nodes for transferring messages.
- **Information and Data Systems Management** with 440 patents and publications from 2006 to 2011. Illustrative applications include: indexing data; collaborative work flow process data management; data error detection; chat room management systems; information archiving; information search engines; data mining; enhanced in-document searching; information directories; embedded software to check for program upgrades; validating data/information between computers; image mapping and detection; transmission of graphics to personal communication devices ; human-computer interaction (using input devices such as stylus, digital pen); data tracking and analysis (such as email); data transmission and messaging; personalized data delivery based on customer identification or events; decision support tools and systems; predictive data and modeling tools; data visualization; data recovery; computer simulation and modeling.
- **E-commerce** with 241 patents and publications from 2006 to 2011. Illustrative applications include: health care payments; pre-paid financial accounts; wireless point-of-sale transaction system; wireless financial transfer systems; security in electronic transactions; use of biometric data for transactions; use of RFID in transaction systems.

- **Information Security** with 138 patents and publications from 2006 to 2011. Illustrative applications include: information security (web analytics code, secure ballot codes, secure data storage, encryption, data authentication); user access management through various computer device applications (e.g., time delay responses, remote user devices, data structures/files); monitoring peripheral devices using transmitted information; credentialing and identifier approaches; use of user information cards; biometric information for computer security.

The **Electronics and Processing Technologies** technology competency encompasses the following patent and publication cluster focus areas:

- **Semiconductor and Solid-State Devices** with 364 patents and publications from 2006 through June of 2011. Illustrative applications include: semiconductor processing; trench and shielded gate field fabrication for power semi-conductors; electronic packaging; nano-based electronics; thin-film transistors; organic semi-conductor development; wafer testing systems; removal of particulate contamination in semi-conductor fabrication; carbon nanotube fabrication; PV development including germanium wafers.
- **Image Processing** with 344 patents and publications from 2006 through June of 2011. Illustrative applications include: methods for processing images for various applications (such as vehicles, 3d animation, 3D spatial data, TV, magnetic media, x-rays); imaging devices (e.g., magnetic resonance imaging, computer image generator); LIDAR and electro-optical image capture and processing; document imaging; image rendering; image replication (e.g., holograms).
- **Optical Sciences** with 334 patents and publications from 2006 through June of 2011. Illustrative applications include: scanning systems using lasers; image projectors; light generators; optical communications; laser-absorption spectroscopy; pulsed laser deposition; optical data storage systems; optical based spectroscopy; fluorescence detection systems; fiber optic tuning; optical interconnects and converters; electro-optic sensors; many uses of optical imaging for medical applications.
- **Signal Processing** with 149 patents and publications from 2006 through June of 2011. Illustrative applications include: voice recorder systems; audio signal processing; video game control devices; video distribution systems; video compression; video data transfer; media content management systems.
- **Communications Processing Technologies** with 120 patents and publications from 2006 through June of 2011. Illustrative applications include: wireless devices; communications tracking systems; transmitter technologies; asynchronous transmission of communications; aeronautical communications systems.
- **Data Storage & Memory** with 90 patents and publications from 2006 through June of 2011. Illustrative applications include: wireless data storage; portable memory device; removable memory cartridge; computer memory devices (e.g., a hard drive, an optical drive, a flash drive, etc.), memory cells for integrated circuits; electronic memory cards; recording medium; methods for storage/retrieve data from memory (such as disk drive, file); virtual memory; magnetic domain memory.

Below is a chart that presents the further analysis of these two core technology competencies, including an examination of fields of publications excellence, institutional research activities, productivity, presence of detailed industry strengths, and presence of venture-backed companies.

Table A-3: Core Technology Competencies Within the Information Technology Industry Cluster

Breadth of Patent and Publications Cluster Focus Areas Number of patent and publication records in cluster groupings from 2006 to 2011	Presence of Institutional Research Centers and Other Specialized Strengths	Publications <i>High Share/High Quality:</i> Greater than 1.5% of U.S. pubs and greater than 40% higher citation impact than U.S. average <i>High Share Only:</i> Greater than 2% of U.S. pubs <i>High Quality Only:</i> Greater than 50% higher citation impact than U.S. average	Productivity Relative level of 2009 value added per employee for detailed industry sector in Utah compared to U.S. average	Presence of Detailed Industry Strengths <i>Current Industry Strength:</i> both specialized (greater than 20% higher industry employment concentration in 2009) and growing in jobs from 2001 to 2009) <i>Emerging Industry Strength:</i> Growing in jobs from 2001 to 2009, but not specialized <i>Specialized Industry Strength:</i> Specialized, but lost jobs from 2001 to 2009	Presence of Venture-backed Companies Number of companies receiving venture funding from 2006 to 2011
INFORMATION SYSTEMS					
Networking: 856 Information and Data Systems Management: 440. E-commerce: 241 Information Security: 138	The Center for High Performance Computing (USU) and Flux Research Group; Center for Parallelism (U of U) NSA Utah Data Center to open in 2013 Hill Air Force Base Software Technology Support Center	<i>High Share Only:</i> Software Engineering Applied Math	Computer Systems Design Services: 92% Custom Computing Programming Services: 77% Data Processing, Hosting, ISP & Web Search Portals: 70% Software Publishers: 65%	<i>Current Strengths:</i> Custom Computer Programming Services Data Processing, Hosting and Related Services Software Publishers Electronic Shopping Internet Publishing, Broadcasting and Web Search Portals <i>Emerging Strengths:</i> Computer Systems Design Services <i>Specialized Strengths:</i> Other Computer Related Services	24 Info & Data Systems 15 Networking 5 Info Security 3 E-Commerce 2 Data Storage & Memory
ELECTRONICS AND PROCESSING TECHNOLOGIES					
Semiconductor and Solid-State Devices: 364 Image Processing: 344 Optical Sciences: 334 Signal Processing: 149 Communications Processing Technologies: 120 Data Storage & Memory: 90	Computer Graphics/Computer Animation – Animation programs at BYU & U of U Scientific Visualization and Imaging Analysis – SCI – Scientific & Computing Imaging Institute (U of U) Communications Systems and Technologies – Digital Signal Processing considered a strength of USU & U of U ECE Depts.	<i>High Share/High Quality:</i> Imaging Sciences <i>High Quality Only:</i> Telecommunications	Other Electronic Component Mfg.: 104% Audio and Video Equipment Mfg.: 83% Bare Printed Circuit Board Mfg.: 72% Semiconductor and Related Device Mfg.: 65% Cable and Other Subscription Programming: 25%	<i>Current Strengths:</i> Semiconductor and Related Device Manufacturing <i>Emerging Strengths:</i> Other Electronic Component Manufacturing <i>Specialized Strengths:</i> Cable and Other Subscription Programming Bare Printed Circuit Board Manufacturing Audio and Video Equipment Manufacturing	3 Image Processing 4 Signal Processing 8 Communication Processing Technologies

Possible Opportunities for Future Growth

From interviews with industry executives and university leadership as well as the guidance from Digital Media cluster acceleration strategy supported by the Utah Higher Education System, Battelle suggests two specific niches stand out for Utah in Information Technology:

- Networked Information systems
- Digital gaming and other digital media.

