Smart Manufacturing – Industrial Internet of Things (IIoT) Roadmap for Northeast Ohio

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Prepared by:

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and
Partners
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HIGHLIGHTS

The Industrial Internet of Things (IIoT) Roadmap is the result of a six-month collaboration of Team NEO, prominent manufacturers (both end-user and supply-chain companies) and lead academic institutions. The purpose is to identify and quantify IIoT implementation opportunities in Northeast Ohio using the Team NEO In-Seven® Road Mapping Process. This document recommends a path forward for developing a regional IIoT commercialization strategy, tactical framework and plan of action that leverage Northeast Ohio’s rich manufacturing heritage, unique assets and talented workforce.

Why focus on IIoT in Northeast Ohio? Manufacturing is an essential component of NEO’s economy and is projected to continue growing in the future. To gain the benefits of IIoT, NEO’s current manufacturing base will need to change their processes and how they work. While Moody’s Economy.com projects $4 billion in gross regional product (GRP) growth by 2025, taking GRP to $49 billion, calculations developed by the IIoT Roadmap Working Group reveal that greater IIoT application in a factory setting has the potential to further grow GRP – from $53 billion to $62 billion by 2025.

Drawing on the strengths identified through the roadmapping process and Voice of the Customer (VoC) interview findings, and building upon existing regional programs, the Roadmap Project Team articulated pathways for proliferation of the IIoT in Northeast Ohio in the form of several initiatives:

- Implementation - Drive demand for IIoT implementation.
- Innovation - Spur advances in IIoT product innovation.
- Resources - Support programs with institutions that create the specialized intellectual capital that enables IIoT implementation and innovation.

Manufacturers are invited to take the IIoT Readiness Assessment at bit.ly/NEOIIoTRoadmap. The IIoT Roadmap Project Team will provide a complimentary, confidential, high-level assessment of the organization’s readiness to adopt IIoT solutions and a comparison of how their readiness compares with the overall region.
1 INTRODUCTION

1.1 Scope of Work

The purpose of the Smart Manufacturing – Industrial Internet of Things Roadmap for Northeast Ohio (IIoT Roadmap) is to establish a regional Industrial Internet of Things (IIoT) commercialization strategy, tactical framework and plan of action for Northeast Ohio (NEO). This Roadmap represents a vision derived from a collaboration of several regional stakeholders.

The IIoT Roadmap document will provide background on the Internet of Things (IoT) and why a subsegment known as the IIoT offers one of the best opportunities for impacting the prosperity of the NEO region. It will also present an accounting of the region's IIoT resources and capabilities, a proposed vision of what improvement in the business and economic activity is possible, and finally, the necessary steps in innovation to take us from where NEO is today to the point of success offered by that vision.

This Roadmap builds on the “Recommendations for the NEO IoT Collaborative – Industry Impact Perspective” study that was prepared for the IoT Collaborative by the Lanterman Group. It focuses on the business-to-business aspects of the IIoT opportunity, along with both the demand- and supply-side considerations of the regional implementation of the IIoT.

A Roadmap Working Group consisting of stakeholders throughout the region was assembled in April 2018 to guide all roadmapping activities and participate in the process of roadmapping the regional commercialization landscape to identify IIoT opportunities.

Intended objectives from this roadmapping activity include:

- Elucidating regional IIoT supply chain
- Identifying and addressing gaps in the IIoT supply chain
- Determining how to drive IIoT supply chain innovation
• Determining how to foster regional IIoT demand
• Identifying gaps and drive the region’s IIoT human resource proficiency
• Promoting jobs, new payroll and capital investment around IIoT

1.2 Value of Work
The opportunity the IIoT presents within Northeast Ohio includes building on the already robust supply of manufacturers and manufacturing solution providers to aid the region’s ability to remain competitive. There is a direct opportunity for companies that embrace the IIoT to positively impact their bottom line through production efficiencies, performance and the implementation of new-business and customer-service models.

The ultimate outcome of the roadmapping work is to identify growth and commercialization opportunities to help the region retain and grow jobs and advance the region’s competitiveness.

It has been determined that by defining the regional IIoT value chain and identifying economic use cases of merit, we can facilitate successful adoption of the technology and market entry into value chain gaps by in-region companies. A robust regional IIoT value chain and ecosystem should enable in-region companies to better contend with global competition and capitalize on the technology, bringing benefits directly to all the discrete and process control-based manufacturers, and all the original equipment manufacturers (OEMs) and service providers that supply or implement IIoT systems and products in Northeast Ohio.

Economic development organizations in Northeast Ohio such as MAGNET, JumpStart, and chambers of commerce, for example, could benefit from increased awareness and demand for the technology, generating greater wealth creation within their target regions. The area’s institutions of higher education with IoT-related curricula could benefit significantly, as they are better able to link their research to industry. Entrepreneurs will especially benefit as they gain access to services, value-chain partners and know-how to help them launch their businesses.
1.3 Roadmapping Process

The roadmapping process employed in this study is the InSeven® model (Figure 1). This model is designed to identify key regional strengths as the basis of long-term regional development opportunities surrounding those assets.

The first half of the process, “Where We Are Now” (chevrons 1, 2 and 3) deals with defining and setting up the roadmapping project, assessing current conditions of the IIoT market and regional asset space. During this phase, a substantial number of market studies and industry intel are canvassed and VoC survey information is collected. The information is then used to populate a value-chain model and validate the needs of the region. More than 50 VoC interviews were conducted among resources that represent the core assets and stakeholders from the region, in addition to industry thought leaders with forward-looking visions for innovation.

The second half of the process, “What is Possible” (chevrons 4, 5 and 6) deals with outlining the potential for growth opportunities in the targeted IIoT market segment. After comparing other competitive regions to NEO’s IIoT strengths and capabilities, a NEO IIoT Commercialization Framework plan was formulated and distributed to the Working Group for their approval.

VoC interviews rely on direct interactions with end users and key supply-chain assets; for this reason, the VoC method is deemed most effective for the identification of key use cases and the determination of short- and long-term IIoT opportunities.
The Working Group members include representation from prominent end-user companies, key supply-chain participants and leading academic institutions. The role of the Working Group has been to provide a plan structure, market and technical guidance, connections to market participants, consistent engagement during development of the work product, and review of all plan outcomes and recommendations.
Throughout the course of the Roadmap project, there were multiple additional participants from the organizations that comprise the Working Group. All participants are critical to the success of the Roadmap and the quality of the final deliverable.
1.5 Roadmap Project Team

The Roadmap Project Team consists of a blend of Team NEO’s Industry and Innovation and Research teams, with the generous support of The Lanterman Group, Rockwell Automation, Hitachi Vantara and MAGNET. The Roadmap Project Team drove the roadmapping process and relied on the guidance and recommendation from the Working Group.

1.6 Strength of Collaboration

Team NEO Mission Statement: Team NEO enhances the economy of Northeast Ohio by collaborating with our partners and others to attract new businesses, help those that are here grow, and accelerate the impact of innovation in the region. We also help bring together local, regional and state resources to raise the profile of the region and make the case for investment in Northeast Ohio, focusing on proven businesses that will
contribute to the region’s success. Our board serves as the “Regional Table” for Business and Philanthropy around which challenges regarding economic competitiveness are identified, prioritized and advanced.

The IIoT Roadmap Project is a direct result of collaboration among economic development organizations, higher education institutions, philanthropy and private companies. The enriching roundtable discussions during each Working Group meeting serve as testament to the strength of collaboration. The Working Group and additional participants brought their own unique perspectives to the table. These different groups, based across the region, each with their own goals, came together to create a strategic plan for the widespread implementation of IoT technology with an industrial application for Northeast Ohio.
2 FOUNDATIONAL ASPECTS OF INDUSTRIAL IOT (IIOT)

2.1 IoT – The Fundamentals of Industrial IoT

The IoT is about generating, aggregating, sharing and analyzing data to generate keener insight and better behavior. According to Deloitte in a study completed for JobsOhio, “The Internet of Things is disrupting the economy as we know it, with companies across the world starting to understand the competitive advantage of IoT in streamlining their business operations and delivering better customer experiences” (Deloitte, 2017).

Global projections for the impact of the IoT over the next decade forecast the potential for significant output growth across multiple sectors of the economy, with estimates from the McKinsey Global Institute projecting as much as an $11.1 trillion total annual global impact (Dobbs, Manyika & Woetzel, 2015).

Accenture Strategy estimates that the cumulative impact of IoT on total global gross domestic product (and additional measures) could range from $10.6 trillion to $14.2 trillion by 2030, depending upon the investments made as shown in Figure 3 (Davarzani & Purdy, 2015).
According to Accenture, the U.S. is also positioned relatively well to compete on a global scale for our share of IIoT. Accenture can “assess a nation’s economic diffusion potential from the National Absorptive Capacity (NAC) index, which shows the potential for economic diffusion of the IIoT in a given country. Nations in higher positions on the index are more likely to reap the rewards of IIoT diffusion” (Davarzani & Purdy, 2015). The U.S. has the highest IIoT economic diffusion potential with a NAC score of 64 (Figure 4).
McKinsey estimates that the potential economic impact of IoT on factories will range from $1.7 trillion to $3.7 trillion annually by 2025 (Dobbs, Manyika & Woetzel, 2015). This potential economic impact can be broken down into several application segments including operations optimization, predictive maintenance, inventory optimization, and health and safety, as can be seen in Figure 5.

**Figure 5: Potential Economic Impact of IoT on Factories in 2025**

Source: McKinsey Global Institute
The Deloitte study maps the market segments against current and future market spends, and includes the compounded annual growth rate for each of the market verticals. An important aspect of their analysis is that it distinguishes between the demand-side market verticals and the supply-side market verticals (Figure 6). This is an important distinction for NEO since both segments have a major presence in the NEO economy and will require visibility in the final NEO IIoT Growth Strategy and Tactical Implementation Plan (Section 5.1.1).

![Figure 6: Comparing the Global Supply and Demand Current and Future Market Sizes by Growth Rates](source: Deloitte)

This graphic also shows that manufacturing, one of Northeast Ohio’s strengths, is the largest sector in terms of current and future spending in dollars – showing $120 billion currently being spent, with the potential of an additional $80 billion being spent between 2020 and 2022. The total spent when also considering the supply portion appropriated to manufacturing exceeds $260 billion and, according to McKinsey, has the potential to create more than 500,000 new jobs globally.
This Roadmap focuses specifically on the IoT opportunity related to the manufacturing sector, which can be referred to by many labels: smart manufacturing, digital manufacturing, Industry 4.0, etc. However, for purposes of clarity and consistency with market norms, the term Industrial Internet of Things (IIoT) is used in this Roadmap.

According to The Lanterman Group, “IIoT marries advanced manufacturing techniques with the IoT to create a digital manufacturing enterprise that is not only interconnected, but communicates, analyzes and uses information to drive further intelligent action back in the physical world.”

General Electric estimates that 46% of the global economy could benefit from the Industrial Internet. This broad impact is possible in part because business-to-business (B2B) applications will drive significantly more value than consumer products, with manufacturing factory settings alone likely accounting for nearly a third of the value of IIoT. Globally, estimates from Dresner Advisory Services indicate that IIoT will be either critical, very important or important to nearly 50% of all manufacturing (Columbus, 2016).

2.2 Why Focus on IIoT in Northeast Ohio?

Manufacturing continues to be an essential component of Northeast Ohio’s economy, and its importance is only projected to grow, moving forward. Though much of the recent “Rust Belt” narrative around manufacturing has emphasized the admittedly painful job loss in the sector, decreasing from 450,000 workers in 1990 to 270,000 in 2017, that narrative has masked manufacturing’s continued significance as a building block of the regional economy. Accounting for more than 21% of the region’s total GRP, the sector has seen productivity growth of 92% between 1990 and 2015, with an additional 73% productivity growth projected by 2025.

