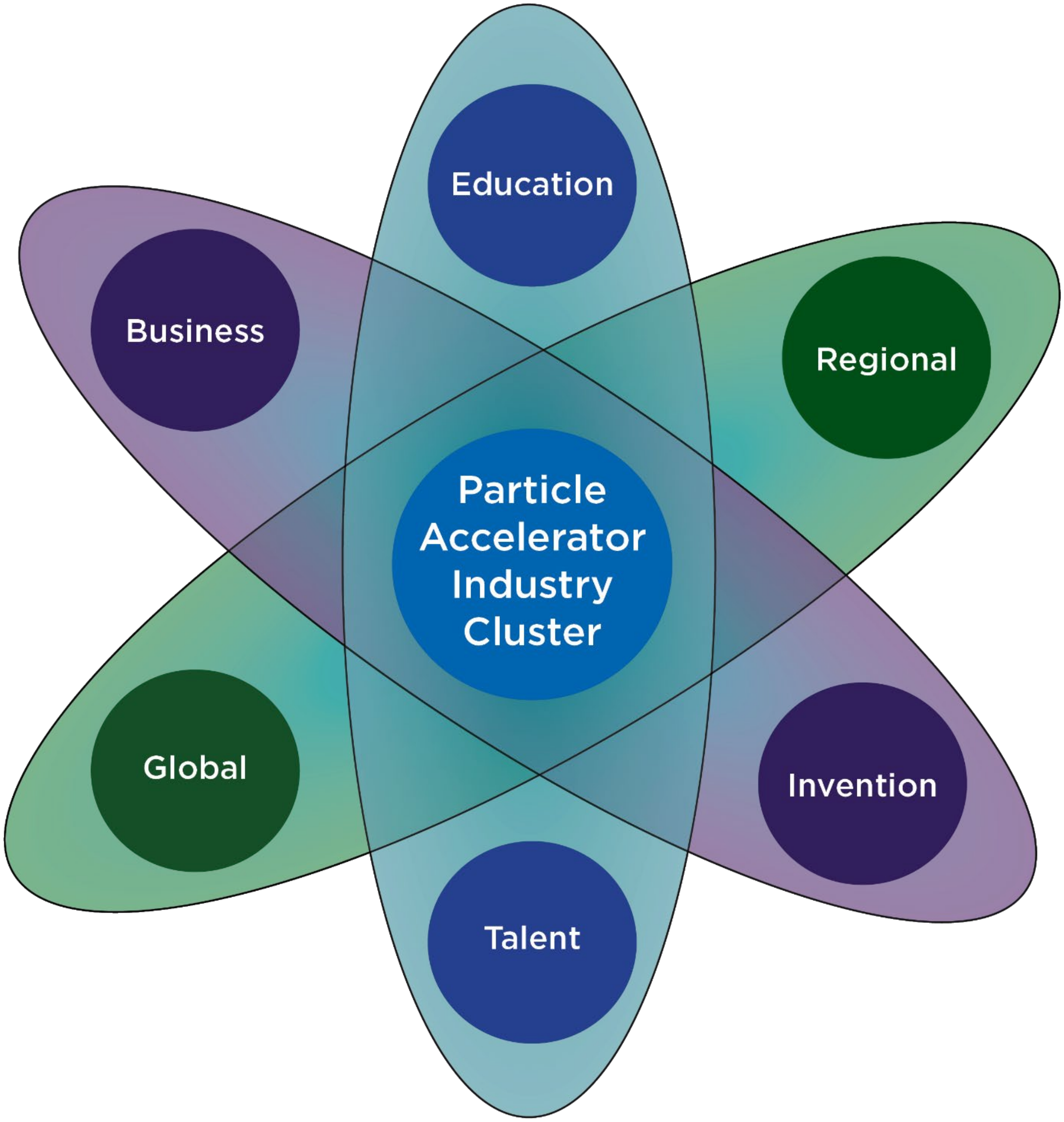
LANSING REGION PARTICLE ACCELERATOR CLUSTER

SUPPLY CHAIN ANALYSIS AND ECONOMIC DEVELOPMENT STRATEGY FOR AN EMERGING PARTICLE ACCELERATOR INDUSTRY IN THE LANSING REGION

2018

MSU CENTER FOR COMMUNITY AND ECONOMIC DEVELOPMENT [CCED]

LANSING ECONOMIC AREA PARTNERSHIP [LEAP]



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Acknowledgments

This project is the result of years of prior research and leadership and was supported by a U.S. Department of Commerce, Economic Development Administration Technical Assistance grant.

Throughout the course of this project, the research team was guided by a diverse stakeholder Advisory Committee, which offered its expertise and network connections as they pertained to the study. The members of this committee include Andrew McColm, Spartan Innovations; Cal Coplai, AICP, Ford Smart Mobility, Ford Motor Company; Daniel Medrano, McLaren Health Care; Dr. David Closs, Department of Supply Chain Management, Michigan State University; Dr. John Vincent, Ionetix Corporation; Keith Lambert, Lansing Economic Area Partnership (LEAP); Lori Mullins, Michigan Economic Development Corporation (MEDC); Mike Zamiara, Niowave, Inc.; Mikhail Murshak, Loomis Law Firm; Dr. Raymond DeVito, CLP, Michigan State University Innovation Center; Dr. Terry Grimm, Niowave, Inc.; Terence O'Neill, Michigan State University Library; and Dr. Zachary Constan, FRIB Outreach Coordinator, Michigan State University.

Research Team

The research team was led by John Melcher, Associate Director of the MSU Center for Community and Economic Development, and included Managing Editor Lauren Ross, Project Coordinator Nicholas Joblonski, and Research Assistants Bruce Allen, Rebekah Church, Sydney Jackson, Grace Michienzi, Ashita Nichanametla, Joshua Pichardo, Tommaso Randazzo, Tristyn Walton, and Joshua Weidenaar. Additional contributions were made by Jennifer Bruen, John Schweitzer, and Rex LaMore.

MSU Center for Community and Economic Development

Michigan State University (MSU) is the nation's premier land-grant university, and in that tradition, the MSU Center for Community and Economic Development (CCED) is committed to developing and applying knowledge to address the needs of contemporary society.

Our mission is to advance MSU's land-grant mission by creating, applying, and disseminating valued knowledge through responsive engagement, strategic partnerships, and collaborative learning. We are dedicated to empowering communities to create sustainable prosperity and an equitable knowledge economy.

Since its establishment in downtown Lansing, Michigan in 1969, CCED, in partnership with public and private organizations, has developed and conducted numerous innovative programs that address local concerns while building the capacity of students, scholars, and communities to address future challenges. Student, faculty, and community involvement is a crucial element of the CCED's mission. The CCED focuses its resources on the unique challenges of distressed communities throughout the state of Michigan.

In carrying out the mission of the CCED, we:

- Create and support an innovative environment for collaborative learning in community and economic development
- Provide training and direct assistance designed to increase the capabilities of community-based organizations, private enterprises, and public institutions
- Conduct research that assists in the development and implementation of effective problem-solving strategies
- Provide a multidisciplinary capacity to respond to the complex, interrelated issues of distressed communities
- Promote and expand MSU's capacity to provide needed training, direct assistance, and research to address the issues of communities

Lansing Economic Area Partnership

The Lansing Economic Area Partnership (LEAP) is a coalition of Lansing area leaders committed to building a prosperous and vibrant region where businesses can thrive. To that end, LEAP helps entrepreneurs start new businesses, works to grow existing businesses, and attracts new businesses to the region, while also focusing on building a better place through targeted real estate redevelopment and place-making projects and initiatives. LEAP is one of ten Collaborative Development Councils (CDCs) across Michigan as designated by the Governor and Michigan Economic Development Corporation (MEDC). LEAP represents the entire Lansing market that includes Ingham, Eaton, and Clinton counties, and also has contracts for micro-level services with the City of Lansing, Ingham County, and the Lansing Regional SmartZone.

LEAP is a private, not-for-profit 501(c)(6) organization. It is financially strong, enjoying broad support across the private and public sectors with a Board of Directors made up of a wide variety of CEOs, university/college presidents, and political leaders of the region. Funding for LEAP is provided by both the private and public sectors. LEAP currently has a staff of 13 and growing.

Lansing Region Particle Accelerator Cluster Advisory Committee

In order to leverage the combined expertise of a number of stakeholders in the particle accelerator industry, the project team created an Advisory Committee to help guide the research. Advisory Committee members provided assistance by:

- Advising the research team as they expanded, refined, qualified, and mapped a list of accelerator-related companies that would be ideally suited for the region
- Facilitated networking with key local, state, and national stakeholders
- Provided other assistance and guidance as appropriate

Introduction

Historically, Michigan's economy was dominated by the logging, mining, and agriculture industries and later by the automotive, manufacturing, and tourism industries. Over the last several decades, however, as the nation and the world experienced a shift toward information and technology-based industries, Michigan has struggled to define its place in the new global economy. Michigan has struggled to re-equip its workforce for the needs of the 21st century due to a mismatch of transferrable skills from a historically manual-labor-based economy to a now intellectual and technology-driven economy known as the "knowledge economy."

The knowledge economy is driven by discovery and innovation which puts a premium on the value of research institutions in local and state economies. Michigan State University's research capacity, coupled with a significant private sector research capacity, makes the Lansing region a legitimate contender in the global knowledge economy. This becomes most obvious when considering the development of the Facility for Rare Isotopes Beams (FRIB) at Michigan State University.

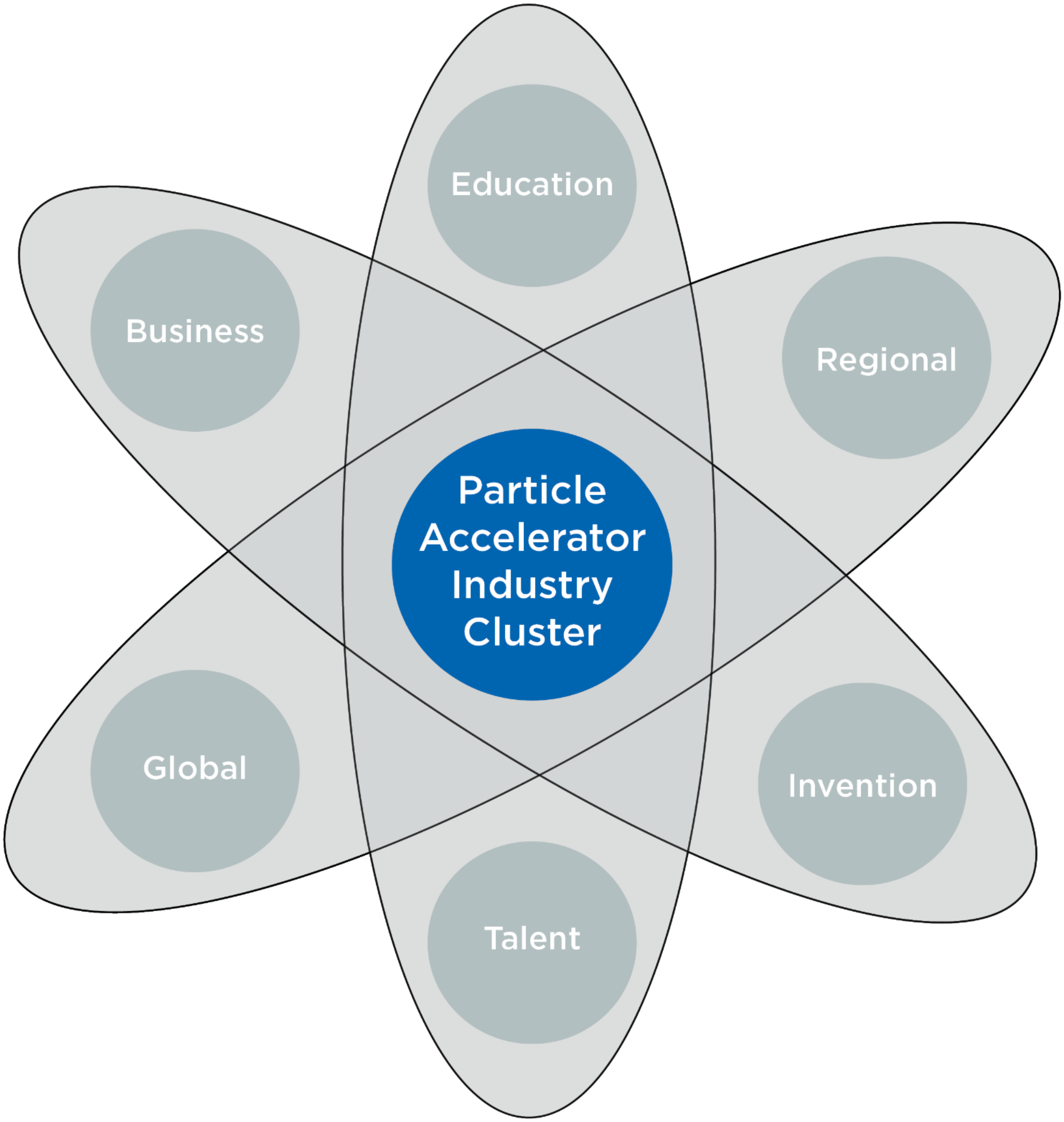
When operational, FRIB will stand apart from other research facilities around the globe with its ability to create and study new isotopes that are not normally found on Earth. This opportunity is built on a history of nuclear physics research which began at MSU in 1958 with the hiring of Dr. Henry Blosser, a young nuclear scientist then working at Oak Ridge National Laboratory. Notable accomplishments include the first accelerated proton beam in 1965, the establishment of the National Superconducting Cyclotron Laboratory (NSCL) in 1980, and recognition as the number one nuclear physics graduate program in the country since 2010 (U.S. News & World Report).

In addition to this rich history, two private sector businesses were established in the Lansing region as a direct result of the MSU research capacity. Niowave Inc., was established in 2005 by a former NSCL researcher, and Ionetix Inc. was established in 2010.

In 2004, a team of nuclear physics researchers began an effort to host the Facility for Rare Isotope Beams (FRIB) at MSU. In 2008, the US Department of Energy (DOE) awarded MSU a $550 million grant to establish FRIB with construction expected to be completed in 2020, and the facility expected to be operational by 2022 at a total cost of $730 million. FRIB is expected to create a total of 390 direct jobs with an average total state-wide labor income of $55.6 million.

The implications and opportunities related to this investment for the Lansing region seem to be significant; however, understanding these opportunities and being prepared to make the most of it is a challenge that government, business, and higher education leaders must embrace. The capacity to design, build, and operate particle accelerators is a proven strength of the region. The ability to supply the labor, technical support staff, and researchers is also a proven strength. The challenge that remains is understanding the factors driving economic development in the global knowledge economy and translating that understanding into strategies that can best nurture the economic opportunities emerging from this dynamic nuclear physics research and the particle accelerator knowledge base. This report is an attempt to build on past research and provide an understanding with recommendations to foster the development of an economic cluster based on the powerful nuclear physics knowledge base abundant in the Lansing region.

Project Overview



Project Overview

The MSU Center for Community and Economic Development (CCED) first partnered with the Lansing Economic Area Partnership (LEAP) in 2014 to sponsor a MSU Urban Planning student practicum team to explore potential economic opportunities that might relate to the FRIB investment. Recognizing the particle accelerator industry's capacity, LEAP (with funding from the Michigan Economic Development Corporation) contracted Kuntzsch Solutions to develop a supply chain business development strategy and a set of recommended marketing and outreach strategies for the region's particle accelerator industry brand.

In December 2016, researchers with MSU's Product Center Food-Ag-Bio Center for Economic Analysis, Steven Miller and John Whims, published a report titled, *Estimated State and Regional Economic Impacts of the Facilities for Rare Isotope Beams,* which outlines the potential state and regional impacts of the construction and operation of FRIB. This report details the impact of federal, state, and university allocations to FRIB as they relate to the facility' s construction and operation, but notably omitted the impact of potential spinoff businesses related to particle accelerator technology.

In 2017, MSU/CCED partnered again with LEAP and was funded by a grant from the US Department of Commerce Economic Development Administration to build on past research and develop recommendations for regional stakeholders to foster a particle accelerator industry cluster in the Lansing region. The research team identified four main areas of focus:

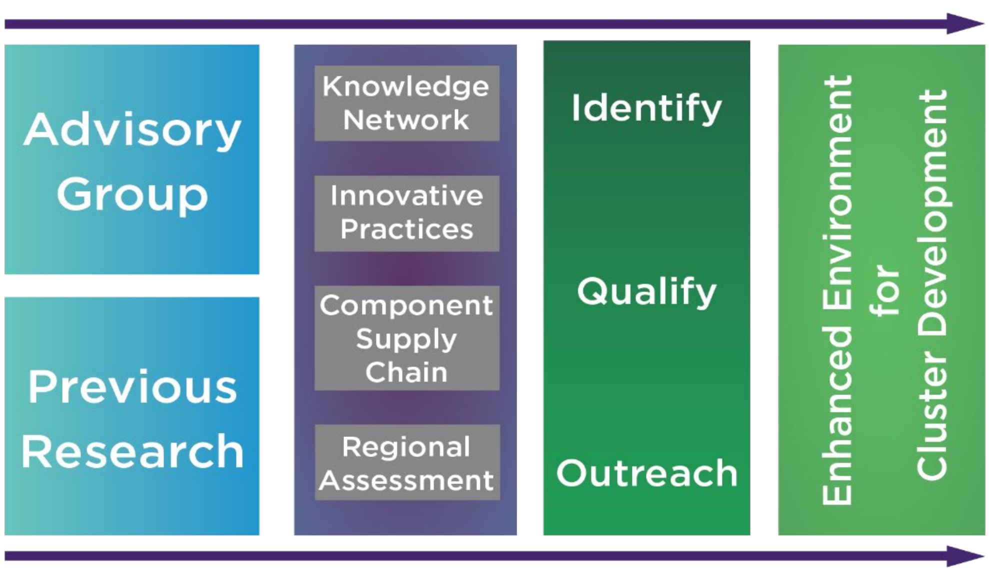


Figure 1: Diagram showing the process of the research project.

Accelerator Component Supply Chain Analysis

Building on previous research, expand a list of accelerator related companies that can be prioritized in a business retention and attraction strategy for the region, with guidance from the Advisory Committee. Identified companies related to the major sub-systems of particle accelerators assembled in a data base are maintained by LEAP (see Figure 1).