Networked Information Systems

The use of computer software and networks to advance business operations has been underway for more than a generation. Today, advanced information systems has been dramatically changing with the rapid deployment of the Internet, which is leading a new era some have called “ubiquitous networking” where computing and communications technologies are converging. With the advent of ubiquitous networks, businesses no longer will be bound by physical locations and their interactions with customers will profoundly change as the use of computer/network-driven technology becomes pervasive. Related to this advancement of Networked Information Systems are key activities including:

- Cloud computing which refers to both the applications delivered over the internet and the hardware and systems software at datacenters that enable the services to be delivered. Cloud computing may be best understood as “computing as a utility;” a technological shift similar to the change from on-site electrical generation to plugging into the electrical grid at the turn of the 20th century.
- Information security, which in the context of the highly networked enterprise goes well beyond placing data behind a firewall as information attacks today are aimed at entire processes. Identity management, intrusion detection systems/Antivirus, and security management are among the most active approaches to addressing information security needs.
- Business analytics and Knowledge Management providing organizations with timely access to relevant data reporting and analysis, including online analytical processing (OLAP) tools providing multi-dimensional data management environment to model business problems and analyze data, data mining technologies such as neural networks, rule induction and clustering to discover relationships in data and make predictions, and packaged data mart/warehouse products that are preconfigured software that combine data transformation, management and access in a single package, usually with modeling software included.

How It Builds on Utah Strengths

- In industry development, the leading detailed industries found in Utah’s Information Technology cluster fall within Networked Information Systems, including Custom Computer Programming Services, Data Processing and Hosting, Software Publishing and Computer Systems Design Services.

- There are four patent and publication cluster focus areas found in Information Systems in Utah along with publications excellence in software engineering.
- The National Security Agency Utah Data Center, which will be completed in 2013, will be a leading data complex responsible for intercepting, storing and analyzing intelligence data as it moves through both domestic and international networks. It will push current technology approaches to data storage, mining and pattern recognition.
- Hill Air Force Base's Software Technology Support Center is responsible for software technologies in weapon, command and control, intelligence and mission-critical systems. As the complexity of aerospace vehicles grows the demands for new software technologies, testing protocols and software maintenance is expected to increase and create new skill sets in Utah.

Among research centers at Utah universities involved in Networked Information Systems are:

- The Center for Parallel Computing at the University of Utah is focused on parallel programming techniques, verification techniques, and performance evaluation/tuning techniques, with an emphasis on education and training. The Center has worked with Microsoft Research to develop a computer science curriculum in high level development of concurrent and parallel programs, known as **PPCP**, or Practical Parallel and Concurrent Programming.
- The University of Utah's Center for High Performance Computing provides large-scale computer systems, networking, and the expertise to optimize the use of these high-end technologies. CHPC facilitates advance in academic disciplines whose computational requirements exceed the resources available in individual colleges or departments. Since 1996 these collaborations have resulted in more than 651 technical publications. CHPC's purview is to support faculty and research groups whose main focus requires computing and advanced networking as core instrument(s) central to their research.
- The Flux Research Group focuses on local and distributed operating systems, networking, component-based systems, programming and non-traditional languages, compilers, information and resource security, and some software engineering and formal methods.

Video Gaming and Other Digital Media

- Digital media has emerged as a high value and broad economic driver. Digital media technologies are leading the convergence of information technology, communications and content. As Gartner, a leading market research firm, explains the “convergence of technologies is allowing users to access and exchange information and content in ways that were not possible before. Industries such as media and communications that once had clearly defined boundaries are seeing business models converge and perhaps collide as technologies change the possibilities.”²⁰ The primary digital media industries today include not only the traditional industries of movie, video and television production, but newly emerging industries involved in video gaming and digital rendering software. It is not only in the emergence of video gaming and video rendering software that digital media stands out, but in how pervasive digital media technologies are becoming across industries today to make it possible to access digital content virtually anywhere and at anytime. A broader definition of digital media certainly needs to incorporate advertising, marketing, e-commerce and Internet publishing and portals.

How It Builds on Utah Strengths

- The Digital Media cluster acceleration strategy for Utah points out that Utah boasts a pioneering history in animation, digital media and information technology. Fostered from research conducted in the early years at the University of Utah, many of the leading experts and founding companies in the digital media industry have roots with Utah, such as Atrai, Adobe Systems, Silicon Graphics and Pixar. Today, Utah boasts the presence of a number of industry leaders including Silverlode Interactive, Electronic Arts operations in Salt Lake City, Disney’s Fall Line Studio in Salt Lake City and Smart Bomb Interactive, among others. The strategic focus of the Digital Media UCAP is to have Utah become the creative and technology epicenter for educating, training and stimulating the future of the digital media industry.
- Utah’s core technology competency in electronics and processing technologies provides the know how to advance video gaming and other digital media developments.

Utah has a wide range of active and successful research centers advancing digital media including:

- The Entertainment Arts & Engineering program at the University of Utah, which involves a collaboration of the School of Computing and the Department of Film and Media Arts in the areas of video games, computer animation, special effects, etc. The Entertainment Arts & Engineering program is offered at both the undergraduate and graduate level with three tracks: 1) Art Track focused on the tools and techniques required to understand and use the components of design, story, drawing, and storyboarding for games; 2) Engineering Track focused on the technical aspects of video games including game engines, graphics, artificial intelligence, and novel input devices; and 3) Production Track focused on the variety of tasks undertaken by producers involved in video game development and focuses on theory, praxis, and performance.

- BYU Center for Animation operates under the direction of three colleges: the Ira A. Fulton College of Engineering and Technology; the College of Fine Arts and Communications; and the College of Physical and Mathematical Sciences. It is focused on developing students with a sound understanding of and skill in design, composition, storytelling, and current software packages used in the industry today. The program has attracted faculty from companies like Disney, Pixar, DreamWorks, and Warner Bros. A key resource is the Interactive Reality Auditorium, a virtual reality screening room capable of displaying images in 3-D through the use of dual projectors and polarized glasses, is also used for industry and student presentations as well as advanced student critiques. This highly successful program has consistently won awards from the Academy of Television Arts and Sciences, the Oscars, Nickelodeon's Producers' Choice Award and Viewers' Choice Award.
- The Scientific & Computing Imaging Institute is active in graphics research which is closely tied to its work in scientific visualization and information visualization. This research area focuses on algorithm development where graphics meets large scientific datasets. This area of research also involves the use of new platforms such as the iPad, iPhone, large storage systems such as isilon or the latest generation of graphics processing unit and the creation of tailored algorithms to those platforms.

