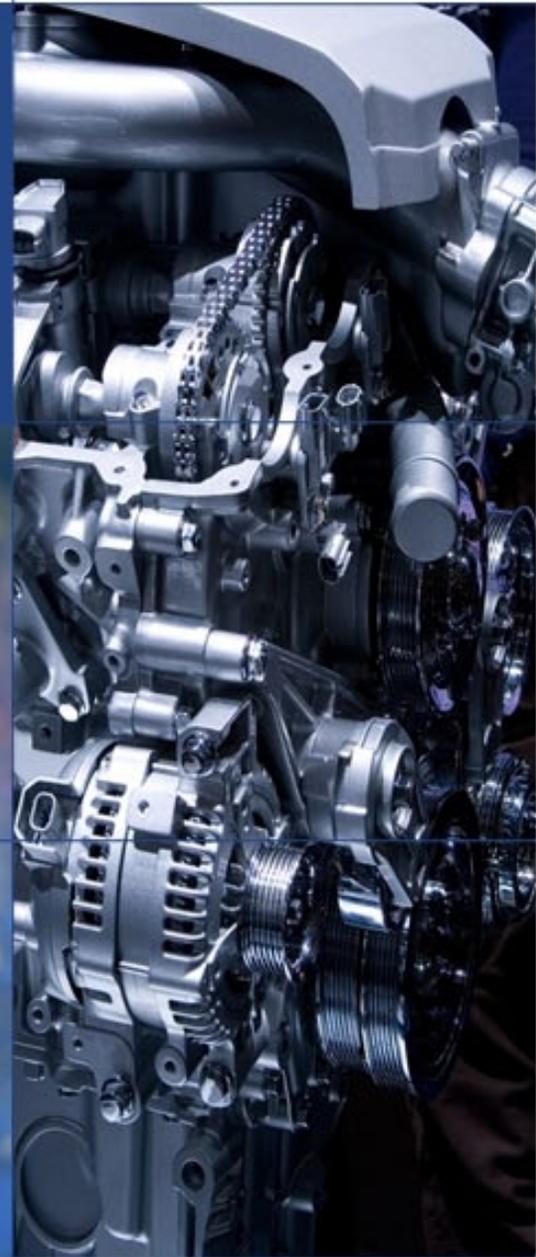


# Making an Impact

Assessing the Benefits of Ohio's Investment in  
Technology-Based Economic Development Programs:

Industry and Company Case Studies



Science • Technology • Innovation • Economic Development



# Making an Impact:

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September 2009

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## BIOMEDICAL IMAGING CLUSTER IN OHIO

The biomedical imaging industry is a large, science-based sector with a long history in Ohio. Ohio is the birthplace of some of the earliest imaging technologies and the state's early ingenuity has helped build a huge worldwide imaging device market estimated at \$15 billion in revenues in 2008. Projected compound annual growth rates of 3 percent to 7 percent are estimated for the industry as a whole with higher growth forecasted for certain product segments such as MRI and CT.<sup>1</sup> The U.S. medical imaging market was valued at more than \$9.2 billion in 2008 with an expected compound annual growth rate of 4.5 percent through 2015. Magnetic Resonance Imaging (MRI) technology accounts for nearly 20 percent of the market, with a doubling of market size expected for high end machines.<sup>2</sup>

Ohio's biomedical imaging cluster includes about 81 core companies, anchored by Philips Medical, GE Healthcare, Siemens Medical, Hitachi Medical, and Toshiba Medical. These Tier 1 companies all have manufacturing and/or an R&D presence in Ohio. Ohio companies generate an estimated \$1 billion to \$2 billion in revenues, or 1-2 percent of the global market, and about 15 percent of the U.S. market for this emerging industry. The state is globally recognized as a center for biomedical R&D and manufacturing, and this activity creates spillover effects for suppliers, many of which are locally resident in the state. In addition, there are major economic and health benefits from clinical trials—which can generate \$6 billion over a 10-year period<sup>3</sup>—and from medical tourism and the enhancement of the health care of the people of Ohio.

This case describes the origin, ebbing, and rebirth of the biomedical imaging cluster in the Northeastern and Central Ohio corridor. The case will show that this corridor has a history of inventive activity in biomedical imaging that has experienced a resurgence, due in part to the partnership between industry, academia, and the Ohio Third Frontier (OTF) and Thomas Edison Programs. Key factors in the advance of the biomedical imaging corridor include: (1) strong and flexible relationships and networks involving longstanding experts in medical imaging and related sectors and academia, (2) entrepreneurial spinoffs and relocations, and (3) OTF and other state

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<sup>1</sup> Based on SRI's survey of growth projections for the biomedical imaging industry, including projections from Frost & Sullivan (1999, 2007, 2009), the UK Dept of Trade and Industry (2005), and BCC Research (2007)

<sup>2</sup> Chapdelaine, Sarah and Zamanian, Kamran, "Imaging Market Recovers by 2010." *Imaging Technology News*, November/December 2008.

<sup>3</sup> Johnston SC, Rootenberg JD, Katrak S, Smith WS, Elkins JS. "The impact of an NIH program of clinical trials on public health and costs." *The Lancet*, April 22, 2006, Vol. 367, pp. 1319-1327.

technology development investments in academic research, capabilities and equipment, and entrepreneurial assistance and seed capital.

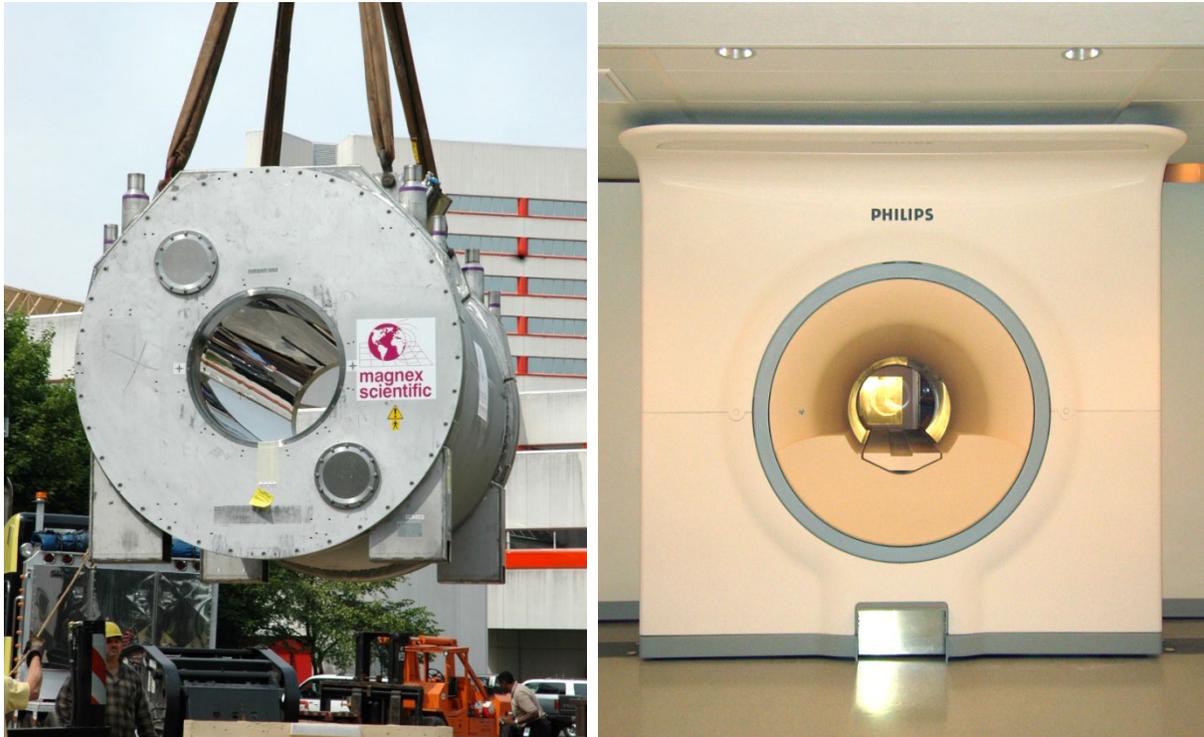
## **BIOMEDICAL IMAGING TECHNOLOGY**

Biomedical imaging technologies create visual representations of the human body for diagnosis and medical evaluation. These technologies are relatively recent advancements that allow low risk examination of areas of the body not well represented by conventional x-rays. These technologies include:

- Computed tomography (CT) imaging uses x-ray images from multiple points of view to scan slices of human body structures.
- Ultrasound uses high frequency sound waves to produce human body images.
- MRI is a favored application for soft tissues (such as brain) that are subject to error from x-ray based techniques. MRI uses magnets and radio waves with computer processing to produce structural images of the body with minimal risk compared to x-rays.
- Positron emission tomography (PET) and single-photon emission computed tomography (SPECT) use tracer chemicals injected into the patient to provide images of blood flow and chemical reactions in the body.
- Hybrid nuclear systems such as PET/CT and SPECT/CT are also prevalent.

Biomedical imaging technologies are typically housed in large, tubular-shaped scanning machines (See Figure 1).

**Figure 1. MRI Scanner, Philips Medical Systems. Courtesy of the Wright Center of Innovation in Biomedical Imaging**



The leading biomedical imaging companies in the world are Philips Medical Systems (the Netherlands), GE Healthcare (Wisconsin) and Siemens (Germany). These companies purchase technologies, components, and services from a range of suppliers, most of which are located in close proximity to the companies' manufacturing and R&D facilities to speed product development. The core imaging technologies are the coils and software, which enhance the speed and clarity of diagnostic applications. In addition, imaging systems involve magnets, crystals, printed circuit boards, electromechanical systems, gantry systems (the device that revolves around the patient), imaging agents (i.e., chemicals), prototyping, and machining (See Table 1).

Biomedical imaging has broad-based societal benefits. Hospitals and medical research institutes carry out clinical trials using biomedical imaging technologies and techniques.<sup>4</sup> These trials can lead

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<sup>4</sup> See for example the National Cancer Institute's Cancer Imaging Program. The program conducts clinical trials using bioimaging techniques to advance the imaging procedures themselves and cancer treatment overall. Last accessed 22 Jun 2009. Available at: <http://imaging.cancer.gov/imaginginformation/CancerImagingClinicalTrials/>

to health care improvements and have an impact on their surrounding economies through what is known as medical tourism. Broader societal impacts include the enhanced level of care available to residents of Ohio (and beyond) and dramatically reduced medical costs. The benefits of the biomedical imaging industry extend from the activities of core companies to a range of economic sectors, and ultimately to society as a whole. Moreover, all of the technologies and components that the industry requires, with the exception of magnets, are available within Ohio.

Table 1. Biomedical Imaging Industry: Core and Related Industries, Customers, and Beneficiaries*	
Core Imaging Companies	Philips Medical Systems, GE Healthcare, Siemens Medical Systems, Hitachi Medical Systems, Toshiba Medical Systems
Types of central suppliers	Coil and magnet providers, software companies
Types of other related suppliers	Crystal companies, printed circuit board manufacturers, robotics and electromechanical system manufacturers, gantry systems manufacturers, imaging agent suppliers, machine shops, prototyping houses
Types of key customers	Hospitals, universities, clinics, doctors’ offices
Societal impacts	Medical tourism, enhancement of health care

\*Philips Medical Systems has a 1 million square foot operation in Cleveland. GE Healthcare’s MRI coil R&D center is in Cleveland. Hitachi Medical Systems’ imaging sales and marketing operations are located in Twinsburg. Toshiba America Research Inc. has a small R&D facility in Cleveland, and Siemens Medical Solutions is also located in Cleveland.

## HISTORY OF OHIO’S BIOMEDICAL IMAGING INDUSTRY AND STATE INVESTMENT IN CLUSTER

The Northeastern and Central Ohio corridor has a strong history in the biomedical imaging sector. The origins of the medical imaging industry can be traced to two startup companies, Ohio-Nuclear Inc. and Engeln Electric Co., both in the Cleveland area. Engeln was formed in the early 1900s to manufacture X-ray equipment and was later acquired by Westinghouse and sold to Picker International. Picker was subsequently acquired by Marconi Medical Systems in the 1980s, which in turn was acquired by Philips Medical Systems in 2001. Philips Medical now has its U.S. headquarters in Cleveland. A large piece of Ohio’s imaging industry (embodied by Ohio-Nuclear/Technicare) wound up leaving the state, though. Established in 1958, Ohio-Nuclear Inc. was a manufacturer of CT and MRI scanners and other medical imaging equipment. It was purchased by Technicare in the 1970s. Technicare merged with Johnson & Johnson, retaining its Cleveland area manufacturing facility in Solon. Facing economic pressure in the 1980s, Johnson & Johnson sold Technicare to General Electric, and much of the medical imaging operations that had

belonged to Technicare moved out of Ohio.<sup>5</sup> A few of Technicare's highly-trained employees formed spinoffs in the region, but much of the activity left the state and Ohio's historic position in the medical industry was threatened.

The OTF made several important investments that served to stimulate the biomedical imaging corridor. In 2003, the state awarded a Wright Center of Innovation in Biomedical Imaging to Ohio State University (OSU) and several partner organizations: Case Western Reserve University in Cleveland, Philips Medical Systems in Cleveland, and the Ohio Supercomputer Center in Columbus. The proposal for OSU's Wright Center was born from two original grant submissions, one from a Cleveland-based team and one from a Columbus-based team. Professor Michael Knopp of OSU's Department of Radiology took the lead on uniting the two original proposals. He states that the proposal process in and of itself created synergies across these two neighboring regions: "Bringing these regions together that have different opportunities and strength allowed new people to talk to each other. Bringing new networks together really brought a fresh level of synergies."<sup>6</sup>

The Wright Center is headquartered at OSU as a result of the \$17.1 million OTF award that was granted. The award was primarily used to support powerful state-of-the-art scanning equipment — including 3-Tesla, 7-Tesla, and 8-Tesla MRI scanners built by Achieva and Philips Medical Systems. The award allowed OSU to construct facilities to house equipment that would protect the scanners from external disturbances and vibrations while allowing for features to facilitate patient access and comfort.<sup>7</sup>

Importantly, the equipment at the Center represents a significant and distinctive partnership within the biomedical imaging industry in Ohio. Much of the cutting-edge equipment at the Center comes from Ohio imaging companies and is used in academic research. The unique partnership between industry and academia has been used to help manufacturers and their suppliers to accelerate commercialization. Industry participants in this environment can further implementation of reimbursable procedures, develop new procedures for patient care, and conduct clinical trials toward use of biomarkers. Most of the groups that use this equipment have substantial in-state operations, though some equipment users come from outside Ohio. Many of these companies come to Ohio to seek out expertise to accelerate their commercialization. This helps to further the

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<sup>5</sup> Encyclopedia of Cleveland History, Case Western Reserve University, <http://ech.cwru.edu/index.html>. GE Medical Systems also purchased MRI coil developer manufacturer USA Instruments, Inc. in 2002.

<sup>6</sup> Personal interview, Professor Michael Knopp, April 14, 2009.

<sup>7</sup> Robert McKenney "Insight Article". Ohio State University College of Medicine. Last Accessed 07/04/2009. Available at: <http://www.radiology.osu.edu/11319.cfm>

state's reputation in the biomedical imaging industry and lay the groundwork for potential economic development opportunities.

It is unusual for companies in the same industry to develop equipment in a common research center. However, the OTF Wright Center at OSU offers flexibility in its approach to intellectual property. The Center has intellectual property protections that enable companies to bring their equipment to the Center, leverage the Center's expertise, and create new inventions in a user-friendly environment. There are also opportunities for joint research and patenting, as well as for university-specific discoveries within the Center. This distinctive intellectual property environment is facilitated by extensive cross-licensing within the imaging sector, in which one piece of equipment may embody several hundred patents.

Case Western Reserve University, a partner with the OTF Wright Center, has also received investments from the state to support its biomedical imaging activities. The Physics Department at Case Western Reserve received awards from the Wright Center to further extend the university's work in imaging physics and applied industrial applications. In another part of the university, the Case Center for Imaging Research (a joint venture between Case Western Reserve University School of Medicine and the University Hospitals of Cleveland) maintains four high-field multi-nuclear systems, four nuclear imaging systems, and two optical imaging systems which were installed in 2005. That same year, the Case Western Reserve School of Medicine was awarded \$4 million from the OTF to study Targeted Nanoparticles for Imaging and Therapeutics. An additional \$3.9 million was awarded in FY 2008 for a related topic. The school won these awards in collaboration with several Cleveland-area companies, including Cleveland NanoCrystals, Copernicus Therapeutics, Inc., iMedd, Inc., and Ricera Biosciences, Inc.

In addition, OSU won a \$24.9 million Ohio Research Scholars Program grant award in 2008 to the OTF Wright Center of Innovation in Biomedical Imaging, with Case Western Reserve and Wright State University as partners. The Research Scholars Program paid for several new faculty hires at the university and attracted senior researchers and biomedical imaging scholars to Ohio. These research activities have strong commercialization ties through organizations such as BioEnterprise and JumpStart Ventures in Cleveland and Columbus-based BioOhio and TechColumbus. BioEnterprise is an Edison Technology Incubator; BioOhio is an Edison Technology Center; and JumpStart and TechColumbus are key players in the OTF-supported entrepreneurial assistance networks in their respective regions, in addition to being Edison Technology Incubators. JumpStart Ventures and other funds have invested more than \$1 million in four startups, including Tursiop (making a nanomaterial-based MRI coil) and CardioInsight (making electrical activity imagers) in the medical imaging market. TechColumbus has invested at least \$500,000 of early-stage financing in biomedical imaging companies. As OTF ESPs and Edison Technology Incubators, these organizations

have supported startup activity in the biomedical imaging domain by providing business assistance and guidance—such as networking meetings, technical assistance, and business plan review—to entrepreneurs, and connecting small businesses to other funding sources and imaging-related companies in Ohio. Overall, the OTF has committed more than \$77 million in the last seven years to support academic and industry collaborations in biomedical imaging.<sup>8</sup>

### RESULTS

In 2008, 91 companies comprised the core of Ohio's biomedical imaging cluster, which accounted for 5,267 jobs—up 87 percent from 2004. These are companies for which biomedical imaging is a central part of their business and produce either imaging systems or key components of the systems. The Ohio biomedical imaging cluster includes large multinationals (Philips Medical Systems, GE Healthcare, Hitachi Medical Systems, Siemens Medical Solutions, Toshiba Medical Systems) that set up operations through acquisition or creation of an R&D facility; mid-sized firms (such as PartsSource, Codonics, Merge EFilm); and startups (such as Imalux, MIMVista, Quality Electrodynamics, Tursiop Technologies).<sup>9</sup> In addition to the core companies, there are a larger number of other companies that supply materials, equipment, components, or services to biomedical imaging companies, but often supply other industries as well.

As the largest operation in the cluster, Philips Medical Systems has 1,100 employees and a 1 million square foot facility in Cleveland. This facility is the location of all of Philips' North American training, which was formerly distributed throughout the region. It is the company's global headquarters of nuclear medicine, high field imaging (i.e., ultra-strong magnetic imaging which is an important future development area), PET, CT, and refurbishment. The refurbishment center recently expanded into a new facility. Philips executives note that Ohio's investment in the Wright Center of Innovation was critical to the creation of their high field imaging operations, which are a central R&D investment for the company. Their proximity to Ohio's other imaging investments has created ongoing relationships that enable product development at Philips to happen more quickly, on multiple fronts, and with mitigated risk. The Wright Center has also leveraged relationships between Philips and other Ohio-based companies; Philips has recently connected with a company providing vibration solutions that could further improve Philips' imaging machines.

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<sup>8</sup> BioEnterprise, Cleveland: The Nation's New Health Care Innovation Destination. November 2008. At <http://bioenterprise.com/assets/biomedreport.pdf>

<sup>9</sup> Ibid.

OSU has received global recognition for its recent imaging research activities. OSU's Wright Center sponsored a symposium in 2007 titled "Ohio: The Global Pioneer in Biomedical Imaging." This event hosted participants from around the world, who discussed biomedical imaging opportunities and collaborations. In addition, the investment in the Wright Center has helped to attract several high profile federal R&D awards, including a \$1.5 million grant awarded to the Wright Center from the National Institutes of Health in 2007 for research on imaging standards. OSU and the Cleveland Clinic were both able to attract a Phase III clinical trial sponsored by Wilex to demonstrate the utility of 124-Iodine as an imaging agent in a PET/CT of masses in the kidney prior to surgery.<sup>10</sup>

Case Western Reserve University also reports significant benefits from their collaboration with the Wright Center. Case's Professor Robert Brown has long maintained industry ties, but without investment from the OTF, there was not sufficient critical mass to generate economic development outcomes. With the creation of the Center, "all the sudden we had the ability to think big," recounts Professor Brown.<sup>11</sup> The director of his industrial imaging research group at the time, Hiroyuki Fujita, approached the professor about forming a company that would manufacturer miniaturized coils using radio frequency (RF) technology for MRI machines. Most coil developers are not at the stage of producing a manufactured product, but Dr. Fujita set manufacturing as a goal and took a target-based approach to achieve that goal<sup>12</sup>. The result was the creation of Quality Electrodynamics (QED), which started in 2007 with Dr. Fujita and several of the students from Case Western. Startup financing is always a barrier, but QED paid its way by successfully achieving the following: (1) US Small Business Innovation Research (SBIR) phase 1 award<sup>13</sup> for \$117,850 (2) two State of Ohio grants to purchase equipment and undertake training, (3) a \$320,000 grant from the Cleveland Clinic's Global Cardiovascular Innovation Center, the OTF Wright Mega-Center, and (4) technical advice from BioEnterprise, an Edison Technology Incubator, about additional funding opportunities. As of 2009, QED sells product to multinational medical system companies, is expanding its facility to four-times the original space at 27,000 square feet, and plans to double its base of 40 employees over the next two years. QED was awarded a 2009 Innovation Award by NorTech, the Northeast Ohio Technology Coalition, for its breakthroughs.

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<sup>10</sup> ClinicalTrials.gov (2008). "Pre-Surgical Detection of Clear Cell Renal Cell Carcinoma Using Radiolabeled G250-Antibody" Last accessed 22 Jun 2009. Available at: <http://clinicaltrials.gov/ct2/show/NCT00606632>

<sup>11</sup> Personal interview, Professor Brown, April 14, 2009.

<sup>12</sup> Dr. Fujita's targets for manufacturing were: international quality certification, U.S. Food and Drug Administration (FDA) registration and approval, and registration with the Japanese government (Japan is a target market)

<sup>13</sup> The Small Business Innovation Research (SBIR) program provides funding for commercialization of R&D to small businesses in awards made by 11 federal agency. Phase 1 SBIR awards of up to \$100,000 test technical merit or feasibility of an idea. Phase 2 awards of up to \$750,000 supports R&D and commercialization work.

Two additional Cleveland-area imaging startup companies with significant potential are Imalux and MIMVISTA. Imalux is developing a product with the potential to reduce unnecessary surgical biopsy procedures. The startup received \$542,000 from the OTF in conjunction with an SBIR award from the National Cancer Institute that could provide an additional \$7.4 million in venture capital.<sup>14</sup> MIMVISTA develops software that merges imaging findings to produce readily interpretable information. The 50-plus employee company collaborates with Case Western Reserve and Philips Medical Systems.

The OTF Wright Center in Biomedical Imaging also has several university spin-offs in the imaging area and has worked with academic and industry partners to increase opportunities and growth. One company working with the Wright Center is Hyper Tech Research Inc., which was formed in 2001 to use superconducting technologies for lowering the cost of cooling of MRI systems. To support technological development Hyper Tech has received some 25 SBIR grant awards from 2000 to 2007 totaling nearly \$9 million from various federal agencies: the U.S. Dept. of Energy, Dept. of Defense, and National Institutes of Health. Hypertech won grants from the OTF, too: a three-year \$800,000 development grant in 2002 and a \$150,000 commercialization grant in 2005 which enabled the hiring of a marketing and sales manager. This Federal and State funding served an important bridging role until the company completed development. The Wright Center made a significant contribution by connecting the company with MRI equipment manufacturers. These connections led Hyper Tech to work on new technological directions to fill a gap in the regional MRI supply chain for magnet systems. As of 2009, Hyper Tech has 20 employees and \$2.5 million in sales. The Wright Center also has an R&D collaboration with Enlyton, which is a startup company with six employees founded in 2004 out of the research at OSU's College of Medicine, Pharmacy, and Engineering. The company develops and synthesizes imaging tracers for use in PET/CT scans to detect cancer in lymph node tissue. The Wright Center offers a partnership of facilities and expertise as the company moves toward a Phase 1 clinical trial

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<sup>14</sup> Mary Vanac, Imalux lands \$5.1 million in venture round, Cleveland Plain Dealer, September 27, 2007.