When considering not only the direct impact, but also the indirect and induced impacts of manufacturing, the sector is far and away the largest economic engine in the Northeast Ohio economy. That said, to maintain our competitiveness in a global
economy, innovation will become increasingly important to how we manufacture, both in our products and the processes we employ.

Moving forward, IIoT offers an opportunity to gain an additional competitive advantage in manufacturing and change the growth trajectory of the sector.

**Figure 7: Northeast Ohio Manufacturing Productivity: 1990-2025 (Projected)**

![Graph showing Northeast Ohio Manufacturing Productivity](image)

Source: Moody's Analytics Economy.com

### 2.3 IIoT Sector Segments

As depicted in Figure 6, the IIoT is made up of two sectors: the **demand side**, where IIoT is implemented into an operation, and the **supply side**, where the product innovation for the IIoT product portfolio, used by the demand side customers, is actualized.

Both sectors require equal attention, and because of the symbiotic relationship between the IIoT demand side and supply side sectors, both sides will be addressed in the Roadmap.

Each side has its own associated supply chain comprised of “seekers” and “solvers” (terms used in an “open innovation” framework). Further, **seekers** (those organizations seeking solutions) and **solvers** (those organizations providing solutions) play a critical role in both sectors (Figure 8). More comprehensively:

A **demand side seeker** is an organization that is implementing IIoT into the manufacturing operation
A **demand side solver** is an organization that supplies products and services in support of the implementation of IIoT solutions.

A **supply side seeker** is an organization that supplies IIoT-enabled products/services and is seeking assistance with the integration of advanced technical capabilities into their products.

A **supply side solver** is an organization with advanced technical capabilities that can assist the seeker with the integration of these advanced capabilities into the seeker’s products.

**Figure 8: Demand Side and Supply Side Symbiotic Relationship**

In some instances, a company can have different roles in both sector supply chains. For example, take a smart sensor OEM that wants to integrate a cellular link to the cloud into their product. In this case, as a Supply Side Seeker, the OEM solicits assistance from a Supply Side Solver. On the other hand, this same OEM becomes a Demand Side Solver when they sell their smart sensor, with its new cloud link feature, to their customer. And of course, the customer is a Demand Side Seeker that is implementing a smart sensor solution into their manufacturing operation.
This segmentation terminology will be used throughout the narrative of this Roadmap to explore the needs of all stakeholders, identify the wide array of resources in the region and make recommendations on how to drive IIoT demand, drive IIoT product innovation and create the needed skill sets and intellectual capital to support both sectors.

2.4 Role of IIoT in the Digital Transformation of a Business

Most legacy manufacturers have been involved with a digital transformation of their business for years (or decades, depending on the age of the business), while newer manufacturers are implementing digital manufacturing on an ongoing basis as a matter of best practices. Both instances are manifestations of the “paperless office,” or the disposition of computerized processes and information networks, which is now called IT. These business improvement methods all require the data used and generated by the business to be converted and handled in digital form. All interpersonal communications, reporting, production drawings, information storage and business analyses are converted to, and conducted in, a digital format. This is typically referred to as digitization and is considered a component of the digital transformation effort.
When a digital-based hardware and software data-processing infrastructure is implemented, continuously collecting and analyzing all the available digital information, quicker, better-informed, more diverse decisions for improving business efficiency and performance can be made (Figure 9).

Traditionally, the digital transformation of a business has mostly been relegated to the front office – normally the office side of the ERP system (marketing/sales; customer relationship management, or CRM; financial management; product/manufacturing engineering; production/resources planning; etc.). On the other hand, the opportunity to acquire meaningful production-related data from the manufacturing process (production automation side – Figure 9) has not been capitalized on as much; therefore, the opportunity to further improve the operational performance has not been ultimately realized.
More recently, however, with the components of the 5-layer automation architecture shown in Figure 10 becoming more affordable and higher functioning digitally, the implementation of the IIoT into operations is now becoming more warranted and fundamental to the digital transformation of a business. Even though a comprehensive Digital Transformation Plan includes all aspects of a business’s operations, we will focus throughout the rest of this section on the digital transformation aspects currently associated with IIoT as it applies to manufacturing operations.

**Figure 10: Application of Digital Transformation to IIoT**

Convergence of IT and automation

Digital transformation is primarily about understanding the existing information and data in your business and then remodeling your business processes and systems. Following how data flows through your business (how it is generated, captured, stored, shared and used, by which people, at which times and for what purpose) can both ensure that you maximize the use of digital technologies and help you challenge existing ways of doing things so you can restructure accordingly (Wonderware West, n.d.). A digital transformation plan (DTP) outlines a course of action for this “remodeling” of the business processes and systems.

As this IIoT Roadmap focuses on the digital transformation of the production side of the business, the DTP is also known as an IIoT implementation plan. This plan can exist in
several different forms depending on the characteristics of the business. A plan can range from a sophisticated proposal with an associated substantial price tag all the way to a series of use case proof of concepts (POCs) that are phased in over a period with incremental cost added as each project demonstrates a positive return on investment (ROI). The content of the proposal is influenced by the attributes of the business, such as:

- Sales revenue (Small to Medium Enterprise, or SME, plans are typically less involved that those of large companies and gravitate toward a stepping-stone implementation approach)
- Type of manufacturing (discrete or process control – see Sections 3.1.1.1 and 3.1.1.2)
- Amount of legacy equipment to be instrumented
- Digital maturity of the organization (see Section 2.4.2)

Manufacturers that want to implement IIoT into their operations are considered demand side seekers and typically (due to the potential complexity of the transformation project) need help from a demand side solver, as they have experience as an IoT Solutions Partner (one who can assist in the development of the IIoT DTP; see Section 3.2.1). Of course, if a company has a staff with enough digital experience and appropriate culture, the DTP can be internally developed. Either way, before the digital transformation plan is developed, the company needs to identify its goals, where it is now and where it wants to go. After that, this clear plan can be shared with all stakeholders within the company, among its business partners and across its supply chain partners.

As part of the IIoT roadmapping process, several VoC interviews were conducted (see section 4.0). A subset of the interviews focused specifically on asking demand side seekers explicitly about their understanding of digital transformation and experience with the implementation of IIoT. A summary of the results from this exchange is presented in Section 4.1 (Demand Side) and Section 4.1.1 (Demand Side – Seeker).
These sections will provide insight and understanding of the challenges that the IIoT digital transformation journey entails.

There are several IoT Solution Partners and consultants in NEO that have developed a stepped process to aid manufacturers in the creation of a successful IIoT digital transformation plan. Based on Advisory Council meeting comments, one specific article from the Rockwell Automation Blog stands out as being highly encompassing. “7 Key Steps to a Successful Digital Transformation” lists the following as being critical:

1. Create and socialize a shared company vision among C-level stakeholders.
2. Establish a steering committee (make sure all the stakeholders from the business are represented on the committee and are providing input).
3. Partner with a technology provider that understands and supports your overall business objectives.
4. Carefully and completely assess your company’s operations to develop an unvarnished picture of strengths, gaps and opportunities.
5. Conduct a value workshop to secure buy-in and evaluate potential gains against the picture developed in step #4.
6. Develop and socialize a comprehensive plan and schedule.
7. Establish an infrastructure for change management and intercompany communication (Kueppers, 2017).

2.4.2 Digital Maturity

Digital maturity (DM) is a measure of how far along a business is in its digital transformation journey as laid out in the IIoT digital transformation plan. A high-level estimate of DM was used by the IIoT Roadmap Project Team to evaluate the digital transformation of the companies involved in the VoC interviews (as self-reported – see Section 4.1.1). More information on evaluating digital maturity can be found in Section 8.1.2 – IIoT Maturity Model.

Additional factors used to evaluate digital maturity include whether a digital transformation plan or digital strategy is put in place within the organization, the amount
of investment in digitization and digitalization, employees’ knowledge and endorsement of the digital strategy, and the extent to which the strategy has been implemented. As mentioned previously, the assessment of the business’s maturity directly affects the scope of the IIoT digital transformation plan.

2.5 IIoT Market Segmentation by Technology Level

Developing an end-to-end IIoT solution for an application requires the use of multiple levels of technology that fuse together a diverse set of elements. Many IoT consulting firms use a 5-level model to define a complete solution. The Roadmap Project Team took the company IoT Analytics technology level model (Leuth & Scully, 2016) and modified it to reflect both the unique characteristics of the IIoT and the innate aspects of NEO’s smart manufacturing environment.

This Roadmap and NEO’s IIoT Technology Architecture (Figure 11) focus on the most popular IIoT applications and include an expanded smart device layer in lieu of a hardware level (used by most other models) due to the extensive instruments, controls and electronics cluster in NEO that is centered on IIoT product innovation. At the Smart Device level (1), new high-fidelity operational data is generated from each device that is critical to the manufacturing operations of the business. At the Communications level (2), the data created by level 1 is acquired and is routed to the appropriate device in level 3. At the Systems level (3), the data from level 2 is stored, then useful relationships from that data are identified that can potentially be used in any of the applications in level 4. At the Applications level (4), value is further harvested from the collected data and used to drive new actions and policies to improve business efficiency and performance. Of course, any of the reporting, requested information or commanded actions generated at level 4 will be routed back to level 1 at the manufacturing floor using the structures provided by levels 3, 2 and 1.

These technology level designations are another way the IIoT market opportunity is segmented. They can be used as a way for IIoT seekers to quantify requirements and for IIoT solution providers to quantify their capabilities. The terms used in this section
are used repeatedly throughout this Roadmap, especially where the supply chain is defined.

![Figure 11: NEO’s IIoT Technology Level Architecture](image)

### 2.5.1 Smart Device Level

Smart machines and devices perform critical functions in the operation and can interact with one another. Driving down cost and driving up functionality through the continuous application of embedded intelligence is key to accelerated growth of the IIoT.

- **Smart Device**: Devices that perform a control or sensing function that can communicate their operational status and react to critical events
- **Device Components**: Sensors, actuators, communications hardware, microcontrollers and other supporting hardware that, when integrated together, comprise a smart device
- **Device Manufacturing**: Smart/Functional materials and coating, roll-to-roll fabrication, printed electronics, device packaging and die thinning are the same
processes smart phone manufacturers use to continuously drive down cost and add functionality.

### 2.5.2 Communications Level

In general, the communications level is responsible for aiding an internet or intranet host in extracting the data from a connected smart device and delivering that information to the requesting host. The host can also send control commands and information to the smart edge device. Hardware infrastructure at this level may include bridges, gateways and routers.

- **Connectivity**: Offers connectivity network/hardware modules enabling air interface connectivity
- **Industrial Protocols**: Includes sessions, network and data link protocols that provide host communication, internet/intranet access and connection to the smart devices
- **Hardware**: Enables manageability, security, identity and interoperability based on on-site devices or a cloud-enabled hardware device

### 2.5.3 Systems Level

Ingesting, analyzing and interpreting the data at scale through internal capabilities or cloud technologies generates insights (Leuth & Scully, 2016).

- **Data Storage**: Scalable storage of device data brings the requirements for internal storage capacity or hybrid cloud-based databases to a new level in terms of data volume, variety, velocity and veracity.
- **Device Management**: Enables remote maintenance, interaction and management capabilities of devices at the edge
- **Event Processing**: Brings data to life with rule-based event-action triggers, enabling execution of “smart” actions based on specific sensor data
2.5.4 Application Level

Connecting and enhancing these insights to the greater ecosystem through a system of engagements enables “action” through a vast range of new applications and connected services (Leuth & Scully, 2016). The applications listed are those that are mentioned most in the literature; their descriptions can be found in Section 3.1.2. Following are the elements of system engagement.