Life Sciences

The life sciences industry cluster is both specialized and growing in Utah. In 2010, it stood at 22,983 jobs, which translates into an 82 percent higher employment concentration in Utah than the nation. Employment in the life sciences industry also grew a healthy 25.8 percent over the 2001 to 2010 period, which included a 9.2 percent increase in jobs from 2007 to 2010, a period which includes the deep recession years of 2008 and 2009 and the nascent recovery that began in 2010.

The life sciences industry is composed of four subsectors including Medical Devices and Equipment; Drugs and Pharmaceuticals; Research, Testing, and Medical Labs; and Biomedical Distribution. It is important to note that the life sciences industry is closely related to but not the same as healthcare industry, which provides direct clinical services. The breadth of Utah's life sciences industry cluster comes across, since all of these subsectors of the life sciences are specialized and growing rapidly in Utah.

Detailed Industry Strengths

At the detailed industry level, there are 11 industries within the life sciences industry cluster with 500 or more jobs in 2010—all are either specialized and/or growing in employment.

Six of the 11 detailed life sciences industries are both specialized and growing, including:

- **Pharmaceutical Preparation Manufacturing**, with 3,892 jobs in 2010, a 105 percent higher concentration in Utah than the nation and growing in jobs by 25.6 percent from 2001 to 2010.

- **Medical Laboratories**, with 3,237 jobs in 2010, a 127 percent higher level of concentration in Utah than the nation and growing in jobs by 91.0 percent from 2001 to 2010.
- **Drugs Wholesalers**, with 2,194 jobs in 2010, a 53 percent higher level of concentration in Utah than the nation, and increasing in jobs by 28.6 percent from 2001 to 2010.
- **Irradiation Apparatus Manufacturing**, with 1,270 jobs in 2010, a 10.7 times higher level of concentration in Utah than the U.S. and increasing in jobs by 21.9 percent from 2001 to 2010.
- **Medicinal and Botanical Manufacturing**, with 760 jobs in 2010, a 330 percent higher level of concentration than the nation, and increasing in jobs by 7.8 percent from 2001 to 2010.
- **Dental Equipment and Supplies Manufacturing**, with 684 jobs in 2010, a 394 percent higher level of concentration than the nation, and increasing in jobs by 11.6 percent from 2001 to 2010.

Four of the 11 detailed life sciences industries are growing in jobs, but not yet specialized in the concentration of industry employment in Utah.

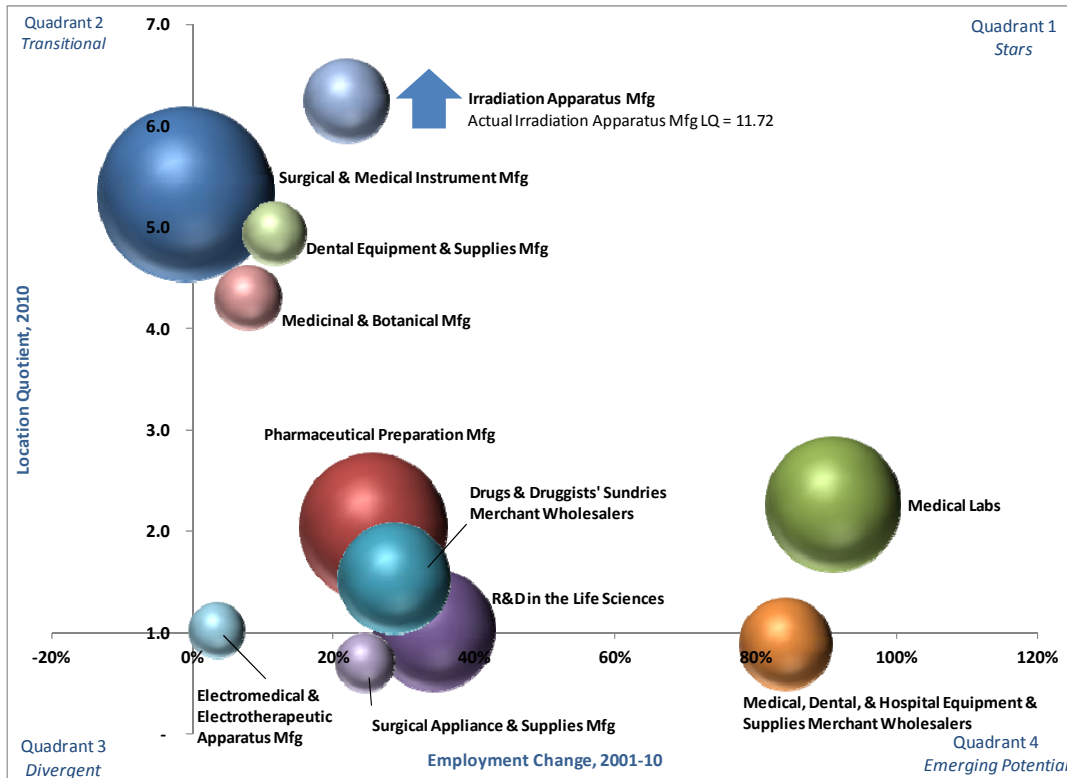
- **Life Sciences Commercial Research & Development**, with 2,620 jobs in 2010, increasing in jobs by 34.3 percent from 2001 to 2010, but only equal to the U.S. level of employment concentration.
- **Medical, Dental, and Hospital Equipment and Supplies Wholesalers**, with 1,489 jobs in 2010, increasing in employment by 84.3 percent from 2001 to 2010, but 11 percent lower in concentration than the nation.
- **Surgical Appliance and Supplies Manufacturing**, with 611 jobs in 2010, increasing in jobs by 24.4 percent from 2001 to 2010, but still 30 percent less concentrated in Utah than the nation.
- **Electromedical and Electrotherapeutic Apparatus Manufacturing**, with 540 jobs in 2010, increasing in jobs by 3.4 percent from 2001 to 2010, but only equal to the U.S. level of employment concentration.

One of the 11 detailed life sciences industries is highly specialized, but not growing in jobs:

- **Surgical and Medical Instrument Manufacturing** with 5,490 jobs in 2010, a 434 percent higher level of concentration in Utah than the nation, but a decline in jobs of 1.0 percent from 2001 to 2010.

It is important to note that natural products and dietary supplement firms fall in various industry classifications including pharmaceuticals, biomedical distribution industries, and other food and beverage categories.

Figure A-5: Life Sciences: Employment, Growth, & Specialization Trends, 2001–10



Note: Includes only those detailed Life Sciences industries with at least 500 jobs in Utah in 2010.