Knowledge Supply Chain and Network

Identify the skills and talents needed in the particle accelerator industry and assess the current employment and training capacity of the region to fill potential positions in the industry. Facilitate the development of a strategy to "pipeline" or bridge training or education that could result in more employment within the industry (see Figure 1).

National Innovative Practices

Conduct a scan to identify communities and economic development organizations who have successfully collaborated with accelerator research facilities, and who have incorporated the accelerator industry into their economic development strategies. Special attention is given to national research facilities similar to FRIB to identify promising practices that could serve as models for the Lansing region. Based on this assessment, identify actions that can be taken to enhance the economic opportunities related to the particle accelerator industry in the region.

Regional Assessment

Identify regional indicators that best reflect the region's assets as they relate to the particle accelerator cluster development and foster an innovative regional ecosystem. Indicators are organized around three themes; population demographics, economic make-up, and communication and transportation infrastructure.

Each focus area is detailed in its respective section, with the methodology, findings, and recommendations to improve the identified assets. These recommendations will help regional leaders and stakeholders identify opportunities for research and business development that will leverage the region's powerful nuclear physics knowledge and talent base.

An Emerging Lansing Region Particle Accelerator Cluster

In recognizing MSU's rich history and accomplishments related to particle accelerator science, it is logical that innovative ideas and capacity would be translated into business development opportunities. As a result, the Lansing region is the home of two accelerator companies in addition to the particle accelerators at MSU. Each of these companies meet a specific opportunity need in the industry but utilize similar components and are based on the same science.

The following is a brief discussion of the two private sector companies that are key players in the regional particle accelerator cluster.

Niowave Inc.

Niowave was founded in 2005 by former National Superconducting Cyclotron Laboratory researcher, Terry Grimm, and a group of private investors. Since then, Niowave has become a world-wide leader in research, development, manufacturing, and operation of superconducting electron linear accelerators. Their platform technologies are their particle accelerators and subsystems which are utilized for the following applications: Medical & Industrial Radioisotopes, Radiography & Active Interrogation, Sterilization & Advanced Manufacturing, and Nuclear Energy Advanced Technologies. Based in Lansing, MI, Niowave is one of few companies in the world with the capability to design, build, test, and commercialize superconducting electron linear accelerators.

Ionetix, Inc.

Since its initiation out of San Francisco, California in 2010, Ionetix Corporation has been on the cutting edge of development, manufacturing, and distribution of superconducting accelerator technology. Initially developed at the MIT Plasma Fusion Laboratory, this innovation has evolved into a compact, affordable, and user-friendly cyclotron for the production of PET (positron emission tomography) radioisotopes. Ionetix Engineering based in Lansing, Michigan designs, assembles, and tests the compacts cyclotrons at their facility. Due to this design aspect, the system can be installed directly in a clinic or hospital and provide patients with on-demand radiopharmaceutical (radioactive compound used for diagnostic or therapeutic purposes). Ionetix is pleased to offer specific services when partnering with them such as; radiopharmaceutical production, risk mitigation, flexible design, regulatory navigation, expert training, reimbursement assistance, and marketing support.

Summary

Each company utilizes several of the same or similar components and produces some of the same or similar outputs in their processes. By supporting a collaborative relationship between these facilities, the Lansing region can cultivate a cluster economy around their activities, thereby increasing the economic diversity of the state. This report seeks to identify the opportunities for growing this cluster through a supply chain analysis, identification of replicable economic development models, and recommendations to build regional capacity.

Regional Cluster Development in a Global Knowledge Economy

In order to build upon the MSU's assets (including the FRIB investment) and the two existing businesses in the Lansing region it will be helpful to understand the fundamentals of cluster development and management. An analysis of cluster dynamics is presented here, including drivers of cluster formation and economic impacts. These elements will provide a foundation on which to assess the regional capacity to support a particle accelerator cluster.

For the purposes of this report, clusters are defined as geographically-based concentrations of multi-industry companies and institutions, related by a common product (Porter, 1998). Economic development policies and industry initiatives have sought to capitalize on the benefits that occur when cluster economies thrive, namely higher rates of job and wage growth, as well as increases in innovation as indicated by high levels of patent requests (U.S. Cluster Mapping Project).

Cluster theory is still somewhat reliant on the old industrial ideologies, stressing the importance of clusters for optimizing supply chain logistics in a region. While this is important, it is increasingly argued that knowledge exchange and spillover effects are more integral to the productivity and success of a cluster in the knowledge economy (Günther & Meissner, 2017).

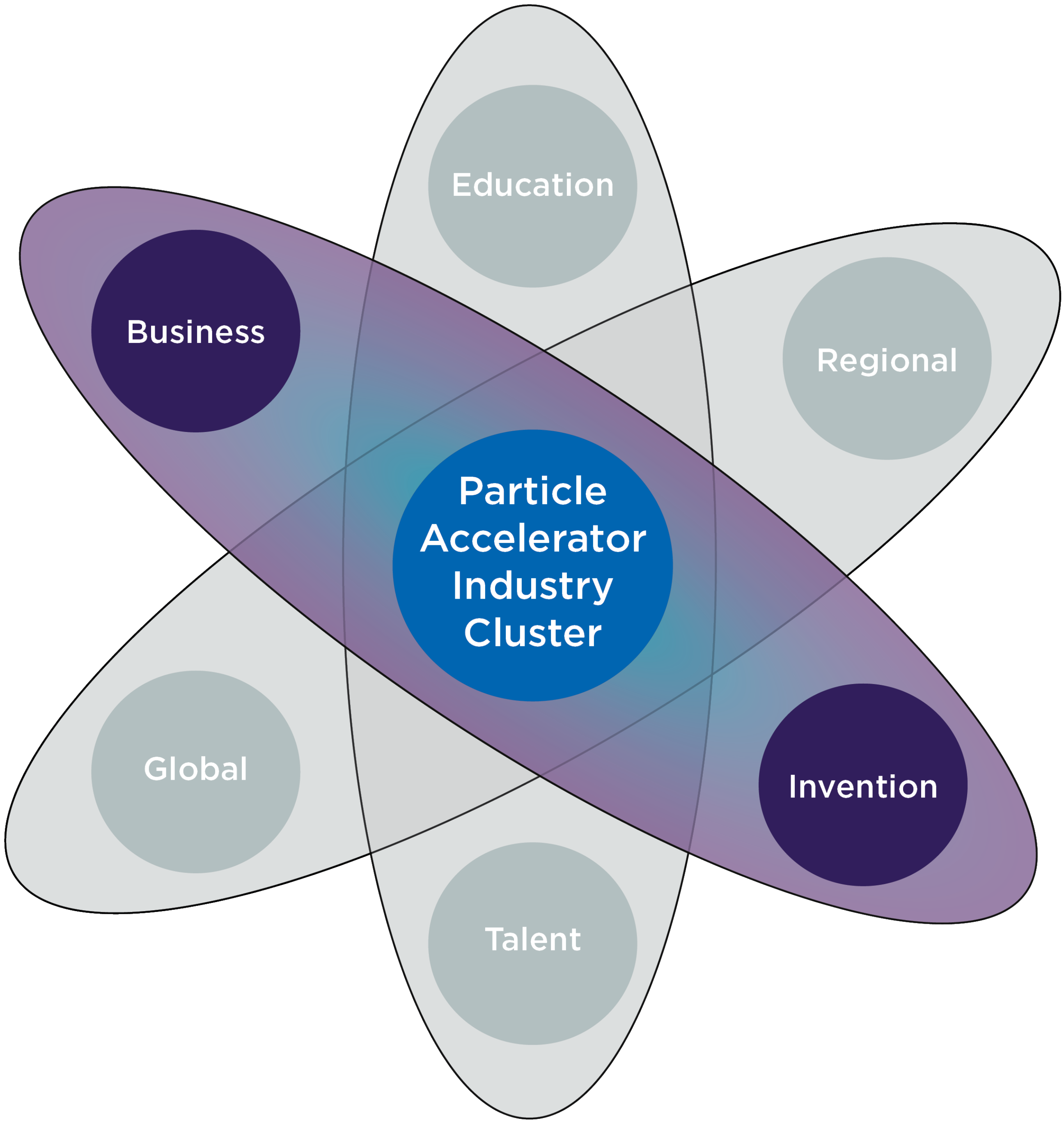
As the world experiences a shift toward an increasingly knowledge-based economy, the understanding of the value of knowledge as an economic asset has grown. Understanding how knowledge works in a cluster is vital to understanding specific relationships between key stakeholders within a region.

Knowledge exchange happens between people and organizations, generally in two ways; explicit knowledge which can be written or conveyed through some form of media, and tacit knowledge which is conveyed from person to person, that is hands-on rather than book taught. Think about learning to ride a bike. You can read about how it all works together (explicit knowledge) but to do it requires other information (tacit knowledge) that cannot be conveyed through writing.

Explicit knowledge tends to be mobile, meaning that it can be shared globally, whereas tacit knowledge is geographically bound and is shared person-to-person or organization to organization. Within clusters, the cost of transferring knowledge from one person to another is much lower because of geographic proximity. This is especially important when skilled workers, or those who have years of hands-on experience working in the field, are able to pass their learned knowledge to talented workers, or those who are in entry-level positions with degrees or certifications but not much hands-on experience. Even when employed by different companies, cluster dynamics allow for the efficient sharing of this knowledge throughout the region.

Clusters with highly skilled labor create a demand for multiple categories of talented, certified workers. Clusters become competitive areas for wages and become an important place not only to learn new skills that may be difficult to learn elsewhere but also a place where workers tend to earn more. Because of these efficiencies, clusters generally have a strong positive impact on regional economic performance and contribute to an innovative ecosystem where industry, policy makers, and research institutions work collaboratively toward creating innovative products and processes.

Accelerator Component Supply Chain



Accelerator Component Supply Chain

Particle accelerators are used for many different applications ranging from sterilizing equipment to producing medical isotopes. Depending on their purpose, particle accelerators are designed for specific applications but share a basic set of components and systems that are purchased and/or fabricated as a part of the design and build process. Given the particle accelerator production capacity of the Lansing region, the opportunity to attract suppliers and producers to the area has long been a goal of the economic development community. The private sector businesses in the region are interested in any assistance that could help them create more efficient supply chains thus improving their overall competiveness.

Methodology

In 2015, LEAP contracted with Kuntzsch Solutions to create a business development strategy for the particle accelerator industry. Using methods based on standard industrial classification codes, 181 businesses were identified and prioritized. In 2017, LEAP migrated the list to a new proprietary database named Gazelle.ai to support its business development work which coincided with the beginning of this project. Using Gazelle.ai, additional businesses were identified.

A description of the methods employed and a discussion of the limitations of the methods are included in this section, along with a description of the major components and systems that compose a particle accelerator supply chain. Interviews were conducted with representatives from Niowave, Ionetix, and MSU to discuss their supply chain needs and garner their insights for developing the particle accelerator production capacity of the region.

Findings

The supply chain for the production of particle accelerators is diverse and technical. The use of standard industrial classification systems proved to be insufficient to identify business development opportunities. The use of Gazelle.ai in combination with key words and phrases based on the North American Industrial Classification System (NAICS) proved to be beneficial in identifying component supplier companies particularly ones at an early stage of growth and expansion.

The supply chain for particle accelerator components is national and international in scope. Local business development opportunities for component suppliers are limited due to the low volume of demand for highly technical products.

The diversity of applications for particle accelerators requires a great deal of customization in design and production which creates opportunities for local business development and employment. Low volume, technically oriented production capacity is a proven local strength and is closely connected with the knowledge and talent base of the region.

The low volume of particle accelerator production contributes to a low volume of patents being generated. Although this is a highly technical field, it should not be expected to generate a high volume of patents. The greatest potential for patents may be more closely related to the application of the accelerator rather than production of the accelerator. In other words the innovation value may be higher with the discovery of a medical isotope rather than the machine that produces it.

Understanding the Accelerator Component Supply Chain

In order to support the emerging accelerator-based industry, an understanding of the major accelerator components/systems and their supply chain is important. The basic component functions are described at a macro-level to give a broad look at how accelerators operate and to serve as a basis for a supply chain analysis. The basic functions of a linear accelerator can be grouped into four main areas:

First at the ion source, the starting element goes through a process of ionization, where electrons are removed, creating a charged particle, which is then pushed through transport pipes by the use of electric and magnetic fields creating a beam that is injected into the linear accelerator.

Second, the accelerator pushes the beam of charged particles down the transport pipes through superconducting cryomodules increasing the particles speed.

Third, the beam strikes a target with such intensity that the accelerated particles break off into isotopes or variants of the original element.

Fourth, and mainly for research purposes, detectors collect data that is used to measure the properties of the isotopes produced. See figure 6.

(For an in-depth look at how FRIB functions, watch this informative video: https://youtu.be/EPG919IJK8s).

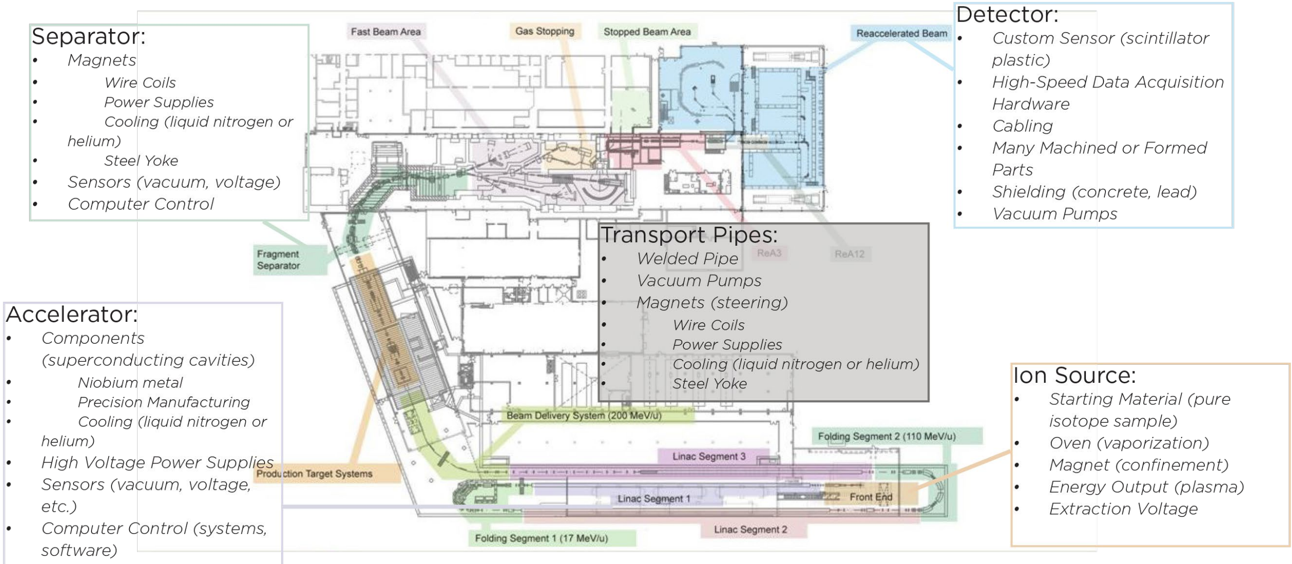


Figure 2: Linear Accelerator Diagram and Components
Source: MSU National Superconducting Cyclotron Laboratory

These functions can be further refined into seven basic components or systems which can serve as a basis for understanding the supply chain. These components/systems are: superconducting magnets, cryogenic systems, clean room support, vacuum systems, electron beam welding technologies, accelerator systems & radiofrequencies, and control systems. An explanation of the core components and how they fit into the basic function of a linear accelerator is included here.

MAGNETS

The magnetism of an accelerator is controlled by running an electric current through the coils. When the coils are cooled with liquid helium, they become superconducting magnets. Superconducting magnets have many advantages over a generic electromagnet, including a lower energy consumption, a higher magnetic field, and occupying a much smaller space. Superconducting magnets are used to maintain a specific beam trajectory in a particle accelerator. The efficient energy transfer and steady magnetic field guide the beam of charged particles through the transport cavity reaching the target with the desired element.

CRYOGENIC SYSTEMS

Operating these superconducting magnets at low temperatures requires the use of cryogenic cooling systems. Cryogenics is the process of using super cooled liquids to cool equipment. The most common gas used in cryogenic systems for particle accelerators is helium. Helium changes state from gas to a liquid at a temperature of 452.47°F (4° Kelvin). The liquid helium is used to cool the copper coils and magnets. This cooling system is essential to create a resistance-free electrical environment that a superconducting magnet requires in order for the particle accelerator system to run at high speeds while keeping resistance and heat low.

CHEMICAL CLEAN ROOM SUPPORT

A clean room is a required aspect to assemble the parts of the particle accelerator. A clean room is crucial to achieve the purest environment while assembling the intricate mechanisms and inner working of the transfer pipes, accelerator, and other key components, and ensure the particle will not become contaminated with unwanted materials as it moves along the path toward detection.

VACUUM SYSTEMS

Vacuum systems are used to create a controlled environment inside the transfer pipe, or superconducting cavities, void of all atoms, dust and condensation. Preserving the cleanliness of the cavity is key as it allows the beam to have a precise trajectory toward the target area to achieve the best results possible. The assembly processes of the superconducting cavities is performed in a clean room to make them completely particle free. These components are bound together using a technology called electron beam welding.

ELECTRON BEAM WELDING TECHNOLOGIES

Electron beam welding emits accelerated electrons toward a joint and fuses the two metal objects together without the introduction of another metal which creates a much stronger quality weld. The higher quality and smaller weld line produces a high precision product that is structurally superior. It also can withstand a more intense environment such as heat and pressure that the components in a particle accelerator are consistently exposed to during operation.

ACCELERATOR SYSTEMS AND RADIOFREQUENCY

The accelerating system used to move a charged particle through the cavity is referred to as radiofrequency (RF) cavity. The radiofrequency emitters produce a strong electromagnetic field with alternating current (AC) many number of times per second. This electromagnetic field is used to push the particle to the desired speed before it impacts the target.

CONTROL SYSTEMS

Diagnostic and control systems are a tool that sense the status and achieve the desired beam from the machine. The control system helps with machine installation and off-line analysis. The development of control systems are important because of the scale and complexity of the accelerators; any future enhancement of the machine; and the ever changing demand of technology in electronics hardware and software. These factors are important throughout the life cycle of the accelerator to maintain the interconnectivity to the accelerators equipment.