- **Human-Machine Interface (HMI):** After value from the operational data has been harvested for business improvements, the information must be presented to the operator for a bidirectional engagement. Most popular interfaces are dashboards, augmented reality and voice command.
- **Advanced Analytics:** Performs advanced stream analytics and learnings that can drive predictive or prescription actions (Leuth & Scully, 2016)
- **Data Reduction:** Processing events and handling big data analytics (Leuth & Scully, 2016)

2.5.5 Security Level

Protection from unauthorized or unintended alteration of data or commands is essential in establishing trust in the data or directed actions that now flow throughout the networked system. Should a breach “sneak through” all established defenses, the system must have the resiliency to failsafe, isolate the fault, report it and recover to normal operation as soon as possible. This protection crosscuts all levels of an IIoT application.

- **Application level:** Ensure only authorized personnel or trusted entities have access to the system and that no commanded action has the potential to cause injury or destruction of physical assets.
- **System level:** Protect the integrity of the data and its history while it is at rest in storage. Make sure “prying eyes” are not able to peek at the data without permission.
- **Communications level**: Infuse strong encryption in all the bidirectional data and communications flows within the system.

- **Smart Device level**: Security policy is implemented in hardware/firmware and relies less on software for protection – each smart device should be its own island of secured activity, should be tamperproof, and provide the highest degree of resiliency.
3 WHERE WE ARE NOW

3.1 Segmentation of IIoT Opportunity in NEO

The segmentation of Northeast Ohio’s IIoT opportunity is complex and multidimensional. This is driven by the vast diversity of the stakeholders that need to come together to fully realize the potential impact on business growth that is possible in this region. We have already seen that the IIoT opportunity is divided into demand side and supply side sectors and that each sector has its own associated supply chain of stakeholders (see Section 2.3). Also, we have seen that an IIoT solution is made up of five different technology levels where a diversity of stakeholders play a role (see Section 2.5).

To complete the characterization of segmentation, the target markets in Northeast Ohio that can benefit from the implementation of IIoT to stimulate business growth are identified. Accordingly, the potential IIoT use case applications that can be employed in those target markets are identified in the following sections.

3.1.1 IIoT Segmentation by Markets in Northeast Ohio

Market segments within NEO that can benefit most from the IIoT are listed here and broken into two classifications: discrete manufacturing and process control. This distinction reflects the digital maturity associated with each classification. Process control manufacturing is typically more sophisticated than discrete manufacturing and includes sensor-infused processes with substantial amounts of data aggregation, data analytics and automation control – all characteristics of a more mature digital manufacturing environment.

An assumption was made and anecdotally validated by the Roadmap Working Group: Because of the higher maturity of process control type markets, any further IIoT-based improvements would be essentially different and more expensive than those directed toward the less mature discrete control market segments. Since the services, technologies and money spent differ for each type of market segment classification (and therefore, will have different impacts on the growth of NEO), we have separated,
quantified and broken the market segment into two lists. This is also reflected in the market growth projections described in Section 5.1.2 IIoT’s Potential Impact on NEO Target Markets.

3.1.1.1 Process Control Target Markets

Process control manufacturing is typically a continuous production process that uses industrial control systems to achieve a production level of consistency, economy and safety that could not be achieved purely by human manual control. The applications can range from controlling the temperature and level of a single process vessel to a complete chemical processing plant with several thousand control loops. Today, most process control is based on distributed control systems (DCS) composed of networks of input/output (I/O) racks with their own localized control processors. These are distributed around the plant and communicate with the graphic display in the control room or rooms. DCSs allow easy interconnection and reconfiguration of plant controls such as cascaded loops and interlocks, as well as easy interfacing with other production computer systems. It enables sophisticated alarm handling, introduces automatic event logging, removes the need for physical records such as chart recorders, allows the control racks to be networked and thereby located locally to production control devices to reduce cabling runs, and provides high-level overviews of plant status and production levels.

Since the digital maturity of most process control installations is relatively high, the implementation of IIoT tends to focus more on initiatives aimed at improving operations, predictive maintenance and augmented reality. Process control installations also focus on adding more process-monitoring sensors to extrapolate key performance indicators (KPIs) more effectively. It does this while using the newly sourced, high-fidelity and real-time data to support advancement in predictive/prescriptive analytics application of AI.

Process-based manufacturing industries in Northeast Ohio are projected to grow their output marginally from $21.9 billion to $22.1 billion from 2018 to 2025, based on estimates from Moody’s Economy.com.
Process Control Target Markets. Manufacturing industries that were identified by the Roadmap Project Team as having process control uses for IIoT include:

- Food
- Beverage & Tobacco Products
- Textile Mills
- Textile Product Mills
- Paper
- Printing and Related Support Activities
- Petroleum and Coal Products
- Chemical, Nonmetallic Mineral Products
- Primary Metals

3.1.1.2 Discrete Manufacturing Target Markets

Discrete manufacturers make “things” and they make things that are exact. The products are typically manufactured in individually defined lots through a sequence of work centers with workflow varying for each type of product. Thus, in discrete manufacturing, the product is made by sequential steps in the same process and uses complex multilevel bills of materials (BOMs), and value serial numbers, engineering change notices (ECNs) and assemblies.

Discrete manufacturing is based on production orders, wherein the products change frequently from order to order and require sophisticated planning, scheduling and tracking capabilities to improve operations and profitability.

By implementing IIoT, the manufacturer can create digital networks linking KPI sensors and pieces that make up their production process to allow real-time process data to be collected. The information can then be analyzed, which leads to optimized instructions that, when distributed back to the workers and their machines of production, will contribute to improved efficiency and performance of the business. The information generated from the implementation of IIoT can be used to track products and orders,
monitor operational efficiency in real time, monitor the maintenance of equipment to optimize product quality and improve the safety of plant workers.

The digital maturity of most discrete manufactures is relatively low due to the absence of data networks linking all the critical production machines together. Subsequently, this leads to a lack of real-time high-fidelity information’s being available to support continuous improvement of the operation. However, this also means that a host of IIoT proof-of-concept projects requiring relatively small investments and effort can be justified and then used to validate case studies more quickly, thus providing the manufacturer with a means to accelerate their continuous improvement process.

Under current conditions, the output of Northeast Ohio’s discrete manufacturing industries is expected to see a growth of only 16% between 2018 and 2025 — from $23.2 billion to $30 billion.

**Discrete Manufacturing Target Market.** Discrete manufacturing industries that were identified by the Roadmap Project Team include:

- Apparel
- Leather and Allied Products
- Wood Products
- Plastics and Rubber Products
- Fabricated Metal Products
- Machinery
- Computer and Electronic Products
- Electrical Equipment
- Appliances and Components
- Transportation Equipment
- Furniture and Related Products
- Miscellaneous Manufacturing
3.1.2 IIoT Application Segments

To identify the most popular applications for IIoT, the Roadmap Project Team canvassed several studies from the IoT consulting firms, polled the websites of the largest suppliers of manufacturing execution systems (MES) and asked manufacturers implementing IIoT what applications were of greatest interest to them. The following applications were identified. Many of the MES OEMs have implemented IIoT solutions into their own operations and have turned their findings into canned software/hardware packages that are now available to their customer base (in some instances, this includes white label software and white box hardware products). Many IIoT solutions providers have also created use case reviews that are available to the public to help with the selection and buying decision. Additionally, there is a rich portfolio of IIoT solution providers in NEO that can assist a manufacturer with the implementation of a custom solution if they require specific features not found in the off-the-shelf solutions. Following are brief overviews of the seven most popular IIoT applications.

3.1.2.1 Supply Chain Management (SCM)

SCM encompasses the integrated planning and execution of processes required to optimize the flow of materials, information and financial capital in the areas that broadly include demand planning, sourcing, production, inventory management and storage, transportation (or logistics), and return for excess or defective products. Both business strategy and specialized software are used in these endeavors to create a competitive advantage. On average, companies that aggressively digitize their supply chains can expect to boost annual growth of earnings before interest and taxes by 3.2% (the largest increase from digitizing any business area) and annual revenue growth by 2.3% (Bughin, LaBerge, & Mellbye, 2017).

- Track the physical status of goods, the management of materials and financial information involving all parties.
- Improve the time-to-market of products, reduce costs and allow all parties in the supply chain to better manage current resources and plan for future needs.
- Determine the best way to fill an order through advanced algorithms.
3.1.2.2 Operating Efficiency

Operating efficiency refers to how well a business manages its resources and uses them to produce profits. While best practices are different for each individual organization, businesses use many of the same measurements and techniques to maximize operating efficiency and eliminate inefficiencies that stifle earnings or growth. Through the application of the IIoT, operating efficiency can be improved by placing sensors and intelligence on every piece of production equipment, including utilities, lighting, new machines and legacy machines. The purpose of this is to monitor, analyze and adjust influences on production, like energy consumption and quality, in real time. According to McKinsey, (Figure 5), the application of the IIoT to improve operating efficiency has the potential to reduce cost anywhere between 5% and 12.5% (Dobbs, Manyika, & Woetzel, 2015).

- Enable process modeling (workflow analysis, for example) and real-time optimization.
- Implement standard sensor and intelligence into new machines and legacy machines.
- Greatly improve workflows through analytics of the production data being collected.
- Monitor, analyze and adjust influences on production, like energy consumption and quality, in real time.
- Facilitate radio-frequency identification (RFID) and barcode systems to play a greater role in tracking product, inventory and quality.
- Increase overall equipment effectiveness (OEE), which relies on operational data coming from the production equipment to sense performance and uptime (see Section 3.1.2.7).

3.1.2.3 Product Quality

Quality focuses on how well each part of the product manufacturing process, including getting it into the customer’s hands, is working. The process being analyzed in a case may have a very broad scope, or it may focus in on minute details of a single step – for example, the precise temperature used when molding a component, or the torque used
when driving a specific screw. The application of IIot makes it possible to ensure each step of the process is digitally monitored for quality and corrective actions are taken immediately. McKinsey believes that manufacturers can see a 10-20% improvement in cost of quality through application of IIoT.

- Stave off performance degradation after leaving the factory. Infuse the product with sensors and monitor conditions of operation to identify parameters out of range. Send corrective actions to user and/or download updated control software.
- End scrap and rework. Monitor mechanical, electrical, chemical and physical parameters of each production machine. The machine can communicate its output variation to downstream equipment, which automatically adjusts to ensure the final product is within specifications.
- Use embedded sensors to collect legacy data that will drive decisions on further product improvements.
- Ensure quality is measured at each step of the production process and monitored in real time so that any corrective action can be taken immediately. Machine vision systems are becoming more popular for this application.
- Improving overall equipment effectiveness (OEE) relies on operational data’s coming from the production equipment to sense quality (see section 3.1.2.7).

### 3.1.2.4 Predictive Maintenance

Predictive maintenance is a technique that checks the “health” of an item while it is operating, using one or more sophisticated tools. The capabilities to support predictive maintenance are maturing and becoming more available, due to the implementation of IIoT and the increased sophistication of equipment monitoring instruments. Too much or too little maintenance is avoided because the equipment is monitored on a regular basis, providing trend data that can be used to project probable machine alarm dates. According to the Electric Power Research Institute (EPRI), the annual maintenance cost of such a program is between $7 and $9 per horsepower – a reduction of 50% or more (NASA).
• Monitor mechanical, electrical, chemical and physical parameters of machines/processes through the inclusion of vision and infrared sensors.
• Mine historical data from machine to identify trends for potential failure and use sensors to identify anomalies that indicate potential failure.
• Use machine learning to reduce opportunity for defective parts in final product.