Linkage to Core Technology Competencies

The Medical Device core technology competency encompasses five patent and publication cluster focus areas, including:

- Surgical Devices, Catheters, Instruments, and Equipment** with 1310 patents and publications from 2006 through June of 2011. Illustrative applications include: Medical needles, suturing systems, catheters, vascular surgery instruments and systems, surgical instruments for wound, ophthalmology and heart surgery; prosthetic valve implementation; minimally invasive surgery devices and systems.
- Cardiovascular & Pulmonary Diseases and Conditions** with 805 patents and publications from 2006 through June of 2011. Illustrative applications include: right and left ventricular assist devices; prosthetic heart valves and heart transplantation; risk factors for various heart conditions; treating cardiac arrhythmias; heart failure outcomes research; lung function and respiratory physiology; treatment of obstructive lung diseases; pulmonary arterial hypertension treatment strategies; measuring pulmonary function; acute lung diseases and respiratory distress.

- **Medical Imaging** with 325 patents and publications from 2006 through June of 2011. Illustrative applications include: X-ray imaging systems and components; MRI; ultra-sound; surgical imaging systems.
- **Musculoskeletal Implants and Devices** with 268 patents and publications from 2006 through June of 2011. Illustrative applications include: spinal implants and fixation devices; navigation systems for implants; bone implants; bone growth systems; medical screws for bones and joints; osteoporosis assessment and treatment; biomechanics; knee prosthetics and surgical approaches to implants; role of exercise in muscle formation.
- **Ion Channel Research** with 165 patents and publications from 2006 through June of 2011. Illustrative applications include: Focus on membrane excitability/bioelectricity to address diseases caused by defects in ion channel function. An ever-increasing number of disorders, such as cardiac arrhythmias, epilepsy, ataxias, migraines, diabetes, and end-stage renal disease, are attributable to ion channel dysfunction.

The Disease Research, Drugs and Pharmaceutical core technology competency encompasses eight patent and publication cluster focus areas, including:

- **Drug Development & Discovery** with 794 patents and publications from 2006 through June of 2011. Illustrative applications include: polymer based delivery systems; encapsulated nanoparticles; innovative pharmaceutical formulations; wide variety of compounds for anti-virals, neurodegeneration, anti-tumor and other disease therapies; screening technologies for therapeutic identification; pharmacokinetics and pharmacodynamics studies; natural products drug formulations; treatment of skin conditions and diseases; transdermal drug delivery.
- **Cancer Research and Treatments** with 1,143 patents and publications from 2006 through June of 2011. Illustrative applications include: Wide range of cancers from colon to pancreatic to prostate to breast to ovarian to pediatric; cancer therapeutics, particularly protein kinase inhibitors; surgical approaches and innovative radiation; cancer screening and biomarkers; cancer tumor biology; cancer risk factors; cancer clinical trials; radiation therapy approaches and evaluation; innovative radio-therapies; innovative radiation approaches from microwave to external beam to involved field radiation therapies.
- **Neurosciences** with 1,226 patents and publications from 2006 through June of 2011. Illustrative applications include: mechanisms of neuroprotection; neuronal precursors and neural development; novel compounds for CNS and Neurological Diseases and Disorders; studies of neural activity; memory development and processes; neuropsychological assessment; temporal memory processes; traumatic brain injury; epilepsy and seizures; visual functioning and impairments; neuro-stimulation methods and measurements.
- **Infectious Diseases, Pathogens and Immunology** with 727 patents and publications from 2006 through June of 2011. Illustrative applications include: wide variety of infectious diseases from hepatitis C to influenza to West Nile to Yellow Fever to HIV; research into humoral immune

responses (b-cells) and cell mediated immune responses (t-cell); anti-viral and anti-microbial mechanisms.

- **Reproductive Medicine** with 482 patents and publications from 2006 through June of 2011. Illustrative applications include: neonatal care; birth defect corrections; fetus development studies; prevention of premature births; genetics of pregnancy loss; birthing approaches and outcomes; development biology of embryos; fertility research.
- **Diabetes** with 294 patents and publications from 2006 through June of 2011. Illustrative applications include: diabetic genes and biomarkers; biology of metabolic syndrome; insulin resistance; diabetic retinopathy; diabetic cardiomyopathy; care management of diabetes.
- **Transplantation and Stem Cell Therapies** with 226 patents and publications from 2006 through June of 2011. Illustrative applications include: transplantation treatments involving biological fluids, renal, bone marrow, grafts, lung, liver; stem cell treatments for multi-organ failure; work with various stem cells—endothelial, adipose, hematopoietic; tissue engineering involving scaffolds, directed tissue assembly.
- **Transplantation Treatments** involving biological fluids, renal, bone marrow, grafts, lung, liver; stem cell treatments for multi-organ failure; work with various stem cells—endothelial, adipose, hematopoietic; tissue engineering involving scaffolds, directed tissue assembly.
- **Ophthalmology** with 180 patents and publications from 2006 through June of 2011. Illustrative applications include: eye injuries; cataract surgery approaches; lasik surgery; contact lens usage; vision correction treatments; intraocular lens materials and design; macular and retinal degeneration; retinal ganglion cell pathology (glaucoma).

The Basic Biological Research core technology competency encompasses two patent and publication cluster focus areas:

- **Genomics and Biologics** with 1,269 patents and publications from 2006 through June of 2011. Illustrative applications include: methods for detecting genomic variations; approaches to genotyping; microarray assays; biomarkers and molecular diagnostics; population based gene association studies; monoclonal antibodies.
- **Molecular Genetics and Cell Biology** with 386 patents and publications from 2006 through June of 2011. Illustrative applications include: DNA detection and characterization; DNA amplification methods; DNA methylation (cell differentiation); epigenetics; DNA transcriptional regulation; processes of cell death.

The Natural Products core technology competency aligns with the natural products patent and publication cluster focus area.

- **Natural Products** with 209 patents and publications from 2006 through June of 2011. Illustrative applications include: dietary behaviors and outcomes; use of supplements to treat diseases; chemical analysis of nutritional content; functional food development; artificial sweeteners;

food processing approaches on nutritional content; probiotics; impacts of fiber intake on weight reduction; cheese production and improved content.