The dynamic clustering of multinational and startup companies in the medical imaging sector has attracted several imaging-related startup companies to the corridor. In 2004 ViewRay was established by a University of Florida oncology professor to address the issues of movement and interference in imaging science. Venture capital firms were lined up to provide \$25 million in startup venture capital, but the VCs encouraged ViewRay to relocate to a region with more bioscience strength before receiving the startup funding. ViewRay's board considered the San Francisco and Boston areas but decided that the company could start up faster in Ohio given the proximity to Case Western Reserve's physics and biomedical department, access to patients via the Cleveland Clinic, access to equipment and researchers at Wright Center of Biomedical Imaging's facility at OSU, and the cluster of imaging companies in Northeastern and Central Ohio. In April 2008, ViewRay announced that it would move to Cleveland and committed to hire 25 employees at an estimated \$100,000 salary per position in the first 12 months of operation and 90 employees over a three year period.<sup>15</sup>

A second startup—"m2mImaging"—announced that it would move its headquarters and seven R&D employees from New Jersey to Cleveland. The company makes coils for MRI, PET, CT, and other equipment used in clinical and preclinical imaging research. M2mImaging is a combination of

#### Return on State's Wright Center Investment

The Ohio Third Frontier's \$17.1 million investment in the Wright Center of Innovation in Biomedical Imaging generated the following economic impacts through December 2008:<sup>1</sup>

- \$48.8 million cost share for the \$16.7 million of state investment expended, much of which comes from private industry
- Federal research grant awards coming into the state in the amount of \$17.8 million.
- 366 jobs, including 108 private sector jobs, with average annual salaries of \$136,600
- New sales totaling \$78.5 million
- Five new companies created and two companies attracted to Ohio from out of state.

<sup>15</sup> Mary Vanac, "Florida medical firm ViewRay picks Cleveland, pledges jobs," *Cleveland Plain Dealer*, February 25 2008.

spinoffs from two universities (Columbia University and University of Queensland in Brisbane Australia). The company expects to hire 30 employees and consultants in the 2008-2009 time period.<sup>16</sup> Navotek and GammaStar Medical Group are two other imaging startups moving to the region.

## CONCLUSIONS

The biomedical imaging industry in the Northeastern and Central Ohio corridor has developed a critical mass in the last five years. The core cluster in Ohio encompasses 81 imaging companies and showed 86.7 percent employment growth between 2004 and 2008. The industry is R&D intensive, driven by innovation, embedded in an extensive supply chain across multiple economic sectors, and connected to the health and well being of citizens. The OTF and other state technology development programs have driven the advancement of this industry cluster.

This cluster had been present in the region for many years and Ohio's universities have had ongoing imaging research and industrial development activities. That said, the evidence suggests that the vitality of the industry was enhanced by OTF investments. First, the industry had begun to leave the state, most visibly in GE's acquisition and closure of Technicare. In contrast to the Technicare situation, when Philips Medical completed its acquisition of the former Engeln facility in Cleveland, the facility gained functions across Philips' multinational network. It became the North American headquarters for training and the center for product refurbishment. The innovative high field imaging project that existed prior to the Philips acquisition could have been moved to the company's global headquarters in The Netherlands, but the facility's proximity to OSU's Wright Center for Biomedical Imaging indicated to Philips that its investment in the future would pay off more quickly by keeping the project in Ohio.

Secondly, university programs focused on imaging had been longstanding but thinly staffed. Industrial opportunities, while available, were thus difficult to pursue. Once the OTF investments were put into place, faculty members felt that economic development became a larger part of their mission. As OSU's Prof. Knopp describes it, "It required us to be proactive. We were driven by the vision to embrace what the state wanted to do to establish industry-academia collaborations. That has been part of the success of the Center, bringing individuals together."<sup>17</sup>

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<sup>16</sup> Mary Vanac, "m2m Imaging joins region's imaging technology cluster", *Cleveland Plain Dealer*, April 7 2008

<sup>17</sup> Personal interview, Professor Michael Knopp, April 14, 2009.

Third, the imaging industry had a history of entrepreneurship starting in the early 1900s with Engeln Electric Company. However, many of these Ohio startups fizzled as a result of a lack of resources, connections, or acquisitions. Today’s entrepreneurs describe the importance of Ohio’s early stage funding programs to help them bridge the period before they are ready to seek venture capital or go to market. In addition, the Wright Center plays a critical matchmaking role because of its leaders’ experience in the imaging field. Dr. Knopp says about his relationship with one of the startup companies, “we were their mentor in the [magnetic resonance] market. We would help them open the doors to approach the different vendors with already conceptual strategies that would resonate with the vendors.”<sup>18</sup>

One major driver in the revitalization of the biomedical imaging corridor in the Northeastern and Central Ohio regions is the interpersonal relationships and networks of industry and academic experts. Several of the leaders on the industry side have collaborated in multiple settings in the imaging industry. On the academic side, some faculty members have been involved with these industrial experts as their professors and contract researchers. Others have held positions of national and global importance that allowed them to make connections with existing and emerging companies. The ability of the OTF to stimulate these networks by encouraging cross-regional connections has certainly strengthened the imaging cluster. Another key factor is the pervasiveness of entrepreneurial risk-taking by industry and academia that further supports the vitality of the industry. Finally, these factors are reinforced by the availability of support from the OTF and other state technology development investments to academic research, capabilities and equipment, and to entrepreneurship, commercialization, and seed capital.

Table 2. A Timeline of Ohio’s Biomedical Imaging Cluster	
<b>Early to mid 1900s</b>	Medical imaging develops in Northern Ohio led by Engeln Electric Company (Picker X-Ray) and Ohio-Nuclear Inc. (Technicare)
<b>1980s</b>	Technicare acquired by Johnson and Johnson, and eventually GE, moved out of Ohio to Milwaukee  Picker X-ray acquired by Marconi Medical Systems (GE of England).
<b>2001</b>	Philips Medical acquires Marconi Medical Systems, headquartered maintained in Cleveland. GE Healthcare acquires Cleveland-based coil R&D and manufacturer USA Instruments the following year.

<sup>18</sup> Ibid.

<b>Table 2. A Timeline of Ohio's Biomedical Imaging Cluster</b>	
<b>2003</b>	OTF Wright Center of Innovation in Biomedical Imaging awarded \$17.1 million grant
<b>2004-5</b>	Imaging equipment installed at the Wright Center.
<b>May 2005</b>	Case Western Reserve School of Medicine awarded a \$4 million from the Ohio Third Frontier for Targeted Nanoparticles for Imaging and Therapeutics.
<b>2007</b>	Quality Electrodynamics (QED) founded by Case Western Reserve researcher
<b>October 2007</b>	Wright Center holds global symposium on medical imaging.
<b>Early 2008</b>	ViewRay Inc. announces move from Gainesville Florida at the request of its \$25 million investing venture capital firm to Cleveland. Two months later m2m Imaging announces move from Newark, N.J. to Cleveland.
<b>2008</b>	\$24.9 million grant from the Ohio Research Scholars to OSU and Case to attract senior faculty in biomedical imaging
<b>January 2009</b>	QED announces expansion, doubles workforce
<b>Early 2009</b>	Philips completes new refurbishment facility.

## THE FUEL CELL CLUSTER IN OHIO

A fuel cell is an electrochemical device that uses fuel (typically hydrogen, hydrocarbons, or alcohol) and a source of oxygen to produce electricity. Fuel cells are currently used as portable battery replacements, residential generators and commercial generators used in “distributed generation” to power the electrical grid, and have been piloted as a power source for various types of vehicles. Ohio’s fuel cell industry originated in the 1990s and is currently entering an intermediate phase of development, with a number of fuel cell manufacturers and their suppliers beginning to sell products and several more companies on the cusp of commercialization. Global sales of fuel cells were estimated to be \$3 billion to \$4 billion in 2008 and are projected to rise to \$6 billion to \$12 billion by 2016, representing compound annual growth of 9-15 percent.<sup>19</sup> Fuel cells have applications in a wide range of markets, with customers that include electric utility companies, the military, and consumer electronics manufacturers. Ohio companies are developing fuel cell products for each of these markets, but because Ohio’s fuel cell companies are just now commercializing their products, it is difficult to estimate the share of the global market that they stand to capture. The leading fuel cell manufacturers in the world are FuelCell Energy, Inc. (Connecticut), UTC Power (Connecticut) and Ballard (Vancouver). These manufacturers purchase materials and components from a range of suppliers, including several companies in Ohio.

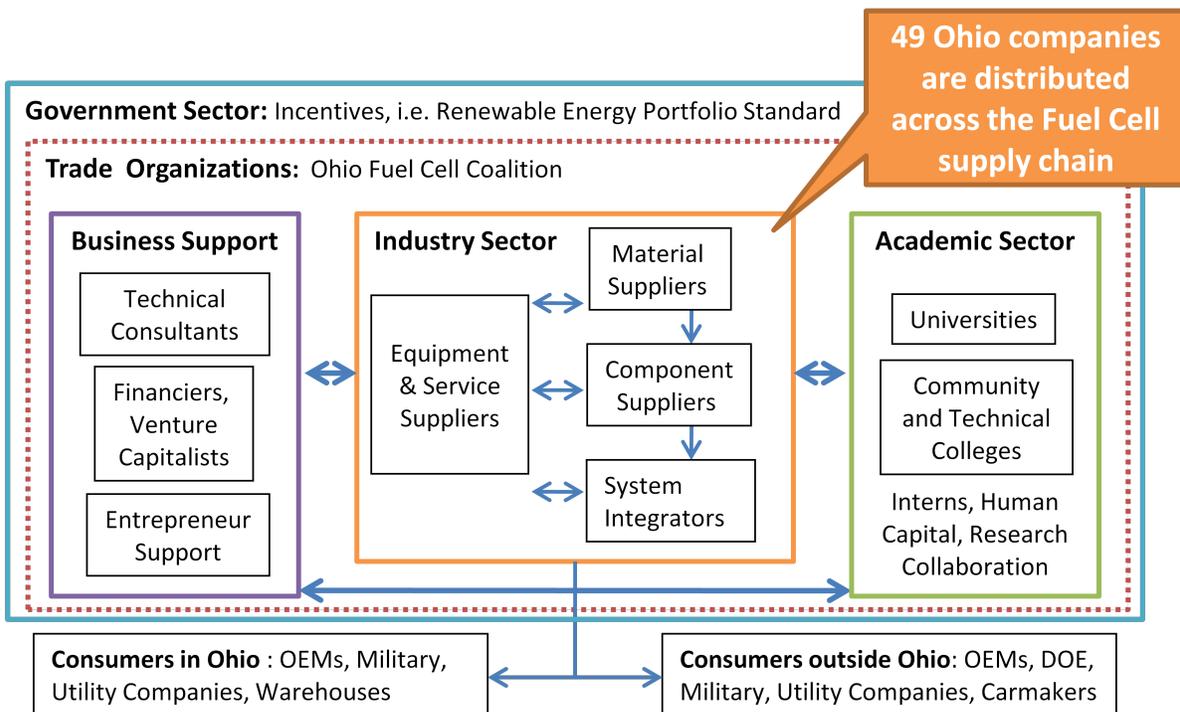
Ohio’s fuel cell cluster is vertically integrated and includes fuel cell integrators, companies that manufacture production and test equipment, and the second-tier suppliers that serve them. SRI's definition of the "fuel cell industry cluster" is the group of fuel cell manufacturers, specialized suppliers and service providers concentrated in Ohio. It is important to note that the companies comprising the core cluster are a small fraction of the total number of companies and employment represented in the entire supply chain and downstream market for fuel cell products. In 2008, approximately 49 companies constituted the core of Ohio’s fuel cell cluster, accounting for 4,435 jobs. These include companies like Rolls-Royce Fuel Cell Systems, NexTech Materials, UltraCell and Catacel. Employment among these core companies has grown 26 percent since 2004. As noted earlier, when one considers the actual number of companies and employment supported by procurements by these core companies, the size of the cluster is significantly larger. For example, Rolls-Royce Fuel Cell Systems procures materials, components and services from nearly 200 Ohio companies.

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<sup>19</sup> Based on SRI’s survey of growth projections for the fuel cell industry, including projections from G. Weaver (Ed.) (2002); Freedonia Group (2007,2008,2009); and Energy Business Reports (2008).

From 2003 to 2008, the Ohio Third Frontier (OTF) Fuel Cell Program invested \$40.3 million in Ohio companies and research institutions working to commercialize fuel cell products. The growth of the fuel cell sector in Ohio has been driven by the state's existing advanced manufacturing base and by the OTF and related technology investments by the state. In particular, the OTF and Edison programs have catalyzed the cluster's growth by attracting companies and investors from other states and countries. The state's investments have helped support the emergence of a true cluster of fuel cell companies. The actors and interactions in Ohio's fuel cell cluster are mapped in the figure below. The cluster includes many new startup companies alongside older, more established companies, some of which only recently got into the fuel cell business.

**Figure 2. Major Actors in Ohio's Fuel Cell Cluster**



In sum, Ohio's fuel cell cluster is characterized by: 1) a strong presence and recognition on the national stage; 2) the ability to leverage state funding in applying for and winning Federal grants; and 3) a strong network of potential in-state collaborators for development of an integrated supply chain. This case study describes the growth of the Ohio fuel cell cluster from its birth in the early 1990s to its current stage of development in 2008.

## FUEL CELL TECHNOLOGY

Fuel cells were first used by NASA as a source of electricity and drinking water on space missions. Since then, the technology has gained popularity as a possible replacement for the gasoline engines used in automobiles. Although experts predict that fuel cell automobile applications are still a decade away, fuel cell products are already manufactured for non-automotive applications. Fuel cell products that are commercially available today include 25W portable battery replacements, 35 kW residential generators, and larger commercial generators used in “distributed generation” to power the electrical grid. But before widespread commercialization can occur in the industry, more development is needed to increase fuel cells’ durability and cost competitiveness with conventional fuels.

A fuel cell is an electrochemical device that uses fuel (typically hydrogen, hydrocarbons, or alcohol) and a source of oxygen to produce electricity. Fuel cells can replace conventional batteries in many applications, but fuel cells do not need to plug into an electricity source for recharging; they will produce electricity as long as fuel is supplied. Fuel cells are one of the most attractive technologies for generating electricity because of their numerous advantages over conventional electricity sources. Compared to conventional energy sources, fuel cells are cleaner, quieter, more efficient, and lighter weight. A big advantage of fuel cells over conventional power plants (like coal, gas and nuclear) is that fuel cells allow flexible expansion of the power supply. That is, rather than constructing a large 1,000 MW power plant, utility companies can install smaller 1 MW fuel cells over a period of time to incrementally increase their base load power supply. Utilities can locate these facilities closer to customers to decrease the electricity loss that occurs with long distance transmission.

Fuel cells can be constructed in many different configurations, each with different characteristics and operating conditions. This variety makes fuel cells suitable for a wide range of applications. A manufacturer’s choice of cell chemistry depends on the requirements of their application. Some of the more common configurations, characteristics, and applications are listed in Table 3.

The core technology components used in fuel cells are the electrodes and electrolytes inside the cell. Other fuel cell components include catalyst materials, bipolar plates, membranes, heat exchangers, gas and liquid sensors, electronics for power regulation and control, and plumbing

fittings and regulators. Most of the components in commercial fuel cells can be sourced in Ohio.<sup>20</sup> Ohio has more primary metals and polymer companies than any other U.S. state and these materials are critical for fuel cell systems.<sup>21</sup>

**Table 3. Fuel Cell Technologies in Ohio: Characteristics, Applications, and Vendors**

Fuel Cell Technology	Characteristics	Development Stage		Ohio Assemblers Using Technology
		Application	Availability	
Proton-Exchange Membrane Fuel Cells (PEMFC)	Fuel: Hydrogen Temp.: Low (150°F) Quick Startup.	Stationary power..... Portable power..... Automotive.....	Available now Available now Rollout 2012-15	Battelle, GrafTech International
Reformed Methanol Fuel Cell (RMFC)	Fuel: Methanol Temp.: Warm (250°F) Allows sub-freezing storage	Small portable power..... Battery replacements.....	Rollout 2010 Available in OH now	UltraCell
Solid Oxide Fuel Cells (SOFC)	Fuels: Natural gas, ethanol, methanol, carbon monoxide, hydrogen, others Temp.: Very High (1800°F)	Emissions reduction..... Military applications..... Distributed generation.....	Available now Available now Available elsewhere	Rolls-Royce Fuel Cell Systems, Technology Management Inc., NexTech Materials Battelle
Direct Carbon Fuel Cells (DCFC)	Fuel: Coal or coke Temp.: High (1400°F) Good for co-generation	Distributed generation.....	Early commercial	Contained Energy

<sup>20</sup> Frank Beafore, Vice President of Manufacturing for UltraCell, said that there are only three (out of approximately 30) components of UltraCell’s model XX-25 fuel cell that the company *cannot* purchase in Ohio. Mr. Beafore is currently negotiating with the vendors of those components to convince them to locate at least part of their operations in Ohio.

<sup>21</sup> “Creating Energy Alternatives: Wright Fuel Cell Group” Last Accessed: April 28, 2009. Available at: [http://energy.case.edu/pdf/energy\\_brochure.pdf](http://energy.case.edu/pdf/energy_brochure.pdf)

**Table 3. Fuel Cell Technologies in Ohio: Characteristics, Applications, and Vendors**

Fuel Cell Technology	Characteristics	Development Stage		Ohio Assemblers Using Technology
		Application	Availability	
Metal Hydride Fuel Cells (MHFC)	Fuel: Hydrogen Temp.: Low (150°F) Inexpensive construction	Niche transport..... Portable generation..... Military Apps.....	Available now  Early commercial In qualification stage	Energy Technologies, Inc.

**HISTORY OF OHIO’S FUEL CELL CLUSTER AND STATE INVESTMENT IN CLUSTER**

Northern and Central Ohio have a strong manufacturing base, due in part to their proximity to the auto manufacturing center of Detroit. In the late 1990s, Ohio turned its interest to fuel cells, which some consider a likely candidate to replace the internal combustion engine in automobiles. Many automotive suppliers feared that, if they were not on board when fuel cells supplanted gasoline engines, they would go out of business. At the time, the public did not realize that significant fuel cell markets exist *outside* of automotive applications, which, interestingly, are where many of Ohio fuel cell developers are focused today in portable device and stationary fuel cell applications.

Ohio’s Technology Action Fund (TAF), the predecessor to the OTF, began investing in fuel cell development in the year 2000. Over a five-year period, TAF disbursed about \$3.8 million in total fuel cell grants across four companies and one Edison Center. In November 2001, the Ohio Department of Development (ODOD) and the Cleveland Engineering Society hosted Ohio’s first Fuel Cell Symposium, even though no fuel cell manufacturers yet existed in Ohio. After the symposium, a group of about 20 fuel cell enthusiasts met with ODOD officials to discuss state support for developing a fuel cell industry. The president of fuel cell developer, Technology Management, Inc., floated the idea of long-term, 20-year fuel cell development plan for Ohio. The central theme of this meeting—that state support of the fuel cell industry was necessary for the state to become competitive—was recognized by grants from Ohio’s Technology Action Fund and by the creation of the Fuel Cell Program component of the ten-year, \$1.6 billion OTF (2002).

The state’s first major investment in fuel cells came in May 2003, when the OTF awarded an \$18 million Wright Center grant to Case Western Reserve University to establish the Wright Fuel Cell Group, a consortium of manufacturers and universities headquartered at Case Western Reserve University. The founding objective of the Wright Fuel Cell Group was to further fuel cell R&D and commercialization in Ohio. Stark State College of Technology was a collaborator on the Wright Center grant, and Stark State received \$2 million to construct a new Fuel Cell Prototyping Center to develop fuel cell technology. The Wright Center at Case Western and Stark State’s Prototyping

Center have both housed fuel cell companies at various stages in the startup process. Since 2003, the OTF's Fuel Cell Program has awarded 51 competitive grants in the range of \$250,000 to \$1 million for collaborative R&D projects.

Overall, from 2000 through 2008, OTF has awarded approximately \$74 million on research and commercialization grants, loan programs, and financing and training subsidies for fuel cell manufacturers and component suppliers.<sup>22</sup> About half of that spending has come from the OTF Fuel Cell Program, which has awarded over 50 grants totaling \$39.9 million, mainly to companies.<sup>23</sup> The OTF's fuel cell grants are awarded in what many applicants described as a fair, transparent, and rigorous process. Many fuel cell executives in Ohio stated that the application process for OTF grants has improved since the program's inception. In the early years of the OTF, the bulk of the available funding had to be spent for capital investments at educational institutions (e.g., equipment purchases and research lab construction). Over time, as new funding sources become available through a bond initiative, the OTF was able to shift funding toward more applied research awards to companies seeking to commercialize their products.

#### **The Ohio Fuel Cell Coalition (OFCC)**

Several executives<sup>24</sup> in Ohio's fuel cell industry noted that in the early 2000s, at the very early stages of growth in the industry, different fuel cell companies were fighting for funding and many companies wanted to build an entire fuel cell assembly on their own. After the state's first Fuel Cell Symposium in 2001, the Ohio Fuel Cell Coalition (OFCC) was formed with initial funding of \$300,000 over three years from the ODOD. Charles Lucius, Vice President of Battelle's Alternative Energy Solutions group, said that the money that OFCC received from ODOD was instrumental in the coalition's formation and continued operation<sup>25</sup>. In early 2002, the OFCC commissioned a study to help guide fuel cell R&D investments in Ohio. Through OFCC's annual symposiums and trade shows, companies have shared their experiences and progress, and they have established important relationships that have driven industry growth. The OFCC has grown to become a consortium of 200 companies, academic institutions, and government organizations that helps to

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<sup>22</sup> In March, 2008, the Ohio Fuel Cell Corridor estimated Ohio's total fuel cell investment to date at \$70 million in research and other subsidies. <http://www.fuelcellcorridor.com/mc/page.do?sitePagelid=68530>

Since 2008, the Ohio Third Frontier Fuel Cell Program has Invested an additional \$4.3 million in fuel cells, as reported on Ohio Third Frontier's website, <http://thirdfrontier.com/>

<sup>23</sup> Ohio Third Frontier Metrics, Ohio Department of Development.

<sup>24</sup> Including Roger McKain (Rolls-Royce Fuel Cell Systems) and Doug McClelland (President, Mound Technical Solutions)

<sup>25</sup> Personal interview with Charles Lucius (VP of Alternative Energy Solutions, Battelle), April 22, 2009.

organize the state's fuel cell companies into an *industry* with a shared goal rather than just a collection of competing interests.

The OFCC was incorporated in 2003 as a tax-exempt, nonprofit organization with a board of directors. In that same year, the coalition asked its members to begin paying dues of between \$375 and \$1,500. OFCC is professionally managed and it uses money from dues and some continuing ODOD grants to host its annual Fuel Cell Symposium and to help communicate its message to the public and industry. OFCC creates an industry voice that helps focus the state's support for the industry. Several companies noted the OFCC's strong presence at the U.S. Fuel Cell Council's national trade show. Executives who have attended the annual show said that the OFCC brands the region as the "Ohio Fuel Cell Corridor," which has attracted attention to the growing fuel cell cluster in Ohio. Mike Martin, Vice President of Fuel Cell Technology at the Edison Materials Technology Center (EMTEC), in Dayton, Ohio, noted that this presence at the national level builds confidence among the state's fuel cell companies.

## RESULTS

The fuel cell industry in Ohio is currently at an intermediate phase of development. In 2008, 49 companies comprised the core of Ohio's fuel cell cluster, which accounted for 4,435 jobs—up 26 percent from 2004. This total includes fuel cell system integrators, component suppliers, and equipment and service providers. These companies are at various stages of commercialization: several have begun manufacturing operations, several have prototyped products and are ready to commercialize, and others are developing products that they expect to commercialize in three to eight years. Ohio's growing fuel cell cluster contains multinational companies with fuel cell operations, like Rolls-Royce Fuel Cell Systems and Lockheed Martin. There are large companies that provide contract research and engineering services to the industry, such as Battelle and SSOE Inc., and traditional Ohio manufacturers that are diversifying and working to adopt and commercialize new technologies, such as Caterpillar Power Systems, Crown Equipment, and American Trim. The lion's share of fuel cell companies are startup firms, such as UltraCell, Contained Energy, NexTech Materials and others.

The higher education system in Ohio has responded to the growing industry demand for a workforce acquainted with fuel cells. Stark State College of Technology (North Canton, OH) has established a one-year certificate program in fuel cells that offers hands-on training with the technology. Stark State has begun work on an expansion of the school's Fuel Cell Prototyping Center; the expansion will allow interaction between the students and startup fuel cell companies housed on Stark's campus, such as Rolls-Royce Fuel Cell Systems. OTF grants have encouraged fuel cell companies in Ohio to establish collaborative relationships with higher education institutions,

including Case Western Reserve University, Ohio State University, University of Toledo, Sinclair Community College, and Hocking College. Additionally, college students have interned with companies like Battelle, Contained Energy, and Rolls-Royce Fuel Cell Systems through the OTF Internship Program.