3.1.2.5 Inventory Control

IIoT-based inventory systems can track items in real time. Products usually have either an RFID tag or barcode label, so they can be scanned and identified by the system. Currently, this is how systems can provide visibility into inventory levels, expiration dates, item location, forecast demand and more. Using the IIoT, the ability to track and communicate with products will greatly increase. For example, RFID tags will hold more information about an object and communicate it to an inventory system. Built-in RFID tags can send info about temperature, weather, damage to the object, traffic, etc. The ability to view, track and monitor inventory will improve enormously with IIoT — inefficiencies that you never noticed will become simple to spot and act on. Although still in an early stage, the IoT carries enormous potential for both consumer and company (Clear Spider, n.d.). McKinsey believes that manufacturers can see a 20-50% cost reduction from inventory optimization through application of IIoT (Figure 5).

• Use optical and presence sensors, smart inventory bins and smart pallets to monitor inventory locations around the plant for in- and outflows.
• Use analytics to take order data, supply chain data and machine/process health data to adjust order rates in real time and stay in step with the dynamic conditions of production (e.g., minimizing time in inventory).
• Analyze parts/product rejections and machine/process health to pinpoint QC issues and adjust inventories accordingly.

3.1.2.6 Occupational Safety

Based on an article in Digitalist Magazine titled “Improving Workplace Safety with IoT,” there is hardly a shortage of worksite environments — factories, plant facilities, oil rigs
and more — that pose potential danger to workers. By using the IIoT and pervasive cloud connectivity, organizations can now pull in work environment data, analyze it, and respond in ways to help keep workers safe and healthy.

What kind of data should be tracked? Common points of concern are temperature, humidity, noise levels and air quality. One startup focused on tracking such metrics using Heads Up, a U.S.-based device manufacturer providing a wearable communication system that workers can attach to an eyepiece.

On its own, the Heads Up technology can detect out-of-tolerance conditions for heat, humidity and noise levels, flashing different colored lights that alert workers to act accordingly. When you connect Heads Up or similar technology to critical business applications, enterprise data and analysis engines on the back end, you can achieve even more. Here are some examples (Geiger, 2018):

- **Ensure long-term safety.** By analyzing data over weeks and months, you can calculate long-term exposure to potentially hazardous conditions. With integration into HR and scheduling solutions, you can then trigger re-rostering processes to keep exposure levels below acceptable limits.

- **Improve compliance.** With integration into business data regarding local, regional or national worker safety regulations, you can monitor compliance and demonstrate your adherence to the rules as needed.

- **Predict issues and take proactive action.** Using machine learning algorithms, you can analyze data across worksites to detect patterns that can predict potential issues before they impact workers.

- **Track workers with context awareness.** With geolocation capabilities and schematics on worksite environments stored in business applications, you can track workers’ locations and alert them, for example, to not enter secured areas for which they may lack authorization.
• Speed and improve rescue operations. In a disaster, you can collect critical data in real time, enabling rescue crews to understand the situation quickly and plan rescue operations that have a higher chance of success.

3.1.2.7 Overall Equipment Effectiveness (OEE)

OEE is a very powerful metric. This KPI is calculated from actual equipment availability, performance, and quality losses relative to maximum expected performance, essentially capturing when an asset is available, the speed at which it operates and the number of products out of quality specification (Wonderware West, n.d.).

Figure 12: The Components of OEE

As shown in Figure 12, OEE is calculated with the formula Availability \times Performance \times Quality. Real-time OEE visibility empowers operators to make corrective actions quickly. Detailed historical data of production performance and equipment utilization enables root cause analysis of capacity losses to determine areas for continuous improvement. Through the implementation of the IIoT, the data needed to calculate availability, performance, and quality are readily available. Implementing real-time OEE is typically one of the most popular proof-of-concept and scale-up projects that manufacturers like to tackle first.
3.2 Supply Chain Characterization for NEO

Recall from Section 2.3 that the IIoT ecosystem is made up of two sectors and that both (demand side and supply side) have their own unique supply chain. Accepting that a supply chain is a system of organizations, people, activities, information and resources involved in moving a product or service from supplier to customer, we can conclude each entity in that system must have a characteristic role to play in the delivery of the product/service to the customer. In the case of the demand side sector, the supply chain system of “solvers” helps the manufacturer (the customer) implement IIoT into its operation. In the case of the supply side, the supply chain system of solvers helps the IIoT product OEMs and service providers (the customer) infuse advanced capabilities into their IIoT products/services. As displayed in Figure 13, the characteristic roles comprised by the supply chain system are identified for each supply chain. The following two sections provide further definitions for the supply chain stakeholders.
3.2.1 Demand Side: Solver Supply Chain

- **IoT Solutions Partner (IoT SP):** An end user-facing organization that has established a comprehensive network of IoT domain experts in hardware, firmware, software, connectivity, data analytics and vertical market applications. The organization assists in new business model definition and provides total integration of customer-specific IoT solutions. An IoT SP offers some combination of elements from hardware to data analytics expertise and not necessarily the “whole package.”

- **IoT Systems Integrators (SI):** A company that stitches solutions together, providing hardware installation and software field deployment, IoT security and access control.
management, IoT system provisioning and configuration, field deployment, training services, system maintenance and support

- **Manufacturing Execution System Vendor (MES):** A company that provides “out-of-the-box” and “canned” hardware and software products for integrated IoT solutions, typically comprising smart devices, connectivity hardware and software, cloud interface and application software

- **Enterprise Security Company (ESC):** A company having expertise in any aspect of the software, hardware and best practices related to protecting the IoT system (i.e., smart connected devices, communications, cloud services and application interfaces) from nefarious activities

- **Testing, Certification and Registration Providers (TCR):** Organizations that validate the functionality, performance, compliance and security of the products and services that utilize smart devices and systems

- **Consultant (CON):** An expert or experienced professional having a background in any of the subject areas vital to the successful implementation of an IIoT system

3.2.2 Supply Side: Solver Supply Chain

- **Cloud Hosting Provider (CHP):** A cloud hosting service provider that supplies the software and hardware (SaaS, Paas and/or Iaas) required to interface with the cloud

- **Independent Software Vendor (ISV):** A software/firmware producer that is not owned or controlled by a hardware manufacturer; a company whose primary function is to develop and distribute software for imbedded intelligence

- **Independent Firmware Vendor (IFV):** A firmware producer that is not owned or controlled by a hardware manufacturer; a company whose primary function is to develop and distribute embedded software and/or code firmware for embedded intelligence, cloud and mobile apps

- **Network Equipment Provider (NEP):** A company that sells products and services to communication service providers such as fixed or mobile operators, as well as to enterprise customers
• **Device OEM**: A company that produces a highly integrated device (usually includes hardware, software and communications) and equipment that may be marketed by another manufacturer

• **Original Design Manufacturer (ODM)**: A company that designs and manufactures products as specified and eventually rebrands by another firm for sale

• **Design and Engineering Service**: A multidisciplinary company that can design several aspects of a smart device, including electronics, controls (both software and firmware), hardware, communications, packaging, design for manufacturability, design for human factors and cybersecurity

• **Contract Electronics Manufacturer (CEM) or Electronics Manufacturing Service Provider (EMS)**: A company that designs, tests, manufactures, distributes and provides return/repair services for electronic components and assemblies for original equipment manufacturers (OEMs)

• **Chip Vendors (CV)**: Designers and suppliers of specifically purposed, highly integrated chips for embedded systems

• **Software Intellectual Property (IP) Vendors**: Firms that have IPs that can be licensed for use within the ecosystem of IoT – examples of such uses include data analytics, edge computing platforms, motor control algorithms used in microcontrollers, and security and encryption

• **Engineered Materials Developer & Supplier (EMD)**: A company that develops advanced materials that support the creation and commercial viability of smart devices (for example, sensors and packaging) and/or the supply of newly developed material

• **Fabrication Machine Builder/Integrator (FMB)**: Any company involved with the integration of new processes used in the advanced fabrication of highly functional and low-cost smart devices, including, for example, integrated roll-to-roll machines with continuous in-process printing of electronics and IC component placement and new form factors for highly integrated packaging
• **Testing, Certification and Registration Providers (TCR):** Organizations that validate the functionality, performance, compliance and security of the products and services that utilize smart devices and systems

• **Smart Systems Research Institutions (R&D):** Any institution that sponsors IoT-related development programs (hardware- or software-based) that deal with the product or processes for smart devices, communications, data gathering and storage, data analytics and market vertical applications

• **Consultant (CON):** An expert or experienced professional with a background in any of the subject areas vital to the successful implementation of the IIoT system

### 3.3 Region’s Core Assets and Resources

#### 3.3.1 Smart Devices and Systems Cluster

Team NEO and industry leadership are leading a Regional Innovation Cluster (RIC) for Smart Manufacturing to accelerate the adoption of IIoT in the region. RICs are the demonstrated method for effectively connecting with open innovation networks. RICs are a geographic concentration of interconnected businesses, suppliers, service providers and associated institutions in a technology. RICs drive enhanced growth through the creation of high-value commercial platforms and world-class supply chains. They create prosperity, strengthen entrepreneurship and drive structural change.

The vision of the Smart Manufacturing Cluster is to accelerate growth in the Northeast Ohio economy through the implementation of the IIoT that leverages the region's rich manufacturing heritage, unique assets and talented workforce.

Cluster members collaborate to create a supply chain of interconnected businesses and institutions to advance smart embedded intelligent devices and systems. The scope of work includes developments in hardware, software, communications and security at the smart system physical level, communications level, systems level, and end-user application level, with a goal of providing a coordinated collaborative environment for all stakeholders involved in the realization of these smart systems.
The value proposition for the Smart Manufacturing Cluster will focus on building networks that will advance knowledge and drive adoption of IIoT, identify innovation gaps as identified by major market segment leaders and develop programs that create the specialized intellectual capital that enable IIoT implementation and innovation.

The cluster will serve as a mechanism to operationalize the findings from the IIoT Commercialization Roadmap, implement the goals and establish working groups and enlist an active base of members to participate. The cluster will host quarterly networking events and knowledge building activities. A steering committee of industry participants leads the cluster and advises on picking events and activities that will add value to cluster members.

### 3.3.2 The Internet of Things Collaborative (IOTC)

The IOTC is a union of academic institutions — Case Western Reserve University (CWRU) and Cleveland State University (CSU) — through the philanthropic support of the Cleveland Foundation. The IOTC is a unique regional public-private academic collaboration focused on advancing the state of the art and practice in the IoT in manufacturing, energy, health and infrastructure/smart city sector, and building an IoT hub in Northeast Ohio. Its initiatives surround higher education, industry outreach, public sector outreach and economic development. This partnership will expand research and educational opportunities in the emerging technology of the IoT through the development of transdisciplinary research partnerships across the universities, new courses and student exchanges, and by partnering with third-party economic development initiatives.

**IOT Collaborative Goals:**

- Improve life quality while creating stronger and more connected communities and neighborhoods
- Recruit the best and brightest researchers and developers to Cleveland
- Demonstrate thought leadership and be the bridge that connects broad and deep IoT knowledge with key partners
• Lead the way in assessment and outcomes measurement
• Build a world-class talent pool, and further expand IoT research, education and training programs for students and professionals in the region
• Serve as a strong consultancy partnership by offering industries customized IoT solutions and research
• Establish Cleveland as an epicenter for creation and translation of connected products, services, and solutions to make the region a model as a progressive, smart IoT adopter

The initial grant funding the IOTC has received from the Cleveland Foundation will assist the universities in attracting top talent, creating research labs and formally establishing the IOTC organizational ecosystem. The grant was part of the Cleveland Foundation’s Digital Excellence Initiative, which invests in efforts that grow community connectivity, boost digitally related skills development, increase digital civic engagement, advance regional digital leadership and develop technology innovation for public good.