The components and systems described above are critical to most particle accelerators. Many of these components are sourced from a number of out-of-state suppliers demonstrating the national and international dimensions of the supply chain. Figure 7 shows components being used in the construction of FRIB identified by where they are sourced.

Figure 3: Examples of Accelerator Component Sources
Source: MSU National Superconducting Cyclotron Laboratory

NAICS Code Limitations and Gazelle.ai Software Platform Analysis

The following discussion highlights some of the limitations of the North American Industrial Classification System (NAICS) and the strengths of the Gazelle.ai software platform.

The North American Industrial Classification System (NAICS) originated in 1997, replacing the Standard Industrial Classification (SIC) which was established in 1937. Industrial Classification systems can be separated into two categories: production oriented and market oriented systems (Ormsby, 2016). NAICS is a production oriented classification system which is updated every five years.

Cluster analysis and business attraction efforts using 6-digit NAICS code analysis is a normal practice for economic development organizations. This practice is passable for broad cluster development; however, the particle accelerator industry is unique, and thus the use of NAICS code analysis is limited.

A major weakness of the classification system is the way that classifications are assigned. “NAICS classifications obtained from databases are assigned by employees .... The quality of this work will depend on training and time allocated, which in turn depend on the importance of the field to the database. The amount of inconsistency and error found in these classifications suggests that assigning NAICS codes is not a high priority task in database companies” (Hicks, 2011).

In 1999, a market oriented classification system named Global Industry Classification Standard (GICS) was established providing a broad classification of 156 sub-industries. Diana Hicks at the Georgia Institute of Technology tested both NAICS and GICS to see how accurate they categorized the ever-changing structure of today’s economy and emerging industries. The industry testing showed NAICS inability to be dynamic and representative of the changing structure of the modern American economy. Hicks goes on to argue that, “neither (NAICS nor GICS) produces an entirely satisfying result. NAICS seeks to maintain continuity with the past, which leads both to a reluctance to add new categories and a plethora of outdated categories … GICS is strong precisely where NAICS is weak” (Hicks, 2011).

In 2017, Gazelle.ai was established as an investment attraction tool for economic development organizations. The core ability of the software is detecting companies at an early stage for potential growth and expansion. This detection allows economic developers to prospect and interact with companies in a business attraction setting. The software utilizes NAICS industries, keywords, and clusters to further define the classification of a company.

Each company profile provides a detailed description and summary, potential competitors list, web link, personnel contact information, company newsfeed, and NAICS code industries with the keywords most affiliated to the company. In addition, a G-score™ using the heuristic algorithm is used to indicate how likely a company is to expand. Another “company targeting” search tool within the Gazelle.ai platform is the industry heat mapping tool, which is a visual representation of areas of concentration using indicators (employment, employment growth, total net sales, salary growth, and establishments) to portray the expansion or relocation potential of a company.

The development of software platforms, databases, and classification systems assists economic development efforts but have limitations as they apply to the particle accelerator industry. The use of any single approach can be limiting but when combined with other analytical tools can lead to new insights and adaptations. For example, companies that were identified as potential targets using the Gazelle.ai platform were crossed referenced with the NAICS six-digit codes. Three codes seem to be the best match to the companies identified using Gazelle.ai. These codes are: 334419 "Other Electronic Component Manufacturing," 423690 "Other Electronic Parts and Equipment Merchant Wholesalers," and 541712 "Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)." Combining this information with other economic development tools such as keywords, clusters, and industry heat mapping has allowed for deeper searches and more accuracy when researching companies that relate to the particle accelerator industry for attraction purposes.

Recommendations

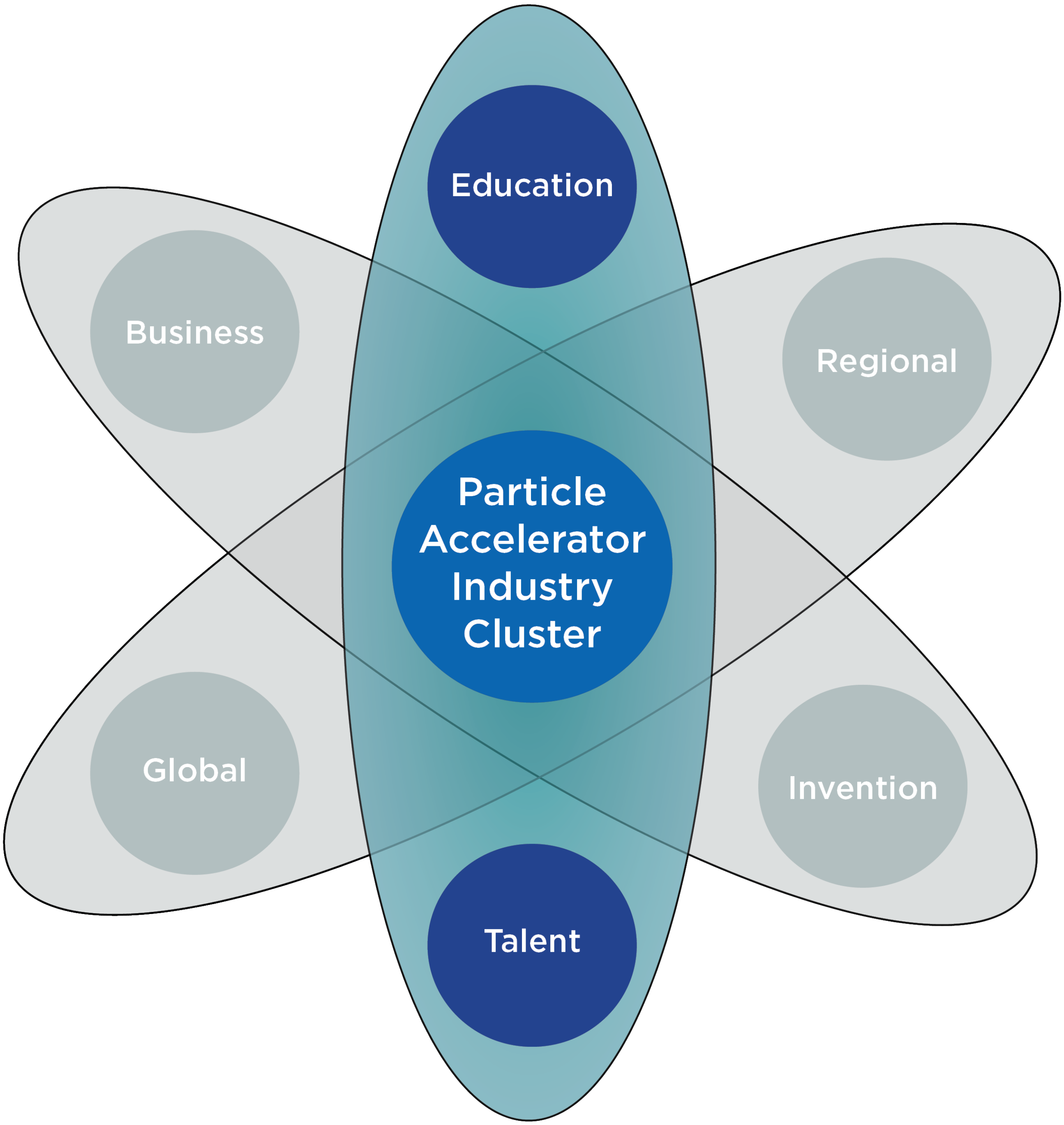
Based on the research and findings, three recommendations related to the particle accelerator supply chain are proposed.

First, recognizing that the sustained demand for particle accelerators and components is likely to remain limited in the region, it is recommended that a means of monitoring demand on a regional basis be developed. This would require regular communication and cooperation between our regional stakeholders; namely MSU, Niowave, Ionetix, and LEAP. Quarterly meetings could allow for identifying common need, sharing vendor information, and exploring opportunities to collaborate and support new component industries. Given the strong design and build capacity of the Lansing region and recognizing that future production opportunities may be related to specific applications of particle accelerators (sterilization, active interrogation, medical isotope production, etc.), and meeting regularly with stakeholders could create opportunities for new and innovative business collaborations and development.

Second, economic development organizations such as LEAP play a key role in business development and attraction; and, in the fast-paced knowledge economy, the ability to seek new information and apply new tools is crucial for success. It is recommended that LEAP and MSU seek support to maintain a student research position directly related to business development and the use of analytical tools to enhance the local business environment. One area of focus could be to explore the usefulness of Gazelle.ai to the supply chain needs of our regional businesses. Structured conversations with MSU departments can be arranged to explore opportunities to support students who have interests in urban planning, economics, supply chain management, or other relevant subjects. It is crucial to invest in our regional capacity and formalizing support for a student intern position dedicated to business development that will help the region compete in the global economy.

Third, recognizing that the knowledge and talent supply chain may be more crucial than a hardware supply chain for the long-term success of the cluster, it is recommended that stakeholders meet on an annual basis to explore new developments in the industry. Given the heightened visibility of the region with the construction of FRIB, the systematic sharing new discoveries can prove to be one of the most significant inputs into the success of a particle accelerator cluster in the region. An annual “Accelerate Lansing” meeting/conference can be established to attract businesses, researchers, and educators.

Knowledge Supply Chain and Network



Knowledge Supply Chain and Network

The Lansing region particle accelerator cluster is built on a research and knowledge foundation that was first established at MSU in 1958 with the hiring of Dr. Henry Blosser, a young nuclear scientist then working at Oak Ridge National Laboratory. Today the region hosts the National Superconducting Cyclotron Laboratory, two private sector companies (Niowave Inc. and Ionetix Inc.,) Michigan State University's number one ranked nuclear physics graduate program in the country, and the home of the Facility for Rare Isotope Beams. These assets underpin the nuclear physics knowledge cluster in the Lansing region.

A successful knowledge economy business environment relies on a steady supply of talented workers, and the development of this workforce is crucial. The success of a cluster may depend on its ability to take technically talented workers and transform them into highly-valued knowledge workers, processing skills and understandings that can only be learned through hands-on experiential learning. An important role of a region in the knowledge economy is to facilitate the transfer of tacit knowledge from highly-skilled workers who have years of experience to the talent pool of inexperienced workers who are recent graduates of degree and certification programs. This phase of the study identified a knowledge model that guided an assessment of the supply and demand of talent needs related to the particle accelerator cluster.

Methodology

A literature review of research related to cluster and workforce development in the knowledge economy was conducted and analyzed. With advice from the Advisory Committee, a working model and set of definitions were established to serve as the foundation for data collection and analysis.

Interview data from private sector employers was used to develop a demand profile of knowledge requirements for workers in this industry. A statewide survey of education programs and offerings was conducted and the data was used to characterize the supply of accessible knowledge workers.

Findings

Overall, clusters allow for less costly knowledge transfer (spillover) in a region, especially when the knowledge is tacit (learned through experience) in nature. As a result, clusters with highly skilled labor create a demand for multiple categories of talented, certified workers. Clusters become competitive areas for wages. They are an important place to not only learn new skills that are harder to learn elsewhere, but also a place where workers tend to earn more. Knowledge cluster development generally causes a strong positive impact on regional economic performance.

The particle accelerator employment demand is not large compared to other regional industries; however, the workforce demands are based on specific knowledge in scientific fields. Over fifty percent of workers employed at the two private sector businesses in the Lansing area possess degrees or certifications in engineering, physics, information technology, chemistry, and general science.

Michigan educational institutions offer a variety of degree and certification programs relevant to the particle accelerator industry. Programs from ten colleges and universities and two community colleges were identified that hold particular relevance to the particle accelerator industry. Program descriptions, enrollment numbers and degrees conferred are included in the analysis.

Knowledge and Clusters

Understanding how knowledge works in a cluster is vital to understanding the specific relationships of key stakeholders within a region. Knowledge spillover is the exchange of knowledge between people and frequently occurs through written media. However, tacit knowledge, is geographically bound and is shared most often person-to-person. Within geographic clusters, the cost of transferring knowledge from one person to another is much lower because businesses that are developing similar products are located near each other and have a greater opportunity to share tacit knowledge. This is especially important when skilled workers, or those who have years of hands-on experience working in the field, are able to pass their learned knowledge on to less experienced talent workers, or those who are in entry-level positions with degrees or certifications but lack hands-on experience. However, even if workers are employed by different companies, geographic clusters allow for the sharing of knowledge throughout a region.

Particle Accelerator Industry Knowledge Demand

The region's two particle accelerator businesses, Niowave and Ionetix, employ people from a variety of knowledge backgrounds. 53% of their combined employment base hold degrees or certifications in engineering, physics, information technology, chemistry, or general science. 47% are employed in administration, business operations, and production.

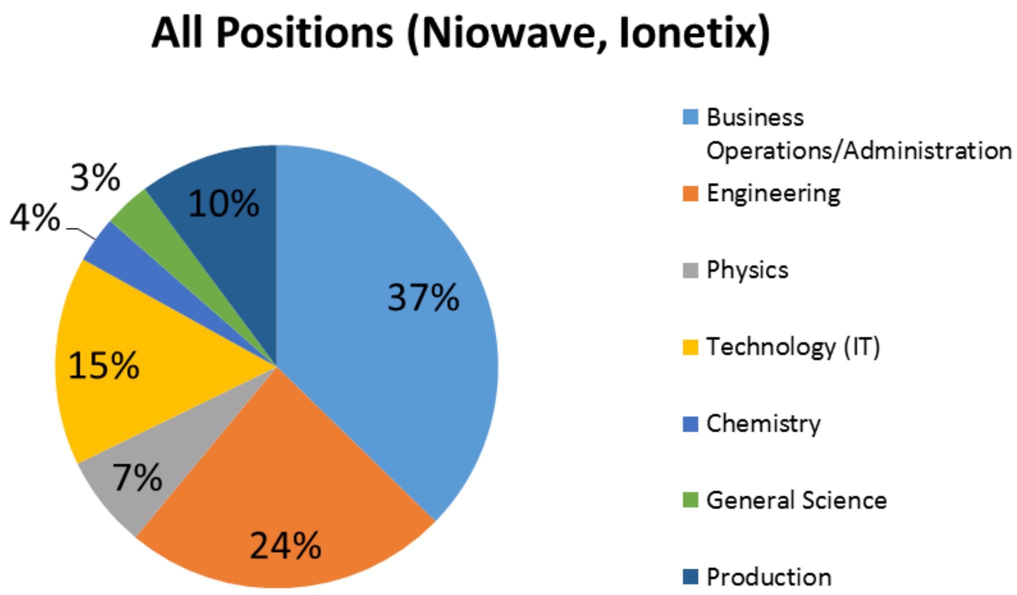


Figure 4: Position Classifications at Niowave and Ionetix, Inc.
Source: Niowave, Ionetix, Inc.

MSU and FRIB Training Opportunities

MSU offers opportunities other than the standard undergraduate and graduate degree programs to learn about nuclear physics. For instance, FRIB hosts high school student tours to increase exposure in this area of study. They provide summer camps to high school students and teachers from across the country. FRIB is planning a “physics day” learning event for Lansing area students, teachers, and residents for March 2020. Additionally, undergraduate and graduate student employment positions at FRIB are regularly available with over 200 students being employed at any given time.

Given MSU’s expertise in nuclear physics, working with graduate students at FRIB and MSU is an important part of the knowledge assets in the region. There are a wide variety of programs at FRIB, which equip students with practical knowledge in their respective fields, and graduate students have the opportunity to pursue fellowships and other financial supports. Students are encouraged to explore advanced coursework in areas such as energy analysis, thermal systems modeling, and other aspects of Science, Technology, Engineering, and Mathematics (STEM) education (FRIB Student Opportunities).

Talent Supply Chain

In the highly technical field of particle physics, a supply of knowledgeable and talented workers is required. To efficiently and effectively attract this talent, economic developers, and workforce leaders in the Lansing region should have a general understanding of where this talent comes from. The identification of specific skills and aptitude in this industry is also essential to filling potential positions and can be utilized in guiding new talent through available programs to enter this emerging industry. The research team has therefore conducted an analysis of surrounding area colleges and institutions that have programs to produce talent which can support the particle accelerator industry. Specific programs were reviewed identifying curriculum, degree programs, and certifications. The data collected pertains to enrollment and degrees conferred (see Appendix).

Of the many of the degree programs directly related to particle accelerator technology, Michigan State University has the highest enrollment and graduation numbers in the state (see Appendix). Some of the major degree programs include: Mechanical Engineering, Chemical Engineering, Materials Science and Engineering, and Industrial and Operations Engineering. The enrollment in each of these programs varies from year to year but is generally increasing. This indicates a recognition of the value of these degrees, and also an increasing availability of related talent in coming years as enrollees graduate and enter the workforce.

Universities

The institutions analyzed for this report are described in detail below, including the degree programs offered that contribute to the particle accelerator knowledge supply chain.

Central Michigan University (CMU) – Mount Pleasant, MI

Central Michigan University is home to multiple scientific facilities that provide students, outside researchers, and scientists with the opportunity to test samples, observe through microscopes, and become more experienced in science. One of which is the Center for Elemental and Isotopic Analysis (CELISA). CELISA has the potential to expand opportunities for research and the procurement of external funding for research. CMU researchers have found a better mechanism to understand trace element signatures in a variety of materials, resulting in: the ability to test advanced materials, gaining insight into new mineral resources, and an improvement in environmental quality.

Ferris State University – Big Rapids, MI

With its high academic standards, Ferris State University meets both current and future needs of the industrial and business sectors. The College of Engineering Technology offers a variety of degree programs to prepare students for futures in areas, such as Mechanical Engineering Technology, Welding Engineering Technology, and Advanced Manufacturing Engineering Technology. These programs reside within the Swan Annex building that recently went through a renovation expanding the facility to almost 90,000 square feet, twice as big as its former operations (Ferris State University, n.d.).

Grand Valley State University (GVSU) – Allendale, MI

At the GVSU Robert C. Pew Campus, bachelor's degrees in areas of business, education, and engineering are offered. More importantly, majors that relate directly to the particle accelerator cluster are offered in: electrical engineering, mechanical engineering, chemistry, biochemistry, and engineering majors along with graduate degrees. GVSU's general engineering program encompasses computer engineering, electrical engineering, interdisciplinary, mechanical, product design, and manufacturing engineering (Grand Valley State University, 2018).