Ohio's commitment to fuel cell technology has prompted several out-of-state companies to locate in Ohio. The California startup UltraCell chose Dayton, Ohio as the location for its new fuel cell production facility. UltraCell Vice President, Frank Beafore, cited Ohio's good business environment, strong resource base, and strong workforce as the reasons behind that decision.<sup>26</sup> Contained Energy, Inc. is developing direct carbon fuel cells with technology licensed from Lawrence Livermore National Laboratory. The company's President, Alex Perwich, said that when Contained Energy was deciding where to incorporate in 2005, the OTF and the growing fuel cell cluster in Ohio were the reasons that Contained Energy incorporated in the Cleveland area.<sup>27</sup> In 2007, UK-based Rolls Royce made a strategic decision to locate its North American fuel cell operations in Ohio when the company acquired SOFCo, a startup fuel cell company located on the North Canton campus of Stark State.

In addition to attracting companies from other states, Ohio's TBED programs have attracted traditional manufacturers to work with fuel cells. Catacel Corporation (Garrettsville, OH), for example, was a producer of heat exchangers and catalyzed metal that added fuel cell components to their expertise. Since 2003, Catacel has received several fuel cell-related grants, resulting in company growth from four employees to 18 employees. Catacel's Vice President, Phil Furber, hopes to commercialize the company's fuel cell products in the near future. The OTF also helped Mound Technical Solutions (Miamisburg, OH) to grow a fuel cell division. Mound was previously focused entirely on the detection and cleanup of nuclear by-products. With an OTF grant, the company was able to apply its expertise in sensors to the detection of gas concentrations in fuel cells. Currently, Mound sells its fuel cell test units commercially and 10 of the company's 12 employees are engaged in fuel cell work. Mound's President, Doug McClelland, says the company is pursuing two new fuel cell technologies that he hopes to spin off as new companies in the next few years<sup>28</sup>.

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<sup>26</sup> Personal interview with Frank Beafore (VP of Manufacturing, UltraCell Corp.), April 22, 2009.

<sup>27</sup> Telephone interview with Alex Perwich (President, Contained Energy, Inc), April 21, 2009.

<sup>28</sup> Personal interview with Doug McClelland (President, Mound Technical Solutions), April 22, 2009.

Ohio's rate of patenting for fuel cell technology doubled in the five year period from 2001 to 2006. U.S. Patent & Trademark Office data indicate that, since 2001, fuel cell patenting activity in Ohio has increased at about the same rate as fuel cell patenting in the U.S. overall. While Ohio is not leading the pack in patenting fuel cell technology, it's not falling behind either. It's important to keep in mind that patent statistics alone are not a good measure of commercialization outcomes in the fuel cell industry. Many fuel cell executives interviewed by SRI indicated that they rely more on trade secrets (i.e., cost-effective manufacturing process, rather than product patent) to protect their intellectual property.

Ohio's investments have increased fuel cell companies' leverage when they apply for Federal grants. This leverage is important for companies because fuel cell development is still an extremely R&D-intensive activity that requires significant investment. Leveraging Federal grants is important to the state, too, because these grants supplement the state's financial contributions to the growing cluster. Stark State College of Technology has been particularly adept at leveraging their involvement with the Wright Fuel Cell Group. The college received nearly \$800,000 in funding in 2004 from the National Science Foundation to develop their fuel cell curriculum and recently received a \$1.45 million Federal earmark to construct a new Fuel Cell Learning Center. In 2008, Stark State partnered with Lockheed Martin and won an \$800,000 Department of Energy grant that funded two test beds for fuel cell reliability testing. Altogether, Stark State has received \$6.8 million in fuel cell-related grants<sup>29</sup>. In 2008, the U.S. Department of Energy's Solid State Energy Conversion Alliance (SECA) awarded Rolls-Royce Fuel Cell Systems with a grant of \$25 million over eight years. Other Federal grant recipients in Ohio include NexTech Materials, Catacel, and UltraCell. NexTech has received over \$20 million of Federal grants that have helped the company build its infrastructure. Catacel partnered with the University of Toledo on several Federal grant projects. UltraCell will receive \$1 million from a U.S. Department of Energy grant they are sharing with Pacific Northwest National Laboratory. UltraCell's Vice President, Frank Beafore, said that receiving OTF grants "helped a lot" in his company's ability to win Federal grants.<sup>30</sup> The ability of OTF grantees to win large Federal grants demonstrates the cluster's prominence at the national level. This prominence creates a feedback mechanism for the state, wherein new fuel cell companies locate in Ohio to take advantage of cluster effects, and they themselves contribute to the cluster's expansion by growing and attracting more companies.

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<sup>29</sup> Support for Fuel Cell Initiatives at Stark State, <http://www.starkstate.edu/fuelcell/>

<sup>30</sup> Personal interview with Frank Beafore (VP of Manufacturing, UltraCell Corp.), April 22, 2009.

Aside from the state and Federal governments' direct investment in research and fuel cell initiatives, several statewide policy choices have benefitted the fuel cell industry. One of the more significant choices is the recent ruling by the Public Utilities Commission of Ohio that fuel cells can be included in the state's alternative energy portfolio standard as a renewable energy source<sup>31</sup>. The alternative energy portfolio standard requires that 12.5 percent of the state's energy come from renewable sources by 2025, which significantly increases the local market for fuel cells.

#### Fuel Cell Companies' Interactions Outside of Ohio

- NexTech Materials' fuel cell components are distributed in over 35 countries, including India.
- Graftech International in Cleveland (a division of UCAR) is the exclusive supplier of carbon components for Ballard Power Systems, a major fuel cell integrator based in Vancouver, Canada.
- Graftech's GRAFCELL plates are included in 11 of 14 prototype automotive vehicles in California's Fuel Cell Partnership.
- Catacel's Stackable Structural Reactor (SSR) produces hydrogen fuel from natural gas and is currently undergoing a field test with a customer in Turkey.
- Catacel supplies all of the catalyzed metals for one of the largest fuel cell manufacturers, works with three of the four largest commercial hydrogen vendors, and partners with several NASA suppliers.
- UltraCell expects to receive orders for 200 to 2,000 portable fuel cell kits from the U.S. State Department in the next two years for shipment to developing countries.

## CONCLUSIONS

The fuel cell cluster in Ohio has taken form and grown over the past decade. The industry is still in a developmental stage, and many of the cluster's core fuel cell companies are on the cusp of commercialization. Fuel cell technology builds upon Ohio's existing advanced manufacturing base: the polymers, metals and components that go into fuel cells can all, for the most part, be manufactured in Ohio by Ohio companies. This means that the fuel cell industry has high spillover potential for employment in other manufacturing and services industries. In fact, several firms that

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<sup>31</sup> Eiselstein, Shana. "PUCO adopts rules for Ohio's alternative energy portfolio standard." April 15, 2009. Last Accessed 05/08/2008. Available at: <http://www.puco.ohio.gov/PUCO/MediaRoom/MediaRelease.cfm?id=9330>

have begun manufacturing operations purchase over three-quarters of their components from within the state<sup>32</sup>. Even firms that are still in the development phase show high spillover rates: Rolls-Royce Fuel Cells claims that 92 percent of the last \$10 million they spent was spent inside the State of Ohio.<sup>33</sup>

Several fuel cell companies moved to Ohio because of the growing cluster and the availability of grant monies. Because of OTF, a number of Ohio companies in related industries expanded their operations to include fuel cell materials. These companies and others that have entered the fuel cell business have formed a network in Ohio that connects researchers to industry, vendors to customers, and suppliers to purchasers. The knowledge exchange that takes place across this network partly explains Ohio's strong fuel cell industry growth. The Ohio cluster faces competition, though, from a more established cluster in Connecticut and from increasing fuel cell investments in other states, such as California, Massachusetts, and New York. Without Ohio's financial commitment to fuel cell technology, it is hard to imagine that the state's cluster would have grown the way it did, if it formed at all. In the absence of government investment, startup companies looking for favorable business conditions might have landed in other states. But with Ohio's support, these Ohio companies are primed to take a piece of the commercial fuel cell market, which is expected to triple in size to \$9 billion to \$12 billion by 2016.

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<sup>32</sup> UltraCell claims 90 percent of their components are sourced in Ohio; Energy Technologies claims 90 percent; Mound Technical Solutions claims 80 percent.

<sup>33</sup> Personal interview with Laurie Wessel (Commercial & Contracts, Rolls-Royce Fuel Cells), April 21, 2009.

<b>Table 4. A Timeline of Ohio's Fuel Cell Cluster</b>	
<b>Early 1960s</b>	The first practical use of fuel cells was in the U.S. space program.
<b>1970s to early 1980s</b>	The U.S. Dept. of Energy worked with fuel cell developers to create the first commercial fuel cell.
<b>Nov. 2001</b>	No fuel cell manufacturers exist in Ohio. Fourteen other states have fuel cell manufacturing programs. The first Fuel Cell Symposium is hosted in Cleveland by ODOD and the Cleveland Engineering Society. The Ohio Fuel Cell Coalition is formed afterwards.
<b>Mar. 2002</b>	Case Western Reserve University uses its Eminent Scholar Award to recruit Dr. Thomas Zawodzinski Jr., a top fuel cell researcher from Los Alamos National Lab.
<b>May 2002</b>	Ohio's Gov. Taft introduces the \$1.6 billion Ohio Third Frontier, with a three-year, \$100 million Fuel Cell Program aimed at making Ohio a national leader in fuel cell R&D.
<b>May 2003</b>	Stark State College of Technology in North Canton, OH receives a \$2 million Ohio Third Frontier grant for a new Fuel Cell Prototyping Center.
<b>Sept. 2004</b>	Ohio Third Frontier begins using demonstration projects and government procurement in attempts to stimulate early market demand for fuel cells.
<b>Aug. 2005</b>	Ohio's EMTEC hosts a Symposium on Manufacturing of Membrane Electrode Assemblies for Hydrogen Applications
<b>Dec. 2006</b>	Battelle debuts their fuel cell-driven Multipurpose Electric Power System, funded partly through ODOD and Ohio Third Frontier.
<b>Early 2007</b>	Rolls-Royce acquires fuel cell subsidiary SOFCo in North Canton, OH, on the campus of the Stark State College of Technology
<b>Jul. 2007</b>	UltraCell makes plans to open the first North American volume-production micro fuel cell facility in Vandalia, OH.
<b>Oct. 2007</b>	Cleveland-based Technology Management Inc. demonstrated the world's first kilowatt-scale solid oxide fuel cell system to generate electricity using vegetable oil from soybeans.
<b>May 2008</b>	The USDOE's Solid State Energy Conversion Alliance (SECA) awards Rolls-Royce Fuel Cell Systems (North Canton, OH) with a fuel cell project worth \$25 million over eight years.

Table 5. Comparison to Other State Fuel Cell Programs	
<b>California</b>	California Fuel Cell Partnership and California Hydrogen Highway (1999)—The projects involve car manufacturers, energy companies, fuel cell developers and government agencies, and aim to develop fuel-cell vehicles and hydrogen refueling infrastructure. California also offers self-generation incentives and an Emerging Renewables Program.
<b>Connecticut</b>	Clean Energy Fund—Pays for distributed energy demonstration programs and provides grants & loans for customer-side distributed generation.
<b>Michigan</b>	NextEnergy (2002)—A comprehensive set of actions and incentives designed to position Michigan as the world’s leading center for alternative energy technology, research and development, education and manufacturing.
<b>New York</b>	The NY State Energy R&D Authority spends approximately \$13 million a year to support combined heat and power technology, which includes fuel cells.
<b>Massachusetts</b>	Massachusetts Renewable Energy Trust Fund (1998)—A component of efforts to restructure the electric utility industry and to promote the development of renewable energy in the Massachusetts.

## THE PHOTOVOLTAICS CLUSTER IN OHIO

The photovoltaics (PV) industry is an emerging industry in Ohio, based on solar cell products that convert sunlight to electricity. The industry is still “emerging” because the technology is not yet cost competitive with traditional energy sources. However, PV manufacturing costs are coming down, and industry stakeholders have estimated that, with continued R&D investment, PV solar power may be competitive with coal power by 2012. Global sales of PV were estimated to be \$22 billion in 2008 and were projected to rise to \$35 billion to \$40 billion by 2012, representing compound annual growth of 12–16 percent.

Companies, suppliers and research institutions comprising Ohio's PV industry cluster are located predominantly in the Northwest region of the state, although the cluster is beginning to expand statewide. The industry is anchored by First Solar, one of the top five largest PV solar module manufacturers in the world and the largest in the United States. First Solar has R&D and manufacturing facilities in Perrysburg employing over 700 people. First Solar's Ohio production accounts for roughly 3-5 percent of the global PV market, and Ohio's share of the global market will increase as other PV firms begin production (First Solar also has operations in Malaysia and Germany).<sup>34</sup> In 2008, approximately 25 companies constituted the core of Ohio's PV cluster,<sup>35</sup> accounting for 3,218 jobs. These companies experienced significant employment growth of 38.2 percent from 2004. It is important to note that the 25 core companies in this cluster are a small fraction of the total number of companies and employment represented in the entire supply chain and downstream market for PV products. Though it is in the early stages of development, the Ohio PV cluster is positioned to play an important role in the rapidly growing global market. Many companies in the PV cluster are focusing on second-generation PV products—“thin-film” devices with lower production costs than first-generation silicon crystal devices.

Thin-film PV technology is a fast growing sector: thin film devices currently account for 14 percent of the global PV market, but are expected to grow to 27 percent of the PV market by 2013.<sup>36</sup> PV technology attracted more than \$3 billion in early-stage venture funding in 2008, and roughly one-

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<sup>34</sup> Based on SRI's survey of growth projections for the photovoltaics industry, including projections from GTM Research (2009); SolarBuzz (2008); and Frost & Sullivan (2007).

<sup>35</sup> SRI's definition of the "photovoltaics industry cluster" is the group of photovoltaic cell manufacturers, specialized suppliers and service providers concentrated in the Toledo and larger Northwest Ohio region.

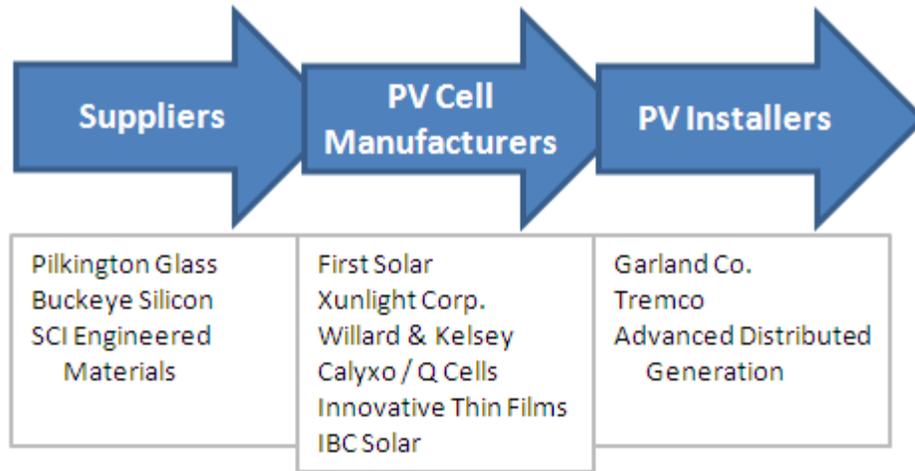
<sup>36</sup> Mark Osborne (22 May 2009) "Thin film solar market growth rates limited by conversion efficiencies, says IC Insights."

Available at:

[http://www.pv-tech.org/news/\\_a/thin\\_film\\_solar\\_market\\_growth\\_rates\\_limited\\_by\\_conversion\\_efficiencies\\_says/](http://www.pv-tech.org/news/_a/thin_film_solar_market_growth_rates_limited_by_conversion_efficiencies_says/)

third of that funding went to companies focused on thin-film technologies.<sup>37</sup> The largest thin-film PV module manufacturer in the U.S., industry analysts predict First Solar will become the top PV producer in 2010.<sup>38</sup> The company manufactures its thin-film PV modules at three sites: Ohio, Germany and Malaysia. Two other Ohio companies, Xunlight Corp. and Willard & Kelsey Solar Group, are commercializing their PV products and expect to begin global sales in 2010 or 2011. Figure 3 below shows how companies in Ohio are distributed along the PV supply chain.

**Figure 3. Ohio Companies along the PV Supply Chain**



On the research side, Ohio's PV cluster has strong connections to the University of Toledo which provides research support, technical workforce, and Federal funding for complementary solar energy research initiatives. In 2008, the University of Toledo hired two new PV faculty and created one PV endowed chair through the Ohio Research Scholars Program (part of the Ohio Third Frontier), bringing the total number of PV researchers at the university to 16.<sup>39</sup> The influx of world-

<sup>37</sup> *Venture Capital Reporter*. January 6, 2009. "Clean Technology Venture Investment Reaches Record \$8.4 Billion in 2008 Despite Credit Crisis and Broadening Recession" Last Accessed Jun 23, 2009. Available at: [http://www.venturecapitalreporter.com/Clean\\_Technology\\_Venture\\_Investment\\_Reaches\\_Record\\_8\\_4\\_Billion\\_in\\_2008\\_Despite\\_Credit\\_Crisis\\_and\\_Broadening\\_Recession.htm](http://www.venturecapitalreporter.com/Clean_Technology_Venture_Investment_Reaches_Record_8_4_Billion_in_2008_Despite_Credit_Crisis_and_Broadening_Recession.htm)

<sup>38</sup> Mark Osborne (17 June 2009). "Analyst predicts First Solar to become largest solar module manufacturer in '09" *PV-Tech.org*. Available at: [www.pv-tech.org/news/a/analyst\\_predicts\\_first\\_solar\\_inc\\_to\\_become\\_largest\\_solar\\_module\\_manufacture/](http://www.pv-tech.org/news/a/analyst_predicts_first_solar_inc_to_become_largest_solar_module_manufacture/)

<sup>39</sup> Jim Winkler (Jun 24, 2008) "UT to get state funds for photovoltaics, spine research" *UT News*. Last accessed: Jun 22, 2009. Available at: [http://utnews.utoledo.edu/publish/Research\\_12/UT\\_to\\_get\\_state\\_funds\\_for\\_photovoltaics\\_spine\\_research.shtml](http://utnews.utoledo.edu/publish/Research_12/UT_to_get_state_funds_for_photovoltaics_spine_research.shtml)

class researchers, each bringing new ideas, networks and resources, helps position the University for achieving its 2001 commitment to focus on solar technologies with significant market potential.

The industrial PV activity in Ohio has grown from a small collection of companies to a vertically-integrated cluster. Ohio has a long history in glass and polymer manufacturing and developing glass-related technologies to support the auto industry and other applications. The PV industry builds on the glass industry based in the Toledo region, and the rise of solar cell manufacturing in Ohio represents a shift from a traditional industry to a new and emerging one. Key factors in the development of this cluster include:

- interest and commitment from a broad set of stakeholders in the cluster, including private firms, university faculty and local economic development organizations, who actively seek partnership opportunities in the development and marketing of thin-film photovoltaics;
- an experienced workforce in the glass and other advanced manufacturing industries – including the automotive industry;
- PV spinoffs from the University of Toledo and other PV companies;
- the OTF and other state investments that have contributed to the formation of a world-class research base, increased research collaboration toward technology commercialization outcomes, and supported PV startups and the diversification of traditional manufacturers to support the growth of this new cluster.

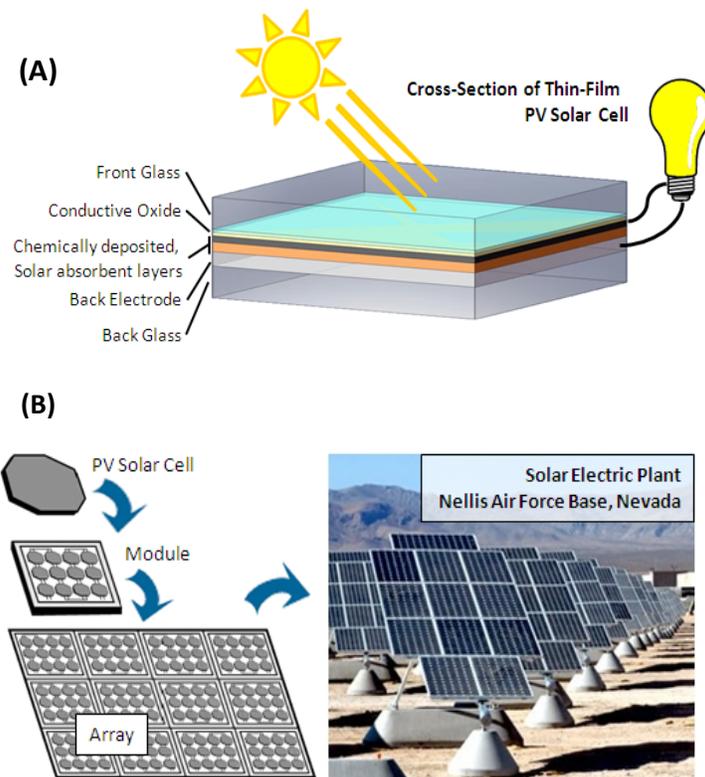
Between 2003 and 2008, OTF invested \$39.3 million in Ohio's PV research base and in Ohio companies working to commercialize PV solar cell products, components, and manufacturing processes.

#### **PHOTOVOLTAIC TECHNOLOGY**

Photovoltaic technology converts light into electricity, and the PV industry produces solar panels to be used in electricity generation. The technology dates back to the 1800s, but it has become more popular in recent years as a clean source of alternative energy. Figure 4A and Figure 4B illustrate the construction and operation of a PV cell, also called a "solar cell." Certain "photoelectric" materials can absorb sunlight and release energy; the thin film PV solar cell in Figure 4A has thin layers of these photoelectric materials in between glass plates. When sunlight shines on the cell, it produces a small amount of electricity. Figure 4B shows how multiple solar cells are linked together

in PV arrays to produce a large amount of electricity.<sup>40</sup> The first generation of PV solar cells was made primarily of silicon semiconductor materials, which are very expensive to process. In the Ohio PV cluster, several companies are working on the second generation of PV cells, which use thin films of material to reduce costs. Glass in particular is a good surface for thin film PV technology, and Ohio has a solid industry base in glass manufacturing to support the production of second generation PV. The thin film PV industry is looking at new applications as well, such as the deposition of thin film PV on flexible surfaces like metal and polymer sheets. Toledo's Xunlight Corp. is currently ramping up production of solar arrays on flexible stainless steel sheet.

**Figure 4. Illustration of (A) a typical thin film PV solar cell in operation, (B) PV cells assembled into an array and used in a solar electricity plant<sup>41</sup>**



<sup>40</sup> Information on the basics of photovoltaics was excerpted from materials found at <http://science.nasa.gov/headlines/y2002/solarcells.htm>. Please visit this site for more information and a detailed history of photovoltaics.

<sup>41</sup> Images adapted from Display Plus, NASA, and Clean Technica at [http://www.displayplus.net/bbs/data/design\\_focus/AVA\\_Solar\\_CdTe\\_thin\\_film\\_technology.jpg](http://www.displayplus.net/bbs/data/design_focus/AVA_Solar_CdTe_thin_film_technology.jpg), <http://science.nasa.gov/headlines/y2002/solarcells.htm>, <http://cleantechnica.com/2008/12/02/ibm-predict-solar-sidewalks-in-5-years/>

Companies that manufacture PV assemblies primarily support the electric industry, but there are applications in residential and commercial building, like the development and installation of Building Integrated Photovoltaics (BIPV). BIPV are PV solar cells that are directly integrated into the building materials, themselves, rather than being installed post-building construction. For example, instead of using window tints, BIPV companies may integrate solar cells into buildings' windows. Two Ohio-based roofing companies, the Garland Company and Tremco, are developing BIPV products for commercial roofing applications. Other companies connected to the PV industry include:

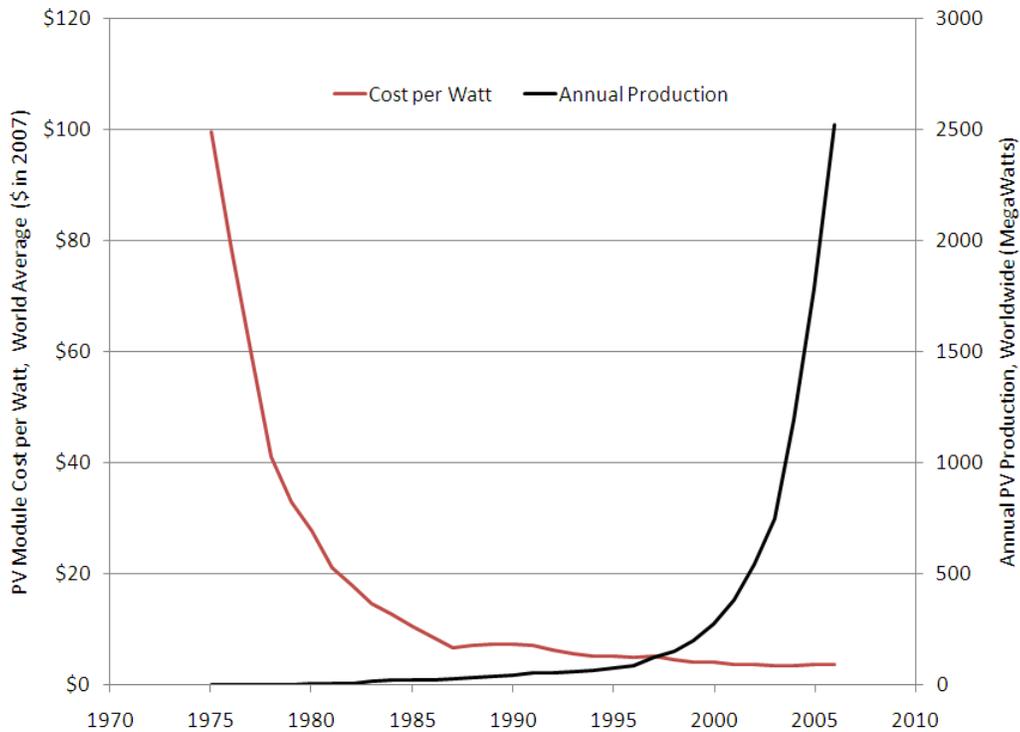
- Glass/substrate suppliers, chemical and specialty coatings companies, process equipment manufacturers;
- Electrical engineers, electricians, technicians, and building product integrators;
- Residential and commercial builders, architects and engineering services; and
- Utility companies and other energy generators.