The IOTC is a resource for communities and companies in the Northeast Ohio region having specific needs that can be addressed by leveraging the complementary research strengths of CWRU and CSU. It integrates a variety of academic disciplines, including law, engineering, urban studies, health, management and education. It is a regional asset that serves industries and neighborhoods through research and development, consulting, workforce programs and training, and data outcomes measurement.

For more information, please contact the IOTC at info@iotcollaborative.org or visit http://iotcollaborative.org/.

3.3.3 Regional Institutional Programs and Professional Associations

The following is a brief summary of some regional institutional programs and professional associations in Northeast Ohio. This is not an all-inclusive list but rather a feature of a few of the region’s core assets and resources.
### 3.3.3.1 Case Western Reserve University

Case Western Reserve University (CWRU) is home to the Institute for Smart, Secure and Connected Systems (ISSACS). The ISSACS was launched in the spring of 2016 with a focus on activities on the IIoT.

To meet the challenges and opportunities of IIoT, ISSACS is organized as a technology core of key laboratories and four vertical themes. The core laboratories address both the foundational and translation aspects of IIoT, including sensing, embedded systems, communications and networks, cybersecurity, data management, data analytics, visualization and signal processing, control, and decision-making across applications. These tools span manufacturing, infrastructure, hospitals, homes and virtually every other area where products and services are produced and delivered. The four thematic verticals are Manufacturing, Healthcare, Energy and Infrastructure, with a focus on Smart Cities and Communities.

ISSACS is administered out of the CWRU Vice President of Research's Office, with a faculty leadership team that represents the fundamental labs and key faculty from across the university representing the vertical IIoT applications for the growth/renewal of manufacturing, city infrastructure, energy and the medical/healthcare field.

### 3.3.3.2 Cleveland State University

The Cleveland State University (CSU) Office of Research, in conjunction with the IOTC, sought proposals for the development of innovative courses focused on the IoT and the application of connected devices, including emerging and adjacent technologies. Multidisciplinary courses that leverage the complementary teaching and learning strengths of CSU’s colleges and foster collaborations among faculty across campus were strongly encouraged. The selected courses appropriately align with CSU curricula (including prerequisite courses, applicability to existing or new majors/minors/concentrations, potential applicability for continuing education, etc.).

Over $90,000 in funding, provided by the Cleveland Foundation, Cleveland State University and Case Western Reserve University, has been awarded to these projects,
which each include at least one principal investigator (PI) from each institution. The winning projects are:

- Sunnie Chung (EECS) and Ming-Chun Huang (CWRU): “Protect Privacy in a Distributed Learning Platform with a Natural Language Processing Example”
- Wendy C. Regoezzi (CAS) and Roberto F. Galán (CWRU): “Predictive Modeling of Drug Offenses and Gun Violence in Cleveland”
- Haodong Wang (EECS), Philip Feng (CWRU), and Mark Griswold (CWRU): “Integrating Wireless Sensors and Data Streams into Virtual Reality of Smart Buildings”
- Christopher Wirth (CBE) and Emily Pentzer (CWRU): “IoT Enabled Chemical Analysis”
- Chansu Yu (EECS) and Chris Papachristou (CWRU): “An Indoor Navigation and Localization System”

### 3.3.3.3 Cuyahoga Community College

Cuyahoga Community College (Tri-C) opened its beautiful and spacious 50,000-square-foot Advanced Technology Training Center (ATTC), featuring high-bay labs, multipurpose training areas and an energy-efficient and naturally lighted environment for learning, in October 2012. The ATTC links workforce education to the latest technology. In combination with the College’s Unified Technologies Center (UTC), it is the largest technology training complex in Ohio. The ATTC was designed and constructed to achieve LEED Gold certification.

The ATTC provides students with education, hands-on training and employment preparation skills for well-paying jobs. Many of the programs offered take just 10 to 18 weeks to complete, providing employers with a constant feeder system of job-ready candidates for the in-demand high-tech industry.
3.3.3.4  Lorain County Community College

The Richard Desich SMART Commercialization Center for Microsystems offers back-end packaging solutions for companies that manufacture sensors and other silicon-fabricated devices. It was founded on the simple premise that providing solutions to the industrial problems of the 21st century is the best path forward for economic development in our region and for securing a successful future for our students.

The Desich SMART Center provides cost-effective technical, facility and equipment resources to startups, multinational organizations, industry/academic researchers and federal agencies that are developing micro-electro-mechanical systems (MEMS)-based sensor products. Located on the main campus of Lorain County Community College, the Desich SMART Center is a world-class MEMS development foundry with cleanroom facilities, providing microelectronic packaging, assembly and test capabilities. The center works with client companies and partners in Ohio and across the United States that focus on "human interface" sensor technologies in markets such as industrial controls, health monitoring and clinical systems. The Desich SMART Center provides access to capital-intensive resources such as cleanroom facilities and semiconductor packaging equipment to enable clients to reduce the cost of product research and pre-production development.

The Nord Advanced Technologies Center is a 50,000-square-foot facility with a focus on today’s manufacturing processes. On-site training includes everything from computer numerical control (CNC) machining and programming to computer-integrated manufacturing. The Nord Advanced Technologies Center has the instructors, facilities, equipment and dedication to help you meet the challenges of a competitive, global marketplace.

3.3.3.5  Firmware Engineers of Northeast Ohio (FENEO)

Firmware Engineers of Northeast Ohio (FENEO) is run by USA Firmware. FENEO is the largest organized and active regional group of firmware professionals in the United States. FENEO holds events that typically include networking, dinner and guest speakers.
3.4 Competitive Analysis

3.4.1 Benchmarking Northeast Ohio Against Other Regions

A comparison between IIoT activity in Northeast Ohio and other regions of the U.S. reveals that the IIoT industry remains relatively immature and fragmented, with no one region currently monopolizing the resources of production. Most initiatives can be found in high-tech hubs and regions with an economy deeply rooted in legacy manufacturing.

Leading competitors include the following.

**New Hampshire**: Manufacturing is the largest economic sector in New Hampshire. To maintain its competitiveness, The University of New Hampshire opened the John Olson Advanced Manufacturing Center in the spring of 2016. This center focuses on a few areas — high-precision machining, light materials and flexible electronics — and gives this region a competitive advantage in retaining highly skilled talent. The center is supported by the National Science Foundation (NSF) INCLUDES program, aimed at enhancing U.S. leadership in science, technology, engineering and mathematics discoveries and innovation through a commitment to diversity and inclusion (Briand, 2018). The grant program from the NSF also aims to build and expand working relationships between area community/technical colleges and training centers and companies.

**Detroit**: The Motor City is home to the Big Three auto-makers in the United States as well as Accenture's Detroit Industrial Internet of Things Innovation Center. This center helps industrial manufacturers keep pace with the growing demand for customized products and services by providing an educational experience for these clients (Irwin et al., 2018). It gives manufacturers the opportunity to work alongside IIoT experts, industry partners and research experts to develop smart, scalable IIoT solutions. At the center, one can expect to experience real-world IIoT demonstrations with practical use cases and design thinking workshops. This is Accenture's only center dedicated entirely to IIoT.
**Pittsburgh:** The Integrated Innovation Institute at Carnegie Mellon University explores the potential for IoT through research and education. The institute explores not just how to connect products but how to connect them in meaningful ways. Inventive student projects that offer IoT-based technologies are fostered here. Specialized IoT coursework instructs students on designing for the future with a hands-on IoT introductory course. Advanced IoT coursework furthers skills by developing a product prototype during the seven-week course. An IoT Ecosystems course explores how to create interactive, intelligent spaces. The Mobile Apps for IoT course provides an overview of how IoT interacts with software, while focusing on building mobile apps and capturing data for meaningful analyses. In 2017, the Innovation Institute formed a partnership with Particle, an IoT device platform that helps companies manage their connected solutions. They provide syllabus input, guest speakers and hardware for the student labs.

**Atlanta:** Georgia Tech’s Center for the Development and Application of the Internet of Things Technologies (CDAIT) partners with industry experts such as Georgia-Pacific, AIG, Cisco Systems, 3M, Eaton, Comcast, Intel, IBM, Honeywell, The Coca-Cola Co., Michelin, Stanley Black & Decker, Verizon, UPS, Landis+Gyr, VMware and Boehringer Ingelheim to intersect sponsors with research. Georgia Tech sponsored an IoT workshop in 2015, which focused on transportation and brought together academic institutions, the government and private sector, industry, research and nonprofit organizations.

**Austin:** In 2017, National Instruments opened the National Instruments Industrial IoT Lab to serve as a location to test IIoT applications such as predictive maintenance, time-synchronized industrial networking and “microgrids” for renewable energy. In addition to being a space where vendors can collaborate to ensure that their technologies developed for IIoT are compatible with one another, this lab serves as a showroom where solver companies can show off their solutions to customers. The Industrial IoT Lab was brought together in collaboration with many partners, including

**Germany:** The industry 4.0 market in Germany is one of the largest in the world and is only expected to grow, as stated in the IIoT study “The German Industrial IoT Market 2017-2022,” conducted by eco (an association of the German internet economy) and consulting company Arthur D. Little (Becker, 2018). According to this study, the sector is estimated to grow 19% per year. The biggest sector that will benefit from IIoT is the automotive market. The main driver of growth will be the digitization of analog production and delivery processes. The IIoT market in Germany is currently ahead due to its vast industrial innovation structure and high concentration of artificial intelligence. Additionally, thousands of exhibitors and visitors attend Hannover Messe, an annual trade fair in Hannover, Germany, that showcases technology innovations.

Many more regional IIoT initiatives can be found around the region and world, including Oregon State University Center for Applied Systems and Software (CASS) and St. Louis’s CORTEX Innovation Community. One common trend is the strong presence of higher education and private industry collaboration, often in the form of an innovation center. The presence of an innovation center is key to advancing the excellence and proficiency of an IIoT workforce, spurring product innovation and boosting the implementation of innovative technology.

**California:** The Clean Energy Smart Manufacturing Innovation Institute (CESMII), headquartered in Los Angeles, is the most closely matched organization to Team NEO’s Smart Manufacturing Cluster. (In Northeast Ohio, Youngstown-based America Makes is a core component of Team NEO’s Additive Manufacturing Cluster and the flagship Institute for Manufacturing USA.)

CESMII is the ninth Institute for Manufacturing USA awarded by the Obama Administration, under the Department of Energy.
In August 2017, CESMII published a roadmap outlining a plan to accelerate smart manufacturing through several goals and objectives. Its roadmap is unique in that it includes goals surrounding improvement in energy efficiency and energy productivity in addition to boosting adoption and deployment of smart manufacturing.
4 VOICE OF THE CUSTOMER (VOC) INTERVIEWS

The future success of IIoT in Northeast Ohio depends on the perceptions of the regional manufacturing companies as much as it depends on objective statistical analyses.

For this reason, nearly 50 companies comprising Northeast Ohio’s IIoT supply chain were interviewed during this roadmapping process. The objective was to obtain a relatively comprehensive picture of the integration of IIoT into regional manufacturing. Specific information regarding each participating company’s familiarity with the IIoT concept, reason and expectation around its implementation were gathered. Also explored were specific application areas for the IIoT’s implementation and the need for help in the digital transformation associated with operational integration of the IIoT. General insights about training opportunities and workforce issues were also obtained. All of this content was de-identified before analysis by the Roadmap Project Team. The VoC interviews questionnaires can be found in Section 8.2.