Kettering University – Flint, MI

Kettering is home to a multitude of laboratories and research centers. The Advanced Power Electronics Laboratory provides students with the opportunity to test power electronics, power supply, and various battery-oriented systems. The Brain-Inspired Intelligent Systems Laboratory involves robotized sectioning and sub-micron imaging for researching biological issue volumes. The five areas of interest offered are: computational neuroscience and neuroanatomy, Tera voxel image processing, imaging device instrumentation, artificial intelligence, and intelligent mobile robotics. The Computational Physics Laboratory (CPL) maintains a space for theoretical and computational research. Specifically, research that includes quantitative analysis of experimental images, mathematical models, computer simulations, and large data sets. The Environmental Scanning Electron Microscope (ESEM) Laboratory implements a microscope with high vacuum, low vacuum and gaseous environments to support material characterization applications. This cross-disciplinary idea is promoted by allowing user selection of accelerating voltage, magnification, gas type, gas pressure, and detector type (Kettering University, 2018).

Michigan State University (MSU) – East Lansing, MI

MSU takes pride in expanding the participation in STEM majors, most importantly the Nuclear Physics program. These majors have proven beneficial to MSU as they continue to construct FRIB. Scientists are given the opportunity to discover rare isotopes, but also the chance to partner with graduate students obtaining their degree in the field of nuclear physics. In addition to its nationally ranked program, MSU has been able to expand into other programs, initiatives, and internship programs that further increase the talent pool at the university.

With its permanent location on MSU's campus, FRIB is an ideal venue for educating the next generation of accelerator scientists and engineers. One area of educational expansion is the introduction of the Accelerator Science and Engineering (AS&E) Traineeship program in 2017. Both PhD and Masters graduate students will earn a certification in AS&E after participation in the program, with specialization in one of four major areas of critical workforce needs; Physics and Engineering of Large Accelerators, Superconducting Radiofrequency Technology, Radiofrequency Power Engineering, and Large Cryogenic Systems. After being certified, trainees will be placed in U.S. Department of Energy (DOE) national laboratories to further their training. The partnerships with DOE national laboratories will include: internships, practicums, focused long or short-term credit-bearing courses, and workshops related to professional development of non-scientific skills (project management, entrepreneurial skills, science communication, and technology transfer) required for large accelerator design, construction, and operation. The partnerships will integrate AS&E Traineeship students into their research program beyond the third year and support them until the completion of their thesis (Michigan State University, 2018). The objective of the program is to produce 4-6 MSU graduates each year, who are certified, well-trained, and ready for productive careers in accelerator science and engineering.

MSU recently established a Cryogenic Initiative, a collaboration between FRIB and the College of Engineering, which offers a combination of rigorous course work, fundamental and applied research, and training to students on the production and behavior of materials at very low temperatures. The course provides an introduction to this discipline with applications to 4.5° Kelvin and 2° Kelvin helium systems used to support particle accelerators. The goal is to provide a rigorous graduate-level academic and applied research program focused on training and educating engineers in cryogenic system design, technology, and skills (Michigan State University, 2018). Students are trained at MSU Facilities in FRIB and the NSCL, along with the Department of Physics and Astronomy, the College of Engineering, and the U.S. Particle Accelerator School.

Each summer MSU holds an internship program titled "Research Experience for Undergraduates" (REU). This 10-week internship is funded by the National Science Foundation (NSF) and MSU. On average, over 300 applicants apply (preferably sophomores and juniors who have completed introductory physics and are currently enrolled in an advanced physics course) for the 12 available spots. The students work one-on-one with a MSU faculty member in one of the following research areas of their choosing: Accelerator Physics, Astrophysics, Biophysics, Computational Physics, Condensed Matter Physics, Low Temperature Physics, Nanoscience, Nuclear Physics, Particle Physics, Physics Education, Psychoacoustics, or Theoretical Physics. The program includes career development workshops, social activities, and excursions. At the end of the program, students present their research results as a poster and submit a "practice" NSF Graduate Fellowship application (Michigan State University, 2018).

Michigan Technological University (MTU) – Houghton, MI

The multitudes of degree programs at MTU are very advantageous as six engineering programs within MTU rank in the top 100 for research supported by the National Science Foundation. Another six engineering programs are tailored especially toward veterans. The College of Engineering provides degrees, such as: biomedical engineering, chemical, civil, computer, electrical, environmental, geological, mechanical, and materials science. All customized engineering programs are ABET accredited. In the first year of engineering, MTU professors focus on hands-on experiments to engage students and help them discover their specialty. Job placement for graduating undergraduate engineering degree holders is upwards of 93.5% employment, with a starting average salary of $60,000 or more. Each student must take part in undergraduate research that focuses on promoting interest and understanding challenges within the engineering field. Students in engineering are encouraged to use the 35 research centers and institutes that belong to MTU. Along with research opportunities, students are expected to take two engineering exams to become a licensed professional engineer. This leads to greater advancement opportunities, more benefits, and higher pay when looking for employment (Michigan Technological University, 2018).

Oakland University – Rochester, MI

The School of Engineering and Computer Science (SECS) holds about 3,300 undergraduate and graduate students combined at Oakland University. Students are divided into four departments within the college: Computer Science and Engineering, Electrical and Computer Engineering, Industrial and Systems Engineering, and Mechanical Engineering. Within the Electrical and Computer Engineering department, there are two ABET-accredited degrees offered: BS in electrical engineering, and a BS in computer engineering. Year-round undergraduate research experiences are offered to enhance the student's roles in engineering into the future (Oakland University, 2017).

The SECS department holds a number of important state-of-the-art research and development laboratories, including: the Fastening and Joining Research Institute (FAJRI), the Center of Advanced Manufacturing and Materials (CAMM), and CLIC-form specializing in sheet metal forming, intellectual property and applied research. The FAJRI is an academic nonprofit applied research facility that specializes in new technologies in fastening and joining of materials (Oakland University, 2017). Lastly, the Center of Advanced Manufacturing and Materials (CAMM), specializes in sheet metal stamping, tool wear, the mechanics of material fracture in stamping and joining operations, and the analysis of sheared edges. CAMM includes an automated press cell capable of physically stimulating sheet metal processes for research (Oakland University, 2017).

University of Michigan (U-M) – Ann Arbor, MI

The college of engineering graduate program at U-M is ranked fourth in the country. Out of the College of Engineering, the department of Nuclear Engineering and Radiological Sciences (NERS) comes an opportunity for students to engage in research as undergraduates seek out challenging fields. Only 160 students make up NERS, which allows close connections to be made between faculty and students. This unique characteristic of the degree program lets students participate more actively within their field of study in preparation for a career in the field.

University of Michigan is home to three particle accelerators which are located within the Department of Nuclear Engineering and Radiological Sciences in the College of Engineering. With an advanced Ion Beam Laboratory, U-M is capable of understanding complex ion interactions, ion irradiation, and ion beam analysis. x *Wolverine*: 3 MV Tandem particle accelerator is used for high energy ion beam irradiation experiments. This accelerator has three sections: the ion sources, the ion beam accelerator, and the beamlines. The *Maize*: 1.7 MV Tandem particle accelerator is used for a variety of experiments including ion implantation, ion beam analysis, and irradiation experiments. Lastly, the *Blue*: 400 kV Implanter is an open air accelerator used for ion implantation. The laboratory was created for the purpose of advancing the understanding of ion-solid interactions by providing a unique and extensive facility to support both research and development in the field (University of Michigan, 2018).

Wayne State University – Detroit, MI

Wayne State University is home to the Integrative Biosciences Center (IBio), which is dedicated to research, discovery, and education in the biomedical classification. The 200,000 square foot laboratory houses research teams with the initiative of understanding the effects of health in evolving urban environments. Notable career opportunities within the IBio center include: Brain & Behavioral Health, Bio & Systems Engineering, Interface of Genes, Ethnicity, Environment and Health, Metabolic Diseases, and Urban Health Equity. Each opportunity contributing to the overall initiative of evolving and improving the medical realm (Wayne State University, 2018).

The Eugene Applebaum College of Pharmacy and Health Sciences (EACPHS) is one of the largest academic medical facilities in the U.S. This college is accredited by the National Accrediting Agency for Clinical Laboratory Science (NAACLS). NAACLS and EACPHS are located near the Detroit metropolitan area where healthcare graduates are high in demand. With a degree in Clinical Laboratory Science, students can develop and conduct lab tests, such as analyzing blood and body fluid samples. This is important in the use of pharmaceutical drugs and other FDA approved uses.

Western Michigan University (WMU) – Kalamazoo, MI

Western Michigan University has a long history with engineering and accelerators. High Voltage Engineering (HVE) started WMU over 30 years ago with its 6-MV model EN tandem Van de Graaff accelerator. The main use for this accelerator is focused around student involvement. Both undergraduates and graduates alike are able to participate in physics and laboratory courses that use this accelerator. This facility is continually growing and looking to become more accessible to students. In addition, high school students with specific science projects use the facility which is supported by the Kalamazoo Area Mathematics and Science Center (Western Michigan University, 2018).

Community Colleges

Lansing Community College (LCC) – Lansing, MI

With growth of local STEM opportunities, LCC has become a leader in advanced manufacturing training at the Center for Manufacturing Excellence (CME) located in the West Campus Building. Currently, the programs offered are Robotics & Automation, Computer Automated Design, Precision Machining, and Welding (Lansing Community College, MI, 2018). As more skilled workers are sought after, programs within the college are prevailing. From 2016 to 2018, the welding program at LCC has increased by 151 students.

Each programs' curriculum offers either a designation of Certification of Completion (CC), Certification of Achievement (CA), or Associate of Applied Science (A.A.S.) degree. A new curriculum offering a CA in Advanced Materials and Processes is set to be available in 2019. This course will require areas of study in safety, manufacturing processes, introduction to materials, basic coating and painting, material repair and replacement, advanced coatings, composite assembly, damage repair, and additional available credits in sheet metal welding and fabrication. A base level certificate of achievement in this area of study will give students the ability to enter into an entry level (or higher) manufacturing position within one year (Lansing Community College, MI, 2018).

The CME facility offers hands-on training with top-of-the-line equipment, including Motoman, ABB, and Fanuc. This training is essential for the program Mechatronics (AAS), which consists of studies in basic electrical, electronic, computer, and mechanical engineering, fluid power, and robotic and programmable logic controller systems. A trained and graduated mechatronic technician will have the ability to install, maintain, troubleshoot, test, and repair technologically diverse equipment in industries such as manufacturing, aerospace, automotive, medical, material processing, consumer products, and defense systems.

Based on enrollment numbers obtained between the fall, spring, and summer semesters, enrollment in the Associate degree program in Mechatronics increased 56% between 2015 and 2016, and then an additional 29.33% from 2016 to 2017. This is an example of how technology growth can be attributed to the collaboration of electronics and mechanical engineers is a growing field. In this program, students graduate with the necessary basic skills to enter into entry level positions in the manufacturing field.

Washtenaw Community College (WCC) – Ann Arbor, MI

Washtenaw Community College asks, "What do you call someone who went to WCC?" and responds, "Employed." As a community college accredited by The Higher Learning Commission, Washtenaw is committed to producing excellence in every field. Within the Advanced Manufacturing Systems program, WCC offers a certificate in industrial electronics technology, advanced machine tool programming, and welding and fabrication advanced application. A certificate is common and useful when pursuing a career in a skilled trades. WCC also provides students with the opportunity to receive an associate's degree in engineering technologist-manufacturing, mechatronics, and welding technology (Washtenaw Community College, 2018).

Recommendations

A skilled knowledge worker is one who possesses both explicate knowledge (book learned) and tacit knowledge (experientially learned). A regional cluster can provide opportunities for efficiently exchanging knowledge (spillover) and moving workers along a development path from "talented worker" to "skilled knowledge worker." First, it is recommended that the economic development community and other regional stakeholders advocate for research to map the supply chain of talented workers related to STEM employment and identify the regional opportunities to optimize tacit knowledge exchange for workforce development efficiency. It is suggested to work with existing workforce development stakeholders and MSU faculty and students to develop a research effort that would provide a blueprint for future knowledge worker supply chain development.

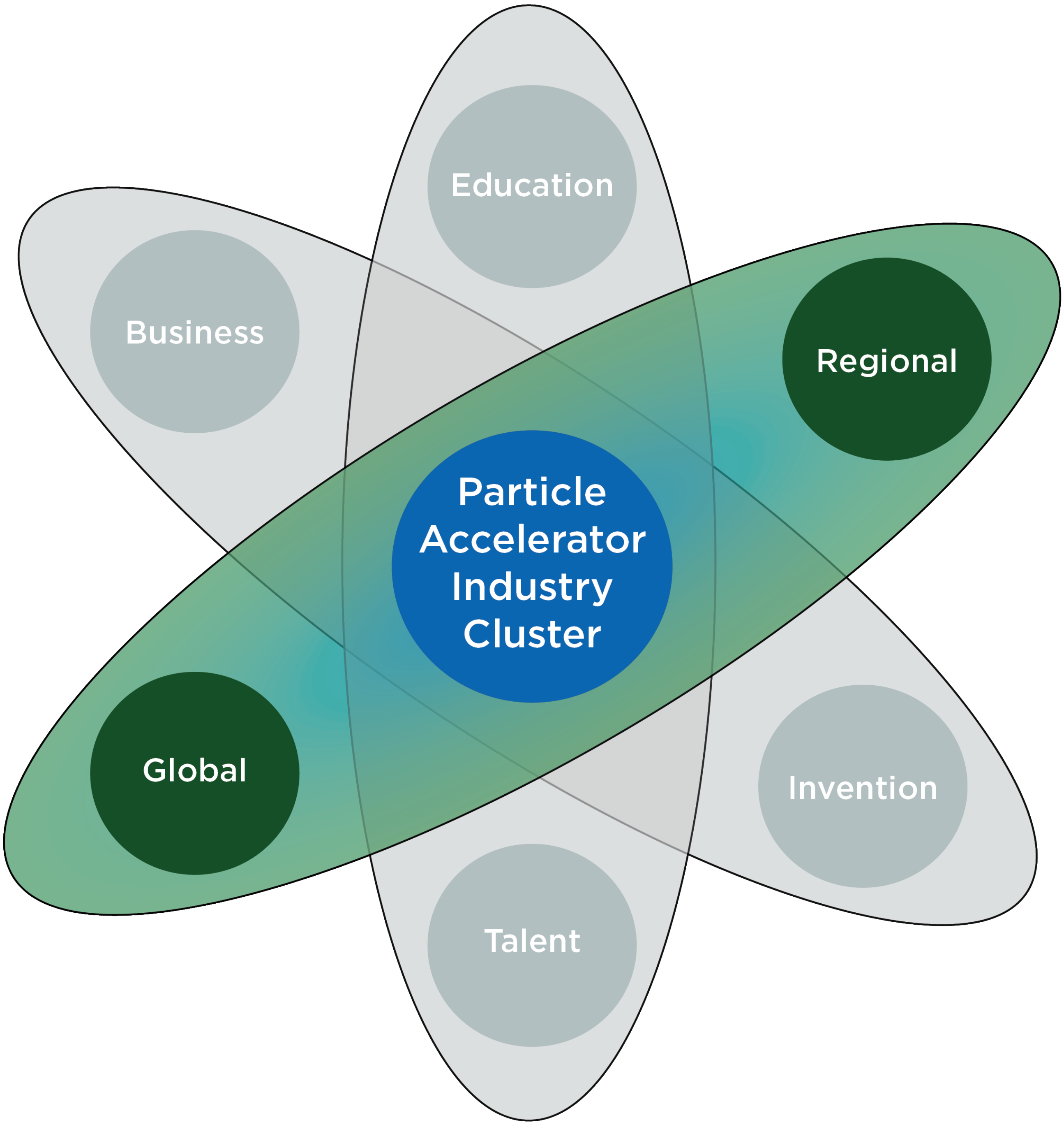
Second, recognizing the current employment demand in the particle accelerator and nuclear science area and anticipating even greater opportunities as a result of FRIB operation in the future, it is important to help prepare young students in the region to successfully embrace those opportunities. It is recommended that the private sector and workforce development organizations seek to sponsor and support unique learning opportunities related to particle accelerators and nuclear physics. One such activity is the result of a partnership between the Wharton Center for the Performing Arts and the Facility for Rare Isotope Beams at MSU. Scheduled for March 21, 2020, "Of Equal Place: Exploring Isotopes in Motion" is an interactive learning experience for area students that will introduce some of the key concepts of particle accelerator and nuclear science and offer an opportunity to tour the FRIB facility. A draft program description is included here:

> Of Equal Place: Exploring Isotopes in Motion will present an exhilarating performance that combines dance, video, and physics while featuring professional dancers and guest performances by local youth. The show highlights the wonders of science and illuminates the research at the Facility for Rare Isotope Beams (FRIB) and was inspired by Dance Exchange's critically acclaimed work The Matter of Origins. Following the performance audience members are invited to participate in a series of activities which explore dance, physics, and FRIB.

Third, it is recommended that an effort be made to connect vocational education options with mentoring and employment opportunities in the region. The Wilson Talent Center is a Career and Technical Education programming center for high school juniors and seniors located in Mason, Michigan. The Wilson Talent Center has an Engineering Technology program to teach students problem solving skills related to science, math, technology, and engineering. FRIB, Niowave, and Ionetix should consider partnering with the Wilson Talent Center, as this could benefit the students and increase availability of welders and machinists. Efforts should be made to develop partnerships between technical training programs, private sector businesses, and research laboratories to develop the knowledge workers needed to build the cluster.

Finally, recognizing the importance of the knowledge and talent supply chain, it is recommended that stakeholders advocate for a regional branding campaign that emphasizes the regional capacity to train and employ knowledge workers particularly related to nuclear science. The “tacit knowledge capacity” of the region should be emphasized along with other regional amenities that are attractive to young knowledge workers.

National Innovative Practices



National Innovative Practices

To determine a set of replicable practices that could be useful to foster the development of a Particle Accelerator, the research team identified several communities and economic development organizations that have successfully collaborated with accelerator laboratories and facilities, and that have incorporated the accelerator industry into their regional economic development strategies. These communities and their associated facilities, were selected based on their similarity to FRIB and the Lansing region and are outlined in detail in this chapter.

The examples from this section may be used by local economic developers to replicate the policies, practices, tools, and models that have proven successful or helpful in other communities. It is important to understand the economic ecosystem associated with those facilities, paying particular attention to the impact on the regional economy.