Below is a chart that presents the further analysis of these four core technology competencies, including an examination of fields of publications excellence, institutional research activities, productivity, presence of detailed industry strengths, and presence of venture-backed companies:

Table A-4: Core Technology Competencies Within the Life Sciences Industry Cluster

Breadth of Patent and Publications Clusters Number of patent and publication records in cluster groupings from 2006 to 2011	Presence of Institutional Research Centers and Other Specialized Strengths	Publications <i>High Share/High Quality:</i> Greater than 1.5% of U.S. pubs and greater than 40% higher citation impact than U.S. average <i>High Share Only:</i> Greater than 2% of U.S. pubs <i>High Quality Only:</i> Greater than 50% higher citation impact than U.S. average	Productivity Relative level of 2009 value added per employee for detailed industry sector in Utah compared to U.S. average	Presence of Detailed Industry Strengths <i>Current Industry Strength:</i> both specialized (greater than 20% higher industry employment concentration in 2010) and growing in jobs from 2001 to 2010) <i>Emerging Industry Strength:</i> Growing in jobs from 2001 to 2010, but not specialized <i>Specialized Industry Strength:</i> Specialized, but lost jobs from 2001 to 2010	Presence of Venture-backed Companies Number of companies receiving venture funding from 2006 to 2011
MEDICAL DEVICE					
Surgical Devices, Catheters, Instruments, and Equipment: 1310 Cardiovascular & Pulmonary Diseases and Conditions: 805 Medical Imaging: 325 Musculoskeletal Implants and Devices: 268 Ion Channel Research: 165	U of U Cardiovascular Research and Training Institute (cardiac electrophysiology + vascular physiology) U of U Bioengineering Department, including focus on cardiovascular, neural engineering, and novel devices (Utah BioDesign)	<i>High Share/High Quality:</i> Biomaterials: Imaging Sciences Cardiovascular Systems Rehabilitation <i>High Share Only:</i> Orthopedics Biomedical Engineering	Surgical Appliance and Supplies Manufacturing: 87% Dental Equipment and Supplies: 83% Irradiation Apparatus Manufacturing: 75% Surgical and Medical Instrument Manufacturing: 75% Electromedical and Electrotherapeutic Apparatus Manufacturing: 62%	<i>Current Strengths:</i> Irradiation Apparatus Manufacturing Dental Equipment and Supplies Manufacturing <i>Emerging Strengths:</i> Surgical Appliance and Supplies Manufacturing Electromedical and Electrotherapeutic Apparatus Manufacturing <i>Specialized Industries:</i> Surgical and Medical Instrument Manufacturing	9 VC backed firms in Medical Devices 2 VC backed firms in Medical Imaging
DISEASE RESEARCH AND PHARMACEUTICALS					
Drug Development & Discovery: 794 Cancer Research and Treatments: 1,143 Neurosciences: 1,226 Infectious Diseases, Pathogens and Immunology: 727 Reproductive Medicine: 482 Diabetes: 294 Transplantation and Stem Cell Therapies: 226 Ophthalmology: 180	U of U College of Pharmacy among national leaders in medicinal chemistry, pharmaceuticals and pharmaceutical chemistry Eccles Institute of Human Genetics Huntsman Cancer Institute, with close ties to medicinal chemistry and human genetics BYU Cancer Research Center U of U Molecular Medicine	<i>High Share/High Quality:</i> Pharmacology Toxicology Transplantation Urology & Nephrology <i>High Share Only:</i> Ophthalmology Clinical Neurology Obstetrics & Gynecology Neurosciences Physiology Rheumatology <i>High Quality Only:</i> Geriatrics	Life Sciences Commercial Research & Development: 79% Pharmaceutical Preparation Manufacturing: 57% Medicinal and Botanical Manufacturing: 57%	<i>Current Strengths:</i> Pharmaceutical Preparation Manufacturing Drugs Wholesalers Medicinal and Botanical Manufacturing <i>Emerging Strengths:</i> Life Sciences Commercial Research & Development	4 VC backed firms in Medical Therapeutics

	Utah State University's Center for Integrated Biosystems with focused research efforts in flu vaccine production, bioprocessing technologies and reproductive immunology.	Peripheral Vascular Disease Endocrinology & Metabolism			
BASIC BIOTECHNOLOGY RESEARCH					
Genomics and Biologics: 1,269 Molecular Genetics and Cell Biology: 386	Department of Pathology and ARUP Laboratories, a national clinical and anatomic pathology reference laboratory Huntsman Cancer Center Molecular Medicine CTSA with key focus on biomedical informatics and pilot projects	High Share/High Quality: Human Genetics & Hereditary Development Biology Med Lab Tech High Share Only: Biochemistry and Molecular Biology: High Quality Only: Cell Biology:	Medical Laboratories: 88% Life Sciences Commercial Research & Development: 79%	Current Strengths: Medical Laboratories Emerging Strengths: Life Sciences Commercial Research & Development	5 VC backed firms in Biotechnology-related Diagnostics
NATURAL PRODUCTS AND DIETARY SUPPLEMENTS					
209	USU Applied Nutrition Research Program	High Quality Only: Nutrition and Dietetics:	Medicinal and Botanical Manufacturing: 57%	Current Strengths: Medicinal and Botanical Manufacturing	

Possible Opportunities for Future Growth

From interviews with industry executives and university leadership as well as ongoing input from the Life Sciences cluster acceleration strategy steering committee supported by the Utah Higher Education System, Battelle suggests several specific niches stand out for Utah in Life Sciences:

- Molecular medicine, drug discovery, development and delivery
- Molecular diagnostics and personalized medicine
- Nutritional supplements and functional foods
- Novel medical devices.

Molecular Medicine, Drug Discovery, Development & Delivery

With the recent advances in genomics and biotechnology, a new era of molecular medicine is revolutionizing the development of drugs from the traditional trial and error approach to a more predictive and systematic use of detailed information about the operations of cells and molecules to pursue more focused interventions on disease processes. In particular, the use of advances in genomics and proteomics combined with improved disease model systems and computerized or “in silico” high throughput screening is transforming our understanding of the structure and function of genes and proteins and leading to improved ability to identify new potential targets of intervention for diseases. An important use of in silico drug development is assisting in the pharmacological study of drugs to improve drug design for absorption, distribution, metabolism, excretion and toxicity.

Drug delivery is also being advanced through the use of polymer-based drug delivery systems and nanotechnology. Advances in polymer science have led to the development of several novel drug-delivery systems, including biodegradable polymers that can degrade into non-toxic forms in the body, highly absorbent and responsive hydrogels that can be used as biosensors as well as in wound healing and tissue scaffolding, and novel supramolecular structures able to deliver biologics. Often involved in novel polymers, but also other materials for drug delivery, are advances in nanomaterials. Nanomaterials have a number of functions in drug delivery such as encapsulation to protect the drug and prevent it from reacting with non-targeted tissues during transport, and as functional drug carriers in targeted delivery systems. Nanosized particles have higher rates of diffusion and solubility, the ability to penetrate the blood-brain barrier, lower immune rejection rates, better digestibility, more precise timed release and thus increased efficacy. The key value of nanotechnology in drug delivery is the potential to make drugs more effective at lower doses, at minimal or no toxicity, and help convert poorly water soluble drug candidates into products.