The regional footprint for the IIoT in NEO can be broken up into two major segments: demand side, where the IIoT is implemented into an operation; and supply side, where the product innovation for the IIoT products is effectuated. Further, seekers (those organizations looking for solutions) and solvers (those organizations providing solutions) play a critical role in both segments. Therefore, four types of interview forms were used during the conversations, resulting in four unique groups. A complete description of this segmentation can be found in Section 2.3, IIoT Sector Segments.

Copies of the actual questions can be found in the Appendix Section 8.2. The following sections describe the findings extracted from the VoC interviews, each of which falls into one of these four client types.

4.1 IIoT Demand Side – Implementation of IIoT

Demand side companies that participated in the interview process consisted primarily of manufacturing companies that have the potential to implement IIoT in their manufacturing process. These manufacturers engage in both discrete and process
control manufacturing. Also included are solvers that supply products and services in support of an IIoT solution.

4.1.1 Demand Side: Seekers

The seeker VoC interviews on the demand side represent a wide variety of industries, as seen in Figure 14. The Roadmap Project Team interviewed 11 companies in this category. The following are the consolidated findings from the interviews, with the responses organized according to the general segmentation of the interview VoC forms.

**Figure 14: VoC Demand Side Seeker Companies by Industry**

![Bar chart showing distribution ofVoC respondents across industries](chart)

Source: IIoT Readiness Assessment responses

**General Observations**

- IIoT is mostly borne out of traditional IT, which seems to prohibit expansion into the manufacturing setting.
The biggest opportunity to impact NEO manufacturing is to focus on the small- to medium-sized enterprises: They are more agile, and their proof-of-concept cases are less costly and quicker to test for effectiveness.

IIoT Familiarity

- Most of the companies interviewed seem to understand IIoT; however, their understanding gravitates toward the easiest concept to understand: automation.
- Most companies still do not understand where to start in terms of IIoT implementation, or the business value from applications derived.
- The companies are mostly novices to data. However, the most successful IIoT implementations are often focused on data. Data drives more value than automation, and the companies interviewed struggled to understand the value of data-driven insights.
- A shared digital vision and culture is essential for IIoT implementation success. This must be tackled first.
- The concept of digital transformation is not as recognized as smart manufacturing or industry 4.0, and most don’t include the front office operations into the discussion of improved manufacturing.
- In general, most larger organizations require more customization of canned software products for their "unique requirements" and have staff who can modify the functionality at the coding level.
- Small to medium companies tend to use application-specific packaged hardware and canned software to implement their pilot/proof-of-concept projects.
- Discrete vs. process control: Process control-oriented organizations seem to be more mature relative to connected systems and data analytics, so the services provided to these organization will differ when compared to the discrete-oriented businesses.
Reasons and Expectations Around Implementation

- IIoT is implemented for a variety of reasons: managing competitive pressures, taking a natural next step, staying ahead of the competition, improving internal efficiencies and safety, and pushing toward plant automation.

- A major barrier to adoption was the maturity of digital infrastructure. Rather than an all-encompassing digital transformation strategy, companies feel more comfortable implementing IIoT with a stepping-stone approach by first conducting small pilot projects before scaling up implementation.

- Most companies expect a measurable return on investment (ROI) for their implementation of IIoT; however, several companies expressed difficulty with determining the ROI.

- The implementation of a full digital transformation strategy is not possible without the backing of C-level leadership and a hefty seven-figure budget. Often, there is a disconnect between the C-level leadership’s budgetary goals and the plant-level leadership who are already utilizing IIoT in some fashion. Having a budget for IIoT impacts the level of implementation.

- The transformation to smart manufacturing is a journey, starting with lots of homework, then some expectation of operational improvement, then a metamorphosis of the operational culture.

Application Areas

- Top application areas for manufacturing are OEE, predictive maintenance and supply chain efficiency. Safety was not a major application for IIoT, though the companies that noted safety as a reason for IIoT were very passionate about this application.
Every company has multiple areas where they would like to apply IIoT, including process control, plant efficiency, product safety/quality/traceability, supply chain efficiency, asset monitoring, energy management, predictive maintenance, condition monitoring and robotics.

Help Needed for IIoT Transformation

Manufacturing companies seem, on average, still unsure about what specific type of data should be collected for an IIoT transformation.
• Many companies are developing their own internal smart manufacturing roadmaps, where they take a survey of the digital maturity of their plant(s) and evaluate where to start IIoT implementation. Often it is as simple as connecting all plants under the same enterprise resource planning (ERP) system.

• A good start for any level of IIoT transformation is partnering with an IoT solutions partner. This partner can provide a plant audit and recommend how to use data from IIoT devices. An IoT solutions partner serves as a supplement to internal IT or automation control groups.

**Workforce Insights**

• Summary of talent demanded by seekers: Skills in demand include analytics, machine learning and data science skills.

• Apprenticeship and internship programs create a pipeline for workers with in-demand skills.

• Continuing education/training for incumbent workforce comes from vendors or higher-education institution.

**4.1.2 Demand Side: Solvers**

This category of organization is responsible for the supply of products and services that support the implementation of IIoT solutions. These companies range from “full stack” vendors like Hitachi, to MES OEMs like Rockwell Automation, to systems integrators like Rexel. The Roadmap Project Team interviewed 15 companies within this category. Following are the consolidated findings from the interviews, with the responses organized according to the general segmentation of the VoC interview form.

**General Observations**

• Larger companies in this space have been activating IIoT solutions for decades and are generally digitally mature.

• IIoT involves some degree of digital transformation. Demand-side solvers that help companies in this process are critical in moving IIoT implementation forward.
**IIoT Supply Chain Capabilities**

- Many supply chain capabilities are present in Northeast Ohio’s solvers, as shown in Figure 16. Definitions of these classifications can be found in Section 3.2.1

*Figure 16: IIoT Supply Chain Capabilities of Demand-side Solvers*

- Only one of the interviewed companies responded that they were able to provide an end-to-end solution without the assistance of partnerships.

Source: IIoT VoC responses
Technical Capabilities

- The focus of solutions are cybersecurity and the systems level. See full distribution of technical capabilities of demand-side solvers in Figure 17. Definitions of the technical levels can be found in Section 2.5.

**Figure 17: Technical Capabilities of Demand-side Solvers**

- Solvers that are platform agnostic (not tethered to a product or platform) are able to bring in the right solution.
• Technical capabilities are expanded through partnerships; only a fraction are in-house.

Application Areas
• The application areas where solvers had experience providing solutions (starting with the most popular to the least requested) are operating efficiency (73%), predictive maintenance (67%), product quality (67%), supply chain management (67%), inventory control (60%) and occupation/worker safety (60%), as seen in Figure 18.

![Figure 18: Application Areas of Demand-side Solvers](image)

Source: IIoT VoC responses

• Every company has multiple areas where they can provide IIoT application assistance. An estimated 30% of the companies had experience with the full set of applications.
**Workforce Insights**

- Difficulty finding skills at all levels. To overcome this, major solutions providers have their own, often extensive, training infrastructure.
- Difficult to find employees with both an undergraduate degree and OT experience
- Difficult to find employees with both data analytics and OT experience
- Need employees with connected systems background and manufacturing methods experience

**4.2 Supply Side – IIoT Product Innovation**

Supply-side companies that participated in the VoC interview process consisted primarily of IIoT product OEMs/service providers that are innovating their products (seekers). On the supply side are companies with advanced technical capabilities that can assist with the integration of these advanced capabilities into IIoT products (solvers).

**4.2.1 Supply Side: Seekers**

This category of interviewee comprises those organizations that make IIoT-enabled products and are looking to embellish their products further with additional embedded intelligence capabilities. The Roadmap Project Team interviewed 10 companies within this category. Following are the consolidated findings from the interviews, with the responses organized according to the general segmentation of the VoC interview form.

Companies in this space wrestle with the questions of how to best offer industrial IoT solutions, whether the desire for IoT solutions comes from the executive level of a company or plant level, and whether their clients should be connected to their data through cloud solutions or other technology.
Technical Assistance Needs

- Supply-side seekers need assistance in all areas: systems level, smart device level, communication level, cybersecurity and applications level. Definitions of the technical levels referred to here can be found in Section 2.5.

Source: IIoT VoC responses

- There is a widespread need for data analytics capabilities, specifically analyzing and visualizing data.
- Every company surveyed said they are interested in new revenues from new products, but not all companies realize that they need more analytics to do that.
- To conduct data analytics, better technology needs to be put in place to store and access data for analysis rather than relying on a “cloud” model, which is expensive and difficult to retrieve data from. A data lake is a model that many companies
(those with a huge amount of data from thousands of sensors) are currently exploring.

- Data needs to be correlated with ERP and order system data, in addition to raw manufacturing data, for high-value dashboarding.

**Application Areas**

- Figure 20 displays the application areas with which supply-side seekers need assistance to aid with IIoT product innovation.

*Figure 20: IIoT Application Areas in Need of Assistance by Supply-side Seekers*
• Companies will continuously seek to engage in more partnerships to offer more solutions.
• More data requires additional cybersecurity measures and regional hubs of data storage.

Supply Chain Support

• Several companies cited interest in edge (fog) computing, prescriptive analytics, AI, augmented reality, integrated (hybrid) cybersecurity, and highly integrated and highly functional SoCs with isolated architectures.
• Also of interest are 5G networks and open-sourced software container technology.

Workforce Insights

• The larger OEMs are embellishing their own ranks with advanced capabilities in electronics for fog computing, data handling, data analytics and deep learning/AI, and are working with the academic institutions to fulfill their needs (offering internships, for example). Occasionally, they cherry-pick from the capabilities of the supply chain of advanced capabilities.
• The supply chain solutions providers, in some instances, are attractive to the OEMs since the solutions providers’ advanced capabilities are tempered by real-world experience in the applications of IoT.
• There is a tight market for developers; many companies are concerned about retaining this talent.
• Machine learning is rising as an in-demand skill.
• Most supply-side seekers spend a substantial amount of effort and funds in recruiting secondary and postsecondary degreed engineers and data scientists.

4.2.2 Supply Side: Solvers

This category of interviewee comprises those organizations with advanced technical capabilities associated with embedded intelligence that can assist the supply-side seeker with the integration of these advanced capabilities into IIoT products. These
companies and institutions have functional specialists in the disciplines of software/firmware, microelectronic hardware, data analytics, communications and cybersecurity. Following are the consolidated findings from the interviews, with the responses organized according to the general segmentation of the VoC interview form.

**IIoT Supply Chain Capabilities**

- There is wide expertise present in the area, including design engineering, consulting, software, IP and firmware. However, not one provider can offer a full solution. The integration of small and large company partnerships allows for specialized solutions.

**Technical Capabilities**

- Supply-side solvers are proficient in a wide range of technologies, as shown in Figure 21.
Solvers are closely monitoring the market and evaluating future technology trends to develop new and innovative IIoT solutions.

There is an overall weakness in data analytics, both in providing the service and in understanding how data impacts solvers’ clients.

There is a misalignment between the cost of solutions and the budget of seekers. Solvers should do something to correct this misalignment for IIoT adoption to take off.
Application Areas

- Supply-side solvers have documented several unique case studies as examples of how their solutions have enabled the implementation of IIoT. These case studies are provided to manufacturing companies that are seeking an IIoT solution.
- Solutions most frequently provided are those that feed into operating efficiency, predictive maintenance and product quality application areas.