Methodology

In this chapter, each facility and its location are described, including the type of facility, partnerships, and any incentives utilized by the facility's respective community. Information about incentives and partnerships were obtained through searches on each facilities' community webpages, as well as through interviews of facility personnel and community economic development staff. Oak Ridge National Laboratory (ORNL) is explored in great detail because of its similarity to FRIB in funding, and because of its long history in particle accelerators.

Key Points from National Facilities:

Table 1: Key Programs and Missions at National Facilities

Thomas Jefferson National Laboratory (JLAB)	**University/Corporate Research Collaboration** Southeastern Universities Research Association (SURA) has enabled JLab facility operations since its approval in the 1980s through research funding initiatives and university and corporate collaborations in research.	**Investment in Infrastructure** The Newport News region has had success investing in infrastructure to provide amenities such as shopping, dining, and living near JLab. This has resulted in significant economic impacts for the region and incentives for spin-off businesses to locate in the area.

Los Alamos National Laboratory (LANL)	**Implement Youth Programs** Los Alamos National Laboratory has 43 math and science education programs offering scholarships.	**Work With Diverse Communities** LANL has programs specifically designed to work with the diverse surrounding community.	
Oak Ridge National Laboratory (ORNL)	**State Government Involvement** Oak Ridge National Laboratory offers lab time to private industrial users. The state government subsidizes some of this lab time.	**Joint-Faculty Program** ORNL has a joint-faculty program with University of Tennessee.	**Engage Young Talent** ORNL engages young talent through its PhD and undergraduate programs, and has been successful at keeping students interested in STEM.
	Economic Impact Economic Development Councils in the Oak Ridge and Knoxville area have conducted economic impact assessments of the area, and found this to be beneficial.	**Find Motivated Scientists** Administrators at the University of Tennessee recommend finding researchers who are dedicated and motivated to working with private industry.	**Address Cultural Differences** With the laboratory, the government, universities, and private industry all trying to work together on research, projects, and new development, cultural differences in how these institutions operate can get in the way.
	Identify a Key Marketing Arm ORNL partners with Innovation Valley, Inc., a regional economic development group that markets in order to bring talent and knowledge into the area's clusters.	**Revise Faculty Evaluation Structure** ORNL found it difficult to encourage faculty and private business to together. Rather than simply evaluating based on research and publications, researchers should be considered for work in private industry.	**Consider Spatial Layout** ORNL is not located on a university campus, resulting in less of a physical connection between the University of Tennessee and ORNL.

Findings

THOMAS JEFFERSON NATIONAL LABORATORY (JLAB) is a U.S. Department of Economics (DOE) national laboratory and accelerator facility located on 169 acres in Newport News, Virginia. The facility's Continuous Electron Beam Accelerator (CEBAF) is used by researchers throughout the world, primarily to study particles and the forces that bind them. Adjacent to the facility is the Virginia Associated Research Campus (VARC), formerly home to the National Aeronautics and Space Administration's (NASA) Space Radiation Effects Laboratory from 1962 to 1978. In 1983, the Southeastern Universities Research Association (SURA) approved construction of CEBAF, and now oversees its operations through Jefferson Science Associates, LLC. SURA provides support to the lab by fostering research collaboration among its member institutions and through its Initiatives Fund which supports education, outreach, and career development programs at JLab (Southeastern Universities Research Association, 2019).

Beginning in 2014, the lab began a Lab Directed Research and Development (LDRD) program which provides funding for researchers to conduct computer modeling, feasibility, conceptual, and other small-scale projects at the lab. This program requires a JLab affiliation for all principal investigators, but is otherwise open in terms of the research teams. The LDRD program helps to enable timely research into emerging technologies that fit into DOE's research and development mission.

While the facility itself employs more than 650 full-time employees, its impact on the surrounding region's economy has been responsible for supporting close to 2,000 related jobs and upwards of $200 million in direct spending by the laboratory and its users (The Wessex Group, Ltd., 2011).

A collaborative effort in 2016 between W.M. Jordan Company, Virginia Tech, JLab, and the U.S. Economic Development Administration (EDA) led to the establishment of the Tech Center at Oyster Point, a 100-acre corporate research park with supporting amenities such as shopping, restaurants, and housing (Newport News, 2016). This investment in amenities and infrastructure has proven lucrative for the region. The lab has also seen commercial success of its boron nitride nanotube (BNNT), one of the strongest materials ever made. The result has been BNNT, LLC, a spinoff business that according to the Newport News Economic/Industrial Development Authority, "has pioneered the small-scale manufacture of BNNTs" (Newport News, 9, 2016).

LOS ALAMOS NATIONAL LABORATORY (LANL) is a U.S. DOE national lab with a number of user facilities, including the Los Alamos Neutron Science Center (LANSCE) accelerator and isotope production facility located in Los Alamos, New Mexico. Much of the research at LANL is focused on national security, as the facility is operated by Triad National Security, LLC under a contract from the National Nuclear Security Administration (NNSA).

In 2007, LANL joined the New Mexico Small Business Assistance Program (NMSBA) and Sandia National Laboratory to provide technical assistance more accessible to New Mexico small businesses (New Mexico Small Business Assistance Program, 2019). The NMSBA program allows New Mexico small businesses access to the unique expertise and capabilities of Los Alamos and Sandia National Laboratories. Through this program, small businesses can seek assistance from lab scientists or engineers for projects that require testing, design consultation and access to special equipment or facilities that are not available in the private sector.

LANL has also partnered with the Regional Development Corporation (RDC), a private non-profit economic development organization (EDO) to establish the Native American Venture Acceleration Fund (NAVAF). This fund seeks to boost employment and economic diversification by awarding small grants to tribally owned companies, which can be used to leverage revenue, job creation, and diversification resources.

In 2004, the LANL Major Subcontractors Consortium (MSC) was formed and began offering resources in support of economic development in the form of an Economic Development Grant Pool, managed by the New Mexico Community Foundation. The program allows members to leverage corporate resources such as funding, supplies, counseling, marketing/outreach power, and other expertise for the diversification of Northern New Mexico's economy and greater impact in education and economic development.

OAK RIDGE NATIONAL LABORATORY (ORNL) was established in 1943 as part of the Manhattan Project. Located in Oak Ridge, Tennessee, the laboratory has a staff of 4,750 with approximately 3,200 users and visiting scientists annually. ORNL currently manages the Oak Ridge Science and Technology Park, the only research park on a national laboratory campus in America. ORNL’s facilities and expertise have been utilized to advance scientific discovery in clean energy and global security.

ORNL connects with talent through several nearby educational institutions. Its most significant partnership is with the University of Tennessee (UT), which works with Battelle Memorial Institute to form UT-Battelle, the joint contracted management and operating nonprofit of ORNL. University of Tennessee works closely with MSU’s FRIB, connecting students to internships and co-ops and with their joint-faculty appointments between Oak Ridge and the university. A partnership between the

Science Alliance of UT and ORNL has resulted in several joint institutes that connect researchers with complementary resources in their fields such as: advanced materials, computational sciences, nuclear physics, and neutron sciences. ORNL has also partnered with Roane State Community College to establish several innovative programs to help ensure the region has a talented workforce to support growing demand as new composite companies locate in the region. Working with these and other institutions to develop talented workers has shown that ensuring a supply of talented workers is a priority for Oak Ridge.

ORNL offers an internship program for undergraduates from institutions all over the globe. A study conducted by UT students in STEM majors who pursue internships in the field, about 50–60% of them remain in STEM fields. Of students in STEM who pursued an internship at Oak Ridge National Laboratory, 97% remained in STEM fields.

Working with economic development organizations to foster knowledge spillover is a priority for ORNL. The city of Oak Ridge did not exist before Oak Ridge National Laboratory and was completely formed around the facility. The facility and the Manhattan Project exist on federal lands, therefore no tax base for the city existed. The city started an Energy Research and Development Association in the early 1970s to bring people, talent, and private industry into the city.

Several local clusters are supported by the activities and partnerships established at ORNL. The Carbon Fiber Cluster initiative resulted from an award from the *American Recovery and Reinvestment Act of 2009* to design, construct, and operate the Carbon Fiber Technology Facility. The facility is located off the laboratory campus to promote more interaction with private companies. The facility is capable of producing up to 25 tons of new carbon fiber materials a year. East Tennessee's regional economic development team, Innovation Valley, Inc. identified carbon fiber and composites as one of the key target industries in the Knoxville area (Innovation Valley, Inc., 2013). Innovation Valley's 2016–17 Annual Report states that three companies relocated to Oak Ridge and expanded their facilities because the laboratory allowed low-cost licenses for carbon fiber composites (Starner, 2018). Similarly, ORNL supports the local manufacturing cluster by hosting the Manufacturing Demonstration Facility (MDF), which is the Department of Energy's first facility focused on providing private industry with access to affordable and convenient infrastructure, tools, and expertise. ORNL works closely with The Institute for Advanced Composites Manufacturing Innovation (IACMI), to encourage public-private partnerships to increase domestic production capacity, grow manufacturing, and create jobs across the US composite materials industry. IACMI's collaborations between industry, research institutions, and state partners is accelerating development and adoption of cutting-edge manufacturing technologies for low-cost, energy-efficient manufacturing of advanced polymer composites for vehicles, wind turbines, and compressed gas storage. The IACMI, works in partnership with Ashland University, Zoltek Corporation, Michelman Incorporated, University of Dayton Research Institute (UDRI), JobsOhio, and Michigan State University.

ORNL connects with private industry through its Technology Transfer Office. The goal of the office is to turn laboratory discoveries into commercially successful products. ORNL has a license agreement where companies develop and commercialize to be considered for this opportunity. Currently, ORNL has over 150 active technology licenses (Oak Ridge National Laboratory).

ORNL offers lab time to private industrial users; however, it can be prohibitively expensive to smaller businesses. The state of Tennessee, recognizing the impact these partnerships can have on the state's economic competitive advantage, established a voucher program called RevV, a program committed to financially assisting companies with beam time and access to researchers. This opportunity is specifically for manufacturers that are growing and committed to offering job opportunities in the state of Tennessee, as the program is funded by the state government. One finding about partnerships with Universities and other institutions is that there are cultural differences between academia, institutions, government, and private sector, and this can make working collaboratively on projects difficult. One such difficulty is in determining who owns the rights to intellectual property developed in a university facility by an outside entity, especially when considering the role of federal funding to a facility. Finding ways to work through these cultural differences has become a priority for the University of Tennessee in their relationship with ORNL. Because ORNL is not on the university campus, it can be difficult to foster relationships. Representatives at ORNL and University of Tennessee recommend that FRIB and Michigan State University build relationships with the DOE laboratory right on campus.

It can also be difficult to foster relationships between faculty and private industry when the faculty evaluation structure is based on publications and research and not on building relationships with business. Representatives at Oak Ridge have identified this as a problem and have begun to change the ways they evaluate faculty to foster these relationships.

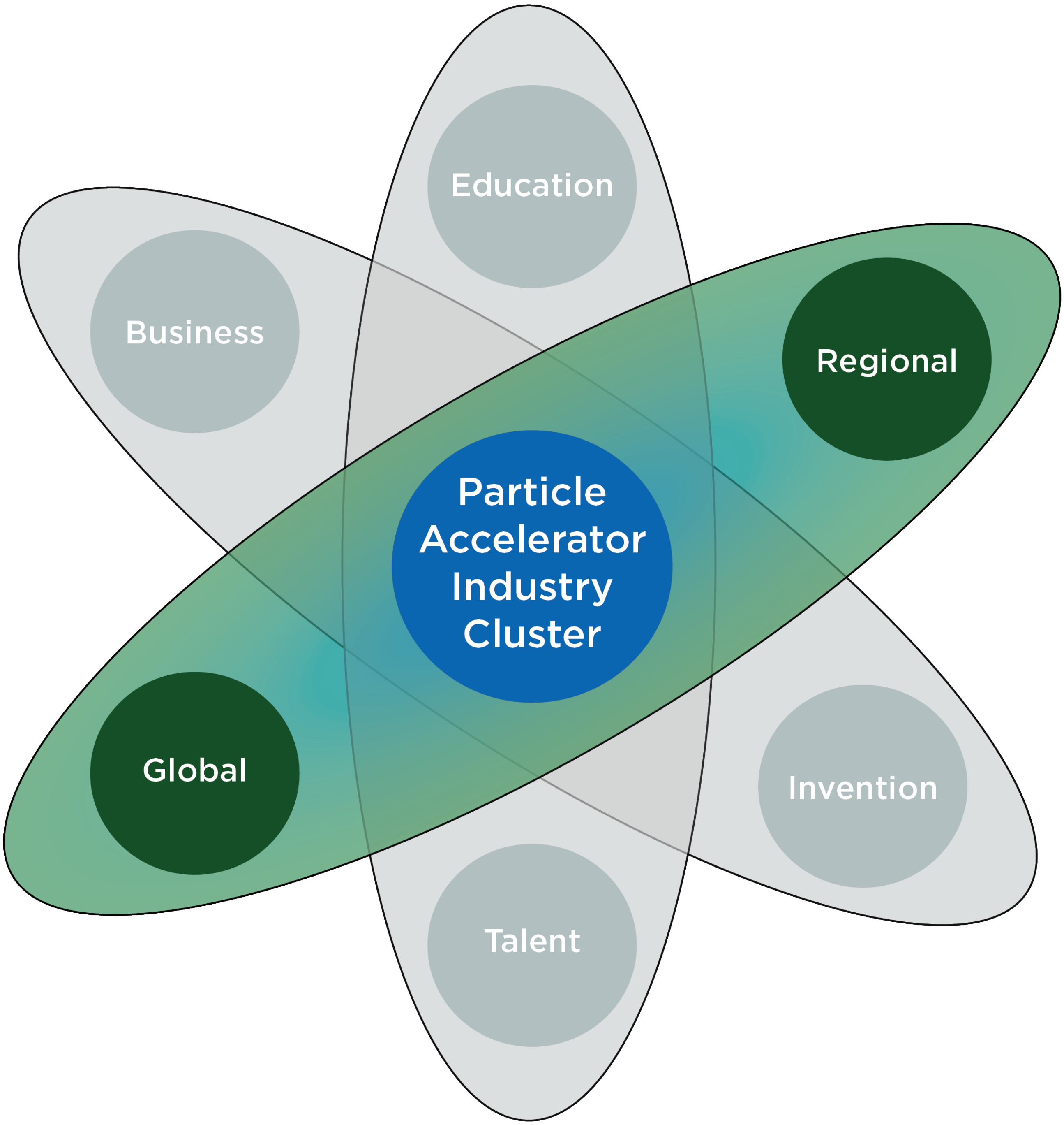
While Innovation Valley, Inc. is the marketing arm in the Knoxville and Oak Ridge area, East Tennessee Economic Council (ETEC) is an independent regional non-profit that works closely with ORNL and works to recruit and maintain federal missions and investments (https://eteconline.org/). ETEC's board is made up of employees from ORNL, UT, and private industry in the area. ETEC's first priority in their 2018 Work Plan is to support ORNL Research and Development Opportunities. ETEC also works with industrial developers in all different stages of the process, whether they are simply coming to ORNL to mine technology temporarily or moving to ORNL in order to make their products better (Oak Ridge National Laboratory, n.d.).

ORNL has an Entrepreneurial Development Program that supports the creation of new startup businesses and licensing technologies, focusing on developing commercial applications. This program includes a technology innovation program, bridging the gap, SPARK!, Tech 20/20 Center for Entrepreneurial Growth, and their Propel Mentor/Protégé Program through their Small Business Programs office. These programs are established from the efforts made by partnerships with staff in the Entrepreneurial Development Program (Oak Ridge National Laboratory, n.d.).

The Tech 20/20 Center for Entrepreneurial Growth was established in 2000 with the goal of providing resources for entrepreneurs and start-up companies related to ORNL technologies. They provide support by offering coaching and counseling to these companies in order to foster their development, and provide guidance in the use of these technologies being developed by the Laboratory.

ORNL extends its economic development partnerships beyond the immediate regions of Oak Ridge and Knoxville. The laboratory is also a part of the Leadership Council of Tennessee Valley Corridor, which is a larger geographic region economic development coalition that brings institutions such as the laboratory, surrounding universities, and NASA together “to sustain existing federal missions, compete for new federal investments and leverage these investments to grow more private sector job opportunities” (Tennessee Valley Corridor, 2017).

Regional Assessment



Regional Assessment

In order to better understand the opportunities for particle accelerator cluster development in the Lansing region, this section will describe the assets in the region currently possesses that will be beneficial in developing a particle accelerator cluster. In addition to assets, this section describes the region's gaps that will need to be addressed in order to further foster an innovative regional ecosystem.

Methodology

The follow three key areas were chosen as focuses for determining the validity of particle accelerator development:

1. Population Demographics
2. Economic Make-up of the Tri-County Region
3. Communication and Transportation Infrastructure

Databases such as the U.S. Census, and other reputable research publications were used to provide data for the selected indicators. The results collected were interpreted in the scope of the study.

Population

Data from the 2016 U.S. Census American Community Survey and the 2010 Census were used to understand the region's population and how prepared the population is for particle accelerator cluster development. Characteristics such as median age, education level, and presence of international persons are all useful in better understanding how the region can develop the knowledge economy and in effect, the particle accelerator cluster.

AGE: According to the 2016 U.S. Census data, the tri-county region consists of 470,348 individuals. Both Eaton and Clinton County's estimated median age is 40 years, slightly higher than the national average of 37 (U.S. Census, 2016). However, the median age for Ingham County is 31.6 years, likely due to the presence of Michigan State University's large student population. The lower median age of Ingham County may provide certain advantages as the region moves towards a knowledge-based economy and cluster development. Young and educated individuals can help fill entry level positions at start-up firms and may take on more entrepreneurial risks.

EDUCATION: Assessing educational attainment throughout the region will help determine how prepared the region is to transition into the knowledge economy. Building on previous work mentioned in the Knowledge Supply Chain section of this study and U.S. Census data, the region has a relatively well-educated population that is prepared for the challenges of a knowledge economy and cluster development. The Lansing region is host to two core educational intuitions, Michigan State University and Lansing Community College, and is neighbored by numerous educational institutions, that all provide a constant stream of highly qualified graduates.