How It Builds on Utah Strengths

- In industry development, Utah has performed well across industries comprising the biopharmaceutical sector, including pharmaceutical preparation manufacturing, medicinal and botanical manufacturing, and life sciences commercial R&D.
- A number of emerging Utah biopharmaceutical companies advancing new therapeutics received venture financing from 2006 through the first quarter of 2011, including:
 - Cognetix focused on pain pharmaceuticals
 - MediProPharma focused on central nervous system drugs.
- A wide number of patent and publication cluster focus areas emerge in disease research, drug-related basic research and pharmaceutical development found in Utah, based on an analysis of the content of patents and publications, including:
 - Neurosciences
 - Cancer

- Drug Development and Delivery
- Infectious Diseases, Pathogens and Immunology
- Diabetes
- Molecular Genetics and Cell Biology.
- In scholarly activity Utah stands out in a number of fields based peer-reviewed publications and related citations over the 2005 to 2009 period including: pharmacology/pharmacy, organic chemistry, genetics & heredity toxicology, biochemistry and molecular biology, neurosciences, medicinal chemistry, cell biology, endocrinology and metabolism.
- The University of Utah, as the state's academic medical center, has a number of specific research centers and colleges that stand out in their excellence:
 - The University of Utah College of Pharmacy is one of the top National Institutes of Health funded colleges of pharmacy, nationally recognized in medicinal chemistry, pharmaceuticals and pharmaceutical chemistry spanning drug discovery, evaluation, delivery and outcomes research.
 - The Huntsman Cancer Institute is a National Cancer Institute designated Cancer Center noted for its contributions in identifying the genetic mutations responsible for inherited susceptibility to a number of cancers, including neurofibromatosis, colon cancer, breast cancer and melanoma. It also has an active experimental therapeutics research thrust and is building capacity for early phase clinical trials.
 - The University of Utah Molecular Medicine Program is an interdisciplinary effort to support and train physician researchers, who are critical to advancing novel treatments for a variety of human diseases and conditions, including cardiovascular and diabetes/metabolism. It is closely aligned with the clinical departments at the University of Utah, the Department of Human Genetics and the Utah CTSA. It also organizes the core faculty to support the MD-PhD program, Summer Medical Research Program, Howard Hughes Medical Institute med-to-grad PhD track and other NIH funded training programs.
- Brigham Young University also has active biopharmaceutical-related research efforts underway including:
 - The BYU Cancer Research Center involving 17 faculty from across the Colleges of Physical and Mathematical Sciences, Life Sciences, Health and Human Performance, and Engineering and Technology, working on cancer-related drug and diagnostic discovery, cancer biochemistry, cancer genetics, cancer immunology and cancer epidemiology and bioinformatics. Among its most active programs are screening for anti-cancer molecules, use of DNA microwires for cancer detection and genetic processes involved in cell division.

- Other biomedical research underway at BYU includes: Research into genetic risk factors for Alzheimer’s disease; Research into targeting AMP-activated protein kinase for prevention and treatment of type 2 diabetes; and Research into HIV treatment to address reservoirs or sites where HIV escapes intervention by drugs or the immune system.

Molecular Diagnostics and Personalized Medicine

The growing knowledge of genomic and proteomic data linked to specific disease states or predisposition is fueling the rise of molecular diagnostics. Molecular diagnostics is not only a new tool for medical diagnosis, it is a gateway to personalized medicine. As we near the end of the first decade of the 21st century, the promise of personalized medicine remains largely ahead of us. Molecular diagnostics are integrally linked with the personalized medicine approach of pharmacogenomics, which considers how genetic variations or differences in gene expression affect the ways in which people respond to drugs. In fact, these personalized medicine approaches to understanding of how genetic variations affect reactions to different drugs can enable diagnostic tests to be established that can guide doctors to make more informed and cost-effective medication decisions for their patients.

How It Builds on Utah Strengths

- Utah stands out in the strength of its medical testing laboratories, with 2,985 jobs in 2009, a specialization 121 percent higher than the national average, strong growth of 76 percent from 2001 to 2009 which well outpaces national growth for the industry.
- Of particular note for Utah is the presence of ARUP Laboratories, one of the nation’s leading clinical and anatomic pathology reference laboratory. ARUP Laboratories was created in 1984 by the University of Utah School of Medicine’s Department of Pathology, and has established itself as a role model for bridging the gap between academic medicine and successful business enterprise. Not only does ARUP Laboratories process more than 30,000–35,000 specimens of blood, fluid, and tissue samples are processed each day, it has become a world leader in laboratory research and development having developed more than 400 clinical laboratory tests and improving and validating more than 200 others, but having an extensive publications track record in peer-reviewed journals.
- While in vitro diagnostics does not stand out as a detailed industry in Utah, Utah is home to Myraid Genomics one of the nation’s leading molecular diagnostic companies with a broad number of diagnostics related to cancer, including for breast, colorectal, melanoma, pancreatic and prostate cancers, along with risks from chemotherapy. There are also emerging diagnostic companies found in Utah, such as Sorenson Genomics focused on verifying human identity and relatedness and Lineagen with a diagnostic on the market for autism and ongoing scientific programs in the areas of multiple sclerosis (MS) and chronic obstructive pulmonary disease (COPD).

- A number of emerging Utah biopharmaceutical companies advancing new diagnostics and testing products and services received venture financing from 2006 through the first quarter of 2011, including:
 - Numira Biosciences, LLC, a specialty contract research organization focused on analysis of tissue samples for disease progression, drug efficacy and drug side effects.
 - LineaGen, Inc. focused on molecular diagnostics for autism.
 - Axial Biotechnology focused on the use of genetics and minimally invasive fusionless devices to diagnosis human spine diseases.
 - BioMicro Systems, Inc. developing micro fluid analysis technologies for genomics, proteomics and diagnostics research.
 - Sera Prognostics providing diagnostics to predict and manage pregnancy complications.
- The Corptech database of technology companies identifies medical diagnostic equipment as a strength in Utah, with 19 firms headquartered or with operating units in Utah, comprising 3 percent of all firms nationally.
- Genomics and biologics stands out as a distinct core technology competency. The types of activities include methods for detecting genomic variations; approaches to genotyping; microarray assays; biomarkers and molecular diagnostics; and population based gene association studies.
- Utah stands out in a number of fields closely associated with molecular diagnostics, including Medical Laboratory Technology and Biochemistry and Molecular Biology.
- Among university research centers and focus areas there are several of note in this area of molecular diagnostics and personalized medicine:
 - The University of Utah's Nano Institute is focused on the development of nano-based diagnostics and therapeutics through the application of nanobiosensors for early disease detection, chromatography and immunoassay applications.
 - The Huntsman Cancer Institute is a National Cancer Institute designated Cancer Center noted for its contributions in identifying the genetic mutations responsible for inherited susceptibility to a number of cancers, including neurofibromatosis, colon cancer, breast cancer and melanoma. This strength of the Huntsman Cancer Institute is closely tied to the Department of Human Genetics at the University of Utah noted for its model systems work in genetics research involving *C. elegans*, *drosophila*, mice and zebrafish.
 - The NIH funded University of Utah Center for Clinical and Translational Science, represents a collaboration with Intermountain Healthcare, University Health Care, Utah Department of Health and the Salt Lake City VA, to build on the university's strengths in genetics and bioinformatics to bring promising bench science into practice.