Several challenges lie ahead for the PV industry: PV manufacturers are still working to make products that are cost competitive with traditional energy sources (such as coal) without the help of government subsidies. If the industry is to make large inroads in the grid-tied electricity market, it needs to reduce module prices to \$1.50 - \$2.00 per watt of installed capacity (without subsidies) over the next decade. Industry sources expect that, with continued R&D investment and increased production levels, private companies will achieve this cost target by the year 2012.<sup>42</sup> Figure 3 below shows the historical cost per watt of PV installation (in 2007 dollars) and the worldwide annual PV production (in Megawatts). Figure 5 illustrates that, with the rapid rise in PV production, the installation cost has dropped dramatically.

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<sup>42</sup> James Kanter (Feb 24, 2009) "First Solar Claims \$1-a-Watt 'Industry Milestone'". *The New York Times*. Last Accessed Jun 23 2009. Available at: <http://greeninc.blogs.nytimes.com/2009/02/24/first-solar-claims-1-a-watt-industry-milestone/>

**Figure 5. The Installation Cost per Watt and Annual Production for Photovoltaic Modules**



Source: The Earth Policy Institute, Eco-Economy Indicators, <http://www.earth-policy.org/Indicators/Solar/2007.htm>

**HISTORY OF OHIO’S PHOTOVOLTAICS CLUSTER AND STATE INVESTMENT IN CLUSTER**

Ohio’s photovoltaics industry is closely tied to the Toledo region’s long-standing glass industry. The first PV company in Ohio was GlasTech Solar, founded in 1984 by tempered glass magnate Harold McMaster. GlasTech Solar focused on developing first-generation solar cells from amorphous silicon. After little success, GlasTech Solar disbanded and McMaster formed Solar Cells Inc. to begin developing solar cells from glass coated with thin films. These second-generation, thin-film solar cells were less costly and less time-consuming to produce than first-generation, silicon-based solar cells.

The State of Ohio’s investment in the PV sector dates back to the late 1980s and early 1990s. The state’s investments in the industry provided the boost that was needed to commercialize early second-generation PV technology. In 1989, the University of Toledo partnered with GlasTech and Solar Cells and won two State of Ohio Edison awards totaling \$600,000 to research thin film PV cells. These awards, which required industry matching, funded the purchase of PV processing equipment and established research linkages between the industry and the university. Solar Cells

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### Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Inc. established a large research facility on the University of Toledo campus, in part because of ties to research undertaken at that university. In 1999, Solar Cells was acquired and renamed "First Solar." The company launched production of commercial PV products in 2002, and the firm has a manufacturing plant and R&D facilities in Perrysburg, Ohio (though the firm is now headquartered in Arizona).

The founding of Solar Cells Inc. (today, First Solar) was a significant milestone in the development of the PV cluster. First Solar's production has grown over time; it is now the second largest PV producer in the world and is projected to become the largest global PV producer by 2010. It marked an important linkage with the University of Toledo, since Solar Cells' research facilities were located on UT's campus. In 2001, UT officially declared its commitment to thin-film PV research. This commitment has been manifested through subsequent research project funding, faculty hires and the establishment of incubators and research centers.

OTF has made several key investments in the PV cluster that have been critical for equipment acquisition and upgrading at the University of Toledo. These investments have enabled more applied PV research by UT researchers as well as by area companies. In 2003, the University of Toledo received a \$2 million Wright Project grant from the OTF to establish the Center for Photovoltaic Electricity and Hydrogen. The Center focused on developing systems that convert solar energy into low-emissions electricity and other energy applications. The companies collaborating with the Center included McMaster Energy, Innovative Thin Films, Xunlight Solar (formerly Midwest Optoelectronics), First Solar, Engineered Glass Products and others. In 2005, the OTF awarded the Center a \$100,000 operating grant to help pay for the installation and use of new equipment.

In 2005, UT created the Clean and Alternative Energy Incubator, a facility that has provided startup services to a number of OTF grantees. The incubator originally comprised 36,000 sq. ft. and expanded by an additional 17,000 sq. ft. in 2008. The incubator gives university spin-off businesses and alternative energy companies who want to collaborate with the university physical space to work and grow. The incubator provides tenant entrepreneurs with business assistance, competitive rents and support in identifying the local, state and Federal resources. The incubator currently houses eight tenant companies, several business development programs, a Wright Center (described below), and a NASA-funded solar cell testing facility.

The OTF's single largest investment in Ohio's PV industry to date was an \$18.6 million grant in 2007 to create the Center for Photovoltaics Innovation and Commercialization (PVIC), an OTF Wright Center of Innovation. PVIC subsumed the Center for Photovoltaic Electricity and Hydrogen (CPEH). PVIC was supported with \$30 million of matching contributions from Federal, university and

industry partners. PVIC is headquartered at the University of Toledo, and PVIC partners include the Ohio State University, Bowling Green State University, multiple Ohio companies, the U.S. Air Force and NASA.<sup>43</sup> The aim of the Center is to bring together researchers and industry partners in the development of second- and third-generation PV materials for applications in clean electricity generation. The diversity of the participants indicates the cross-cutting nature of the work performed at PVIC. In interviews with members of these organizations, PVIC was cited as an important coordinating mechanism within the Ohio PV cluster. PVIC is housed in UT's Clean and Alternative Energy Incubator described above.

Beyond its major investment in PVIC, OTF has awarded grants to several commercial research projects within the PV cluster. Xunlight Corporation is one firm that is anticipated to yield a large return on the state's investment. Xunlight got its start in 2002, and its early efforts were supported by several R&D grants from the Federal government, including a \$2.9 million grant in 2004 from the U.S. Department of Energy. The OTF awarded Xunlight \$4.9 million in 2008 for the development of flexible thin-film PV modules and another \$1 million in 2009 to develop a manufacturing process for the flexible cells. In June 2009, Xunlight finished installing the first of its 25MW roll-to-roll photovoltaic manufacturing equipment lines. The company plans to install three more lines for a total production capacity of 100 MW per year. Xunlight is now conducting pilot production of flexible solar panels and is on track to begin production of high-efficiency thin-film PV modules; the company expects to begin selling product in late 2009 or early 2010.

OTF has invested in other stages of the PV value chain besides the manufacturing of actual PV cells. SCI Engineered Materials, Inc. is a second-tier supplier to the PV industry and has manufactured production materials for thin-film PV processes for over a decade. In December 2008, the company received \$708,000 from OTF to commercialize a new production material. For application and deployment of PV products, OTF awarded \$1 million in 2008 to Tremco Inc., of Beachwood, Ohio to commercialize a durable, high-performance BIPV roofing product. Tremco expects that its product will be easy-to-install and maintain. Tremco's roofing material will incorporate photovoltaic modules produced by Toledo's Xunlight Corp.; the product is currently in the development phase.<sup>44</sup> Another commercial roofing firm, the Garland Company, received \$1 million from OTF in 2008 for the development of roof top solar systems. Garland will collaborate with the University of Toledo

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<sup>43</sup> The University of Toledo received about \$9M of the \$18.6M of funding and the remainder was divided between the other academic partners, Bowling Green State University and Ohio State University.

<sup>44</sup> OTF (2009). "The Ohio Center for Photovoltaic Roofing Innovation and Commercialization". Last Accessed Jun 22, 2009. Available at: [http://www.ohiochannel.org/your\\_state/third\\_frontier\\_project/grant.cfm?grant\\_id=96341](http://www.ohiochannel.org/your_state/third_frontier_project/grant.cfm?grant_id=96341)

to combine its roofing expertise with thin-film photovoltaic technologies to produce turnkey, factory-integrated solar roofing projects.

Toledo's Regional Growth Partnership (RGP) and its OTF-supported Entrepreneurial Signature Program (Rocket Ventures) have also played an important role in developing the entrepreneurial climate of the region. OTF invested \$15 million in Rocket Ventures to increase technology-based entrepreneurial commercialization in Northwest Ohio. From this investment, Rocket Ventures has used \$7 million for operational expenditures; \$6 million (matched by \$7 million of private investment) for equity investment through its Rocket Ventures Investment Fund LLC; and \$2 million for Ignite grants, which are pre-seed grants up to \$50,000 to support startup company activities that transition them from the imagining/incubating stage to the commercialization stage. Rocket Ventures invested \$1 million in Xunlight Corp. and has awarded six Ignite grants (up to \$50,000) to different PV-related startups in Northwest Ohio. Additionally, Rocket Ventures is assisting 10 solar-related startup companies with business plan development, market research, prototype development, beta testing, finding investors, and work and sales support. These startup companies include Buckeye Silicon, Innovative Thin Films, Nextronex Energy Systems, Shadeplex, and Solargystics, among others. RGP also operates "Launch," an Edison Technology Incubator which offers business assistance services to young technology-based businesses in Northwest Ohio. Both Launch and Rocket Ventures works closely with the University of Toledo Clean and Alternative Energy Incubator.

In August 2008, an \$8 million Ohio Research Scholars Program grant and a McMaster family donation of \$2 million will be used to attract two new PV faculty and to create a \$2.5 million endowed PV Chair, as well as provide \$4 million in capital funds for facilities and equipment, at the University of Toledo.

While PV technology is evolving from rigid to flexible surfaces, its ties to the glass industry remain strong. William Mitchell, president and CEO of Willard & Kelsey Solar Group, a startup focused on the manufacture of PV panels, is quoted as saying that the solar industry "evolves naturally" from "the area's traditional strength as a global leader in the glass industry."<sup>45</sup> Mr. Mitchell has also said that, "The skill sets [required by the photovoltaic industry] are very similar to the skill sets in the

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<sup>45</sup> The Sentinel-Tribune Staff (10 Jun 2009). "State awards Willard & Kelsey \$10M" *The Sentinel-Tribune*. [http://www.foxtoledo.com/dpp/news/media\\_partners/wupw\\_Perrysburg\\_solar\\_plant\\_gets\\_10M\\_cash\\_06102009](http://www.foxtoledo.com/dpp/news/media_partners/wupw_Perrysburg_solar_plant_gets_10M_cash_06102009)

automotive industry."<sup>46</sup> Overall the development of the PV cluster is a rich account of a reinvention of a traditional industry and critical partnership with university resources. It demonstrates the development of university capacity and research, ties with a long standing industry, the reinvention of existing industries, and the development of new spin-off firms.<sup>47</sup> While this cluster is still in its developmental stages, these investments provide an important foundation for future development.

## RESULTS

The targeted investments made by the OTF and Edison Program have supported the emergence of the PV industry in Ohio. From 2003-2008, OTF invested more than \$39 million in Ohio PV companies and research institutions. These investments have supported the commercialization of new PV manufacturing processes and products by Ohio companies and have enhanced the research and reputation of the University of Toledo.

The University of Toledo's new faculty hires, capital investments, PV startups and attraction of large Federal research grants provides a complimentary dynamism to developments in the private sector. The University of Toledo's Clean and Alternative Energy Incubator has graduated three PV companies since its establishment in 2005: Xunlight Corp., Solar Fields (acquired in 2007 by Calyxo/Q-Cells) and Innovative Thin Films Ltd.—all of which are still operating in Ohio today. Given the developmental stage of many of the region's PV firms, the next few years should demonstrate accelerated job growth and other related economic benefits.

In addition to supporting the creation of local PV companies, Ohio's commitment to the PV industry has attracted PV companies from out-of-state. German-based Q-cell established a subsidiary, Calyxo, in Perrysburg, and acquired Solar Fields, a UT spinoff, in 2007. California's Sphere Renewable Energy Corp. recently located a silicon-producing subsidiary, Buckeye Silicon (BeSi), in Northwest Ohio. The company has a proprietary process for manufacturing polycrystalline silicon at a much lower cost and with a reduced environmental impact. Sphere Renewable chose Toledo for this new subsidiary because of the region's R&D capacity, location, workforce skill set and proximity to other PV companies and potential clients. The Willard & Kelsey Solar Group, which was

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<sup>46</sup> Chris Miller, Sentinel Staff Writer (25 Mar 2009). "Strickland lauds Perrysburg solar plant." *The BG Sentinel-Tribune*. [http://www.foxtoledo.com/dpp/news/wupw\\_BG\\_Sentinel\\_Tribune\\_Strickland\\_lauds\\_Perrysburg\\_solar\\_plant](http://www.foxtoledo.com/dpp/news/wupw_BG_Sentinel_Tribune_Strickland_lauds_Perrysburg_solar_plant)

<sup>47</sup> For a detailed history of the Toledo Photovoltaics industry, please see a recent working paper "The Role of an Antecedent Cluster, Academic R&D and Entrepreneurship in the Development of Toledo's Solar Energy Cluster" by Frank J. Calzonetti, available at: <http://uac.utoledo.edu/nwoerc/FCalzonetti-SolarEnergy.pdf>

established by former employees of Glasstech and First Solar, plans to manufacture PV solar panels for the global market. The company's executives chose to locate their manufacturing plant in Perrysburg, Ohio because of the state's investment in the PV industry and other economic development incentives.

#### **Xunlight Corp.: Using OTF Investments to Leverage \$40 Million**

Ohio's PV companies have been able to leverage OTF funding to attract funds from other sources both inside and outside of the state. Xunlight, in particular, has been considerably successful in using OTF pre-seed/seed capital and research awards to leverage follow-on investments from private investors and to win additional Federal research grants. Xunlight received a \$1 million investment from Rocket Ventures, the Northwest Ohio OTF ESP, in 2008 and has received over \$40 million in equity investments since then. In June 2009, Xunlight announced the installation of its first full-scale production lines. Xunlight expects to create hundreds of high-paying jobs in the next few years. Xunlight CEO Dr. Xunming Deng said, "We are pleased the State of Ohio was able to play a major role in Xunlight's success."<sup>48</sup>

The University of Toledo's Ohio Third Frontier-supported Center for Photovoltaic Innovation and Commercialization (PVIC) has served as a central node connecting the Ohio companies through research collaboration opportunities. As Norman Stevens, Co-Director of PVIC stated in an interview, "There is more stuff coming out of the labs all the time. We are set up to support any kind of development or improvements of products, and other companies are forming [in the region] to provide materials and support."<sup>49</sup>

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<sup>48</sup> Marketwire. "Xunlight completes installation of its first 25MW roll-to-roll manufacturing equipment," 22 June 2009, <http://ca.sys-con.com/node/1010925/print>

<sup>49</sup> Marsha Johnston, Oct 24, 2008. "Technological Innovation in Thin-film PV Manufacturing Takes Hold in Ohio." Last Accessed: Jun 22, 2009. Available at: <http://www.renewableenergyworld.com/rea/news/article/2008/10/technological-innovation-in-thin-film-pv-manufacturing-takes-hold-in-ohio-53916>

From 2007 through December 2008, PVIC reported the following economic benefits for the State of Ohio<sup>50</sup>:

- \$29.7 million in industry, university and other cost share on the \$18.6 million of state investment
- Attraction of \$30 million in follow-on investment
- Attraction of \$18.7 million in Federal research grants
- Two new companies created
- 145 jobs, including 67 private sector jobs, with average annual salaries of \$55,350

Other Federal investments UT has been able to leverage as a result of the OTF investment in UT's photovoltaics research base include:

- UT was awarded two out of a total of 11 Solar Energy America awards nationwide by the US Department of Energy in 2007. These two research project awards total \$2.5 million.
- NASA chose UT's Clean and Alternative Energy Incubator as the site for a \$1.13 million solar-panel testing center, which will eventually certify panels from all of the regional PV producers.

The economic spillover effects of the development of the PV industry in Ohio have tremendous promise. Mark Tuttle of Advanced Distributed Generation noted that there are more jobs in the installation and proliferation of photovoltaics than there are in the development of the technology. Installation requires technical expertise in basic construction, electrical engineering, solar frame building and installation, among other jobs. This means that, as Ohio's PV companies begin rolling out products, such as roofing materials which incorporate PV modules, new jobs will be created in the production, distribution, installation and maintenance of the products. The local market demand for PV products is supported in part by recent legislation passed in Ohio. The Ohio legislature established an alternative energy portfolio standard for the state in 2008. The law mandates that, by 2025, at least 25 percent of all electricity sold in the state come from alternative energy resources (such as solar PV) and that at least half of this renewable energy be generated in-

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<sup>50</sup>Metrics provided by Ohio Department of Development, Metrics Report of 12/31/2008.

state<sup>51</sup>. Other states (and foreign countries) have enacted similar standards and PV industry players expect the demand for their products to increase nationwide and even globally.

The growing PV industry has stimulated other industries that either use PV products or support their production. For example, the housing construction and contracting industries have been impacted by increased demand for residential solar panel installations. Several construction companies and contractors in the region claim a specialization in “green construction.” Decker Homes (headquartered in Michigan) has built a model home demonstrating residential solar panels in Maumee, Ohio. Decker Homes is the first home builder to offer solar electric power as part of its home package and many of its solar systems are supplied and installed by Ohio companies, including First Solar and Advanced Distributed Generation (ADG). This type of regional relationship provides an important vehicle for reaching a wider consumer market outside the State of Ohio. While ADG focuses on installations of PV panels post-construction, BIPV companies, like Tremco and the Garland Company, expect to provide PV-integrated roofing installation services as part of new building construction.

Community colleges have begun to provide training programs for PV panel installation. Owens Community College in Toledo has hosted several weeklong Photovoltaic Training Programs every year since 2003. Individuals attending Owens' five-day apprentice training program receive instruction within the areas of electricity and PV systems and theory. Course content includes system sizing and construction, codes and standards, battery safety, interconnection safety, troubleshooting and maintenance. In 2008, Owens was the only technical training site for solar installation training in Ohio, although programs are likely to expand as more solar panel and roofing products enter the market.

## CONCLUSIONS

The targeted investments made by the OTF and Edison Program have supported the emergence of the PV industry in Ohio. From 2003-2008, OTF invested more than \$39 million in Ohio PV companies and research institutions. These investments have supported the commercialization of new PV manufacturing processes and products by Ohio companies, the creation of PV startup companies, and the research and reputation of the University of Toledo.

While still an emerging industry globally, the PV sector continues to gain momentum in Ohio. The cluster is anchored by First Solar and Toledo-area PV startups on the verge of commercialization

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<sup>51</sup> See this source for a description of the legislation and its implications: <http://www.pewclimate.org/node/5922>

and production. The University of Toledo's new faculty hires, capital investments, entrepreneurial support programs, creation of PV startups, and the attraction of large Federal research grants provides a complimentary dynamism to developments in the private sector. OTF has encouraged critical research partnerships and cross-sectoral relationships, e.g., bringing together researchers from UT and PV companies, PV module manufacturers with downstream users of PV products, pre-seed/seed funds with UT and "Launch" incubator companies, and so on.

The historical creation and growth of any new technology clusters has depended on a significant amount of start up funds. Through its early investments via OTF-supported research commercialization grants and pre-seed/seed funds, the State of Ohio has boosted the ability of PV companies and research institutions to leverage significant follow-on funding, be it equity investment, Federal grants or additional industry support. Dr. Deng, the founder of Xunlight Corp., observed that his company "is being attracted to other states—but it is convenient to be here because of the University of Toledo group... We have a big cluster and when you have a big cluster everybody wins."<sup>52</sup> Ohio offers the PV cluster the advantages of a skilled, relevant workforce; a dynamic and growing university research base and shared suppliers and distributors and access to early-stage venture capital financing. The long-standing investments creating the foundation for these competitive advantages have made Ohio an attractive location for PV-related companies.

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<sup>52</sup> Personal interview with Xunming Deng (Founder, Xunlight Corp.), April 15, 2009.

<b>Table 6. Timeline of Ohio's Photovoltaic Cluster</b>	
<b>1954</b>	Bell Laboratories (New Jersey) demonstrates the first modern photovoltaic device for converting sunlight into useful electrical power
<b>1958</b>	PV solar panels are first used in U.S. spacecraft
<b>1984</b>	GlassTech Solar is founded in Toledo, OH
<b>1989</b>	The University of Toledo (partnered w/ Glasstech and Solar Cells Inc.) wins two State of Ohio Edison awards totaling \$600,000 to research thin-film PV cells.
<b>1990</b>	Solar Cells Inc. spins off of GlassTech Solar to produce solar panels in Toledo and is awarded \$475,000 from the U.S. Dept of Energy's Solar Energy Research Institute (which later became NREL) to study thin-film PV cells.
<b>1999</b>	Solar Cells is acquired, is renamed First Solar, and builds a factory in Perrysburg, Ohio to produce thin-film solar cells
<b>2001</b>	The University of Toledo (UT) selects thin-film PV as an area of research focus and begins building PV expertise and laboratories
<b>2002</b>	Xunlight spins off from UT to commercialize PV solar technology
<b>2002</b>	First Solar launches production of commercial PV products
<b>2003</b>	Solar Fields spins off from the University of Toledo
<b>2003</b>	OTF Wright Project award to UT Center for Photovoltaic Electricity and Hydrogen
<b>2005</b>	University of Toledo opens the Clean and Alternative Energy Incubator
<b>Dec. 2006</b>	The OTF Wright Center for Photovoltaics Innovation & Commercialization (PVIC) is created with \$18.6 million of OTF support and matching contributions of \$30 million from Federal agencies, industrial and other partners.
<b>Nov. 2007</b>	The Ohio legislature establishes a Renewable Portfolio Standard, which requires that 25 percent of Ohio's electric power come from advanced energy sources by 2025.
	IBC Solar, Germany's oldest solar company, selects Cleveland, Ohio as the site for its future U.S. headquarters.
	German PV manufacturer, Q-Cells, purchases UT spinoff Solar Fields for \$5M.
<b>May 2008</b>	UT and Bowling Green State University are awarded \$8 million from the OTF's Ohio Research Scholars Program to strengthen the PV cluster in Ohio.
<b>July 2008</b>	The University of Toledo receives a \$2 million private donation to create the Harold and Helen McMaster Chair in Photovoltaics, which will support a distinguished research scholar in the field of PV
<b>Feb. 2009</b>	First Solar announces it has reduced its PV production costs below the industry milestone of \$1-per-watt
<b>Apr. 2009</b>	The University of Toledo Board of Trustees approves the creation of a "School of Solar and Advanced Renewable Energy".

Table 6. Timeline of Ohio's Photovoltaic Cluster	
<b>June 2009</b>	Xunlight Corp. announces installation of its first full-scale production lines at its Toledo, Ohio facility.
<b>2009</b>	Willard & Kelsey Solar Group selects Perrysburg, OH as their headquarters for PV panel manufacturing and receives \$10M from the federal Economic Stimulus Plan to expand their manufacturing capacity.

## FLEXIBLE DISPLAYS AND ELECTRONICS IN OHIO

### INTRODUCTION

A new and important industry cluster is emerging in Ohio, one that combines Ohio's traditional strengths in polymers with research capabilities in liquid crystals and other optical and electronic materials. The cluster is still nascent but has enormous potential for growth, with applications in both information technology and energy. The cluster is sufficiently new and novel that it does not have a standard industrial name or clearly defined boundaries. The core capability of the cluster is the ability to develop and manufacture products that put optical and electronic materials on flexible polymer substrates. Examples include displays, eyewear and window coatings, photovoltaics, and batteries.

Although a core part of the cluster's expertise is liquid crystal technology, the cluster is not pursuing the computer and TV flat panel display market, which is a mature and capital-intensive market dominated by large Asian companies. Instead, the cluster is pursuing emerging markets in flexible displays, other electrically-controlled optical materials, and other polymer or plastics-based electronics.