According to 2016 U.S. Census data, 33.7% of adults over the age of 25 currently hold a bachelor's degree in the tri-county Region, slightly higher than the national average of 30.7% (U.S. Census 2016). Many of the individuals graduating in the area hold degrees in STEM-related majors (RC Data). The tri-county region's highly educated population will be conducive to overall economic development (Lutz et al. 2008, Berger et al. 2013) and to the growth of the knowledge economy (Elvira, 2013). The high rate of educational attainment of the region will help the development of the knowledge economy and cluster development.

In addition, the area is home to a variety of technical training programs and institutes, such as the Center for Manufacturing Excellence at LCC and the Wilson Talent Center, that prepare individuals with advanced skills that will be needed to operate particle accelerators and related businesses. These individuals are vital in the successful construction and operation of highly advanced facilities.

POPULATION TRENDS/GROWTH: According to the U.S. Census 2017 population estimate, the Lansing region population has grown 3% in the last eight years (U.S. Census, 2017). This is one of the few regions in Michigan that experienced population growth, since 2010. Since 2010, Clinton County's population grew by 4%, Eaton by 1%, and Ingham by 3% (Mack, 2018). The steady influx of people into the region demonstrates the current economic trends and the attractiveness of the region.

FOREIGN BORN INDIVIDUALS: Michigan State University's presence in the region has attracted many foreign individuals to study, work, and live in the Lansing region. According to the U.S. Census, Ingham County's population is composed of 8.8% foreign-born individuals, Eaton County; Clinton County; state as a whole (U.S. Census, 2016).

Economic Make-Up of the Lansing Region

Similar to the rest of Michigan, the Lansing regional economy has historical roots in the automotive sector. The knowledge and expertise of the manufacturing sector will be vital in developing the particle accelerator cluster. As the area's economy has evolved, the core employers in the region are mainly in the service sector. The largest employers in the region have shifted from manufacturing to government, health, and insurance firms. The region's history and experience will provide the necessary knowledge and expertise to further adapt to the knowledge economy and cluster development.

NEW FIRMS CREATED: To assess the vitality and dynamism of the Lansing region, the number of new firms created in 2017 were examined. Economic dynamism can be defined as the rate and scale of churn in an economy. According to LEAP's data, 22 firms were formed in the tri-county area in 2017 [29 in 2016, 30 in 2015, and 18 in 2014] (LEAP, 2017). New firm creation indicates the development of economic dynamism in a region (Decker et al. 2014). The more dynamic the region's economy is, the quicker the region will be able to respond to new economic opportunities.

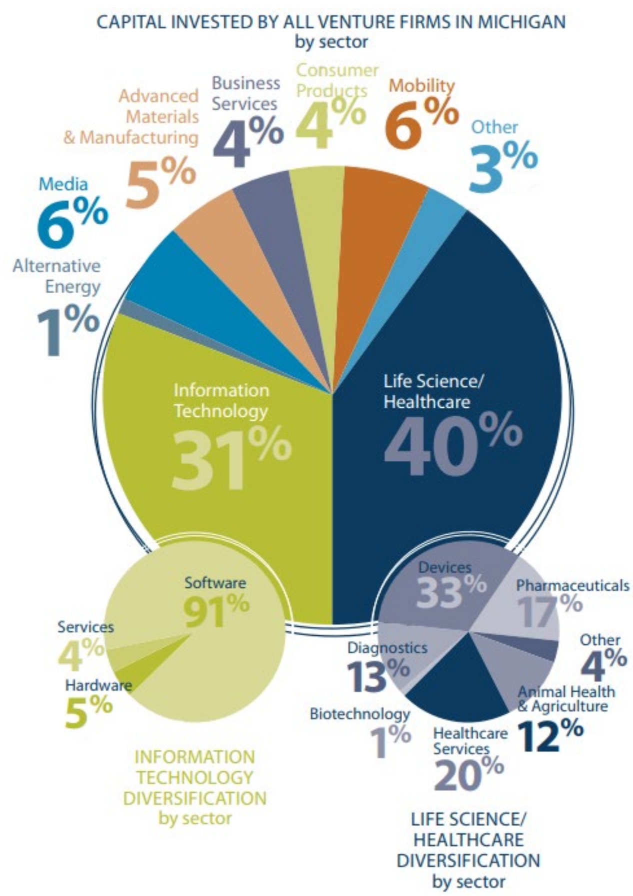


Figure 5: Venture Capital Funding by Sector
Source: MVCA 2018 Annual Research Report

CAPITAL ACCESS: Access to capital is essential to rapidly grow new firms and the particle accelerator cluster. The Lansing region has a developing venture capital sector that can help fund the particle cluster development. The Michigan Venture Capital Association's 2018 research report outlines the capital capacity throughout the state. As of 2018, there are 29 venture capital firms, 87 venture capital professionals, and 797 Angel Investors located in Michigan (MVCA, 2018). These firms and investors provide a significant opportunity for entrepreneurs and startup companies to receive otherwise inaccessible capital for their businesses. Of the 134 venture-backed startups in the state, the majority of funding in 2017 went to either Life Science & Healthcare or Information Technology companies (MVCA 2018 Annual Research Report) — indicating a heavy preference toward knowledge-economy sectors.

There are two capital firms in the Lansing region. While it is difficult to accurately measure the demand for venture capital in a specific region, the availability of multiple sources of capital is vital to the development of the particle accelerator cluster. Multiple studies confirm that greater access to capital spurs help sustain economic development (Bates et al., 2013; Breuer et al., 2018)

Technology Transfer

Technology transfer refers to the process of converting technological or scientific intellectual property into marketable products. The success at which technology advances throughout the region, and between the private and public sphere, will affect cluster development. In particular, firms related to the particle accelerator cluster will depend on developing new technologies to create business models. Many new technologies could be developed at Michigan State University's FRIB. To facilitate intellectual property dissemination, Michigan State University established the Innovation Center, which oversees multiple subsidiaries to connect the University's research efforts with the private sector. MSU currently holds more than 2,000 published patents worldwide (MSU Technologies).

MSU INNOVATION CENTER: The MSU Innovation Center's mission is to "provide the educational and financial support necessary to turn MSU research technologies into successful Michigan businesses — and spur entrepreneurship in the Michigan economy" (MSU Innovation Center, 2018). To accomplish this mission the center oversees three core organizations related to innovation and technology. Within the MSU Innovation Center, there are three core initiatives that support technology and business development, all receiving significant funding from the MSU Foundation.

MSU TECHNOLOGIES: Facilitates the commercial development and public use of technologies and copyrightable materials developed by MSU faculty and staff. Their goal is to move these materials from the lab to the marketplace to improve lives and communities locally, regionally, and around the world. To accomplish that goal, MSU Technology:

- Manages the university's extensive intellectual property portfolio, evaluating the commercial potential of each invention
- Works with MSU researchers on the invention disclosure and technology transfer process

- Protects inventions by filing patent applications
- Markets and licenses commercially viable technologies to large corporations and small-to-mid-sized businesses
- Works with Spartan Innovations to launch start-up companies based around MSU technologies
- Facilitates confidential disclosure and material transfer agreements (CDA/MTA)

For more information on MSU Technologies, visit https://technologies.msu.edu/

Following are just a few of the start-up companies developed in the past several years around MSU technologies:

Biophotonics Solutions	BoroPharm Inc.
Draths Corporation	Drawbridge, LLC
Gema Diagnostics	InPore Technologies
Names for Life LLC	nanoRETE
Neogen Corporation	Niowave Inc.
Phenometrics	Red Cedar Technologies
Retia Medical	XG Sciences

SPARTAN INNOVATIONS: Compliments the work of MSU Technologies to provide educational and financial support to turn MSU research into successful businesses. Spartan Innovations hosts a number of experts who screen innovations for startup potential, review technology and business strategy, engage seasoned entrepreneurs to guide early technology development and capital attraction, engage with various sources of venture capitalists to inform startup strategy. Spartan Innovations also allows startup ventures to access state of the art technology to further their products and designs. For more information, visit https://www.spartaninnovations.org

MSU BUSINESS CONNECT: Helps companies leverage MSU's wealth of resources more efficiently. Business Connect works with companies to align business goals with MSU's intellectual capacity and ability to deliver results by drawing on MSU's extensive base of human knowledge and source materials, high-end scientific equipment and facilities, and invaluable international connections and educational services. Business Connect hosts a directory of university business support services where entrepreneurs can find expertise to support their efforts. For more information, visit https://businessconnect.msu.edu

The resources available through MSU's many technology transfer services provide the necessary support to researchers at FRIB, and associated spin-off businesses, with bringing their discoveries into the local economy. As FRIB becomes operational, the availability of these resources will be of great benefit to ensuring successful development of a particle accelerator cluster in the region.

Business Development Organizations

Business development organizations perform as intermediaries between the public and private sector, ensuring that start-up businesses are able to take full advantage of federal, state, and local programs. These organizations also provide the expertise and advising necessary to assist entrepreneurs in successfully developing their businesses. The Lansing region has a number of business development organizations that provide support and guidance to start-up businesses, creating a favorable environment for the development of the particle accelerator cluster. These organizations are distributed throughout the region, as detailed in Table 2 b. This "Start Chart" is a resource developed by LEAP for the purpose of assisting entrepreneurs in identifying resources for the early stages of business operation and growth, and is used in this report to gauge the capacity of these organizations to provide services in the region. It may be used as a tool by economic developers and entrepreneurs to locate the business services they require.

Table 2: Lansing Region Start Chart

Organization Name	Location	Planning / Assistance	Research & Product Development	Sales	Legal Assistance	Financial Management	Workforce	Funding	Space	Networking	News and Happenings
5minutestops.com	See website for event information										
5X5night.com	See website for event information										
5X5night.com	See website for event information										
Accelerate Michigan	Detroit, MI										
Allen Market Place	Lansing, MI	X		X		X			X	X	X
Altruis Capital	altruiscapital.com										
Capital Area Michigan Works	Lansing, MI						X				
Capital Community Angels	East Lansing, MI							X			
Delta Township EDC	Lansing, MI										
Downtown Lansing Incorporated	Lansing, MI										
Entrepreneur Institute of Mid-Michigan	Lansing, MI	X								X	
Green Light Michigan	East Lansing, MI										
Ingham County EDC	Mason, MI	X	X			X	X		X		
Invest Detroit	Detroit, MI										
Lansing Economic Area Partnership	Lansing, MI	X	X					X	X		X
Lansing Makers Network	Lansing, MI		X						X		
Lansing Mosaic	Grand Ledge, MI										
Lansing Regional Chamber of Commerce	Lansing, MI			X			X		X		
Meridian EDC	Okemos, MI										
Michigan Minority Supplier Development Council	Detroit, MI	X						X			
Michigan Women's Foundation	Detroit, MI										
MSU Business Connect	East Lansing, MI										
MSU Career Services	East Lansing, MI						X				
MSU Federal Credit Union	East Lansing, MI					X		X			
MSU Foundation	Lansing, MI	X								X	
MSU Gast Business Library	East Lansing, MI	X	X								
MSU Product Center College of Agriculture	East Lansing, MI	X	X	X		X					
MSU Small Business & Nonprofit Clinic	East Lansing, MI		X		X						
Quantum Medical Concepts	East Lansing, MI	X				X		X			
Small Business Association of Michigan	Lansing, MI										
Small Business Development Center	Lansing, MI	X	X	X							X
Soup Grant Lansing	See website for event information										
Spartan Innovations	East Lansing, MI	X		X			X		X		
State of Michigan eLibrary	www.mel.org	X	X		X						
Technology Innovation Center	East Lansing, MI										
The Fledge	Grand Ledge, MI	X	X	X	X	X		X	X	X	X
The Hatch	East Lansing, MI										
The Hatching	Lansing, MI							X			
The Runway	Lansing, MI	X	X	X	X			X	X	X	
U.S. Patent & Trademark Office	Detroit, MI				X						
University Corporate Research Park	Lansing, MI		X						X		
Young Entrepreneur Academy	Lansing, MI	X	X								
Youth Startup Challenge	Lansing, MI										

The Start Chart shows that there are 24 business development organizations in the Lansing region, offering a variety of different services to businesses, at different stages of development from idea to start-up, to growth. The list includes several economic development organizations including Clinton County, Delta Township, Ingham County, and Meridian Township, as well as a number of accelerator facilities. A number of these organizations are located in close proximity to FRIB, within East Lansing City limits, and several more are located nearby within the City of Lansing. The geographic proximity of these organizations is beneficial for the development of a particle accelerator cluster, as has been seen at other similar facilities, whose convenient access to business services has resulted in positive economic investment in their communities. For more information about the business development organizations represented in this chart, visit LEAP's website at http://www.purelansing.com/startchart.

Knowledge Economy Indicators

The Lansing region's movement towards a knowledge economy and cluster development has previously been measured based on multiple indicators examined in "Michigan Knowledge Economy Index: A County-Level Assessment of Michigan's Knowledge Economy" conducted by the Center for Community and Economic Development. The knowledge economy indicators chosen from the original study to examine the tri-county region were: information-technology jobs, management jobs, bachelor's degree attainment and patents granted. The growth or decline of the selected knowledge economy indicators, compared to the original study, demonstrates that the region is moving toward a knowledge economy and potential cluster development.

Information Technology Jobs

For the purposes of this study, information technology (IT) jobs were defined using several NAICS code industrial classifications: 5,132 Cable Networks and Program Distribution; 5,133 Telecommunications; 514 Information Services and Data Processing Services; and 5,415 Computer Systems Design and Related Services. The graphic in Figure 6 shows the percent change in the

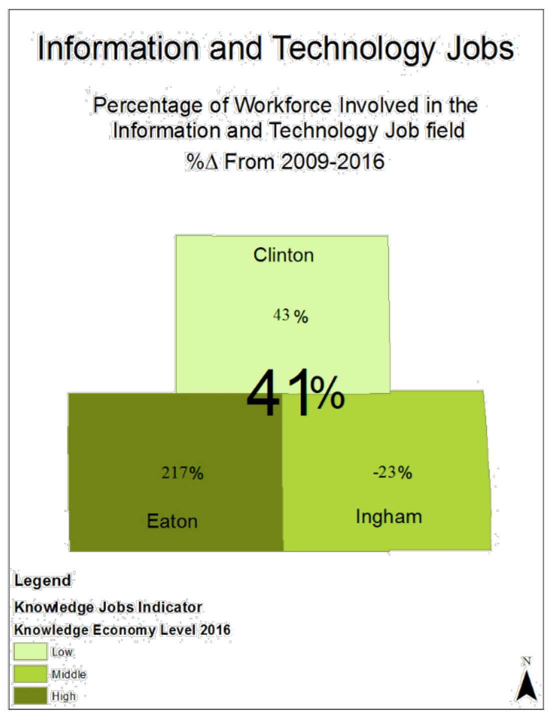


Figure 6: Information Technology Jobs, percent change in workforce from 2009-2016
Source: U.S. Census Data

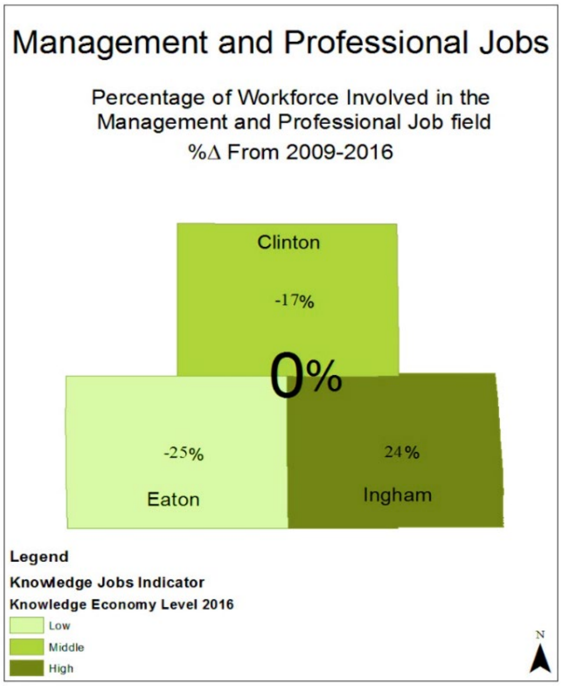


Figure 7: Management and Professional Jobs, percent change of workforce 2009-2016.
Source: U.S. Census Data

workforce from 2009 to 2016 in the Lansing region of Ingham, Eaton, and Clinton Counties. Both Eaton and Clinton Counties saw considerable growth in IT jobs for this period, 43% and 217% respectively, though Ingham County experienced a slight loss of 23% in this industry. While the region as a whole saw an increase in its workforce of approximately 1,000 workers (.67%), the IT industry's growth in the region as a whole was significant at 41%; indicating a strong knowledge economy sector.

Management and Professional Jobs

Management and professional jobs are important indicators of the knowledge economy. Figure 7 shows the change in what proportion of the workforce is classified in this field from 2009 to 2016. Despite the percentages represented indicating decline for Clinton and Eaton Counties, the reality for these areas was rather a lack of growth; the number of jobs in this classification remained nearly identical for the period, while the number of total jobs grew. Ingham County, on the other hand, did experience job growth of approximately 800 workers in the management and professional jobs area, making up nearly 8% of the total workforce in the region.

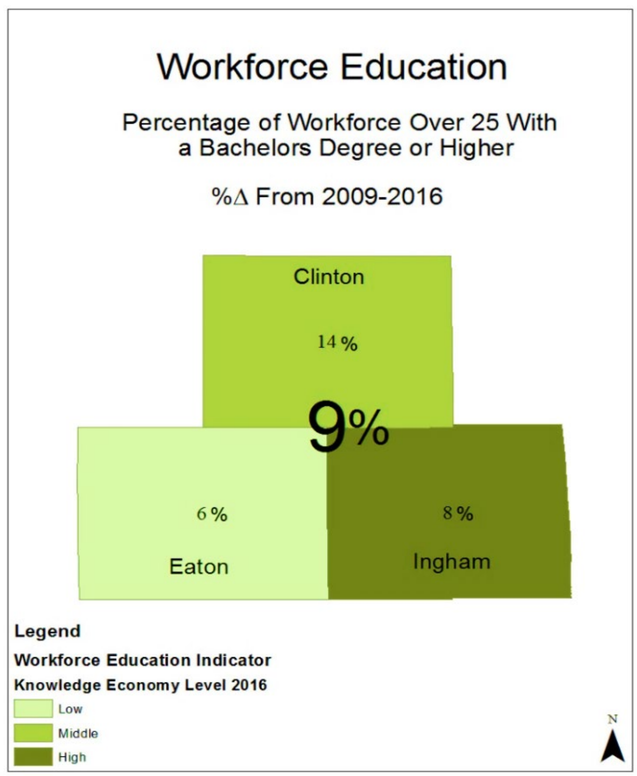


Figure 8: Workforce Education, percent change in population over age 25 with bachelor's degree or higher
Source: U.S. Census Data

Workforce Education

It is well understood that high educational levels have a direct result of higher wage and career levels. The more well-trained and innovative a region's workforce is, the more competitive it is in the global knowledge economy. Workforce education is measured as a percentage of the total population over age 25 who have obtained a bachelor's degree or higher. Figure 8 shows the percent changes in this educational attainment from 2009-2016 in the Lansing region. All three counties in the area saw moderate growth in workforce education, which may indicate that more highly-educated individuals are moving to the region; or more students are choosing to stay in the region post-graduation.