- Brigham Young University also has faculty research ongoing in molecular diagnostics including:
 - Development of lab-on-a-chip tools to detect and quantify clinically relevant biomolecules
 - Development of new bioarrays for tissue analysis using mass spectroscopy in collaboration with the La Jolla Institute for Molecular Medicine (LJIMM).
- Utah Population Database of The Church of Jesus Christ of Latter-day Saints (the Mormon Church) is a rich source of genealogical records on more than 7 million people. UPDB is composed of an extensive set of family histories. It has been linked to the state's cancer registry, inpatient discharge data for all hospitals in Utah and medical records from the enterprise data warehouses of the University of Utah Hospitals and Clinics and from Intermountain Health System, including ICD9 diagnoses, pharmacy data, medical imaging, radiology and pathology reports. So it offers a very powerful tool for epidemiological, public health and health outcomes research. One continued area of development is to associate a biospecimen bank with UPDB to enable it to become an even more valuable resource for genomic analysis.

Natural Products

According to the Dietary Supplement Health and Education Act of 1994, a dietary or nutritional supplement is any product that contains one or more dietary ingredients such as a vitamin, mineral, herb or other botanical, amino acid or other ingredient used to supplement the diet. Dietary supplements come in a variety of forms: traditional tablets, capsules, and powders, as well as drinks and energy bars. Popular supplements include vitamins D and E; minerals like calcium and iron; herbs such as echinacea and garlic; and specialty products like glucosamine, probiotics, and fish oils. Dietary supplements are not food additives (such as saccharin) or drugs. It is estimated by the NIH Office of Dietary Supplements that Americans spend about \$25 billion a year on dietary supplements and at least 50,000 products are available that contain dietary supplements.

There is an active effort at the National Institutes of Health to investigate the potential roles of dietary supplements in promoting health and reducing the risk of chronic disease. Much of this work is done in concert with other NIH institutes and centers; to ODS also engages its federal partners in activities to fill essential needs that would not otherwise be addressed. In 2010, 89 NIH supported projects focused on the health impacts of dietary supplements for conditions such as age-related disease, anti-cancer activity, bone health, inflammatory disease prevention, asthma, cardiovascular disease, heart failure, sickle cell disease, malaria, maternal and child health, obesity and diabetes, among other health conditions.

How It Builds on Utah Strengths

- A detailed listing compiled by the Utah Technology Council identified over 100 nutritional supplement and functional food companies in Utah. It is estimated that these Utah nutritional

supplement and functional food companies account for up to 20 percent to 30 percent of the entire U.S. market.

- While there is not one single industry classification for these nutritional supplement and functional food companies, the strength of this area for Utah is revealed in examined more standard industry databases:
 - 17 of Utah’s nutritional supplement and functional food companies fall into the Pharmaceutical Preparation Manufacturing industry, which is 95 percent more specialized than the nation, grew a robust 22.7 percent from 2001 to 2009, and reached employment of 3,802 jobs in 2009.
 - Another 11 of nutritional supplement and functional food companies fall within the Medicinal and Botanical Manufacturing industry, which is 3.5 times more specialized in Utah than the nation and grew by 14 percent from 2001 to 2009, reaching 804 jobs in 2009.
 - Utah comprises 4.6 percent of all vitamin companies found in the Corptech database of technology companies.
- Natural products stands out as a distinct core technology competency in Utah. The types of activities include research on the use of supplements to treat diseases, chemical analysis of nutritional content, probiotics, and impacts of fiber intake on weight reduction and improved content of cheese production.
 - In scholarly activity, Utah stands out in nutrition and dietetics with 117 publications from 2005 to 2009, which represents 1.2 percent of all U.S. publications. Particularly impressive is that Utah is 174 percent higher in the level of citations per publication, a measure of quality of publications, than the national average.
 - A key new university resource in the area of natural products is Utah State University’s Applied Nutrition Research Program, supported by USTAR. The research program includes a newly constructed 110,000 sq ft building at the USU Innovation Campus with state-of-the-art metabolic kitchen and research facilities in which clinical research can be conducted in collaboration with industry. Currently the research program works with food and natural product companies in and outside the state of Utah to help them better substantiate claims and identify new health-related properties for their products. Among the key research efforts underway at the research program includes identifying new bioactives—plant or animal compounds with health benefits that extend beyond any traditional nutritional value—that can fight obesity, type II diabetes and cardiovascular disease where the team can scale up their research, focus on gut biology and ways to control the appetite for dietary fat as well as the neurological and biological impacts of fatty food consumption and exercise on the brain as a determining factor for type II diabetes and obesity.

Novel Medical Devices

A medical device is a product involved in diagnosis, therapy or surgery for medical purposes. It involves a wide range of products from imaging to monitoring to implants to surgical instruments and equipment. A major revolution is taking place in advanced medical devices involving the introduction of advanced technologies to improve tools for diagnosis and treatment and the development of biological substitutes to restore, maintain, and improve tissue, bone, and organs as well as. Some of the leading technologies being adapted for use in innovative medical treatments and diagnostics include: microelectronics, imaging, nanotechnology-related biosensors, robotics, and biopolymer materials.

How It Builds on Utah Strengths

- Utah has a broad medical device industry including strong specializations in Surgical and Medical Instruments, Dental Equipment, and Irradiation Apparatus, and emerging strengths with growing employment in Electromedical and Electrotherapeutic Devices and Surgical Apparatus and Supplies Manufacturing.
- A number of emerging Utah biopharmaceutical companies advancing new therapeutics received venture financing from 2006 through the first quarter of 2011, including:
 - Amedica Corporation developing orthopedic devices.
 - Catheter Connections, Inc. developing medical infusion accessory products.
 - Coherex Medical developing medical devices for addressing structural heart diseases including closure systems that stimulate tissue in-growth and to close left atrial appendage.
 - Control Medical Technology developing aspirator devices where fluids are aspirated through small devices.
 - Health Line International developing vascular access and infusion therapy products.
 - TechniScan Medical Systems developing automated 3D breast ultrasound imaging system.
 - Vital Access Corporation developing surgical and interventional technologies for vascular access.
 - White Pine Medical focused on cardiovascular, orthopedics and neurostimulation devices.
 - WorldHeart Corporation developing heart assist pumps.
 - Maxtec, Inc. manufacturing oxygen analyzers and monitors.
- A wide number of patent and publication cluster focus areas are found in the Medical Devices core technology competency in Utah including:
 - Surgical Devices, Catheters, Instruments, and Equipment
 - Musculoskeletal Implants and Devices
 - Cardiovascular and Pulmonary Conditions
 - Medical Imaging
 - Transplantation and Stem Cell Applications
 - Ophthalmology
 - Ion Channel Research.