Northern Ohio has for a long time had university research centers that are global leaders in both liquid crystals and polymers, but in the past it has missed opportunities to profit from this expertise because key pieces of the innovation and commercialization system were missing. For example, linkages were not made between different technologies and industries, and commercialization support was not available. As a result, in the past, the centers licensed many of their inventions out of state and overseas. The Ohio Third Frontier (OTF) and related programs now are filling in the missing pieces to allow these technologies to be commercialized in Ohio. As a result, new Ohio-based companies are growing.

This case study describes the cluster and the role of TBED programs in supporting the cluster. There are two important lessons from this case. First, it demonstrates that university research institutes can anchor new industrial clusters, but they are not sufficient by themselves to create the industry. The knowledge produced by research universities needs to be complemented by an environment that supports the commercialization of the technology in order to produce local economic value. Second, the case demonstrates that there is the potential for significant new industries in Ohio that are outside of – or in between – the OTF's targeted technology platforms. Although this cluster has not been one of the OTF's targeted technology platforms *per se*, the OTF

has been flexible enough to recognize the potential of the industry and provide appropriate support.

## **FLEXIBLE DISPLAYS AND ELECTRONICS UNDERLYING TECHNOLOGIES**

The key technologies underlying this cluster are liquid crystals (LCs) and polymers. LCs are substances that exhibit a phase of matter that has properties between those of a conventional liquid and those of a solid crystal.<sup>53</sup> For instance, an LC may flow like a liquid, but its molecules may be oriented in a crystal-like way. There are many different types of LC phases, which have different optical properties. The crystal's light properties depend on the orientation of the crystals, so the optical characteristics of the material can change when the orientation of the crystals change, which can occur under an electrical current. Thus, liquid crystals are often used when it is desirable to have a material whose optical properties can be changed electrically, and are the key material in displays in phones, watches, laptop computers, and most flat screen televisions.

Polymers are a large class of natural and synthetic materials with a variety of properties. Rubber, nylon, neoprene, and plastics are well known polymers, but proteins, nucleic acids, cellulose, and many other materials are also polymers. Polymers can be designed and engineered to have a tremendous range of properties, allowing them to be used in a huge range of products, from fabrics to auto parts and medical devices. Polymer science and technology includes researchers in multiple disciplines including chemistry, physics, and engineering.

## **HISTORY OF OHIO'S FLEXIBLE DISPLAYS AND ELECTRONICS CLUSTER AND STATE INVESTMENT IN CLUSTER**

### **Historical Origins**

Liquid crystal and polymer technology each have a long and separate history in northern Ohio. These technologies have come together in the last ten years to create a new polymer-based optoelectronics and electronics industry.

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<sup>53</sup> Wikipedia contributors, 2009. Liquid crystal. *Wikipedia, The Free Encyclopedia*.

20 June 2009. [http://en.wikipedia.org/w/index.php?title=Liquid\\_crystal&oldid=297532139](http://en.wikipedia.org/w/index.php?title=Liquid_crystal&oldid=297532139)

Ohio has long been a center of liquid crystal technology. The Liquid Crystal Institute (LCI) at Kent State University was started by Glenn Brown, the chairman of the Chemistry Department at Kent State, in 1965. He wrote a seminal review article on liquid crystals, which led to a major international conference at Kent State in 1965 that involved several Nobel laureates. From its start, LCI has been an internationally recognized center of excellence in liquid crystal technology and education, blending basic and applied research on liquid crystals.

James Ferguson joined LCI in the 1966 and was one of the inventors of the twisted nematic liquid crystal display, which was of fundamental importance for the flat panel display industry. Ferguson formed his own company, ILIXCO (now LXD), to manufacture liquid crystal displays, which were widely used in LCD watches. Many LCI inventions were licensed overseas and the display industry eventually moved out of the region and nation. It is now dominated by electronics and display companies in the Pacific Rim. Ohio captured only a very small percentage of the total wealth generated by its liquid crystal technologies. The region has sought to find a way to capture more of the value from recent inventions.

In the 1980s, researchers at LCI began combining liquid crystals and polymers to develop polymer dispersed liquid crystals. The theme of combining liquid crystals and polymers continued when in 1989, under the leadership of William Doane, LCI won a major Science and Technology Center (STC) award from the National Science Foundation (NSF), to establish the Center for Advanced Liquid Crystalline Optical Materials (ALCOM). This was a collaboration with Case Western Reserve University and the University of Akron, and leveraged the capabilities of the three institutions in the fields of liquid crystal and polymer research. The Cleveland Technology Leadership Council, the predecessor of NorTech, helped to support the NSF ALCOM proposal by engaging the business community and by helping to develop the state matching funds required. The State of Ohio provided funding for the prototyping facilities and for industrial partnering. There was a State match of \$250,000 per year. Together, the Department of Development and Ohio Board of Regents made a multi-million dollar contribution to the project, which included \$750 K in operating support from the Edison Program. The STC funding lasted until 2002. Over this period, the Center received about \$60 million in funding, with \$25 million coming from NSF and other major funding coming from the Defense Advanced Research Projects Agency (DARPA) and other U.S. Department of Defense sources. Following the end of the NSF center award period, the Institute has continued to attract funds. In 2003, Kent State won an OTF Wright Project for Flexible OptoElectronic Device Manufacturing, and the Ohio Research Scholars program has been important in maintaining momentum in the Institute.

The history of polymers in Northern Ohio goes back even further. In 1909, Dr. C. M. Knight, a professor and chemical consultant at Buchtel College, the forerunner of the University of Akron, set

up the world's first academic rubber laboratory to begin training workers for new Akron rubber companies like BF Goodrich and Goodyear. The University's program grew along with Akron and its industry, which was significantly tied to the growth of the automobile in America. In World War II, the U.S. government contracted with the University of Akron to establish the Rubber Research Laboratory to aid in the development of the synthetic rubber needed for the war effort. Today, the University's College of Polymer Science and Polymer Engineering and associated research institute, the Institute of Polymer Science and Polymer Engineering, constitute the largest and broadest polymer program in the United States, with over 30 faculty and around 300 graduate students and post-docs.<sup>54</sup>

The liquid crystal and polymer communities have grown closer together in recent years. The University of Akron's polymer program has shifted its emphasis from engineering, primarily to support the big polymer companies, such as Goodyear, Dupont, and Dow, to developing polymers for use in advanced technologies, such as displays, electronics, and batteries. This has reinvigorated the program. In 2006-2007, while on leave from Kent State as a NorTech fellow, LCI Director John West began to develop the concept and funding proposal for an initiative to build a new industrial cluster in Ohio, consisting of companies producing both optical and electronic devices on flexible plastic substrates. This initiative, which involved Kent State University, NorTech, the Fund for Our Economic Future, Team NEO, the University of Akron, and several companies, became Flex Matters, and resulted in a successful OTF Grant. This initiative is intended to generate the manufacturing base for the new industry. While the initial companies are those making flexible liquid crystal displays and related devices, the core manufacturing techniques developed will enable them to print high-resolution electrodes and related films on flexible substrates to support the development of flexible electronics and photovoltaics.

### The Cluster Today

The main elements of flexible displays and electronics cluster are the university centers and a few key companies. The university centers are central players. These include the Liquid Crystal Institute at Kent State and the University of Akron's College of Polymer Science and Polymer Engineering and the Institute of Polymer Science and Polymer Engineering, described above. These centers play a key role in developing knowledge, training researchers and workers who populate companies, and serve as a point of attraction for companies looking for new locations. In addition

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<sup>54</sup> Material taken from <http://www2.uakron.edu/cpspe/> and project interviews.

to the centers at Kent State and University of Akron, several other centers also support the cluster. These include

- The Center for Multifunctional Polymer Nanomaterials and Devices (CMPND), an OTF Wright Center of Innovation, centered at The Ohio State University in conjunction with the University of Akron and University of Dayton. CMPND develops manufacturing protocols and nanostructures for emerging polymer photonic components and devices, among other functions.
- The Center for Photochemical Sciences, at Bowling Green State University. This center focuses on the study of the interaction of light with physical, chemical, and biological systems, and on practical applications. Among other things, this center is working on using ultraviolet treatments of polymers. This Center has received a \$2,000,000 Wright Project award from the OTF.
- The Center for Layered Polymeric Systems (CLiPS) at the School of Engineering, at Case Western Reserve University. This is a new National Science Foundation Science and Technology Center focused on polymer research. The NSF center funding is for nearly \$20 million over five years.

The firms that make up the cluster include a variety of display, polymer, electronics, and optoelectronics companies. Three of the most prominent are Kent Displays, AlphaMicron, and Akron Polymer Systems.

**Kent Displays**, based in Kent, Ohio, is focused on displays based on a flexible polymer substrate that require little or no energy. Many of their displays are reflective, requiring no backlighting, and maintain the display without power. Some of the initial applications are display of security codes in credit cards, cell phone covers that can change color, and electronic paper for electronic book readers. One of the company's key technologies is a roll-to-roll manufacturing process, in which liquid crystals and other coatings are laid down on a continuous roll of polymer; this costs much less than manufacturing on a single plate of glass at a time. Kent Displays won DARPA contracts that supported some of their early work on plastic displays. They have the support of a venture capitalist, Manning Ventures, which owns 95 percent of the company. They have benefited greatly from OTF awards, which have enabled them to develop and expand their manufacturing processes. They are scaling up to 60 employees.

**AlphaMicron**, also based in Kent, produces functional and electronic films, focusing on non-display applications of liquid crystals, such as eyewear and windows. AlphaMicron originally developed

technologies under U.S. Air Force contracts to enable pilots to adapt to changing light conditions. The OTF funding has helped AlphaMicron to adapt and apply these technologies for commercial markets. They are currently producing lenses for ski goggles that can change color and darkness with a touch of a button, as well as automobile mirrors that can change reflectivity for day and night driving. They are now working on another OTF project with Kent Displays to improve manufacturing processes, and have another grant to develop technologies for adaptive windows used in commercial and residential construction. About a third of their funding comes from research grants and contracts, while two-thirds comes from specialty products. AlphaMicron was established ten years ago with one person but has grown to 35 people, with average salaries of \$50,000 to \$60,000.

**Akron Polymer Systems (APS)** is a seven-year-old company focused on applying expertise in high-performance polymers to develop and commercialize innovative technologies and products. They have close links with the University of Akron's College of Polymer Science and Polymer Engineering – their CEO is a former Distinguished Professor and their Chief Technical Advisor is the Dean of the College. They have collaborated for many years and patented a number of innovative polymers, including a family of polyimides that have been commercialized for use in liquid crystals. They also developed a polyimide film that is used commercially in optical interconnects to prevent signal loss and cross talk. APS has 12 employees, nine of whom have doctorates. It is expanding, renovating and moving into a larger building in Akron, and it expects to hire 28 people over the next two to three years. Akron Polymer Systems was wooed by South Carolina but decided to remain in Northeast Ohio, in part to stay close to the University of Akron and in part because of the support from the OTF.<sup>55</sup>

These and several of the other firms in the cluster are shown in Table 7.

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<sup>55</sup> Mackinnon, Jim. "Polymer company to expand. APS wants to stay close to University of Akron." *Akron Beacon Journal*. July 11, 2009 . <http://www.ohio.com/business/50521727.html>

**Table 7. Flexible Displays & Electronics in Ohio: Companies and Products**

Company Name	Technologies and Products	Location
Akron Polymer Systems	High performance polymers for different industries	Akron
Alpha Micron	Sport, automotive and other products using liquid crystal technology	Kent
Global Lighting Technologies	Display backlighting technology	Brecksville
Hana	'Video monitor on a chip' technology of reflective LCOS (Liquid Crystal on Silicon) microdisplays	Twinsburg
Imaging Systems Technology	Touch systems for plasma and LCD displays	Toledo
Kent Displays	Liquid crystal displays	Kent
Lumitex	Backlighting products for medical, industrial and electronic applications	Strongsville
Milacronn	Plastics processing equipment and industrial fluids for metalworking applications	Batavia
Nanofilm	Nanocoatings, nanocomposites and surfactant products for transportation, electronics, architecture, etc.	Valley View
TCP (Technical Consumer Products)	Energy efficient lighting products	Aurora
Valtronic	Development and production of products, from microelectronics and mechanical parts to complex systems	Cleveland

The total employment for these firms grew from 897 in 2004 to 1,012 in 2008, a growth of 12 percent. As noted before, the boundaries of the cluster are not clear, and there are a variety of other companies involved in electronics, photovoltaics, batteries, and polymers that could also be considered part of the cluster.

## ROLE OF STATE PROGRAMS

Participants in the flexible displays and electronics cluster believe that the OTF has played a critical role in the development of their cluster. While the cluster has its roots in university centers that were funded by other sources, such as the National Science Foundation and Department of Defense, these sources provided only funding for research and defense applications. Companies in the cluster found it to be very difficult to obtain money for developing commercial products and the manufacturing processes necessary to produce products for the commercial markets. The OTF has been critical in providing these funds, which were generally not available from other sources.

The OTF has received high marks from cluster participants for bringing together the various elements of the cluster, including the liquid crystal and polymer communities, and the university, industry, and economic development communities. As one participant exclaimed, the OTF is “the best thing the state ever did.”

The OTF was also lauded for its approach, which is atypical of government organizations. The program does not have a government contractor mentality. The Department of Development does not see themselves as the customer for the technology programs, but instead are sensitive of the need to have the technology serve other customers. The programs are cost-shared, and awardees share a significant financial stake in OTF-supported commercialization projects.

## FUTURE GROWTH AND CHALLENGES

The markets for flexible electronics and displays are expected to be large and grow rapidly. The market for flexible displays was estimated to be around \$100 million in 2008 but is expected to grow rapidly to between \$1.9 billion and \$12 billion by 2015.<sup>56</sup><sup>57</sup> <sup>58</sup> The global plastic electronics industry is expected to grow to \$23 billion by 2013.<sup>60</sup> Ohio has the potential to capture a significant share of this emerging industry because it has the key elements required for success: strong

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<sup>56</sup> LG Philips (2007). “LG.Philips LCD Develops World’s First Flexible Color A4-Size E-Paper”

[http://www.lgphilips-lcd.com/homeContent/jsp/eng/inv/inv101\\_j\\_e.jsp](http://www.lgphilips-lcd.com/homeContent/jsp/eng/inv/inv101_j_e.jsp)

<sup>57</sup> - “Display Search Perspective on Displays” quoting Barry Young, SVP of DisplaySearch.

[http://www.wave-report.com/conference\\_reports/2007/FD2007.htm](http://www.wave-report.com/conference_reports/2007/FD2007.htm)

<sup>58</sup> Journal of Technology, June 2, 2008, “Universal Display Corporation Reports Flexible OLED Display Improvements at 2008 SID Conference”

<sup>59</sup> Korea Times, October 30, 2007, Will i®Flexible Displays' Rock World?, By Kim Yoo-chul

<sup>60</sup> Organic & Printed Electronics Newsletter (2008) “Singapore Research Produces Protection from Moisture and Oxygen”  
[http://www.organicandprintedelectronics.com/newsletters/2008/ope\\_newsletter\\_5-08.htm](http://www.organicandprintedelectronics.com/newsletters/2008/ope_newsletter_5-08.htm)

research and development institutions in liquid crystal and polymers; experience in polymer manufacturing and equipment; and a systematic approach to innovation. If Ohio can capture a significant portion of these markets -- and based on Ohio's strong technology and manufacturing this is a viable goal -- the economic benefits to the state would be substantial.

There are, however, challenges. One is that there is substantial competition. Other groups and regions, in the United States and around the world, also understand the potential of flexible displays and electronics. For example, there is a flexible display center at Arizona State University<sup>61</sup> and the FlexTech Alliance is promoting flexible electronics and displays on a national level.<sup>62</sup> There are a variety of technical approaches to meet some of the same market needs.

A second challenge is that the cluster is still in its early stages and has not yet developed the full supply chain of supporting industries and services. There is a need to expand the supply chain, especially supporting materials and manufacturing companies. Cluster companies currently procure key materials, including liquid crystal materials and Indium Tin Oxide (a key optically transparent and electrically conductive material), from outside of the region. Dyes and coating are mostly made locally, and manufacturing and assembly is done locally. There is also simply a need for greater scale. It is easier to attract skilled people to a region when there are multiple employers, so people are not taking as big a career risk in relocating to Ohio. The cluster is close to reaching critical mass, the point at which the cluster becomes self-sustaining and attracts other companies and people due to the accumulation of skills, suppliers, and services in the region. It will take time, and increased scale of operations to reach this, but cluster participants feel that they are on the path to achieving it. More investments in the supply chain are needed. At a later stage, the cluster will also need community colleges to train more workers at a various levels, but at present they primarily need MS and PhD graduates.

## CONCLUSIONS

This case study provides a number of lessons for the OTF. First, it demonstrates that research institutes can anchor new industrial clusters, but they are not sufficient by themselves to create the industry. Ohio's flexible displays and electronics cluster is anchored by world-class university research programs in liquid crystals and polymers that provide ideas, train people, and provide research equipment. Unlike many companies, they are enduring -- unlikely to be bought out and closed, and difficult to move to another state or overseas. As demonstrated by the history of liquid

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<sup>61</sup> See <http://flexdisplay.asu.edu/>

<sup>62</sup> See <http://www.flextech.org/forum/about.aspx>

crystal displays, however, the knowledge produced by research universities does not result in local economic value unless there is a complete environment that supports the commercialization of the technology in the region. There were many missing elements in Ohio's innovation ecosystem in the 1970s through the 1990s. The OTF is now providing critical elements that were missing during the early history of LCDs, and companies are now growing in the region.

Second, the case demonstrates that there is the potential for significant new industries in Ohio that are outside of – or in between – the OTF's targeted technology platforms. The flexible displays and electronics cluster is not one of OTF's targeted technology platforms, but is strongly related to both the Advanced Materials and the Instruments, Controls & Electronics (ICE) technology platforms, and may have applications in Advanced and Alternative Energy. Importantly, the OTF has been flexible enough to recognize and support this cluster even though it is not precisely one of the targeted technologies. There may be several other such potential clusters that fall between the targeted technology platforms, and it is important that the OTF continue to look for existing or emerging areas of excellence that could be the basis of new industries.

## **AKEBIA THERAPEUTICS, INC.: EXPANDING OHIO'S BIOTECHNOLOGY FRONTIER**

[www.akebia.com](http://www.akebia.com)

Akebia Therapeutics is a privately-held biopharmaceutical company in Cincinnati focused on the discovery and development of new drugs for treating anemia and peripheral artery disease. Akebia's origin can be traced to Procter & Gamble (P&G) Pharmaceuticals' decision in 2006 to discontinue internal drug discovery efforts. Akebia Therapeutics was formed in 2007 by a former P&G director and a former Vice President at Reliant Pharmaceuticals licensing two drug development programs from P&G. Currently pre-clinical, the company's therapies, which have blockbuster potential, are approximately five years from market.

state programs have played a critical role in bringing early-stage funding to Akebia. In 2007, Akebia raised \$1.15 million in seed funding from regional investors including CincyTech (an Ohio Third Frontier Entrepreneurial Signature Program which provided a total of \$200,000), Triathlon Medical Ventures, Blue Chip Venture Company, Fort Washington Capital and Queen City Angels. This initial round of funding enabled Akebia to get off the ground: the company was able to start testing its compounds, complete the licensing agreement with P&G Pharmaceuticals, and then raise a second round of funding in 2008 totaling \$15.1 million, of which two-thirds came from out of state. "CincyTech, Triathlon Medical Ventures and the local venture community teamed up to get us launched and bring in those kinds of dollars from out of state," said Dr. Gardner, CEO of Akebia. This later round of investment is supporting Akebia's program for the treatment of anemia of chronic kidney disease, scheduled to enter Phase I clinical trials in the summer of 2009.

Akebia's Ohio location has also enabled the company to land a \$500,000 grant in 2008 from the Global Cardiovascular Innovation Center, a Wright Center of Innovation focusing on cardiovascular technology commercialization led by the Cleveland Clinic and funded by OTF. This grant has proven critical to the development of Akebia's second program for the treatment of peripheral artery disease, which was earlier stage and riskier than the other program, and received little venture capital funding. The grant funded research that will potentially lead to key breakthrough advances in medicine. By working closely with the Cleveland Clinic, Akebia has expanded the program's clinical applications to also include possible treatments for vascular leak syndromes and sepsis, as well as the augmentation of cancer therapies.

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### Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

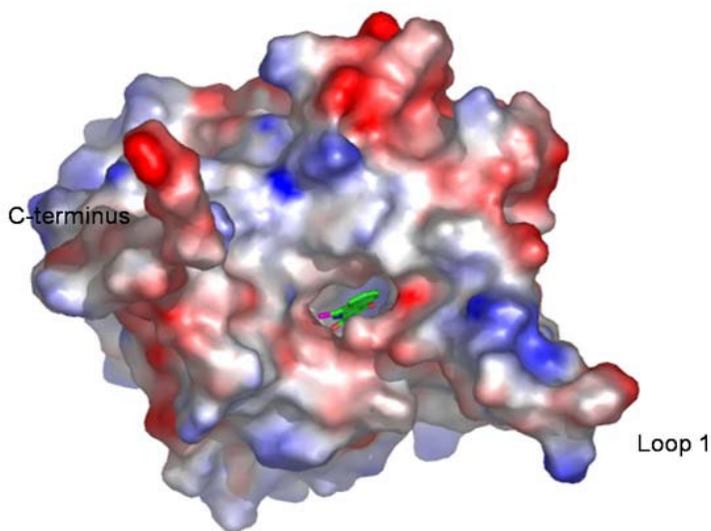
“The medical benefits and health impacts of the treatments from these two programs will be vast. Type 2 diabetes, which causes chronic renal failure, is an epidemic in Ohio. Peripheral artery disease is also associated with type 2 diabetes as well as obesity. Our therapies will mean lower costs and a better quality of life for affected people in Ohio and around the country,” said Dr. Gardner.

In addition to the funding from CincyTech and GCIC, Akebia has also received support from BioOhio, an Edison Technology Center focused on building the Ohio bioscience industry, and BIO/START, a Cincinnati-based Edison Technology Incubator, in terms of publicity, networking and contacts with potential contractors and financial and legal services.

Akebia has a third program in the works in the wound healing arena, related to the company's development of anemia treatments. This third program may eventually be spun out as a separate company. Akebia also plans to engage in more drug discovery work, locally, with universities such as the University of Cincinnati Medical Center, Ohio State Medical Center, Cincinnati Children's Hospital Medical Center and the Cleveland Clinic. “We have major-league medical centers in Ohio, but the state is under-represented in the development of new drugs because it is hard to get enough venture capital and expertise without going out of state,” commented Dr. Gardner. Akebia is positioned to be a key player in the early drug development phase in Ohio, helping to nurture and commercialize potential treatments. “Akebia's long-term goal,” said Dr. Gardner, “is to put Ohio on the map in terms of therapeutic biotechnologies.”



*Image: Dr. Robert Shalwitz, co-founder and Chief Medical Officer of Akebia Therapeutics (left), and Dr. Joseph Gardner, co-founder and CEO (right).*



*Image: 3-D model of an Akebia enzyme inhibitor drug candidate bound to the enzyme structure.*

*Photo Credit: Akebia Therapeutics, Inc.*

## AMERICAN TRIM: ADVANCED TECHNOLOGY REVITALIZING A TRADITIONAL MANUFACTURER

[www.amtrim.com](http://www.amtrim.com)

American Trim is a Lima, OH-based company specializing in metal forming, finishing and coating for the appliance and automotive industries. The company began in 1951 as Lima Tool and Die with only four employees. Today, the company has grown and expanded to 1,200 employees working in three Ohio facilities and five other manufacturing facilities in the United States and Mexico.

Unlike many traditional metal forming companies, American Trim has emphasized innovation through research and development as a strategy to meet the challenge of international competition and the need for environmental responsibility. Support from the OTF has enabled American Trim to develop new coating and metal forming technologies to propel the company forward in both areas.<sup>63</sup>

One technology is physical vapor deposition (PVD) technology,<sup>64</sup> which can apply a “chrome-like” finish on virtually any product. The technology is a major departure from traditional metal plating because it is environmentally friendly and has potentially lower overall costs. American Trim’s position in this technology was strongly supported by \$1.38 million Ohio Third Frontier Wright Project awarded in 2006 to American Trim and Rhodes State College. This grant supported the establishment of an Advanced Materials Commercialization Center and enabled the purchase of a PVD chamber large enough to produce full scale samples of products the size of truck bumpers. The grant enabled American Trim to develop and test coating processes and prepare samples that customers can test. This step of going from concept to full scale demonstration is a critical process of commercializing new technologies. Another collaborator on the project is DuPont CoatingSolutions, which also sees the potential of the technology.