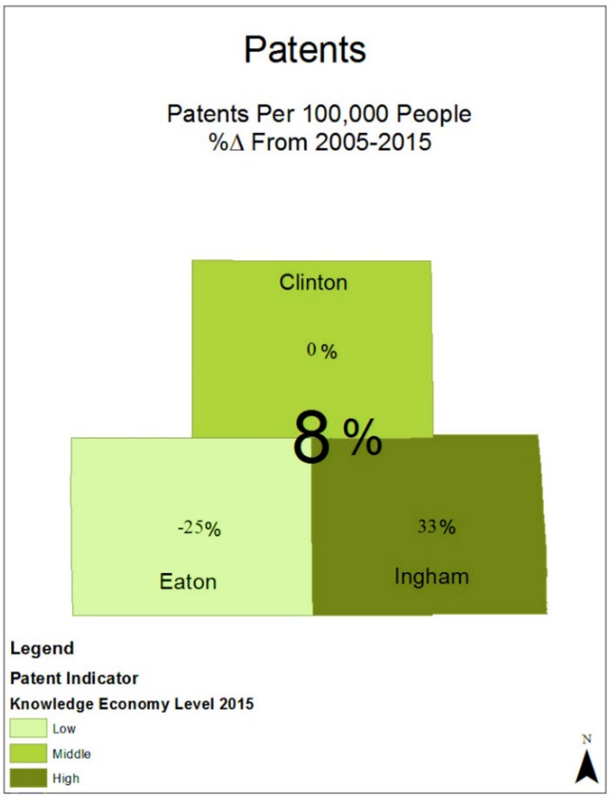


Figure 9: Patents granted per 100,000 people, percent change from 2005 to 2015.
Source: U.S. Patent Office

Patents Granted

According to the NIST Economic Analysis Office, Economic & Policy Analysis Brief, "Novel clusters develop in regions that are geographically distinct centers of breakthrough patenting and subsequent innovations in a specific technological area" (Anderson, Federal Role in Technology Cluster Formation). Therefore, it is important to measure the number of patents granted in an area, a direct result of research and development activities, to understand the region's innovative capacity. The data expressed in Figure 9 shows the percent change from 2005 to 2015 in the number of patents granted per 100,000 residents in Clinton, Ingham, and Eaton Counties. As a whole, the region saw an 8% increase in the number of patents granted during this time, mostly attributable to Ingham County.

Infrastructure

Infrastructure plays a key role in not only attracting a talented workforce to a region, but also in enabling scientific and technological advancements to be discovered. The conditions of the transportation and communications infrastructure in the Lansing region will directly affect the success of particle accelerator cluster development. Various particle accelerator-related industries will require robust transportation infrastructure to ship materials and products quickly to and from destinations, as well as a dependable communications infrastructure to conduct research and collaborate with others in the field. The accessibility of these infrastructure components will make the area more attractive to potential employees and researchers.

INTERNET ACCESS: According to the Federal Communications Commission's 2018 Broadband Deployment Report, the Lansing region has widespread access to high-speed internet, with 92.8% of individuals in the tri-county region having access to a fixed internet connection of 25mbps or faster. High-speed internet access in the tri-county region is slightly higher than Michigan's average of 90.2% (FCC, 2018). Internet access is both vital for regular day-to-day business functions and for the development of the knowledge economy. According to the World Bank, communications infrastructure is the foundation of a knowledge economy, allowing for the effective dissemination and processing of information (World Bank, 2013). In particular, Ingham County hosts a diverse range of telecommunication companies which offer direct fiber-to-home/business internet connections of up to 1 Gbps to 100% of Ingham County's population (FCC, 2018). The internet infrastructure throughout the Lansing region is well-prepared for the challenges of the knowledge economy and future cluster development.

SHIPPING HUBS: Many firms within the particle accelerator cluster will require fast shipping for products with limited lifespans, such as medical isotopes. Therefore, the proximity of distribution centers, namely airport hubs, is important for cluster development. Within the tri-county region, the United Postal Service (UPS) has an air cargo hub at the Capital Regional International Airport (CRIA), which handled 48.5 million pounds of parcels, automotive supplies, and other cargo in 2015. The airport's status as a U.S. Port of Entry, and the existence of an on-site Customs and Border Protection Federal Inspection Station makes it an attractive site for travelers and shipping; the airport's relatively small size compared to Chicago and Detroit make processing packages much faster. CRIA's assets and ease of use are credited in Niowave Inc.'s decision to build their facility on the airport's property (Fly Lansing, 2016). While FedEx has a FedEx Express Hub at the Indianapolis airport, the limited proximity of close shipping hubs could affect the development of the particle accelerator cluster.

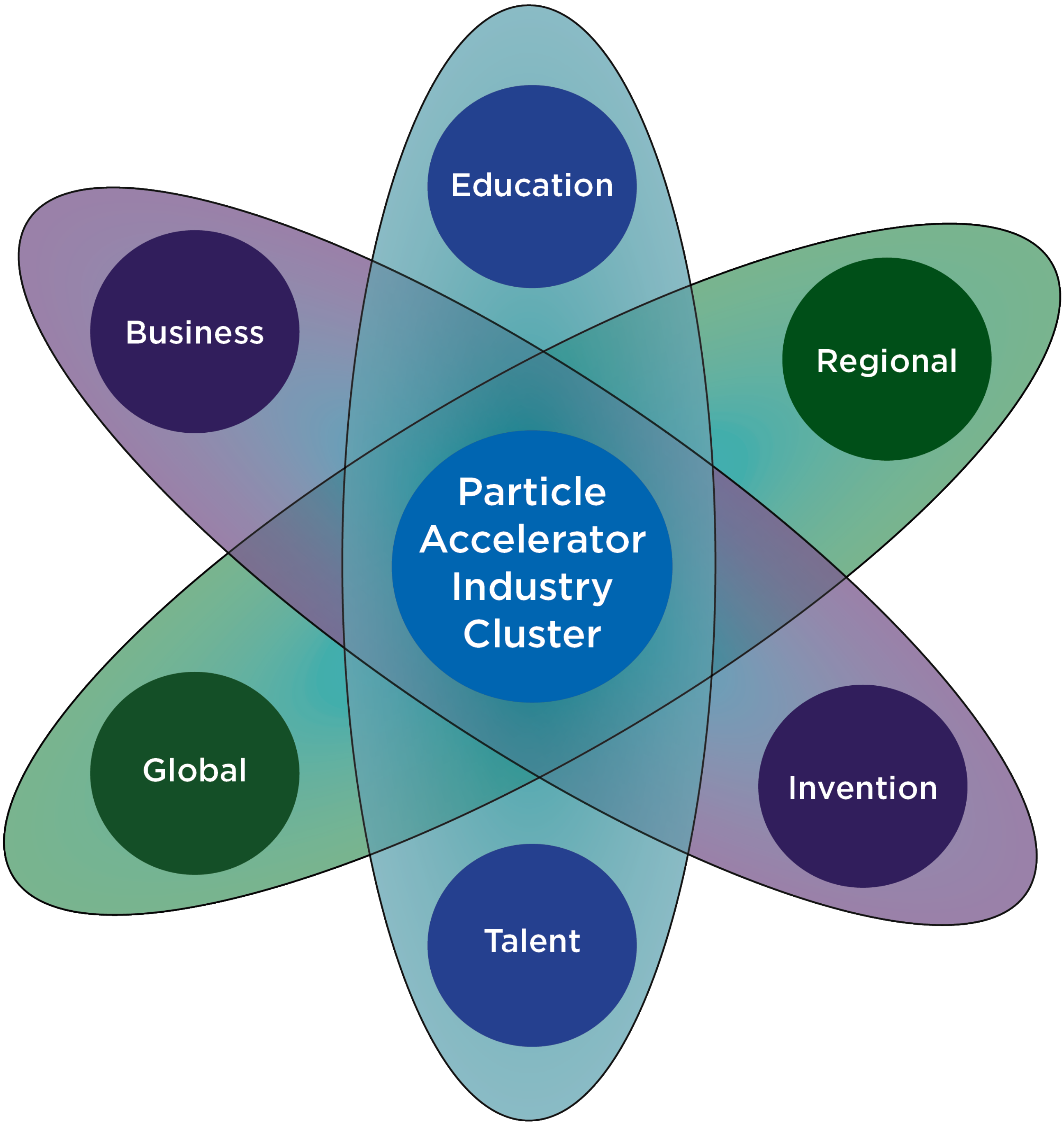
MASS TRANSIT: The Lansing region is connected by three public transit systems, the Capital Area Transportation Authority (CATA), The Clinton Area Transit System, and the Eaton County Transportation Authority (EATRAN). Together, the three transit systems service all high-density areas in the region. According to a 2015 regional transit mobility study, conducted by the Tri-County Regional Planning Commission, these transportation services are widely used by the public, with total ridership for the three services estimated to be 12 million rides (Tri-County Transit Report, 2015). The most developed of these is CATA, providing its services in the cities of Lansing, East Lansing, and Mason, and to Delhi and Meridian Townships. CATA offers dedicated MSU campus routes that operate during the school year, special community event rides, and a weekend "Entertainment Express" trolley bus that travels between popular nightlife activities in Lansing and East Lansing. Through its combined routes, CATA boasts more than 10 million trips in the 2018 fiscal year (CATA).

Assessment of the Region

An important part of encouraging knowledge transfer and cluster development is being able to attract young talent to the area. Extensive research has been conducted on the amenities that people desire in their communities; but to get a better grasp the specific needs of the Lansing region, MSU Center for Community and Economic Development (CCED) hosted a focus group with graduate students whose field of study correlated with the use and technology of the FRIB. In this focus group, CCED staff asked a group of nine physics graduate students about the community and quality of life they, as emerging scientists, would like to see in the community were they choose to study, live, or work. Questions focused on what the students enjoyed about living in East Lansing, what they disliked, what they will be looking for in a community when they move on to professional careers, and how to make MSU and the Lansing region a more attractive place for gaining and retaining knowledgeable workers, such as themselves. The students provided valuable knowledge and insight into how out-of-state and international graduate students view the Lansing area and how to better market all it has to offer, to current and future physics students and professionals.

Some of the amenities and establishments that students said they enjoyed about the University and the surrounding area included the low cost of living, low crime rates, availability of parks and outdoor activities, and the size of Lansing. Many of them enjoyed the clubs they were involved in, the prestige of the MSU physics program and the strong physics community in the area. They also found their healthcare to be easy to use and appreciated the availability of the International Center on campus. However, the participants of the focus group also noted a number of "dislikes" about MSU and the surrounding area. While they found the public transportation to be convenient, they indicated that CATA (Capital Area Transportation Authority) bus system has reduced summer routes making the service unreliable. They also found it difficult to get to other major cities in Michigan, and suggested a train between East Lansing/Lansing and Ann Arbor. They suggested the area invest more into events and facilities that support cultural diversity outside of campus, such as art galleries, street art, music festivals, night life, social events, and restaurants. They also suggested that the Lansing area improve its advertising, such as the availability of fresh food options through urban farming and farmers markets and community-wide events. Offering better attractions and advertising to prospective graduate students and young professionals is important for attracting talent to increase knowledge transfer.

Future Opportunities



Future Opportunities

The goal of this study examines the Lansing region particle accelerator cluster and make recommendations for future development from four perspectives: accelerator component supply chain, knowledge supply chain and network, national innovative practices, and regional assessment. As with any good investigation you pose questions, collect evidence, develop findings and make recommendations, but you also find new questions to ask and new directions to explore; and so it is with this investigation.

Studying particle accelerators and learning about the knowledge economy and technology cluster development has led to the recognition that the growth of the Lansing based particle accelerator industry relies on the ability to find market opportunities for the applications of particle accelerator technology and to connect our regional capacity to design and build particle accelerators to those opportunities. Given the existing capacity to go from research to application as demonstrated by the growth of the accelerator businesses and the construction of FRIB, the region exhibits high innovation potential but requires further research to identify market opportunities, demonstrate capacity, and secure capital investment.

Based on this analysis, the team recommends a market and business feasibility study focused on four broad categories of particle accelerator applications: 1) sterilization, 2) active interrogation, 3) computer model validation, and 4) medical applications be conducted. Information from such a study can help to better design and target business development efforts to take advantage of regional efficiencies.

Sterilization

Particle beams from accelerators are used for applications that include disinfecting drinking water, treatment of solid waste, removal of noxious substances, treatment of waste gases, medical sterilization, and preservation of food.

A package must protect food quality and guard against contamination. While the traditional methods for sterilizing empty packages are simple, they have environmental drawbacks. Low energy electron beams from particle accelerators are more efficient and chemical free. The packaging material passes through an electron beam which kills microbes. Sterilizing equipment is a critical aspect of modern medical care and sterilization can efficiently be done by way of particle accelerators. E-beam processing for medical devices involves the use of high-energy electrons for the sterilization of single-use disposables. The electrons generated by accelerators operate in a pulse and continuous-beam mode.

The presence of FRIB as a related area of nuclear science provides an opportunity to further development in this industry sector.

Active Interrogation

For cargo scanning, accelerators are vital in addressing many of the complications in inspecting cargo in ports of entry, airports, seaports, and other areas. The particle accelerators are used to produce x-rays for radiographic scans, while active interrogation techniques scan and detect characteristic signals for materials discrimination. At airports in particular, carry-on baggage is scanned with dual-energy x-rays that enable both radiography and some material discrimination of the contents, which reduced the number of false alarms during rapid scans. As a related area of nuclear technology, FRIB strengthens the potential for development in this sector.

Computer Model Validation

Particle accelerators require sophisticated measurement and computational tools, which are essential in providing the data needed for the development of computational tools used in national security and defense.

The computational tools are used to predict detector responses, clarify unique signatures, optimize system design and reduce cost and risk. Security and defense applications have specific requirements that are different from the conventional coded applications, so the field often runs into fundamental gaps in the underlying physics models and data.

Medical Applications

Particle accelerators have made huge strides in the advancement of medical applications. Millions of patients receive diagnoses and therapy through accelerator-based procedures in hospitals and clinics around the world. The two primary roles for particle accelerators in medical applications include the production of radioisotopes for medical diagnosis and therapy, and a source of beams of electrons, protons and heavier charged particles for medical treatment. There are a number of radioisotopes currently available, and their range of radiation types allow optimization for specific applications. Medical applications that utilize high-activity radioactive sources include: blood irradiators, external-beam radiation therapy units, gamma knife stereotactic surgery systems for treating brain cancer, high-dose-rate brachytherapy systems for intracavitary irradiation, and research gamma irradiators. Radiation therapy by way of external beams has also developed into a highly effective method for treating cancer patients (see Appendix). FRIB provides a unique opportunity to support spinoff research and development in medical application of isotopes.

Conclusions & Recommendations

Investments made at MSU have helped to advance the Lansing region as a contender in the global nuclear science industry. This report identifies many of the strengths and opportunities available for the nurturing of technology clusters based on the cutting edge discoveries at MSU and its world class researchers. The continued commitment of federal partners and funding has led to the construction of FRIB and a proposal for expanding isotope harvesting capacity at the facility. As isotope-enabled research produces discoveries that translate into applications, it will further increase opportunities for business development and regional prosperity. Indeed that is the model that has produced the success of the two Lansing based particle accelerator businesses today.

Translating basic research into regional business development demonstrates the capacity of the region. However, future success will rely on the ability of the region to continue to bring added efficiencies to the process. As described in this report, supply chains play a crucial role in cluster development with the knowledge supply chain offering the greatest opportunities for optimizing efficiencies. It is knowledge spillover (knowledge exchange) that spurs innovation and drives efficiencies. The exchange of both explicit and tacit knowledge is increasingly impacted by changing technology and new discoveries however future success may depend how effectively new information is exchanged within the cluster. Opportunities to bring industry and university together on a routine basis and increase communication and collaboration should be a priority of the region.

- To advance opportunities for isotope-enable development in the region, the research team recommends facilitating an industry/university panel composed of stakeholders that could develop and support a comprehensive plan for the future of isotope-enabled research and production in the region. The panel could help to leverage key partnerships to advance funding, communications, marketing and business development.
- Funding is a need shared by all stakeholders and the US Department of Energy is a key partner for both university and industry. There is a need for funding to better understand the exact isotopes FRIB operations will be producing and then those isotopes need to be mapped to potential research and commercial value. There is a need to fund infrastructure development both on and off campus to increase the capacity for the timely handling and delivery of

isotopes. Industry has needs for funding research and development and identifying market opportunities. The shared capacity and mutual support of the industry/university panel should enhance investment opportunities for the stakeholders.

- Communication is key to the successful functioning of a cluster. A comprehensive communications plan could address communication between industry, MSU/FRIB, and other regional stakeholders to enhance the exchange of knowledge within the cluster. It would also provide a clear and comprehensive voice on the opportunities for development in the Lansing region.
- Marketing has proven to be an important component of successful knowledge economy development. Oak Ridge National Laboratory is a key partner in the East Tennessee Innovation Valley which markets the region to attract knowledge, talent and investment. A marketing program could be developed to complement the funding, communication and business development efforts of the industry/university panel.
- To facilitate linkages to regional development it is recommended that FRIB Laboratory designate personnel who could serve as: 1) a *visitor experience liaison* who would work with regional partners such as the Chamber of Commerce, Convention and Visitor Bureau, hotel and hospitality industry, arts and culture organizations and entertainment venues; and 2) a *research commercialization specialist* to work with MSU Innovation Center and other MSU units and collaborate with LEAP's business attraction efforts to promote research commercialization and business development opportunities in the Lansing region.