Workforce Insights

- Current higher education curriculum does not meet the workforce education needs for IIoT in Northeast Ohio.
- The competencies of the average college graduate are severally limited in several areas.
- Solvers hire experienced talent or put additional resources into training new hires in-house.
- Workforce incubation will be a critical factor in spurring the adoption of IIoT in Northeast Ohio.

4.3 Supporting Resources

Supporting resources include organizations that supply operational technology skills and training to organizations that implement, use and support IIoT solutions. These resources can also supply smart technology-related skills to organizations that assist in, or are responsible for, IIoT product innovation. Organizations that are part of both IIoT implementation and IIoT product innovation were asked what their critical needs were relative to employee skills development and workforce training. Following are the consolidated findings from each of the Workforce Insights sections listed in Sections 4.1 and 4.2, as well as anecdotal observations made during the interviews and through networking opportunities.
Operational Technology (OT) Skills and Training to Demand-side Solvers

- Generally, the manufacturers implementing IIoT into their operations need assistance retraining incumbent workers to become proficient with OT and recruiting experienced personnel with advanced capabilities to help with the implementation, care and feeding of the IIoT system.
- Most larger companies understand the difference between IT and OT but lament their difficulty in acquiring the OT capability.

IIoT Operational Support Requirements from Demand-side Solvers

- Workers with OT experience who are proficient with customer relations are “worth their weight in gold,” we have been told. This includes proficiency with MES hardware, software, analytics and application expertise.

Smart Technology Needs From Supply-side Solvers

- The organizations that are continuously infusing new IIoT-related features into their products and the supply chains that support their efforts need assistance recruiting both graduate and postgraduate employees through internship programs that expose the personnel to popular IIoT applications and related software/hardware products. Advanced degrees tempered with connected smart systems experience are essential.

Advanced Technology Capabilities to Supply-side Solvers

- A request mentioned by a majority of the VoC interviewees was to implement a “one-stop shopping” service/clearing house for qualified applicants that identifies and promotes available internships.

4.4 Workforce Training and Education

Large-scale transformation of the manufacturing ecosystem through the implementation of IIoT cannot occur without adequate workforce training and education programs.
Additionally, the Roadmap Advisory Team has consistently heard through conversations with seekers and solvers alike that adequate talent and workforce are critical to widespread adoption of this technology. In Northeast Ohio, there are several opportunities for students to become familiar with this technology through industry training and hiring practices, and current IoT education curricula.

**Industry Training and Hiring Practices**

Many businesses in the area have taken it upon themselves to train their own IIoT talent.

- Demand side (systems in-house and care/maintenance): Community colleges
- Those that implement IoT in product (Rockwell): four-year degrees from academic colleges
- Companies investing in training may run their own classes, so their workforce is comfortable with the in-house technology.
- Webinars: Deloitte, Gartner, McKinsey Global Institute, Rockwell

**Current IoT Educational Curricula**

Area universities and colleges that currently have education curricula or other programs include Case Western Reserve University (CWRU), Cleveland State University (CSU), Cuyahoga Community College (Tri-C), Lorain County Community College (LCCC) and Lakeland Community College. These academic institutions are creating a pipeline for graduates in engineering and other related programs to stay in Northeast Ohio as this region continues to develop into an “IIoT hub.” Additional information on these institutions can be found in Section 3.3.3.

**4.5 IIoT Readiness Assessment**

The IIoT Readiness Assessment (sponsored by Hitachi Vantara) was developed collaboratively by the Roadmap Project Team and Working Group to be used as a tool to help a company evaluate its digital maturity and readiness for IIoT implementation. The focus of the assessment is on key readiness indicators, including:
• Level of Engagement
• Organizational Support
• Potential Uses for IIoT
• Workforce Readiness
• Digital Maturity

All survey responses are confidential and complimentary, and will be analyzed by the Roadmap Project Team and returned to those surveyed to provide a high-level assessment of your organization’s readiness to adopt IIoT solutions and how your readiness compares to others in the Northeast Ohio market.

Click here to take the IIoT Readiness Assessment.

5 WHAT IS POSSIBLE

5.1 Potential IIoT Impact on NEO

5.1.1 IIoT Growth Potential and Impact on NEO

According to the estimate provided by McKinsey, Northeast Ohio has the potential to receive an economic impact of between $3.5 and $10.1 billion annually, in year 2025, from the implementation of IoT in various application segments (see Figure 22). This projection is based on a model that assumes that the applications of IoT will create a new surge of factory productivity (Dobbs et al., 2015).
Utilizing research by McKinsey and Infosys, the Roadmap Project Team was able to identify the rate at which manufacturing sectors in Northeast Ohio will capture this economic impact, based on their maturity level for IIoT applications (Enose & Ravikumar, 2016). Complete methodology for potential economic impact in Northeast Ohio can be found in Section 8.1.2.

To gain the benefits of IIoT, NEO's current manufacturing base will need to change their processes and how they work. When manufacturers use connected products to capture and analyze data, they will see a 15% increase in productivity (Columbus, 2016). According to Moody’s Economy.com projections, Northeast Ohio’s manufacturing GRP is projected to grow from approximately $4 billion to $45 billion in 2018, to $49 billion by 2025. Based on the Roadmap Project Team’s calculations utilizing McKinsey Global Institute data and Accenture estimates, IoT’s application in a factory setting, such as IIoT in the manufacturing sector, has the potential to grow GRP from the current projection of $49 billion to $53 billion in 2025 (see Figure 23). The higher end of the potential impact IIoT will have on NEO’s manufacturing sector by 2025 is $62.6 billion.
Figure 23: Economic Impact of IIoT on Northeast Ohio GRP

Source: McKinsey Global Institute/Accenture estimates and Moody’s Economy.com data analyzed by Team NEO
5.1.2 IIoT’s Potential Impact on NEO Target Markets

As stated previously, there are two forms of manufacturing that utilize industrial IIoT technology: process control-based and discrete manufacturing-based. The Roadmap Project Team was able to break down this potential impact by type of manufacturing.

5.1.2.1 Process Control Manufacturing

The process control-based manufacturing industries in Northeast Ohio are projected to grow their output marginally, from $21.9 billion to $22.1 billion from 2018 to 2025. However, through moderate implementation of IIoT technology, these industries could potentially see output increasing $1.4 billion annually, starting in 2025 (see Figure 24). The upper limit of our projection would add as much as $5.5 billion annually to process control manufacturing, which translates to a figure of $6.9 billion for total output in 2025.

Figure 24: Economic Impact of IIoT on Process Control Manufacturing GRP
Each of the process control manufacturing target markets – Food, Beverage & Tobacco Products, Textile Mills, Textile Product Mills, Paper, Printing and Related Support Activities, Petroleum and Coal Products, Chemical, Nonmetallic Mineral Product and Primary Metal – has growth potential (see Figure 25).
The Northeast Ohio process control-based manufacturing industries that will see the steepest output growth from IIoT implementation based on their maturity level in IIoT applications are chemical, primary metal and food manufacturing.

Chemical manufacturing has been identified by the Roadmap Project Team as a most mature sector in its implementation of IIoT for predictive maintenance, and health and safety applications. The chemical manufacturing sector has the potential to grow its
GRP between $0.3 and $1.3 billion per year in 2025 to an upper-case estimate of $7.8 billion.

Primary metal manufacturing companies are also estimated to be most mature in their implementation of IIoT for operation optimization, predictive maintenance, and health and safety applications. This industry is projected to receive an economic impact of between $0.6 and $1.7 billion per year in 2025. The upper-case estimate of output is as high as $7.8 billion if companies aggressively implement IIoT applications.

Lastly, food manufacturing companies are still in the process of maturing their application of IIoT for operation optimization and inventory optimization. This sector has the potential to receive between $0.2 and $0.7 billion in economic impact from applications of IIoT, which could amount to between $3.9 and $4.5 billion per year in 2025.

5.1.2.2 Discrete Manufacturing

The discrete manufacturing-based companies in Northeast Ohio can expect to see tremendous growth in their output through the implementation of IIoT on their shop floor. Under current conditions, the output of Northeast Ohio’s discrete manufacturing industries is expected to see growth of only 16% between 2018 and 2025, from $23.2 billion to $30 billion (see Figure 26). However, IIoT technologies can increase the potential output of these industries between $2.1 and $8.1 billion per year in 2025. IIoT could potentially increase the GRP of discrete manufacturing industries to between $29 and $35 billion in 2025.
Each of the discrete manufacturing target markets that were identified by the Roadmap Team – Apparel, Leather and Allied Product, Wood Product, Plastics and Rubber Products, Fabricated Metal Product, Machinery, Computer and Electronic Product, Electrical Equipment, Appliance and Component, Transportation Equipment, Furniture and Related Product, and Miscellaneous Manufacturing – has unique growth potential. IIoT implementation will most significantly benefit companies manufacturing transportation equipment, fabricated metal products, machinery, and plastics and rubber products (see Figure 27).
Transportation equipment manufacturing has been identified by the Roadmap Project Team as most mature in their implementation of IIoT for all four application segments: operations optimization, predictive maintenance, inventory optimization, and health and safety. The transportation equipment manufacturing sector has the potential to grow its GRP between nearly $1 billion and $3.8 billion per year in 2025, building this sector to a $11 billion industry by 2025.
Fabricated metal products manufacturing companies are also estimated to be developing their maturity in their implementation of IIoT for all four application segments. This industry is projected to receive an economic impact of between half a billion dollars and $2 billion per year in 2025. The upper-case estimate of output is as high as $8.8 billion if companies develop their maturity in implementing IIoT in applications.

Machinery manufacturing companies in Northeast Ohio are estimated to still be developing in their applications of IIoT. However, this sector is projected to grow their output between 7% and 28% per year by 2025, from the implementation of IIoT in operations optimization, predictive maintenance and inventory optimization. By 2025, this sector is projected to grow their output anywhere from $0.3 to $1.1 billion.

Lastly, plastics and rubber products manufacturing companies are thought to still be in the process of maturing their application of IIoT for inventory optimization and health and safety. This sector has the potential to receive between $0.1 and $0.4 billion per year in economic impact from applications of IIoT, which could amount to between $2.9 and $3.2 billion in 2025.
6 NEO IIOT GROWTH STRATEGY AND TACTICAL IMPLEMENTATION PLAN

6.1 SWOT Analysis

The Northeast Ohio region is ideally suited to become a national leader in IIoT. There is an unusually high concentration of instruments, controls and electronics expertise; a historically strong manufacturing base of industry and workforce; a unique application match with seeker need; and a growing presence of global leaders with headquarters and technology hubs within the region. The respective strengths and weakness of the Northeast Ohio region, regarding its opportunity for IIoT, are analyzed in Figure 28.

Figure 28: The IIoT Opportunity for the NEO Region

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>WEAKNESSES</th>
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<tbody>
<tr>
<td>• Manufacturing – Industrial Legacy creates large market size – A+ Pool of Seeker Companies</td>
<td>• Level of Software System Development</td>
</tr>
<tr>
<td>• Instruments, Controls, Electronics Expertise – both industry leaders and strong start-ups</td>
<td>• Data Analytics Expertise</td>
</tr>
<tr>
<td>• Application Match with Seeker Need</td>
<td>• Legacy manufacturing machinery raises ROI challenge</td>
</tr>
<tr>
<td>• Global Leaders with HQ &amp; Technology Hubs here</td>
<td>• Lack of innovation Center of Excellence</td>
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<td></td>
<td>• Lack of capital support to fund innovation</td>
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<tr>
<th>OPPORTUNITIES</th>
<th>THREATS</th>
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<tr>
<td>• Institutional Leadership (e.g. IOT Collaborative, NASA) can baseload Center of Excellence for region</td>
<td>• Global competition</td>
</tr>
<tr>
<td>• Accelerate rate of digital transformation</td>
<td>• Lack of C-level buy-in and organizational budget commitment</td>
</tr>
<tr>
<td>• Help bridge labor shortage</td>
<td>• Better coordinated and funded industry – institutional strategy by another USA region</td>
</tr>
<tr>
<td>• Multiple technologies are converging (e.g. AI, VR)</td>
<td></td>
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</table>

Source: Roadmap Project Team
Drawing on the strengths identified through the roadmapping process and building upon existing regional programs, the Roadmap Project Team articulated a vision for proliferation of the IIoT in Northeast Ohio in the form of the vision and goals.