In 2008, American Trim demonstrated its full-sized, PVD-coated heavy truck bumper. If the sample products pass customer tests, American Trim expects to establish a new factory based on the

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<sup>63</sup> Kivin, Brad. “A Devotion to Innovation”. *Metal Forming*. April 2009, pp.12-15. [www.metalformingmagazine.com](http://www.metalformingmagazine.com)

<sup>64</sup> Destefanni, Jim. “Ramping Up PVD: Big Chamber to Advance Physical Vapor Deposition Applications,” May 2008, pp.39-40. [www.pfonline.com](http://www.pfonline.com)

technology. In a press release, Steve Hatkevich, American Trim Director of Research and Development, estimated the market for this initial product to be over \$90 million annually. "We believe that hitting a home run with this product will result in 90 new manufacturing jobs." The collaboration with Rhodes State College will educate and train students on this specialized equipment to support this expansion.

In a second OTF grant, American Trim, The Ohio State University and General Motors have demonstrated the ability to manufacture a fuel cell bipolar plate using a novel high-velocity metal forming technology. High Velocity Metal Forming (HVMF) is a method of metal forming where the sheet metal to be formed is accelerated to 300 meters per second into a die, and thereby forms the part. It is a breakthrough in metal forming technology which could add more precision to the metal forming process, increase processing speed and reduce cost in terms of equipment and processing. The Ohio Third Frontier support has helped to make American Trim rapidly become one of the top companies in the world in electromagnetic forming. The technology is expected to greatly reduce the cost of fuel cell manufacturing, and also has applications to many other automotive products. "We have demonstrated the very real possibility that we can produce fuel cell bipolar plates for a fraction of what they currently cost," said Rick Pfeifer, Vice President and Chief Technology Officer at American Trim. "We expect the total job creation to exceed 200."

American Trim exemplifies how Ohio Third Frontier funding have helped enable firms in traditional industries position themselves at the leading edge of technology in their field, allowing them to not only survive but to move into new markets. The company is constantly working to make new technologies available to its customers. As John Swigard, American Trim's Director of Marketing said in a magazine interview, "We're committed to applying the grants that we receive, and focusing our own research and development investments in time and money, to advancing technology in a practical way, so that we create jobs. That's our responsibility, and we intend to live up to it."<sup>65</sup>

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<sup>65</sup> Kuvin, Brad. "A Devotion to Innovation". *Metal Forming*. April 2009. P. 12-15. [www.metalfformingmagazine.com](http://www.metalfformingmagazine.com).



*Image (L): Physical vapor deposition (PVD) chamber.*

*Image (R): American Trim's High Velocity Metal Forming (HVMF) team.*

## **ARTERIOCYTE: FROM IDEA TO COMMERCIAL PRODUCT IN LESS THAN FOUR YEARS**

<http://www.arteriocyte.com/>

Blocked or damaged blood vessels are a major cause of illness and death around the world. In the United States, more than 10 percent of the population over the age of 65 is diagnosed with congestive heart failure each year. While treatments, including drugs and vascular interventions, have been developed and are now the standard for care, there are some patients for whom these therapies are not as effective. Based in Cleveland, Ohio, Arteriocyte is a clinical-stage biotech company that targets these patients, developing proprietary stem cell-based therapies to grow new blood vessels in response to a variety of vascular diseases. Arteriocyte's goal is to develop commercially-available stem cell-based therapies from multiple sources of adult-derived stem cells (e.g., bone marrow, peripheral cord blood, etc.) to treat diseases for which the existing therapies are inadequate.

The crux of Arteriocyte's technology is the development of a method that rapidly concentrates multiple stem cell types for delivery into damaged tissues to jumpstart repair. This technology offers distinct advantages, and has the potential to augment conventional therapies, such as artery bypass grafting and angioplasty.

The foundation of today's company was laid in January 2004, when Arteriocyte, Inc. became the first spin-off of the Center for Stem Cell and Regenerative Medicine (CSCRM), an Ohio Third Frontier-supported center of excellence established through a research collaboration that included four major Ohio based universities: Case Western Reserve University, University Hospitals of Cleveland (UHC), the Cleveland Clinic Foundation, and Ohio State University. CSCRM had been created a year earlier as the result of a \$19.5 million State of Ohio Third Frontier (OTF) award for capital investments and operating expenses to support cutting-edge stem cell research with strong commercial potential.

Since its start, Arteriocyte has received a total of \$1.6 million in OTF support, including \$600,000 from the state in 2006 to further develop its technology through collaboration with CSCRM, as part of an \$8 million Ohio Third Frontier Biomedical Research and Commercialization Program (BRCP) award. Then in 2007 and 2008, Arteriocyte received approximately \$1 million as part of the \$60 million Ohio Third Frontier Mega Wright Center of Innovation award to the Cleveland Clinic-led Global Cardiovascular Innovation Center (GCIC). GCIC is a multi-institutional initiative led by the

Cleveland Clinic, and is comprised of Case Medical Center, Ohio State University, University of Cincinnati, and University of Toledo. The consortium also includes companies, such as Arteriocyte, participating as research partners. With the support of this grant, Arteriocyte will initiate Phase II clinical evaluation of the company's STEM-PREP cell therapy to be used in chronic coronary ischemia (restricted blood flow to the heart tissue resulting in damage to the heart).

In addition to R&D support, Arteriocyte has also received assistance from BioEnterprise, a state-supported business accelerator. BioEnterprise is an Edison Technology Incubator, which was founded by Case Western, University Hospitals and the Cleveland Clinic Foundation. Initially, BioEnterprise provided Arteriocyte strategic guidance in developing its product strategy. Arteriocyte leases its research and development laboratory space from BioEnterprise in Cleveland, OH.

Early state funding has helped Arteriocyte create a solid commercialization track record putting the company in a better position for leveraging Federal grants as it diversifies its product line. Arteriocyte has received two grants from the NIH's National Heart, Lung and Blood Institute. The first, in 2005, was a combined \$1.7 million "fast track" Small Business Technology Transfer (STTR) grant award. The grant supported a 10-patient study to test the safety of using stem cells to repair ischemic heart tissue caused by an inadequate blood supply to the heart. In 2008, the company was awarded another NIH fast track \$2.5 million award to clinically evaluate the feasibility of treating critical limb ischemia with stem cells derived from cord blood. With this grant, Arteriocyte has moved another step closer to the commercialization of its second stem cell pipeline product, transitioning to clinical stage evaluation.

In late 2007, Arteriocyte partnered with DW Healthcare Partners and Comerica to create Arteriocyte Medical Systems, in order to commercialize and distribute novel medical devices to improve surgical outcomes for patients, and quickly acquired the Magellan brand platelet and stem cell concentration device business from Medtronic. The Magellan device is used in over 400 hospitals throughout the world to rapidly concentrate platelets and stem cells for surgical procedures.

In 2008, Arteriocyte also received a \$1.95 million award from the Defense Advanced Research Projects Agency (DARPA) for its "Production of Red Blood Cells" project. The goal of DARPA's Blood Pharming program is to develop an automated culture and packaging system that will yield a readily-available "donor-less" supply of universal donor red blood cells for use in advanced battlefield operations. Arteriocyte is currently one of only two companies in the world that DARPA is working with on this novel development project.

In four years, Arteriocyte has grown from a one-person startup to a commercial stage biotech company employing 24 highly-trained workers, with annual revenues in excess of \$10 million. Early state support was critical in advancing the company's commercialization timeline. Arteriocyte's current growth plans are ambitious: over the next six years, the company plans to add another 100 jobs and increase revenues by \$140 million.

Don Brown shared his thoughts on the impact of OTF, "The state of Ohio has been truly visionary in making forward-looking investments in leading technology clusters throughout the state. These investments have led to game-changing advances in commercializing technologies that can rapidly improve the quality of healthcare for all Americans. Arteriocyte is a great example of how successful OTF has been, for we owe much of our success directly to the support we've received from Ohio's Third Frontier Program."



*Image: Arteriocyte's Magellan device used by hospitals to concentrate platelets and stem cells for surgical procedures.*

*Photo Credit: Arteriocyte*

## **ATRICURE, INC.: A GLOBAL LEADER IN CARDIAC ARRHYTHMIA TREATMENT TECHNOLOGY**

[www.atricure.com](http://www.atricure.com)

AtriCure, Inc., a West Chester-based medical device startup, focuses on the development of minimally invasive products for cardiac arrhythmia treatment. It is the leader in cardiac surgical ablation systems, a procedure used to correct abnormal heart rhythms. Driven by strong demand for its products, AtriCure was the third fastest growing, privately-held medical device company in 2007 on Deloitte's Technology Fast 500, a ranking of the fastest growing North American technology companies based on revenues.

One of the most common arrhythmia's, atrial fibrillation (AF), is a rapid, irregular quivering of the upper chambers of the heart, affecting up to 5 million people a year. This condition predisposes individuals to a five-fold increased risk of stroke. AtriCure's primary product employs clamps and radio frequencies to create precise scars on damaged heart tissue to block abnormal electrical impulses. It is one of the few systems worldwide offering a minimally invasive surgical procedure to treat AF. The market for these clamps for use in open-heart surgery and minimally invasive procedures is estimated by the company to be \$2.25 billion. Thus far, these clamps have been employed in more than 40,000 open-heart surgeries and over 2,500 minimally invasive procedures. The clamp is still awaiting U.S. Food & Drug Administration (FDA) clearance to be marketed for AF treatment, but has already gained FDA approval in 2007 for ablation of cardiac tissue.

In 2004, AtriCure was awarded a \$175,000 grant from the Ohio Third Frontier Research Commercialization Grant Program, which was used to support the development of a product design and manufacturing system for its cardiac radiofrequency ablation clamp. In 2005, AtriCure, in partnership with the Cleveland Clinic, Case Western Reserve University and the University of Cincinnati, was awarded a \$26 million Ohio Third Frontier grant to establish the Atrial Fibrillation Innovation Center, a Wright Center of Innovation. AtriCure received \$0.9 million of direct funding and approximately \$1 million in capital equipment from this award.

AtriCure was created in 2000 as a spin-off of Enable Medical Corporation. In 2005, the company raised net proceeds of \$43.2 million through an IPO on NASDAQ. AtriCure has grown from eight employees in 2000 to approximately 200 full-time employees today. The company maintains its headquarters in West Chester, Ohio (near Cincinnati) in a 12,200-square-foot facility. AtriCure manufactures the majority of the disposable products it sells. The company inspects, assembles,

## Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

tests and packages its products in West Chester, Ohio. AtriCure's presence in Ohio lends further weight to a burgeoning medical device industry cluster in the state, helping to attract other companies and highly-skilled workers to the state.

AtriCure's revenues grew from \$9.8 million in 2003 to \$55.3 million in 2008. A significant portion (approximately two-thirds) of these revenues benefit the Ohio economy, through purchases of secondary products and services from other Ohio-based companies. AtriCure continues to expand its presence in markets outside of the United States. Exports grew from 11 percent of total revenues in 2006 to 14 percent in 2007 (\$6.6 million).

AtriCure's strategic priorities include the expansion of its leadership position in the medical device field through product innovation, achieving profitability, and receiving AF approvals from the FDA (anticipated by 2010). In the pipeline are several new cryo ablation and other cardiovascular treatment products.



## CHANTEST CORPORATION: OPENING NEW AVENUES IN DRUG DISCOVERY

[www.chantest.com](http://www.chantest.com)

ChanTest Corporation is the leading provider of ion channel testing services for drug-discovery and development applications. Ion channel screening helps biotech and pharmaceutical companies speed the drug development process, save time and money, and help make better and safer drugs. The company has tested more than 20,000 compounds for over 400 global pharmaceutical and biotech companies. Profitable since the company's inception, ChanTest employs more than 70 people. In 2006 and 2007, the company was ranked the "most trusted fee-for-service provider" for ion channel screening.<sup>66</sup>

Established in 1998, ChanTest is a privately held company in Cleveland Ohio, founded by Dr. Arthur Brown. The company provides drug safety and discovery testing services, and also sells the products (reagents) to client companies to do the testing themselves. Today, ChanTest has the world's largest validated and optimized catalog of cell lines and employs them to produce ion channels.

Ion channels comprise ~ 10 percent of known drug targets at present. Research is continually uncovering potential new ion channel targets in cancer, diabetes and respiratory diseases, as well as pain, cardiovascular disease, and neurological disorders. However, ion channels still remain underexploited as drug targets due to the historical lack of high-throughput, high-quality screening technologies.

A few years ago, ChanTest set out to develop the world's most comprehensive library of cell lines expressing ion channels. In 2006, ChanTest and its collaborators, Analiza, Inc. and the Northeastern Ohio Universities College of Medicine, were awarded a \$4.73 million grant from the Ohio Third Frontier's Biomedical Research Commercialization Program (BRCP). The grant contributed to ChanTest reaching its goal within three years, as opposed to 10 to 15 years without the Ohio Third Frontier funding, allowing the company to capture the leadership position in this field. ChanTest estimates that the grant has already directly generated \$5.4 million in sales, and created approximately 40 high-paying, high-skilled jobs (ChanTest's average annual salary is \$65,000). The

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<sup>66</sup> Comley, John (2006, 2007) *HTStec Ion Channel Trends Survey*

downstream revenue impact of this grant could be at least \$50 million in revenues. The grant was also an important factor in their private equity deal with Ampersand Ventures in 2007 worth \$8 million.

Since 2002, ChanTest has worked with BioEnterprise, one of the state's 13 Edison Technology Incubators. BioEnterprise has provided valuable consulting services and strategic guidance. In particular, BioEnterprise helped ChanTest's spin out ChanRx in negotiating a drug licensing agreement with another pharmaceutical company. ChanRx develops drug candidates identified using ChanTest's ion channel assays platform. Currently, ChanRx has two drug candidates for the treatment of atrial fibrillation and flutter.

In 2009, ChanTest acquired Applied Cell Sciences, a contract research organization in Rockville, MD specializing in G-protein coupled receptors (GPCRs). A GPCR, like an ion channel, is a type of protein targeted by drugs, vital to cell function. As a result of this acquisition, ChanTest's expanded drug discovery and development services, cell lines, and reagents now cover nearly half of the known drug targets. In terms of future plans, ChanTest aims to build a large tissue culture facility for manufacturing cell lines. This will contribute towards ChanTest's ultimate goal of transforming Cleveland into the global center for Ion Channel, GPCR and other less explored drug targets.



## **CLEVEX™, INC.: INNOVATIVE DEVICES FOR DERMATOLOGICAL TREATMENT**

[www.clevex.com](http://www.clevex.com)

Headquartered in Columbus, Ohio, CleveX, Inc., produces innovative dermatological medical devices. CleveX's flagship product is the ExiClip®, a surgical device which efficiently removes moles and skin lesions with minimal scarring. Founded as a joint venture between Cleveland Clinic surgeons and Cincinnati-based IDX Medical Design engineers in 2004, CleveX is poised for growth having received FDA approval of the ExiClip and with other products in the pipeline.

As a startup company based on innovative technology, CleveX benefitted from a variety of Ohio programs geared toward improving access to early-stage capital for young Ohio technology companies. For example, in mid-2006, CleveX secured \$250,000 from the Ohio Bio Validation Fund (a program of the then Edison Biotechnology Center, now BioOhio), which was used to assess the market for ExiClip, write a business plan, and raise more capital to get the company off the ground. With these fundamentals in place, CleveX was able to raise \$1.65 million in its first round of financing in early 2007, with the investment round led by the Ohio TechAngel Fund, and with consulting from TechColumbus, a Columbus-based Edison technology incubator. A total of five Ohio-based investors funded this round, all of whom benefited from the state's Technology Investment Tax Credit (TITC) program, which provides a tax credit to taxpayers who invest in small, Ohio-based technology companies such as CleveX.

This financing enabled CleveX to complete the design and testing of two versions of the ExiClip, complete a clinical trial, and seek U.S. Food and Drug Administration (FDA) approval. CleveX received FDA approval for the ExiClip in 2007.

CleveX was also able to leverage the knowledge and networks of state-supported technology incubators and centers. Currently housed within TechColumbus, CleveX received additional assistance from BioEnterprise, a Cleveland-based Edison incubator which supports the growth of bioscience companies, and BioOhio, an Edison Technology Center focused on accelerating the growth of Ohio's biosciences industry. These organizations have provided invaluable support to CleveX by helping the company tap their extensive networks of potential investors, collaborators, customers and suppliers. CleveX attributes 90 percent of its investments to these networks. For example, these networks connected CleveX to Plymouth Venture Partners and Reservoir Ventures Partners (two venture capital funds attracted to Ohio through the Ohio Capital Fund). These funds

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became the key investors in a \$1.4 million Series A follow-on of financing for CleveX in 2008. This second round of financing allowed CleveX to ramp up to high-volume manufacturing and sales of the ExiClip, as well as to launch new products. CleveX is on track for officially launching the ExiClip product in 2009, with a pilot launch completed in 2008. Product development for the next generation ExiClip will begin in 2010.

CleveX currently has five full-time employees, and the company plans to create four more positions and to generate approximately \$2 million in sales by the end of 2009. Over the next four to five years, the company expects to grow to \$40 million to \$50 million in revenues with up to 20 employees at its Columbus headquarters. With the ExiClip's FDA approval, the company is well-positioned to move forward with its sales and marketing effort in the United States, and also with gaining clearance in Australia, Europe, and other international markets to eventually initiate an international sales effort.



*Image (L): ExiClip*

*Image (R): Gary Smith, President and CEO (left), and Warren Williamson, CleveX Co-founder, (right)*

*Photo credit: CleveX, Inc.*

## CROWN EQUIPMENT: A CLEAN LIFT OFF

[www.crown.com](http://www.crown.com)

A leading global manufacturer of lift trucks, Crown Equipment Corporation is the top brand of electric lift trucks in the United States and the seventh largest lift truck manufacturer in the world. Crown's revenue is approximately \$1.8 billion, and the company has more than 8,000 employees worldwide, with about 2,400 of those located in Ohio.

In 1945, Crown began as a one-room enterprise in the small, rural community of New Bremen, Ohio, where Crown's headquarters remain today. Through the years, Crown's product offering has been quite diverse, starting with temperature controls for coal-burning furnaces, which eventually became obsolete, and then diversifying to antenna rotators for televisions in 1949 until 2001. In 1951, Crown moved into the repair and manufacturing of mechanical and electronic components for private industry and government. In 1957, Crown began manufacturing forklifts, which comprise its primary business today. Crown offers an extensive range of forklifts designed to support diverse applications within almost any type of industry worldwide.

Crown is working closely with primary hydrogen fuel cell manufacturers to research and test fuel cell applications for forklifts. The company is committed to advancing hydrogen fuel cell technology and environmental sustainability, and aims to overcome technical and cost challenges related to replacing lift truck batteries with fuel cell power packs.

"Fuel cell-powered lift trucks can lead to significant productivity gains," said Eric Jensen, manager of research and development for Crown in a recent company announcement. "Power packs save time because changing a fuel cell takes two or three minutes, compared to 30 minutes for changing out a lead-acid depleted battery. In addition, less space is needed for servicing, and it is environmentally cleaner."<sup>67</sup> The material handling industry is poised to be an early adopter of this fuel cell technology.

Crown was awarded grants of nearly \$1 million each in 2008 and 2009 from the Ohio Third Frontier's Fuel Cell Program to explore development of a fuel cell powered line of lift trucks. "The project is important to the technological advancement of our products, which in turn is important

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<sup>67</sup> Crown Equipment Corporation press release, "Defense Depot to Use Hydrogen Powered Crown Forklifts," Oct 21, 2008 < [http://www.crown.com/usa/news/usa\\_company\\_news/2008/fuel\\_cell\\_real\\_world\\_app.html](http://www.crown.com/usa/news/usa_company_news/2008/fuel_cell_real_world_app.html)>.

for our customers and to the long-term future of Crown,” said Crown President Jim Dicke III. “We are pleased with the State of Ohio and its overall efforts in working with Crown to maintain a strong manufacturing base here. Crown also appreciates being recognized as a leader in the progression of fuel cell technology.”<sup>68</sup>

By targeting and qualifying eligible Crown truck models for fuel cell equipment, this project is critical in the widespread adoption of fuel cell-powered lift trucks. Overall, this project expands the company's ability to participate in and support the advancement of clean energy technologies that could provide cost savings for Crown's customers. This project also helps position Crown to take the lead in the fuel-cell-based lift truck market. Thus far, eight jobs have been created directly from the grants, and Crown looks forward to the prospect of adding resources as the program continues.

“We are very thankful for the ongoing support provided by the State of Ohio and the Ohio Third Frontier Commission that has enabled us to become a leader in the advancement of fuel cell technology applications within the lift truck industry,” said Jensen. “We are encouraged by Ohio's strong leadership position in exploring and developing technologies that advance the Hydrogen Highway.”

While it is still too early to accurately predict future job, revenue and market penetration growth, the company is strongly positioned in a highly competitive industry. Upon receiving the first grant, Crown embarked on a research project that focused on addressing the technical and commercial barriers to the application of available battery replacement fuel cell power packs in industrial lift trucks. This ongoing project allowed Crown to respond to its customers' desire to test fuel cells in a number of different locations and truck models.

Crown also established a 25,000-square-foot engineering/testing facility in Huber Heights, Ohio that is dedicated to the research of fuel cell lift truck applications. The research conducted at the facility will increase industry confidence in fuel cell technology and thereby support a broader market introduction of fuel cells to the industrial truck industry. The work enabled by the funding also will allow Crown to actively participate in the development of industry standards, guidelines and regulations.

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<sup>68</sup> Fuel Cell Magazine Online, “Crown awarded \$1 million state grant,” May 2008 <[http://www.fuelcell-magazine.com/eReport/eReport\\_News-0508.htm#Crown](http://www.fuelcell-magazine.com/eReport/eReport_News-0508.htm#Crown)>.

In 2008, Crown was invited to participate with Hydrogenics Corp, a developer of clean energy solutions, to upgrade 20 Crown lift trucks with Hydrogenics' hydrogen-powered fuel cell power packs for the Defense Distribution Depot, Warner Robins, Georgia (DDWG) at Robins Air Force Base. Concurrent Technologies Corp., a nonprofit scientific research organization, is responsible for replacing the lead-acid batteries with the fuel cell power packs.

## DIAGNOSTIC HYBRIDS: IMPROVING HEALTHCARE OUTCOMES THROUGH INNOVATIVE DISEASE DETECTION

<http://www.dhiusa.com/>

Founded in 1983, Athens-based Diagnostic HYBRIDS is a leading in vitro diagnostics company producing cellular-based diagnostic kits for detecting a wide range of respiratory disease, sexually transmitted disease, gastrointestinal disease and autoimmune disorders using monoclonal antibody technology for rapid detection. An Ohio biomedical startup, the company has grown to 220 employees with over 700 current, active customers.

The support that Diagnostic HYBRIDS has received from the State of Ohio has helped the company both in terms of its new product development and commercialization, as well as during critical transition periods in its startup and growth. In a classic example of a small amount of money going a long way, Diagnostic HYBRIDS received a \$100,000 loan in 1993 from the Edison BioTechnology Center (now BioOhio), an Edison Technology Center. This loan helped the company through a struggling period just as it had completed a commercially viable and flagship product, but possessed limited working capital to bring it to market. With this loan, the company was able to launch its first product: a patented, genetically engineered cell line for rapid herpes testing.

From its inception until 2007, Diagnostic HYBRIDS has been housed in various buildings comprising the Ohio University Innovation Center—today, an Edison Technology Incubator. The incubator provided Diagnostic HYBRIDS with physical space and business assistance, and the company benefited from easy access to Ohio University undergraduates, graduates and faculty. In 2007, when Diagnostic HYBRIDS graduated from the incubator and re-located to a state-of-the art 75,000-square-foot research and bio-manufacturing facility, the state's Research and Development Investment Loan Fund supported the critical transition by providing Diagnostic HYBRIDS with a low-interest loan for a portion of the \$6 million renovation and expansion project. The company also used commercial financing sources and private equity capital to finance the project.

Diagnostic HYBRIDS has been able to effectively leverage the state's longstanding investments and competitiveness in biomedical research at institutions such as Ohio University, The Cleveland Clinic, and Case Western Reserve University, and has participated on multiple projects with other Ohio-based partners.

The most direct example of how the company has benefited from state-supported programs is in the early commercialization and development of new products on which its growth is based. In 2000, the company partnered with Ohio University to win a \$1 million grant from the Ohio Third Frontier's Action Fund, formerly the Ohio Department of Development Technology Action Fund (TAF). The TAF grant provided funding to bring world renowned scientist, Dr. Leonard Kohn, from the National Institute of Health to Ohio to support the development of a thyroid stimulating immunoglobulin (TSI) assay, an early detector of Graves' disease (hyperthyroidism).<sup>69</sup> Diagnostic HYBRIDS licensed and commercialized the resulting diagnostic technology. The product has generated substantial economic benefit and now accounts for approximately 10 percent of the company's total revenues since its launch in 2003.