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APPENDIX: TALENT ENROLLMENT AND DEGREE CONFERRED DATA

CENTRAL MICHIGAN UNIVERSITY

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Chemistry (B.S.)	73	8	84	8	87	9
Electrical Engineering (B.S.)	215	17	201	24	166	18
Industrial Engineering Technology (B.S.)	44	5	25	2	15	N/A
Mechanical Engineering (B.S.)	512	37	507	51	489	25
Mechanical Engineering Technology (B.S.)	324	28	283	29	250	21
Physics (B.S.)	24	1	18	4	24	3
Product Design Engineering Technology (B.S.)	94	4	70	3	33	N/A
Chemistry (M.S.)	61	3	72	7	62	5
Engineering (M.S.)	34	7	26	N/A	7	N/A
Engineering Management (M.S.A.)	19	9	20	10	1	1
Physics (M.S.)	31	6	62	9	71	13
Science of Advanced Materials (PhD)	41	3	56	2	59	4

FERRIS STATE UNIVERSITY

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
CAD Drafting and Tool Design Technology (A.A.S.)	35	23	31	9	42	12
Chemistry (BA)	19	3	26	8	26	5
Electrical/Electronics Engineering Technology (B.S.)	38	16	48	21	53	18
Heavy Equipment Service Engineering Technology (B.S.)	34	17	27	13	34	23
Industrial Electronics Technology (A.A.S.)	48	15	59	12	58	7
Industrial Technology and Management (BAS)	84	26	79	26	69	7
Manufacturing Engineering Technology (B.S.)	107	23	97	32	78	23
Manufacturing Technology (A.A.S.)	51	28	54	13	50	8
Mechanical Engineering Technology (A.A.S.)	132	52	141	45	132	22
Mechanical Engineering Technology (B.S.)	70	33	60	32	46	32
Nuclear Medicine Technology (B.S.)	54	36	79	37	94	32
Plastics and Polymer Engineering Technology (A.A.S.)	94	56	141	67	147	33
Plastics Engineering Technology (B.S.)	77	49	59	31	43	20
Product Design Engineering Technology (B.S.)	61	21	56	16	48	25
Welding Engineering Technology (B.S.)	84	37	79	33	77	52
Welding Technology (A.A.S.)	88	44	93	41	91	42

GRAND VALLEY STATE UNIVERSITY

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Chemistry (B.S., Minor)	191	18	217	30	272	34
Computer Engineering (B.S.E., Minor)	238	17	254	9	149	7
Electrical Engineering (B.S.E.)	397	16	401	16	365	10
Engineering (B.S.E.)	13	2	19	5	53	18
Mechanical Engineering (B.S.E.)	1154	62	1190	36	1172	20
Physics (B.S.)	86	5	95	7	107	7
Product Design & Manufacturing Engineering (B.S.E.)	304	22	265	12	294	6
Engineering (M.S.E.)	142	21	128	17	116	12

KETTERING UNIVERSITY

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Chemical Engineering (CHME)	132	12	127	19	116	13
Chemistry (CHEM)	8	2	7	0	8	3
Electrical and Computer Engineering (ECE)	115	16	108	25	193	13
Electrical Engineering (EE)	170	48	168	44	177	32
Engineering Physics (EP)	35	8	31	3	27	5
Industrial/Manufacturing Engineering (IME)	85	13	96	20	112	26
Mechanical Engineering (MECH)	1029	177	979	157	911	147
Physics (PHYS)	19	3	18	4	16	3

MICHIGAN STATE UNIVERSITY

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Applied Engineering Sciences (B.S.)	906	109	881	67	738	41
Chemical Engineering (B.S.)	1625	108	1563	102	1494	78
Chemistry (BA)	199	N/A	211	18	215	30
Chemistry (B.S.)	410	45	438	30	420	23
Electrical Engineering (B.S.)	1038	79	1056	91	1043	97
Materials Science and Engineering (B.S.)	277	209	276	28	268	17
Mechanical Engineering (B.S.)	3393	256	3222	220	3016	167
Physics (BA)	30	32	35	2	38	3
Physics (B.S.)	491	34	508	22	552	29
Chemical Engineering (M.S.)	13	5	12	6	11	3
Chemistry (M.S.)	7	9	3	7	4	9
Electrical Engineering (M.S.)	95	25	81	24	112	23
Materials Science and Engineering (M.S.)	13	5	18	9	20	4
Mechanical Engineering (M.S.)	18	3	19	17	53	20
Physics (M.S.)	10	17	9	12	4	17
Chemical Engineering (PhD)	99	10	113	11	115	12
Chemistry (PhD)	477	33	497	22	501	17
Electrical Engineering (PhD)	302	23	293	21	319	31
Materials Science and Engineering (PhD)	105	N/A	89	5	78	6
Mechanical Engineering (PhD)	223	17	199	12	204	17
Physics (PhD)	382	14	367	15	385	24

MICHIGAN TECHNOLOGICAL UNIVERSITY

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Chemical Engineering (B.S.)	1011	79	994	102	1016	78
Chemistry (B.S.)	82	8	74	7	75	13
Electrical Engineering (B.S.)	749	85	754	70	730	87
Electrical Engineering Technology (B.S.)	111	6	81	5	64	12
Engineering Management (B.S.)	183	8	159	12	123	3
Materials Science and Engineering (B.S.)	383	25	291	29	280	26
Mechanical Engineering (B.S.)	2931	220	2898	249	2884	208
Mechanical Engineering Technology (B.S.)	314	26	288	23	251	34
Physics (BA)	13	5	11	4	13	4
Physics (B.S.)	83	9	85	3	82	5

OAKLAND UNIVERSITY

Degree	Enrolled ’16-‘17	Graduated ’16-‘17	Enrolled ’15-‘16	Graduated ’15-‘16	Enrolled ’14-‘15	Graduated ’14-‘15
Bioengineering (B.S.)	69	14	50	5	33	N/A
Chemistry (B.A., B.S.)	52	11	51	16	64	10
Electrical Engineering (B.S.)	346	55	327	55	312	44
Engineering Chemistry (B.S.)	27	4	28	1	34	5
Engineering Physics (B.S.)	8	N/A	16	2	19	N/A
Mechanical Engineering (B.S.)	743	132	707	68	612	60
Physics (B.A., B.S.)	33	5	36	9	27	6
Chemistry (M.S.)	32	10	32	12	33	5
Electrical and Computer Engineering (M.S.)	107	29	93	34	84	45
Mechanical Engineering (M.S.)	135	67	134	42	142	42
Mechatronics (M.S.)	33	6	32	3	20	3
Physics (M.S.)	3	N/A	4	2	3	N/A
Electrical and Computer Engineering (PhD)	72	4	64	7	52	5
Mechanical Engineering (PhD)	55	6	51	6	51	2
Biomedical Science: Medical Physics (PhD)	9	4	2	4	3	1

PURDUE UNIVERSITY

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Automation and Systems. Integration Engineering Technology (B.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Biomedical Engineering (B.S.BME)	N/A	N/A	N/A	N/A	N/A	N/A
Chemical Engineering (B.S.CHE)	N/A	N/A	N/A	N/A	N/A	N/A
Chemistry (B.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Data Science (B.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Electrical Engineering Technology (B.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Industrial Engineering Technology (B.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Materials Engineering (B.S.M.S.E)	N/A	N/A	N/A	N/A	N/A	N/A
Mechanical Engineering Technology (B.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Mechatronics Engineering Technology (B.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Nuclear Engineering (B.S.NE)	N/A	N/A	N/A	N/A	N/A	N/A
Physics (B.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Sustainable Biomaterials - Process and Product Design (B.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Biomedical Engineering (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Chemical Engineering (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Chemistry (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Electrical & Computer Engineering (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Engineering Technology (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Industrial Engineering (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Materials Engineering (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Mechanical Engineering (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Nuclear Engineering (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A
Physics (M.S.)	N/A	N/A	N/A	N/A	N/A	N/A

UNIVERSITY OF MICHIGAN

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Biomedical Engineering (B.S.)	N/A	N/A	260	73	243	77
Biophysics (B.S.)	N/A	N/A	17	6	22	4
Chemical Engineering (B.S.)	N/A	N/A	435	173	466	144
Chemistry (B.S.)	N/A	N/A	61	23	61	25
Electrical Engineering (B.S.)	N/A	N/A	323	104	310	167
Engineering Physics (B.S.)	N/A	N/A	24	8	28	4
Industrial and Operations Engineering (B.S.)	N/A	N/A	517	202	506	219
Materials Science and Engineering (B.S.)	N/A	N/A	155	54	147	68
Mechanical Engineering (B.S.)	N/A	N/A	807	299	793	313
Nuclear Engineering & Radiological Sciences (B.S.)	N/A	N/A	85	29	73	34
Biomedical Engineering (M.S.)	N/A	N/A	95	71	206	101
Chemical Engineering (M.S.)	N/A	N/A	23	39	54	30
Chemistry (M.S.)	N/A	N/A	2	32	2	31
Electrical Engineering (M.S.)	N/A	N/A	141	78	354	166
Electrical Engineering-Systems. (M.S.)	N/A	N/A	116	44	319	80
Industrial and Operations Engineering (M.S.)	N/A	N/A	97	90	211	94
Materials Science and Engineering (M.S.)	N/A	N/A	115	25	25	27
Mechanical Engineering (M.S.)	N/A	N/A	196	172	401	186
Nuclear Engineering & Radiological Sciences (M.S.)	N/A	N/A	29	28	53	27
Biomedical Engineering (PhD)	N/A	N/A	97	19	195	27
Biophysics (PhD)	N/A	N/A	33	6	65	7
Chemical Engineering (PhD)	N/A	N/A	125	10	245	18
Chemistry (PhD)	N/A	N/A	220	50	457	46
Electrical Engineering (PhD)	N/A	N/A	179	31	372	33
Electrical Engineering-Systems. (PhD)	N/A	N/A	87	22	179	18
Industrial and Operations Engineering (PhD)	N/A	N/A	70	13	123	5
Materials Science and Engineering (PhD)	N/A	N/A	94	29	213	18
Mechanical Engineering (PhD)	N/A	N/A	237	37	468	41
Nuclear Engineering & Radiological Sciences (PhD)	N/A	N/A	89	14	174	18

UNIVERSITY OF NOTRE DAME

Degree	Enrolled ’16-‘17	Graduated ’16-‘17	Enrolled ’15-‘16	Graduated ’15-‘16	Enrolled ’14-‘15	Graduated ’14-‘15
Chemical Engineering (B.S.)	266	111	286	92	285	83
Chemistry (B.S.)	39	13	34	9	37	14
Computer Engineering (B.S.)	70	19	73	20	51	16
Electrical Engineering (B.S.)	102	24	103	37	98	35
Mechanical Engineering (B.S.)	385	141	364	103	349	115
Physics (B.S.)	75	26	72	22	67	18
Chemical and Biomolecular Engineering (M.S.)	0	9	0	13	1	15
Chemistry (M.S.)	1	6	1	9	1	10
Computer Science and Engineering (M.S.)	6	20	5	14	1	10
Electrical Engineering (M.S.)	0	18	4	22	5	19
Mechanical Engineering (M.E., M.S.)	2	7	5	9	2	4
Physics (M.S.)	0	15	0	10	0	19
Chemical and Biomolecular Engineering (PhD)	90	11	75	15	79	9
Chemistry (PhD)	123	26	131	29	133	22
Computer Science and Engineering (PhD)	126	19	120	13	114	18
Electrical Engineering (PhD)	103	11	107	14	101	13
Physics (PhD)	103	14	101	19	102	10

WAYNE STATE UNIVERSITY

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Biomedical Physics (B.S.)	81	12	76	7	76	14
Chemical Engineering (B.S.)	98	30	85	27	96	29
Chemistry (B.S.)	117	12	135	12	137	8
Chemistry (BA)	34	16	53	17	51	16
Electrical Engineering (B.S.)	197	49	160	51	120	34
Electrical/Electronic Engineering Technology (B.S.)	94	19	90	20	86	13
Electromechanical Engineering Technology (B.S.)	9	1	6	0	4	0
Industrial Engineering (B.S.)	50	8	42	22	47	16
Mechanical Engineering (B.S.)	222	74	213	47	145	38
Mechanical Engineering Technology (B.S.)	63	11	58	8	55	16
Physics (B.S.)	54	9	53	4	49	7
Physics (BA)	12	0	8	1	4	0
Chemical Engineering (M.S.)	34	12	21	8	25	10
Chemistry (M.S.)	1	5	3	4	1	3
Chemistry (MA)	1	1	0	1	1	1
Electrical Engineering (M.S.)	215	82	185	57	133	32
Engineering Management (M.S.)	94	21	93	24	88	12
Industrial Engineering (M.S.)	324	163	305	81	195	41
Manufacturing Engineering (M.S.)	55	27	50	12	21	7
Materials Science and Engineering (M.S.)	21	7	21	4	14	3
Mechanical Engineering (M.S.)	365	145	346	110	261	75
Physics (M.S.)	9	3	12	5	8	13
Physics (MA)	1	0	1	0	1	0
Chemical Engineering (PhD)	18	3	22	3	22	3
Chemistry (PhD)	134	20	146	17	153	22
Electrical Engineering (PhD)	52	2	50	1	49	1
Industrial Engineering (PhD)	37	2	37	4	38	8
Materials Science and Engineering (PhD)	10	1	11	2	9	1
Mechanical Engineering (PhD)	40	4	44	8	41	6
Physics (PhD)	57	13	52	7	55	6

WESTERN MICHIGAN UNIVERSITY

Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Chemical Engineering (B.S.E)	147	12	169	1	155	5
Chemistry (B.S.)	57	6	60	6	69	9
Electrical Engineering (B.S.E)	95	47	93	33	70	25
Engineering Design Technology (B.S.)	39	17	46	20	41	18
Engineering Management Technology (B.S.)	25	19	30	14	31	21
Industrial and Entrepreneurial Engineering (B.S.E)	37	21	44	26	42	19
Manufacturing Engineering Technology (B.S.)	29	17	45	27	48	12
Mechanical Engineering (B.S.E)	157	73	155	63	134	61
Physics (B.S.)	38	3	36	5	48	8
Product Design (BFA)	0		0		0	
Chemical Engineering (M.S.)	14	7	11	6	13	3
Electrical Engineering (Accelerated M.S.E, M.S.E)	72	44	115	53	120	38
Engineering Management (M.S.)	52	24	57	10	40	11
Industrial Engineering (Accelerated M.S.E, M.S.E)	110	34	83	22	47	13
Manufacturing Engineering (M.S.)	15	7	12	3	7	4
Mechanical Engineering (Accelerated M.S.E, M.S.E)	88	33	72	13	75	12
Physics (MA)	3	1	2	5	5	4
Electrical and Computer Engineering (PhD)	35	4	34	5	38	3
Engineering and Applied Science (PhD)	30	2	22	2	12	2
Industrial Engineering (PhD)	19	1	16	2	11	1
Mechanical Engineering (PhD)	18	3	16	2	15	3
Physics (PhD)	24	3	21	1	27	3

COMMUNITY COLLEGE

LANSING COMMUNITY COLLEGE

Certificate or Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
CNC Machine Technology (CA, CC)	4	4	1	1	5	5
Machine Tool Technology (CA)	2	2	0	0	2	2
Robotics and Automated Technology (CA, CC)	0	0	0	0	0	0
Chemical Technology (A.A.S.)	2	2	1	1	1	1
Chemistry (A.S.)	3	3	6	6	5	5
Electrical Technology (A.A.S.)	12	12	8	8	3	3
Engineering-Physics (A.S.)	21	21	13	13	16	16
Heavy Equipment Repair Technician (A.A.S.)	5	5	11	11	7	7
Manufacturing Engineering Technology (A.A.S.)	15	17	21	27	15	19
Mechanical Systems (A.A.S.)	2	3	0	0	0	0
Mechatronics - Multi-Skilled Maintenance Technology (A.A.S.)	0	0	0	0	0	0
Welding Technology (A.A.S.)	45	53	40	47	47	50

WASHTENAW COMMUNITY COLLEGE

Certificate or Degree	Enrolled '16-'17	Graduated '16-'17	Enrolled '15-'16	Graduated '15-'16	Enrolled '14-'15	Graduated '14-'15
Engineering and Design Technology (CTWDT)	37	0	26	0	3	0
Fluid Power (CTFPOW)	4	1	6	2	3	1
Industrial Electronics Technology (CFIET)	2	11	2	10	1	2
Machine Tool Programming (CNC)(CTMTP)	5	1	3	2	0	0
Machine Tool Setup and Operation (CTMTSO)	11	2	5	1	0	0
Machine Tool Technology (CTMTTC)	6	0	17	1	14	1
Welding and Fabrication Principles (CTWLDS)	73	33	79	42	84	29
Advanced Machine Tool Programming (CVMTPA)	0	0	0	0	0	0
Industrial Electronics Technology II (CVIET2)	2	0	2	0	1	0
Welding and Fabrication Advanced Applications (CVWLDN)	27	22	23	23	22	16
Introduction to Manufacturing Processes (CCMETI)	0	1	0	0	0	0
Mechatronics (APMETR)	86	9	64	3	36	1
Welding Technology (APWLDF)	168	17	145	20	156	26

In 2004 a team of nuclear physics researchers began an effort to host the Facility for Rare Isotope Beams at MSU. In 2008 the US Department of Energy (DOE) awarded MSU a $550M grant to establish FRIB with construction expected to be completed in 2020, and the facility expected to be operational by 2022 at a total cost of $730M. FRIB is expected to create a total of 390 direct jobs with an average total state-wide labor income of $55.6M.

The implications and opportunities related to this investment for the Lansing region seem to be significant however, understanding these opportunities and being prepared to take best advantage is a challenge that government, business, and higher education leaders must embrace. The capacity to design, build and operate particle accelerators is a proven strength of the region. The ability to supply the labor, technical support staff, and researchers is also a proven strength. The challenge is to understand the powerful economic factors driving economic development in the global knowledge economy and translate that understanding into strategies that can best nurture the economic opportunities emerging from this dynamic nuclear physics research and particle acceleration knowledge base.

This report is an attempt to build on past research and provide understandings with recommendations to foster the development of an economic cluster based on the powerful nuclear physics knowledge base abundant in the Lansing region.

LEAP stronger together

MICHIGAN STATE UNIVERSITY | Center for Community and Economic Development

EDA U.S. ECONOMIC DEVELOPMENT ADMINISTRATION

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