Utah stands out in a wide number of publications fields related to medical devices including: Biomaterials, Transplantation, Cardiac and Cardiovascular Systems, Imaging Sciences, Biophysics, Biomedical Engineering, Orthopedics and Neuroimaging.

Among the many university research centers and focus areas found in Medical Devices are:

- University of Utah Cardiovascular Research and Training Institute, which is focused on electrophysiology seeking to understand how both normal and diseased hearts generate electrical signals and how these signals modulate contraction. Such knowledge provides a basis for more effective treatment of arrhythmias and other disease states that affect ion movements across heart cell membranes.
- University of Utah Bioengineering Department brings an active focus on cardiovascular devices, neural engineering and through its Utah BioDesign the advancement of novel devices through close collaborations with surgeons and other clinicians.
- University of Utah Scientific Computing and Imaging Institute is a renowned center of excellence with a core focus on biomedicine applications to address new image analysis techniques, visualization of complex and rich scientific data, advancement of computational and numerical methods for scientific computing and development of scientific software environments. SCI is home to the NIH funded Center for Integrative Biomedical Computing (CIBC) which is dedicated to producing open-source software tools for biomedical image-based modeling, biomedical simulation and estimation, and the visualization of biomedical data.
- University of Utah Nano Institute has faculty working on biomedical device innovation to improve the performance of implants and promote functional regeneration of tissue, along with work on polymer innovations for gene therapy and enhanced delivery of therapeutics.
- Brigham Young University has a focused effort on Compliant Mechanisms, which can advance novel biomedical devices through the use of microelectromechanical and nanoelectromechanical systems.

Appendix B: Important Infrastructure Issue of Water for Utah's Long Term Economic Health

Utah's economic development infrastructure is a key strength that has resulted in economic growth in recent years. In 2010, Forbes Magazine ranked Utah as the number one state for doing business in the U.S. CEOs interviewed for this project reported that Utah's geographic location and transportation infrastructure are major advantages. Utah is a central location to major western cities and states with a one to two day access to half the nation's population. It has multiple modes of transportation and distribution that are easily accessible. With its location on the Canada/Mexico corridor, Utah is an excellent location for product distribution. Salt Lake City airport offers service to more than 100 cities and numerous international locations. Utah has lower costs and companies reported no difficulties in terms of finding facilities. Utah is recognized as having a good business climate and an excellent quality of life, with many recreational and cultural amenities.

As a result of its attractiveness, Utah's economy is growing as is its population. Since 2000, Utah's population has increased by more than half a million people, due both to natural growth and in-migration. It is estimated that by 2050 Utah's population will double to five million people yet Utah is the third driest state in the nation. The result of this robust population growth is that Utah faces a serious long-term challenge: how to meet future demand for water. With 85 percent of Utah's citizens currently living in the Wasatch Range and most future growth expected to occur in this area, this places real constraints on Utah's quality of life and ability to ensure a key resource for industry activities—water. Further complicating the situation is that approximately 70 percent of surrounding land is federally-owned which constrains where and how economic development can occur.

Climate change and emerging weather patterns also are likely to impact the availability of water in Utah. In the early 2000s, the state faced serious drought conditions. Between 2002 and 2004, every county in the State experienced drought conditions. In 2003, more than 95 percent of the state experienced "extreme" or "exceptional" drought conditions.⁴ For Utah's economy to continue to grow, the state will have to identify future water needs and implement water management, conservation and development strategies.

To address this issue, Utah needs to better apply its environmental strengths found in ecology and atmospheric sciences to better assess and develop strategies related to water issues. An improved understanding of the complex ecological system surrounding Utah's water issues and the development of sustainable solutions will require the better integration of social, hydroclimate, ecological, and engineering knowledge, and closer links between the science community and applied water management institutions. A key challenge is taking large scale ecological and hydrologic systems modeling down to a regional level.

As set out below, Utah is well positioned to address this challenge.

How It Builds on Utah Strengths

- In industry development, environmental services and conservation & management stand out as significant employers in Utah, along with more emerging sectors of energy efficiency and green materials. While the greatest value of addressing water and ecosystem sustainability will be in providing the critical infrastructure needed to buttress all of economic development, it is expected that there will be advanced methods, tools and environmental products that will come out of the efforts in this area that will fuel broader environmental-related industries.
- Involves a broad set of environmental-related patent and publication cluster focus areas found across industry and universities in Utah, along with publications excellence in many environmental-related fields, such as Ecology, Biodiversity Conservation, Meteorology/Atmospheric Sciences, Soil Sciences, Environmental Engineering, and Environmental Sciences.
- Despite the wide span of Utah's patent and publication cluster focus areas and publications excellence in environmental-related areas, the overall environmental research area is one that Utah's universities have been falling behind in. While U.S. universities increased in environmental sciences research expenditures by 61 percent from 2001 to 2009, Utah universities fell in their level of environmental sciences research expenditures by 4.8 percent, and now stand at only 0.4 percent of the U.S. total with \$13 million in environmental sciences research expenditures in 2009.
- Utah does have a number of specialized research centers that offer key resources to be applied to this more specific regional focus on water and ecosystem sustainability, including:
 - Utah Water Research Laboratory at USU which addresses technical and societal aspects of water-related issues, including quality, quantity, distribution, and conjunctive use.
 - Environmental Modeling Research Lab at BYU, which has a long history of research in computer simulation of water resource systems, including groundwater flow and transport, watershed runoff, flooding due to storms or dam breaks, and surface water flow in lakes, rivers, estuaries, and coastal environments.
 - Ecology Center at USU integrates the efforts of faculty and graduate students in 3 colleges and 5 departments with a primary purpose to provide a basic scientific underpinning for the basic and applied ecological programs in the Colleges of Agriculture, Natural Resources, and Science. But many of its research projects address applied natural resources and environmental problems.
 - The Global Change and Ecosystem Center focuses on how different global changes the dynamics and sustainability of natural ecosystems, human-built systems, and regional-to-global climate systems. A common theme is a systems-scale approach that contributes to addressing pressing environmental challenges, such as sustainability,

restoration, and responses of natural ecosystems; variations, vulnerabilities, and dynamics of climate systems; development of sustainable urban systems and interactions at wild land-urban interfaces.

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