What started as a research and development collaboration has enabled Diagnostic HYBRIDS to diversify and expand its product base from clinical virology into clinical endocrinology, thyroidology and chemistry. The second generation product of the TSI assay, is scheduled to be reviewed by the U.S. Food and Drug Administration (FDA) in early 2009. If approved, it will be the first FDA-approved product for Graves' disease.

In June 2008, and with matching funds committed by the participants, Diagnostic HYBRIDS was a recipient of a \$5 million grant from the Ohio Third Frontier's Biomedical Research and Commercialization Program (BRCP), in collaboration with Case Western Reserve University. The specific aim of the project was to accelerate the commercial development of a suite of diagnostic products using yeast-based virus cloning technology, including products and services related to HIV, hepatitis and influenza. In 2009, the two organizations signed an exclusive worldwide licensing agreement granting Diagnostic HYBRIDS rights to this technology which represents the cornerstone of the BRCP project.

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<sup>69</sup> Dr. Kohn remained in Ohio, eventually forming his own company, Interthyr Corp., a provider of biomedical research and development services which invests upwards of \$1 million per year in the development of new drugs for cancer, sepsis and auto-immune disorders.

Diagnostic HYBRIDS has developed a range of products which offer rapid, cost-effective diagnoses based on cutting-edge cellular and molecular biology research. According to the company's President and CEO, Dr. David Scholl, "Multiple and effective programs within the Ohio Development Department, including training grants, low interest loan funds for facility improvement, and support of major collaborative research commitments and tax reform, all have been available and accessible throughout our corporate development. When coupled with sizeable support from private investors and committed management, these targeted programs were effective in securing our survival in the early days, our rapid growth in the formative years, and now as we look forward to the next five years, providing an entrepreneurial environment in which Diagnostic HYBRIDS, and companies like ours, can look to accelerate our growth and future employment opportunities in bio-manufacturing."



*Image: Diagnostic HYBRIDS President and CEO, Dr. David Scholl,  
Photo Credit: Diagnostic HYBRIDS*

## **EGG TECH LTD.: SAFER EGGS THROUGH INNOVATION-FOCUSED COLLABORATION**

[www.eggtechltd.com](http://www.eggtechltd.com)

Formed in 1997, Egg Tech Ltd., is a joint venture between three major egg producers in Ohio: Hemmelgarn & Sons, Inc., based in Philothea, Ohio; Hertzfeld Poultry Farms, Inc., of Grand Rapids, Ohio; and Weaver Bros., Inc., located in Versailles, Ohio. The startup is based on an innovative egg sterilization technology developed and patented by the Ohio State University (OSU), and licensed by Egg Tech, with commercialization assistance from the Center for Innovative Food Technology (CIFT) in Toledo, Ohio.

Ohio is the country's second-largest egg-producing state. The sanitization of fresh eggs is important in preventing the transmission of Salmonella to humans. Current practices include washing eggs to remove Salmonella and other microorganisms from the egg shell and applying thermal and chemical treatments to remove microorganisms from inside the egg. However, there are currently no low-temperature treatments capable of effectively sanitizing eggs on an industrial scale. Low temperatures preserve the quality and safety of fresh eggs during production, storage, transportation and retail sale.

OSU's technology involves sterilizing the egg while it is still in the shell, by integrating gaseous ozone with other variables. This innovative process can produce a fresh egg that is free of Salmonella. The technical challenge to commercializing this innovation was to develop a working system that can apply this process on an industrial scale. Competing technologies include a North Carolina State egg pasteurization technology based on thermal treatment, which is the current industry standard, and others in development, such as a Michigan-based microwave radiation technique.

In the mid 1990s, the Ohio Poultry Association sponsored and hosted meetings between Ohio's egg producers, egg processors and agricultural researchers to explore old and new technology that could kill Salmonella inside a shell egg. This effort was taken in response to a proposed U.S. Egg Safety Action plan that sets forth goals for eliminating Salmonella illnesses due to consumption of shell eggs. An OSU researcher, Dr. Ahmed Yousef, suggested the use of ozone in the sterilization of shell eggs. Egg Tech was formed to commercialize this technology, and Egg Tech was able to negotiate an exclusive license for the OSU patent on which the technology is based. The

researchers, Dr. Yousef and Dr. Rodriguez-Romo applied for and received a patent in 2004. Dr. Yousef continued to refine the process and a second patent was granted in February 2009.

The Center for Innovative Food Technology (CIFT), an Edison Technology Center, provides technical solutions to Ohio food production, processing and packaging companies. CIFT made several contributions to the applied development and commercialization of the ozone sterilization technology. CIFT funded a graduate student to assist Dr. Yousef in refining the sterilization technique. Later, CIFT engineers designed and constructed a big pressure vessel for increasing the number of eggs which could be tested at one time using the OSU technology. This was the original prototype for a production-scale system. CIFT also collaborated in the application and receipt of a Matching USDA Rural Development Value Added Producer Grant of \$ 100,000 in 2003. This grant paid for a marketing consultant and the development of business models for launching the EggTech system in the marketplace.

Egg Tech is currently working to receive approval from the U.S. Food and Drug Administration (FDA) for the ozone-based egg sterilization system. After receiving FDA approval, Egg Tech will begin marketing pasteurized, Salmonella-free eggs and marketing the specialized equipment to other producers enabling them to meet the 2012 requirements for safe eggs per the U.S. Egg Safety Action Plan.



*Image: Egg Tech Ltd.'s technology commercialization collaborators from left to right, Tom Hertzfeld Jr. (Eggtech Co-founder, Hertzfeld Poultry Farms), Ed Sisley (EggTech consultant), Ronald Gross (Eggtech co-founder, Hemmelgarn & Sons), Dr. Ahmed Yousef (OSU), Jack Heavenridge (EggTech Executive Director), Dr. Luis Rodriguez-Romo (OSU), Tim Weaver (Eggtech Co-founder, Weaver Brothers), Dr. Ken Lee (OSU).*

*Photo Credit: Egg Tech Ltd.*

## HEALTHCARE TRANSACTION PROCESSORS, INC.: REDUCING HEALTHCARE COSTS THROUGH INNOVATIVE SOFTWARE

[www.htp-inc.com](http://www.htp-inc.com)

HealthCare Transaction Processors Inc. (HTP), based in Columbus, provides secure software solutions which promote timely reimbursement for patient services, ranging from verification of health insurance coverage to maintaining payment plans to aid in fee collection. Designed to connect providers, health plans and financial institutions in a user-friendly way, these HTP's software tools help to improve clients' profitability, efficiency, service quality and patient satisfaction while helping them meet U.S. Health Insurance Portability & Accountability Act (HIPAA) requirements for secure transactions. HTP's clients include managed care organizations, third party administrators, public sector plans, providers and unions. In 2004 and 2005, HTP was named to the Inc. 500 list, an annual ranking of America's 500 fastest growing private companies. In 2008, HTP was acquired by RelayHealth, McKesson Corporation's online healthcare communications business.

Since its acquisition by RelayHealth, HTP continues to demonstrate strong revenue growth, growing 60-70 percent in 2008. The company has approximately 70 employees. HTP supports 207 customers, including 166 hospitals. The company manages and enables more than 40 million transactions per month.

HTP has received important state support from a variety of programs. The company was founded in 1996 by Dennis Swartzlander and Fred Richards, and in 1999, to raise more capital, HTP became a client of the Business Technology Center (BTC), an Edison Technology Incubator (which later merged with Columbus Technology Council to become TechColumbus). The BTC assisted HTP in refining and strengthening its business plan putting the company in a better position to secure the capital it needed, and also assisted HTP with its marketing strategy and management of its sales efforts. "The BTC provided the guidance we needed as an early stage company," Swartzlander said. "BTC staff members helped us clarify our thinking and solidify our goals."<sup>70</sup>

HTP was the beneficiary of a \$100,000 loan from the Edison BioTechnology Center (now BioOhio) that was awarded in 2000 and turned into equity in 2001 upon achieving a specified investment

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<sup>70</sup> <http://www.litechctr.com/clients.htm>

## Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

level from other investors. "The BioOhio funding came at a critical time in the company's life. HTP was an early-stage company, and we used the loan to certify our software products. Building on this certification allowed us eventually to develop a software product for hospitals that became the main growth engine for HTP and also to create a lot of high-tech, highly paid jobs in Ohio," said Richards, now Vice President of Healthcare Strategy at RelayHealth.

In 2004, HTP became the first recipient of the Innovation Ohio Fund (IOF) loan for \$750,000. The IOF is part of OTF, and provides subsidized debt financing ranging from \$500,000 to \$2 million to established companies for development of next-generation products and services in targeted industry sectors. The loan can be used to pay for facilities and equipment, software development and operating expenses related to the creation and protection of intellectual property, i.e., expenses that can be capitalized under the generally accepted accounting principles. HTP received a second IOF loan for \$1.7 million in 2006. The proceeds were used to assist in the development of an electronic system for managing complex healthcare data.

The state has also offered key incentives to retain HTP's operations in Ohio, such as the Job Creation Tax Credit, which was awarded to HTP in 2006 for a five-year term to expand its corporate headquarters and healthcare software development operation.

The state's early investments and entrepreneurial support to HTP helped to catalyze the company's software commercialization, business strategy and growth, ultimately culminating in the company's acquisition in 2008 by a much larger company, RelayHealth (whose parent McKesson Corporation has over \$100 billion in annual revenues). By bringing McKesson's significant corporate resources to the table, the acquisition enables HTP to scale up its services and product offerings and to create more highly-paid jobs in Ohio in the years to come.



## **INSTITUTE FOR THE DEVELOPMENT AND COMMERCIALIZATION OF ADVANCED SENSOR TECHNOLOGY: A CATALYST FOR COLLABORATION**

[www.idcast.com](http://www.idcast.com)

The Institute for the Development and Commercialization of Advanced Sensor Technology (IDCAST) is a world-class center of excellence in remote sensing and Chemical, Biological, Radiological, Nuclear and Explosive (CBRNE) sensing technology. Led by the University of Dayton and its Research Institute, and including a number of partner organizations, IDCAST was established as a Wright Center of Innovation through a \$28 million Ohio Third Frontier award. The center aims to build on Ohio's existing Federal, academic and industrial strengths in sensor technology,<sup>71</sup> resulting in more rapid commercialization of sensor technology for medical, environmental and military applications. Located in Dayton's Tech Town business park, IDCAST provides 4,600 square meters of collaborative lab space, research facilities and incubator space for startup companies, enabling access to sensor test-beds and other cutting-edge equipment including the world's most advanced infrared camera.

Created in 2007, IDCAST has already played an important catalytic role in connecting Ohio sensor technology companies with new markets and opportunities for research and commercialization collaboration. Especially important is the connection that IDCAST provides to link Ohio companies and universities to the Air Force Research Laboratory (AFRL).

Examples of how IDCAST has benefited the state include:

- Woolpert, a Dayton-based design, engineering, and geospatial firm, was not connected to the AFRL. Woolpert credits IDCAST with helping to make the connection, and Woolpert has since won approximately \$4 million in contracts from AFRL, resulting in

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<sup>71</sup> Ohio's leading organizations and companies in sensor technology includes: the Air Force Research Laboratory Sensors Directorate located at Wright-Patterson Air Force Base; the University of Dayton and its Research Institute, the Ohio State University, University of Cincinnati, University of Toledo, Miami University and Wright State University; and Ohio-based sensor technology companies such as Woolpert, Inc., General Dynamics, UES, YSI Inc., L-3 Cincinnati Electronics, STAN Solutions, etc.

the creation of 45 jobs (and keeping AFRL contract dollars in the state). The work with IDCAST has also contributed to another \$4.5 million in contract work with the Army. IDCAST has also helped Woolpert to connect to university expertise, such as that at the University of Dayton Ladar and Optical Communications Institute. Woolpert has also gained access through IDCAST to high-throughput computing, enabling Woolpert to automate many photo interpretation tasks, keeping work in Ohio that would otherwise have been outsourced to use low-cost labor overseas.

- IDCAST purchased the world's most advanced infrared camera from the Cincinnati Electronics Division of L-3 Communications. The \$4.2 million camera purchase will help keep both IDCAST and L-3 Cincinnati Electronics (CE) working at the frontiers of remote sensing and infrared technology. This, in turn, is helping position L-3 CE to win possible contracts with the Defense Advanced Research Projects Agency (DARPA) and the U.S. Naval Research Laboratory (NRL). As a result of this camera technology, along with related developments, L-3 CE has been able to create 70 jobs over the past three years.
- STAN Solutions, a Dayton-based network systems and sensor technology company, was considering relocating to California to find skilled workers. IDCAST was able to provide access and connections to the sensor technology talent pool in Dayton, enabling STAN Solutions to stay in the area and expand from 14 to 32 employees. IDCAST also helped to broaden STAN Solutions' client base, from being a subcontractor to a single military prime contractor to working with multiple clients in both military and civilian markets.
- Through IDCAST, area companies are able to collaborate on a variety of initiatives that they would not be able to on their own. IDCAST provided a venue for companies to help raise the quality of math and science in public schools. IDCAST members have worked with local schools and regional school authorities to help students from preschool to 12<sup>th</sup> grade gain a deeper appreciation for science, technology, engineering and math. IDCAST has also participated on a trade mission to Israel that has resulted in profitable collaborations with several companies.<sup>72</sup>

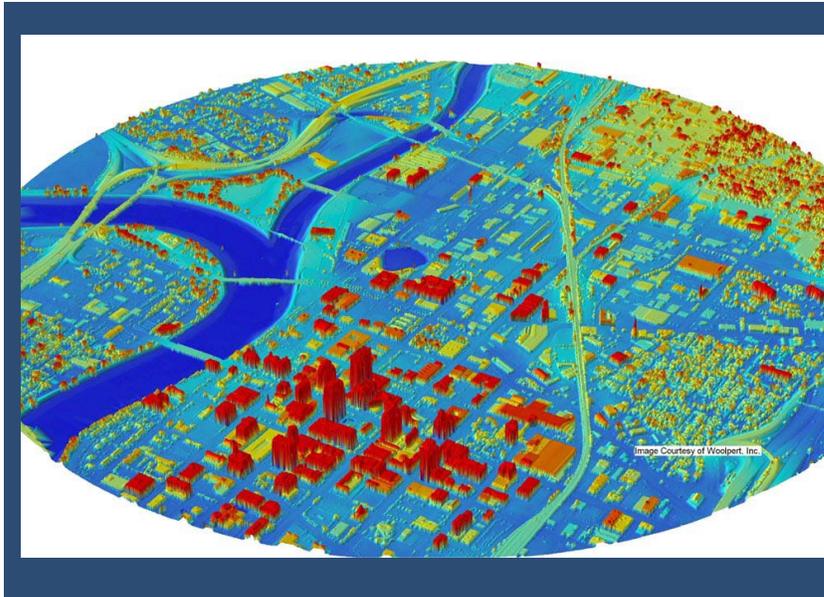
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<sup>72</sup> Dirr, Jacob. "Israeli firm partners with area groups". *Dayton Business Journal*, Friday, March 20, 2009.

<http://dayton.bizjournals.com/dayton/stories/2009/03/23/story5.html?q=idcast>

### Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Overall, IDCAST is working “to create new companies, grow existing companies and attract out-of-state companies to Ohio, to bring sensor technology to market through an alliance of university researchers, the U.S. Air Force and industry,” said Larrell Walters, IDCAST Director. “We have the strength of six universities and can help these companies gain significant and sustainable advantages. All they have to do now is take a short trip to IDCAST and leverage its equipment, expertise and test facilities.”<sup>73</sup>



*Image: Light Detection and Ranging (LiDAR) technology, an optical remote sensing technology that measures scattered light properties to estimate range and other information of a distant target*

*Photo credit: Institute for the Development and Commercialization of Sensor Technology (IDCAST)*

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<sup>73</sup> Robinson, Shawn. “License to Create Jobs”, University of Dayton, July 2, 2007  
<http://www.idcast.com/News/IDCAST%20CRC%20Groundbreaking.aspx>

## OHIO BIOPRODUCTS INNOVATION CENTER: WHERE ADVANCED MATERIALS AND AGRICULTURE MEET

[www.bioproducts.osu.edu](http://www.bioproducts.osu.edu)

The Ohio Bioproducts Innovation Center (OBIC), based at the Ohio State University in Columbus, seeks to capitalize on two of Ohio's long-standing competitive advantages: its agriculture and advanced materials industries and research. OBIC was established through an Ohio Third Frontier award to an alliance of industry and academic institutions focused on the commercialization of renewable, bio-based specialty chemicals, polymers/plastics and advanced materials. Such technology has significant growth potential—a recent report suggests the global market for such bioproducts was \$70 billion in 2003.<sup>74</sup>

OBIC was created in early 2005, through an \$11.5 million Ohio Third Frontier Wright Center of Innovation award to the Ohio State University and a consortium including Albemarle Corporation, Archer Daniels Midland Company, Cargill, Cooperative Business Council, Delphi Packard Electric Systems, the National Renewable Energy Laboratory, the Ohio Polymer Strategy Council, the Ohio Soybean Council, the Pacific Northwest National Laboratory, The Scotts Company, and the U.S. Department of Agriculture. Wright Centers of Innovation are university-based centers of excellence in target technology platforms that have commercial relevance to regional industry clusters. All awards require a 1:1 match of funds.

The Center's stated objective is to develop chemical conversion technologies to develop products from raw materials grown in-state, such as corn and soybeans, in collaboration with universities, private companies, and federal agencies.

OBIC has been instrumental in fostering some ambitious research collaborations in the areas of biomaterials, indigenous rubber, and advanced granules technology. For example, OBIC has partnered with Plastic Suppliers, Inc., a Columbus-based company which has developed a

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<sup>74</sup> Agriculture and Agri-food Canada, Strategic Policy Branch, Research and Analysis Directorate (2007). An Overview of the Canadian Agriculture and Agri-Food System.

cornstarch-based renewable plastic. The two institutions will test renewable plastics with different packaging applications, and Plastic Suppliers expects to commercialize the product by early 2010. The Center has partnered with private companies and other research organizations to further commercialization projects with support from other OTF programs. In 2008, OBIC collaborated with the Ohio State University Research Foundation, Bridgestone Americas Center for Research and Technology, Cooper Tire & Rubber Company, Delta Plant Technologies, and the University of Akron on a proposed project for the development of a domestic source of natural rubber. The project was awarded a \$3 million Wright Project, which provides grants for applied research in technology that has commercial relevance. Specifically, the project seeks to establish the processing system required to produce large quantities of *taraxacum koksaghyz* rubber. This type of rubber, originally from Russia, is used in the tire industry, among others. If successful, this research would create a new industry for Ohio and for the United States and support Ohio's existing tire industry.

Also, in 2008, OBIC introduced The Andersons, Inc., a diversified Ohio agribusiness company developing advanced granule technology, to other big players in granule technology and applications: the Ohio Agricultural Research and Development Center (OARDC), the nation's largest ag-biosciences center; Syngenta Crop Protection; PSB Company, a leading manufacturer of granule applicators; and National Lime and Stone Company, a leading limestone supplier and manufacturer of advanced soil-dispersing granules. Together, this team applied for, and won, a \$5 million Research Commercialization Program (RCP) grant for the development and commercialization of advanced granules and related technologies.

"The grant has allowed our collaborative team to go beyond golf course applications and include horticulture—namely nurseries, floriculture, food (fruits and vegetables), and commodity crops (soy, wheat)," says Anderson. Over the next three years, the team will test multiple technologies and multiple targets at research facilities on The Ohio State University campus. "The collaboration networked by OBIC has brought us to a powerhouse in technical capabilities with OARDC/OSU and encouraged us to expand our market research, see opportunities, and build our thinking into a seven-year commercialization strategy." "The process took lots of discipline to get everything to happen, but the collaboration created value; it literally changed our business plan."<sup>75</sup>

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<sup>75</sup> OBIC (2008), "Collaboration Accelerates Business Development at The Andersons, Inc." OBIC Press Release, <http://bioproducts.osu.edu/index.php/news-room/99-collaboration-accelerates-business-development-at-the-andersons-inc>

## Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The strength of Ohio's agriculture and polymer industries, both national leaders, in concert with strategic investments by the state could position Ohio to be a leader in environmentally friendly biomaterials and bioprocessing technologies in the coming decades. OBIC will be instrumental in this process.

## **OHIO GAS TURBINE LAB: DELIVERING WORKFORCE AND RESEARCH FOR OHIO AVIATION COMPANIES**

[www.gtl.eng.ohio-state.edu](http://www.gtl.eng.ohio-state.edu)

Based at Ohio State University, the Ohio Gas Turbine Laboratory (GTL) is part of the Ohio Center for Advanced Power and Propulsion (OCAPP), a Wright Center of Innovation. The lab was established in 1996 and conducts research to predict heat transfer loading, aerodynamic loading of individual components, and other basic data to help validate design methods. This research is so valuable to General Electric (GE) Aviation and Honeywell that they fund three-quarters of GTL's research and operating budget. Equally significant is the workforce role GTL plays in providing undergraduate and graduate students with hands-on, applied research experience from industry-trained engineers and faculty.

What is today GTL began as Calspan Corporation's Turbine Test Facility (previously Cornell Aeronautical Laboratory, which became Calspan in 1978) in Buffalo, New York. When Calspan Corporation was sold in the early 1990s, researchers working in the Gas Turbine area decided to relocate the effort to a university environment. They narrowed down their list to the University of Illinois at Chicago and OSU in Columbus, Ohio. The decision to move to OSU was directly related to the university's close proximity to the Wright Patterson Air Force Base and Air Force Research Laboratory near Dayton, GE Aviation in Evendale (near Cincinnati), and the NASA Glenn Research Center in Cleveland.

GTL was established at OSU in 1996 through a loan from OSU and the Ohio Department of Development (ODOD). The \$2.3 million loan was used to establish the lab—e.g., laboratory building construction, equipment and other infrastructure—and was repaid in full with interest in May of 2001. All operating funds have always come from Federal grants, industry contracts and other outside sources. The lab's annual operating budget is on the order of \$2 million, and the lab has eight full-time staff (engineers, technicians and a machinist) plus one faculty member.

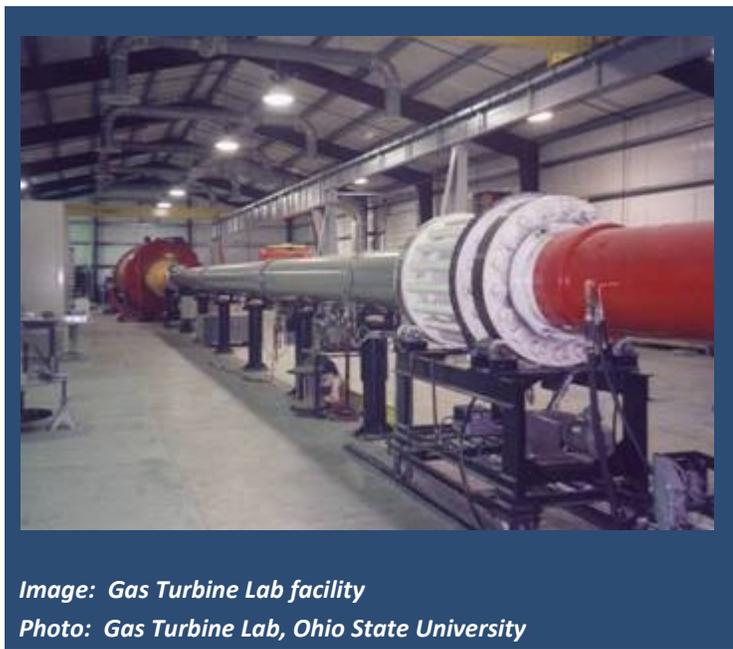
In addition to its research, GTL was the attraction for the establishment of a GE Graduate Program at OSU in 2000. GE sends employees to pursue Masters and Ph.D. degrees from OSU in Mechanical Engineering, with a few pursuing graduate degrees in Material Science Engineering, Aerospace Engineering and Electrical Engineering. In the 2008-09 academic year, OSU had four Ph.D. and 44 Masters students from GE in the program. GE provides a full salary to these employees, as well as

covering the tuition and fees for their graduate studies. Almost all of these students are actively involved in the GTL research group.

While the majority of the lab's operating budget has come from industry, Ohio Third Frontier funds have been instrumental in helping GTL maintain its value proposition to corporate sponsors. In the mid-2000s, GTL was operating two 1939-vintage Ingersol-Rand compressors which were costing approximately \$80,000 a year to maintain. In looking to replace the compressors, GTL's director, Dr. Michael Dunn approached both the university and industry about possible capital investment funds to replace these compressors, but to no avail; each viewed such investments as the role of the other. In 2004, GTL received \$2.4 million funding as part of the \$10.8 million Ohio Third Frontier award to establish the Ohio Center for Advanced Propulsion and Power, a Wright Center of Innovation. Using a portion of this Ohio Third Frontier funding, GTL was able to replace both compressors. With the balance of the Ohio Third Frontier funding, Dr. Dunn was able to purchase 256-channels of very high sampling frequency data acquisition equipment, which is essential to obtaining the quality of data required by the industry and federal sponsors.

Without the Ohio Third Frontier funding, Dr. Dunn believes the OSU Gas Turbine Lab would not be in operation today and neither would the GE Aviation graduate student program at OSU. In addition, two other OCAPP labs, the OSU Gas Dynamics and Turbulence Lab and the OSU Aeronautical and Astronautical Research Lab, would have a difficult time operating in lieu of the Ohio Third Frontier funding, since both require compressed air to operate.

Recently, GE and GTL have collaborated on research proposals to apply for 2009 Ohio Third Frontier Research Commercialization Program funding. The proposals are directed toward the development of new commercial technologies, including the development of an autobalancer device that can be used in place for airplane engines, which could significantly reduce the time an aircraft would be out of service for repairs. A second Ohio Third Frontier Research Commercialization Proposal was prepared describing a new



configuration for internal cooling of high-pressure turbine blades.

Aerospace and aviation companies operate globally. In addition to Ohio, GE operates major aviation R&D facilities in Greenville, South Carolina; Niskayuna, New York; and Bangalore, India. Through both its graduate program and applied research, GTL plays a critical role in keeping GE's long-standing R&D facilities in Evendale, Ohio, anchored to that location.

## **RENEGADE AND MAVERICK: USING TECHNOLOGY TO BRING MORE VALUE-ADDED AIRCRAFT MANUFACTURING TO OHIO**

<http://www.renegadematerials.com/>

<http://www.maverickcorp.com>

Advanced materials is a major industry in Ohio; the state boasts the largest number of primary metals and polymer companies in the country. Long-standing and more recent state investments, made through the Ohio Third Frontier, have supported Ohio advanced materials companies in their efforts to commercialize newer, safer and higher-performance composite materials technologies. These investments are also serving to attract small technology companies to Ohio. Two technology companies—Maverick and Renegade Materials—exemplify the significant mid-term economic impact that linking these technology producers with Ohio's supply chain manufacturers could have.

Formed by two former GE Aircraft engineers/scientists in 1993, Maverick Corporation produces very high-temperature resin systems, called polyimide, which are used in the production of advanced composite materials for aircraft propulsion systems and aircraft structural parts. Maverick's technology is competitive with specialty metal materials because of the high temperatures it can withstand (up to 800°F) and because its resin systems are non-toxic to workers, reducing safety costs for end users. Based in two Ohio locations (Stow, near Akron, and Blue Ash, near Cincinnati), Maverick employs 45 people and, up to now, has sold its resin systems largely to composite materials manufacturers located out-of-state, e.g., California, Texas, etc.

In 2006, Maverick's owners partnered with other investors to form a new company, Renegade Materials Corporation. Renegade will utilize high-temperature resin systems developed by Maverick, as well as other resins developed internally, in the production of pre-impregnated composite fibers, commonly referred to as "prepreg," and adhesive products, thereby completing an integrated supply-chain for advanced materials. Prepreg materials have a variety of applications, including the manufacture of aircraft structures such as wing skins, exhaust fairings, and parts operating in the hotter core of aircraft engines. According to Renegade co-founder and President, Dr. Gray, the decision to locate Renegade in Dayton was made "because of its synergistic proximity

to Wright-Patterson Air Force Base, the University of Dayton Research Institute and the National Composite Center.”<sup>76</sup>

Renegade Materials received critical assistance from state and local organizations in establishing its prepreg manufacturing facility in Springboro, Ohio. The Dayton Development Coalition (DDC) put together a \$5.5 million blended financing package of loans from the Innovation Ohio Loan Fund (an OTF program), the Dayton-Montgomery Port Authority, Montgomery County, City of Springboro and equity assistance from the DDC's Entrepreneurial Signature Program, a Ohio Third Frontier-funded initiative to spur technology commercialization. This financing enabled the purchase of property, construction of Renegade's manufacturing facility, the purchase of prepreg manufacturing equipment, and its AS9100 and ISO-9001 certification programs, and has contributed toward the validation of Renegade's next-generation composite materials for aircraft applications.

The larger value proposition behind Renegade's formation is the potential for shifting more of the value-added aircraft manufacturing activity to Ohio. The state's existing manufacturing base, the end users located in Ohio and the world-class composite and nanomaterials research being conducted in Ohio (e.g., at the Air Force Research Laboratory, the University of Akron, the University of Dayton Research Institute, etc.) make capturing more of this value chain a real possibility. Instead of Maverick selling its resin systems to composite materials manufacturers located out-of-state, Renegade will manufacture the prepreg and other materials in Ohio.

Both Maverick and Renegade Materials, and a number of other small startup companies working on advanced materials technology, have benefited from the tremendous networks of the state's Ohio Third Frontier-and Edison-supported organizations, such as the DDC, Polymer Ohio (an Edison Technology Center) and the Center for Multifunctional Polymer Nanomaterials and Devices (CMPND, an Ohio Third Frontier-supported Wright Center of Innovation based at Ohio State University). These organizations have been instrumental in bringing together the small technology companies, Ohio research institutions, aircraft manufacturers and end users (e.g., U.S. Air Force) required to overcome technical and cost barriers to commercializing advanced composites, nanomaterials and coatings technologies.

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<sup>76</sup> “Renegade Opening Headquarters in Dayton Region,” *The Dayton Regional Quarterly*, Q1 2007, p.3.

<http://www.getmidwest.com/resources/aboutus/newsletter/DDC%20Q1%202007newsletter.pdf>

### Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The Ohio Third Frontier's Research Commercialization Programs, which require university-industry-Federal lab collaboration as an award criterion, have supported this research and commercialization collaboration and linkages. Both Renegade Materials and Maverick have participated in a number of Ohio Third Frontier awards. For example, most recently in 2009, Renegade was a partner on an Ohio Third Frontier RCP award of nearly \$5 million to further develop and manufacture Zyvex Performance Materials-originated carbon nanotubes technology for use in advanced composites. The grant is led by Zyvex, a small Ohio nanomaterials technology company, in collaboration with several partners including aircraft manufacturer Lockheed Martin, materials manufacturer Owens Corning, adhesive and coatings manufacturer Hexion, and research institutions such as CMPND, the National Composite Center, the University of Akron and the University of Dayton Research Institute.

The risk and cost involved in developing these technologies and validating these materials for aircraft applications are so high that they represent a formidable barrier for any one company to undertake. The investment commitment made by the State of Ohio through the Ohio Third Frontier is sending a strong message to innovative companies that resources for technology commercialization and company growth are available in Ohio. Renegade Materials located in Ohio to "help scale-up and commercialize the nanotech materials development work that is being done in the state," and because the founders believe this work "will complete the vision for the Dayton area as a world-leading advanced aerospace materials technology center."—Officially opened in 2008, Renegade Materials is anticipating strong growth over the next five years, expanding from its current 12 employees to 65 employees and \$15 million in revenues.



*Image (L): Renegade prepreg machine.*

*Image (R): Raymund Serranzana, Manufacturing Engineering Manager (L), and John Glidden, Manufacturing Operator and Facility Manager (R), Renegade Materials Corporation, with prepreg material.*

*Photo credit: Renegade Materials Corporation*

## **REXORCE THERMIONICS: RECAPTURING “WASTED” ENERGY**

[www.rexorce.com](http://www.rexorce.com)

Manufacturing consumes a great deal of energy, a significant portion of which is unused and released into the environment as “waste” heat. The ability to capture this energy and convert it into electricity for powering Ohio homes and companies is the basis for the Akron-based startup Rexorce (pronounced “resource”) Thermionics. The company began in April 2007 as a two-person startup housed in the Akron Global Business Accelerator, an Edison Incubator. Today, Rexorce has 20 employees, and is working on raising its second round of venture capital to support the expansions of its proprietary heat engine to a number of heavy industry and automotive markets.

The company's technology is based on a license of a NASA patent for a specialized heat pump originally designed to remove heat from space shuttle rockets. With support through multiple Ohio programs and the City of Akron, Rexorce has extended the core technology to not only remove heat, but also to convert it into usable electricity.

As a promising startup which has demonstrated strong commercial potential and employment growth in a relatively short period of time, the company received several types of assistance from Ohio's network of technology-oriented programs. In addition to being housed in an Edison Incubator in its early days, Rexorce received \$400,000 in seed capital in 2007 from JumpStart, a Northeast Ohio venture development organization which receives funding from the Ohio Third Frontier's Entrepreneurial Signature Programs (ESP). The ESP provides funding for entrepreneurs-in-residence who are paired with high-growth potential technology startups and for pre-seed capital for startup operating expenses. This early-stage risk capital enabled the company to build a 15-kilowatt prototype of its heat engine at the Akron incubator.

In mid-2008, the company was awarded a \$4.3 million grant from the Ohio Third Frontier's Research Commercialization Program. The Rexorce commercialization project, which will continue through 2011, is being conducted in collaboration with a number of other Ohio institutions including Case Western Reserve University and the University of Akron, and companies such as Carbide Derivative Technologies, and Advanced Diamond Technologies.

With the help of this Ohio Third Frontier funding, Rexorce is expanding its laboratory-scale prototype into a 250-kilowatt electrical generating system for deployment at demonstration sites. The company's first demo site will be a Cleveland steel plant where an Alpha version of the system

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## Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

will be installed to capture heat off the main boiler exhaust stream. The Ohio Third Frontier Research and Commercialization Program, which requires a one-to-one funding match, covers operating expenses and capital investments supporting research and development activities.

Rexorce's COO, Phil Brennan, attributes the company's ability to design and launch its innovative system 1.5 years earlier than originally planned to the receipt of commercialization funds through this state program.

The company has been able to leverage another \$9 million in venture capital from private sources and is planning to raise a subsequent \$20 million round of capital in 2010. Rexorce's venture advisors from JumpStart, an Ohio Third Frontier entrepreneurial assistance program, have advised the company through some 25 presentations to venture capitalists.

The passion of Rexorce's two founders, Michael Gurin and Philip Brennan, set the tone for the company's unique culture and commitment to a less carbon-dependant future through the development of renewable energy technology in Ohio. As Brennan puts it, "We have a responsibility as a region to reinvent ourselves by leveraging what we've traditionally been very strong in—manufacturing—in a way that's new and impactful."<sup>77</sup>



*Image: Rexorce co-founders, Michael Gurin (L) and Phil Brennan (R)  
Photo credit: Rexorce Thermionics*

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<sup>77</sup> Johnston, Christopher (2008). "Hot commodity: reXorce Thermionics is making waves," *Inside Business*. 1 November 2008.

## TURNING TECHNOLOGIES: TURNING TECHNOLOGY INTO BUSINESS

[www.turningtechnologies.com](http://www.turningtechnologies.com)

Software and hardware device company, Turning Technologies, has experienced phenomenal growth in its seven-year lifespan. A startup company out of Youngstown, Ohio, *Inc Magazine* ranked Turning the fastest growing privately-held software company in the United States in 2007 and the 18<sup>th</sup> fastest growing privately-held company overall.

Turning began as three founders, Mike Broderick, Mike Crosby and Don Arthurs, working in a single room in 2001. By the end of 2008, Turning employed 165 people having grown to become one of Northeast Ohio's most successful software companies and an international leader in the audience response technology industry. The company's proprietary software and hardware system, TurningPoint, works in Web browsers and with software, such as Microsoft PowerPoint and Excel, to record and measure audience response to a presentation. Turning sells its software and hardware systems to schools, universities, training centers, and corporate meeting environments all over the world.

Turning is a Youngstown Business Incubator (YBI) success story. YBI is one of 13 technology incubators supported by the state's Edison Program. Focused on entrepreneurs and companies in the information technology sector, YBI provides tenants with commercial space, affordable business services, access to capital, and an environment conducive to networking, growth, and market development.

In its early days, Turning Technologies survived on the founders' equity, free YBI work space and assistance, and a 2003 angel investments of about \$150,000. The company's sales have grown from nearly \$500,000 in 2003 to over \$26 million in 2007 representing growth of 5,229 percent. Today, over 10 percent of the company's revenues come from exports. YBI's Director, Jim Cossler, says Turning Technologies is destined to become a billion dollar company based on the organic growth of its sales, the introduction of new products like smart phones and mobile devices, and future strategic acquisitions.

Now able to offer mass market pricing, the company expects to maintain its position as the domestic industry leader in audience response technology for higher education and corporate training, and to increase its presence in the domestic K-12 market and international market. The challenge of promoting the products globally with limited resources has been overcome through new partnerships with large educational publishers and global technology companies, such as

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## Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Thompson Learning, Glencoe McGraw-Hill, AT&T, Apple and others. Turning is also establishing strategic alliances with complementary product and original equipment manufacturers (OEMs) to provide immediate market penetration and awareness.



*Image: Turning Technologies co-founder and CEO, Mike Broderick  
Photo credit: Youngstown Business Incubator*

## WEBCORE TECHNOLOGIES, LLC: AT THE HEART OF WIND ENERGY TECHNOLOGY

[www.webcoreonline.com](http://www.webcoreonline.com)

Based in Miamisburg, Ohio, WebCore Technologies creates and manufactures strong, low-cost, lightweight composite core materials for use in wind, transportation, marine, industrial and defense markets. Founded in 1991, WebCore has grown to 29 employees with annual revenues of under \$10 million. The company anticipates reaching \$50 million in revenues and creating an additional 30 to 50 jobs by 2014. WebCore has rapidly grown to be one of Ohio's leading manufacturers of composite materials for power generation from wind energy.

WebCore has worked closely with the Air Force Research Lab, located at the Wright-Patterson Air Force Base in Dayton, Ohio, and the NASA Glenn Research Center in Cleveland, Ohio. The U.S. Air Force and Navy have awarded WebCore contracts under the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs to explore applications using WebCore's unique materials technology for airfield matting, jet engine containment case, missile fuselage, aircraft door and transportable shelters, among other applications. SBIR contracts have enabled the company to advance its composite material technology, both in terms of design and manufacturing processes, while allowing them to retain their intellectual property.

Two years ago, WebCore's business focus shifted to the wind energy market. The company's proprietary composite core material, branded as TYCOR, is a domestically manufactured, low-cost alternative to balsa wood—the commodity currently used in large utility-scale wind turbine blades. The company has been working with a leading wind turbine blade manufacturer to successfully qualify and certify WebCore's materials for large blades in excess of 40 meters long. Production of TYCOR for wind turbine blades began in mid-2008 and WebCore's business is transitioning from research and development (R&D) to high-volume manufacturing, thanks in large part to significant direct funding from the OTF, including a recent \$989,000 Ohio Innovation Loan to invest in manufacturing and testing equipment.

WebCore has received total Ohio Third Frontier awards of \$3.2 million, beginning with a Technology Action Fund award (now Ohio Third Frontier Action Fund), in 2001, which helped WebCore develop a production process for making its proprietary composite materials and qualifying these products for commercial uses. In 2005, WebCore was awarded a \$175,000 Ohio Research Commercialization Grant to commercialize TYCOR. In 2007, WebCore received \$1.3

### Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

million of a total \$8 million Research and Commercialization Program grant to a consortium led by the Center for Multifunctional Polymer Nanomaterials and Devices (CMPND) at Ohio State University (OSU) to commercialize composite materials for wind energy and other applications. CMPND, an Ohio Third Frontier-funded center of excellence in advanced materials, assembled this consortium which includes OSU, WebCore, Owens Corning, General Electric, University of Dayton, and the National Composite Center. In 2009, WebCore further received a \$1 million Ohio Third Frontier Advanced Energy Program (TFAEP) grant award to commercialize TYCOR in wind turbine blades.

According to WebCore, the Ohio Third Frontier RCP and AEP grant awards, in particular, have been critical in transforming the company into a commercial manufacturer and supply-chain partner in the wind energy industry. In addition, the company has been able to leverage Ohio Third Frontier funding to secure federal grants and venture capital financing. In 2008, WebCore received a Phase II SBIR grant from the U.S. Department of Energy (DOE) for \$750,000. The company also secured \$1 million in seed funding through the Dayton Development Coalition ESP Venture fund, a Ohio Third Frontier supported entrepreneurial assistance program.

Last year, the wind turbine market represented a significant part of WebCore's total revenue, but from 2009 onwards, WebCore anticipates that the wind energy market will comprise a lion share of its revenues. "The Ohio Third Frontier Program investment has helped our transition to the new market become real so quickly. It was a timely investment that helped us enter the wind turbine business in less than two years, enabling WebCore to grow from being an entrepreneurial R&D company to a successful manufacturer of advanced materials for the alternative energy market," said Dan Hutcheson, President of WebCore.



*Image: Dan Hutcheson, president of WebCore Technologies, holds a cross section of a wind turbine propeller, fabricated with composite panels from WebCore Technologies.*

*Photo Credit: E.L. Hubbard, Dayton Daily News.*

## WIRELESS ENVIRONMENT: "GREEN" LIGHTING FOR THE DARKEST PLACES

[www.mrbeams.com](http://www.mrbeams.com)

Wireless Environment, is a Northeast Ohio company making a range of "smart," energy-efficient lighting products. The company's lighting fixtures are based on light-emitting diode (LED) technology for hard-to-reach places, like stairways, attics, closets, garages, decks, and back yards. Current products include a battery-powered LED spotlight and a motion-sensing LED stairwell light.

LEDs are made from semiconductor materials. They require less power than conventional forms of lighting, last significantly longer, and are more environmentally-friendly since they are highly efficient and don't contain mercury light fluorescent lighting. Today, LED technology is increasingly found in high-brightness applications, such as traffic lights and backlights in car dashboards. However, within the next 10 years experts anticipate that LEDs will very likely replace incandescent and compact fluorescent lighting. Philips Lighting Co., the world's largest light bulb maker, plans to stop selling incandescents by 2016.

In developing its proprietary technology, the Wireless founders targeted different LED applications and markets than the large lighting companies, like Philips or General Electric. Instead of focusing on the LED technology itself, Wireless has been building its intellectual property around two important aspects of wireless lighting. The first application is wireless battery operation of LED lights which offer off-grid power (no electrical cord) that can be relied on in power outages and in places that are hard to reach with electrical cords. The second application is wireless controls for dimming, activation, setting timing, photocells, and motion sensing. The company's products have integrated electronics and programmability that give users increased control over features such as brightness.

In 2008, Wireless made \$100,000 in revenue from online and hardware store sales of its products sold under the Mr. Beams™ brand name. The company forecasts revenues of \$1 million by the end of 2009. As one of the Wireless founders said in a magazine interview, "Maybe it was luck, but

we've hit on a big growth area that also promotes energy efficiency.”<sup>78</sup> The global LED market is forecasted to grow to a \$12 billion market within the next four years.

Wireless Environment is headquartered in Elyria (Lorain County), Ohio. In its early days, the company received a product development loan from Cuyahoga County, Ohio, to validate its business concept and assist with startup. In 2007, Wireless Environment moved into the Entrepreneurship Innovation Institute (EII) on the Lorain County Community College (LCCC) campus as a “GLIDE” client company. GLIDE—the Great Lakes Innovation and Development Enterprise—is one of 13 Edison technology incubators providing business assistance to startup companies. In addition to the entrepreneurial assistance Wireless received from GLIDE, the company also received pre-seed capital investments from GLIDE and the LCCC Innovation Fund to continue to develop its technology and products.

In 2008, Wireless received a \$400,000 seed capital investment from JumpStart, a venture development organization receiving funding support from the state's Ohio Third Frontier Entrepreneurial Signature Program. Wireless is using the JumpStart investment to further develop patents and prototypes. The fact that these funds have invested in the company early-on has provided Wireless credibility, and the company has now attracted additional downstream venture funding from the private sector.

Wireless founders David Levine and Michael Recker stated in a recent magazine interview that state-supported programs, like GLIDE, have allowed Wireless to “build a network more powerful than any corporate infrastructure” and to make important strategic business decisions based on those connections which have enabled them to compete with larger, more established companies.<sup>79</sup> They're appreciative of the support they've received to get the business off the ground, and out of gratitude, they've offered a 50 percent discount on their products to Lorain County residents.

New products being planned for next year include two new models of portable lighting fixtures and a light that can screw into standard outdoor lightbulb sockets that will detect darkness as the sun sets and turn itself on.

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<sup>78</sup> Allyn, Scott (2008). “Wireless Environment develops battery-powered lighting products appropriately called Mr. Beams,” *The Morning Journal*. 21 Dec. 2008. <http://www.mrbeams.com/index.asp?PageAction=Custom&ID=38>

<sup>79</sup> Hampshire, Kristen (2008), “Big Ideas,” *PULSE—Lorain County Magazine*. Winter 2008.



*Images: Wireless Environment co-founder and President, David Levine, and Wireless outdoor portable fixtures which debuted in April 2009*

*Photo Credit: JumpStart and Wireless Environment, LLC.*

## ZYVEX PERFORMANCE MATERIALS: CREATING STRONGER, LIGHTER COMPOSITES WITH NANOTECHNOLOGY

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Zyvex Performance Materials Inc. (ZPM), based in Columbus, uses nanotechnology to create high-performing composite materials. ZPM's proprietary technology enhances conventional composites, making them lighter, stronger and tougher. Applications for ZPM's nano-enhanced composite materials encompass all the applications where composite materials are currently used, such as golf shafts, baseball bats, and boat masts, as well as aircraft and auto body parts, making them more fuel-efficient environmentally friendly. ZPM received an R&D 100 Award for its nanomaterials in 2005, a mark of excellence recognized by industry, government and academia as proof that the product is one of the most innovative ideas of the year.

ZPM was created in April 2007 when it spun off from Texas-based Zyvex Corporation. Locating in Columbus was a strategic decision to be close to the epicenter of Ohio's advanced materials industry. A \$1 million grant from the Ohio Third Frontier's Targeted Industry Attraction (TIA) Program also served as a significant incentive to attract ZPM to Ohio, edging out other locations under consideration, such as Texas, Oklahoma, New Mexico and California. Other key factors that drew ZPM to Ohio included support from PolymerOhio, an Edison Technology Center, and the Center for Multifunctional Polymer Nanomaterials and Devices (CMPND), an Ohio Third Frontier Wright Center of Innovation.

PolymerOhio and CMPND have been invaluable in ZPM's transition to Ohio by assisting the company in determining its location within Ohio and finding suitable facilities. ZPM is currently located in the same campus as TechColumbus, an Edison incubator, and this proximity allows the company to work with some of the advanced materials tenants of the incubator. PolymerOhio and CMPND also helped to connect ZPM to the advanced materials business network for supply chain support, materials, transportation services, and potential business partners. For example, ZPM did not have a manufacturing capability for the technology it had developed. Instead of investing money in its own manufacturing equipment, PolymerOhio connected the company with Akron-based APV Engineered Coatings, which then agreed to manufacture the products that ZPM developed.

"This is a win-win situation. APV was able to expand their business, and, instead of investing our money in equipment and permits, we were able to increase our hiring," commented Lance

Criscuolo, president of ZPM. "This example demonstrates why we moved here: there is already a strong advanced materials infrastructure in place, and almost our entire supply chain is in Ohio."

In collaboration with CMPND, PolymerOhio, and University of Dayton Research Institute and other organizations, Zyvex was recently awarded a \$4.9 million grant by the Ohio Third Frontier's Research Commercialization Program to further develop and produce carbon nanotubes which will be used in its composites.

Looking forward, ZPM projects annual revenues of \$50 million to \$80 million and 50 to 100 employees by 2014. The company currently has \$1 million to \$4 million in sales, and employs a total of 20 research scientists, engineers, and sales and marketing professionals, with 15 based in Ohio. The company has entered into agreements with a number of companies which are likely to expand its product offerings. These include a 2008 agreement with Lockheed Martin to provide nano-enhanced composite materials for military applications and a 2009 agreement with PolyOne Corporation, a polymer materials company headquartered outside of Cleveland, to produce nanomaterials for use in medical packaging and consumer electronics. ZPM further extended the reach of its products by entering into distribution agreements with Rudolph Bros's & Co, an Ohio-based distributor of composites with distribution networks across the eastern United States, and Arkema, a key distributor for nano-enhanced liquid epoxy resins in the European market.

"Locating in Ohio has been vital to the development of Zyvex Performance Materials," said Criscuolo. "Ohio programs like the Target Industry Attraction grant and Ohio Third Frontier have helped fund our operations, and the concentration of talent and polymer companies here is very beneficial to our efforts to get our nano-enhanced materials out into the marketplace."<sup>80</sup>

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<sup>80</sup> [http://www.zyvexpro.com/docs/Zyvex\\_Nano-Enhanced\\_Tech\\_Release.pdf](http://www.zyvexpro.com/docs/Zyvex_Nano-Enhanced_Tech_Release.pdf).



*Photo (left): Golf shaft, manufactured by Aldila using Zyvex composite materials and used by PGA Tour players.*

*Photo (right): Bicycle, manufactured by Aegis using Zyvex composite materials.*

*Photo credit: Zyvex Performance Materials*