### 6.2 NEO IIoT Roadmap Commercialization Plan Framework

The NEO IIoT Roadmap Commercialization Plan Framework provides the starting point for defining strategies in three key areas: Implementation of IIoT, IIoT product innovation, and people and skills. These key areas were identified through the collaboration of the Roadmap Project Team and Working Group.

**Smart Manufacturing Cluster**: This leadership function for the implementation of the Commercialization Plan includes program management, marketing, outreach, entrepreneurship and business attraction.

**Implementation of IIoT**: Break down obstacles to integrating smart manufacturing into business operations and grow companies that supply products and services in support of an IIoT solution.

**IIoT Product Innovation**: Expand advanced IIoT features supplied by IIoT products/services providers and promote collaboration around advanced technical capabilities.

**People & Skills**: Leverage smart technology-related skills organizations for IIoT product innovation, and carry out initiatives that create an IIoT workforce pipeline.
6.2.1 Vision

Accelerate growth in the Northeast Ohio economy through the implementation of IIoT that leverages the region’s rich manufacturing heritage, unique assets and talented workforce.

6.2.2 Goals

- Drive demand for Industrial IoT.
- Increase regional productivity.
- Spur IIoT product innovation.
- Develop resources to support IIoT implementation and innovation.
6.2.3 Initiatives

6.2.3.1 Implementation – Drive demand for IIoT implementation: 2019
1. Develop a portal hosting a database of case studies and supporting information to provide context around IIoT implementation. Solvers shall provide success story case studies to drive seeker demand.
2. Follow up on the IIoT Roadmap by exploring different approaches to implementing IIoT through either a top-down or bottom-up strategy.
3. Establish working group surrounding high IIoT implementation application areas: operating efficiencies, predictive maintenance and supply chain management. Identify mechanisms for aligning the suppliers of these application solutions and the companies seeking implementing IIoT for these applications.
4. Expand upon the Roadmap market research to capture the potential economic impact on IIoT solution providers.
5. Distribute the IIoT Readiness Assessment Tool to the regional manufacturing community, deliver relative scoring confidentially to companies and promote summary of collective findings throughout the region.

6.2.3.2 Innovation – Spur advances in IIoT product innovation: 2021
1. Explore the next generation of enabling technologies based on trends such as embedded intelligence, cybersecurity, edge computing and data processing.
2. Grow partnerships to connect the solvers to offer customized solutions to seekers.

6.2.3.3 Resources – Support programs with institutions that create the specialized intellectual capital that enables IIoT implementation and innovation: 2020 - 2025
1. Advance talent development through experiential learning:
   - Expand workforce through innovation hubs (supply)
   - Produce internship opportunities to create workforce pipelines (demand/supply)
2. Spur future collaboration between stakeholders to advance training and curriculum development to create the next generation of an IIoT-proficient workforce.
3. Understand the credentialing requirements of an IIoT workforce and integrate it into future regional talent supply demand analysis.

6.2.3.4 **Develop the Smart Manufacturing Cluster** – To support IIoT implementation, product innovation and resource programming: 2019 - 2025

4. The development of the Smart Manufacturing Cluster to support Northeast Ohio’s IIoT commercialization strategy.
   a. Establish a shared leadership model to implement NEO’s IIoT Commercialization Strategy.
   b. Attract investment to and promote awareness of programs to foster startups and encourage entrepreneurship surrounding IIoT product innovation.
   c. Collaborate on training and workforce development initiatives.
   d. Encourage the attraction of companies engaged in IIoT product innovation to advance the region’s applications of embedded intelligence, cybersecurity, edge computing and data processing.
7 SUPPORTING INFORMATION
7.1 Entrepreneurship and Commercialization

The Ohio Third Frontier seeks to grow tech-based startups through the Entrepreneurial Services Program (ESP). The ESP, as administered by JumpStart, a Northeast Ohio nonprofit, offers mentoring through designated executives-in-residence, access to capital and other support to effectively grow technology-based entrepreneurial commercialization outcomes in Northeast Ohio.

With a focus on commercialization, most startups in the region have products related to healthcare and IT. Very few true IIoT companies have been identified to date, possibly because:

- The entrepreneurial network may not be fully aware of the intricacies of IIoT.
- IIoT is thought of as a product that to be implemented, and consulting businesses that are important to the implementation of IIoT are not supported by the JumpStart network.
- Product innovation for IIoT has focused on high-level integration of embedded intelligence and advanced data analytics, which are not traditionally areas where we find a lot of business startup activity – they have a greater tendency to be spin-offs from established organizations.

An area where we are seeing opportunities for startups is in support of the operations technology (OT) space. Figure 30 represents the distinction between IT and OT. IT is fully supported by the JumpStart network, while the concept of OT has not yet been fully recognized. However, there are opportunities in support of OT in areas like predictive maintenance or process analytics that show promise. In several cases, a startup company has developed a package with a sensor suite that can easily be integrated into any part of the manufacturing process, added user interface software and cloud access. The company then offers a subscription to the customer to monitor and analyze critical data or events and then provide recommendations back to the OT staff.
7.1.1 Northeast Ohio Resources

Northeast Ohio offers many entrepreneurial resources and services to help launch and grow startups. The services are funneled through JumpStart, the regional partner for the Ohio Third Frontier. JumpStart provides venture capital and intensive, high-impact assistance to diverse entrepreneurs and small businesses owners, working one-on-one to establish and achieve value-creating milestones of growth.

The JumpStart portfolio companies fall into four categories: CleanTech, healthcare, IT, and business and consumer. IIoT would fall under IT and is currently not considered a focus of its own. JumpStart supports the following organizations.

**Youngstown Business Incubator (YBI):** This Youngstown-based incubator specializes in entrepreneurial support for companies working in software and 3D printing. YBI’s portfolio companies span Northeast Ohio, and the YBI is currently
expanding its services. It has partnered with Cisco to help increase the adoption of IIoT with area manufacturers.

**Flashstarts:** A Cleveland-based accelerator, Flashstarts is the fourth-largest co-working space in the nation. Flashstarts offers a 10-week accelerator program, internships for area students and a Global education, innovation and research (EIR) program to attract startups from around the world. Flashstarts works closely with IT and software-related companies, and is launching support for blockchain startups.

**Bounce Innovation Hub:** This Akron-based organization offers an incubator program, a mentoring program and a software accelerator, as well as event space for entrepreneurial events. Companies include software/IT and healthcare.

**Great Lakes Innovation and Development Enterprise (GLIDE):** GLIDE provides business assistance through EIR mentoring, and tools and resources to help launch successful startups, including funding for startups in digital economy, advanced materials, electronics, alternative energy, bioscience and information technology.

### 7.1.2 Other Entrepreneurial Support

**Institute for Smart, Secure and Connected Systems (ISSACS):** This institute at Case Western Reserve University is dedicated to advancing research on the IoT. It leads specific initiatives in data science, cybersecurity, networks, embedded systems and more.

**Plug and Play:** The largest accelerator in the world is a network startup accelerator and corporate innovation platform that recently established an office in Cleveland with a focus on biomedical. This Silicon Valley Venture Capital firm attracts startups to the region and plans to focus on IoT soon.

**Manufacturing Advocacy and Growth Network (MAGNET):** MAGNET helps manufacturers grow their operations, workforces and startups in the region.

**Innovation Ohio Loan Fund (IOLF):** The ILOF was established to provide capital to Ohio companies with limited access to capital and funds from conventional financing sources due to the risks associated with the development of new products or services.
**JobsOhio Growth Fund Loan:** This resource provides capital for expansion projects to companies with limited access to capital and funding from conventional, private sources of financing. JobsOhio considers loans to companies in the growth, established or expansion stage that have generated revenues through a proven business plan.

Recommendations for entrepreneurial support include identifying specific product innovation opportunities and working with organizations such as JumpStart and Ohio Third Frontier to educate leadership on IIoT and how resources can be appropriately aligned to support innovation in manufacturing.

### 7.2 Business Use Cases

Business use cases have been identified as being critical to implementation and adoption of IIoT. Seekers place high value on being able to review a use case of a similar IIoT implementation scenario as their own to see exactly how an IIoT Solutions Provider was able to aid. As such, creating a library of use case is a future initiative of this IIoT Commercialization Roadmap.

### 7.3 Industry Terms and Acronyms

- CAGR: Compounded Annual Growth Rate
- IP: Intellectual Property
- OEM: Original Equipment Manufacturer
- ROI: Return on Investment
- SME: Small to Medium Enterprise(s)
- IoT: Internet of Things
- IIoT: Industrial Internet of Things
- KPI: Key Performance Indicator
- PLC: Programmable Logic Controller
- OEE: Overall Equipment Effectiveness
- DM: Digital Maturity
- NAICS: National American Industry Classification System
- VoC: Voice of the Customer
8 APPENDIX
8.1 Data and Methodology Notes

8.1.1 IIoT Economic Impact on Northeast Ohio Manufacturing GRP

This report presents gross regional product (GRP) projections created by the economic impact of industrial internet of things (IIoT) on the manufacturing industry. Projections for this economic impact are based on several assumptions.

1. All the economic impact of IoT in a factory setting of McKinsey’s four application segments – operations optimization, predictive maintenance, inventory optimization, and health and safety, will benefit the manufacturing sector.
2. Manufacturing sectors will have varying rates of maturity in their adoption of IIoT technology.

8.1.2 IIoT Maturity Model

Least Mature:

- **Device connectivity and data forwarding** - Sensors are installed and connected. Sensor data is transmitted and stored (on- or off-site) for analysis and action.
- **Digital Requirements** - Existing IT infrastructure is not required. Solutions providers can assist the business with any technical needs. A digital transformation strategy is not required.

Maturing/Developing:

- **Real-time monitoring** - Data collected from sensors is monitored and visualized on dashboards. Data can initiate use cases for desired business outcomes and promote awareness of equipment status to refine business processes.
- **Data analytics** - Delivers new insights, prediction and optimization with applied data analytics through software algorithms, such as cycle time monitoring, anomaly detection, machine learning, predictive maintenance and artificial intelligence.
- **Digital Requirements** - Existing IT infrastructure is not required but integration with Enterprise Resource Planning or order systems will help drive additional benefits.
Solutions providers can assist the business with any technical needs. A digital transformation strategy is not required, but laying the groundwork for a more agile business will enable fast adoption of new insights.

**Most Mature:**

- **Automation** - Orchestrates automated, complex actions across multiple internal systems such as inventory, quality control, resource planning, scheduling, support or service ticketing systems. Greatest return on investment as waste is reduced and scheduling is improved. There is a dramatic increase in efficiency.
- **Enhanced On-board Intelligence** - Processing data on or very close to the connected equipment, sometimes called distributed intelligence or edge computing.
- **Digital Requirement** - IT infrastructure and future digital strategy becomes more critical as large amounts of data are stored for deeper analytics. Solutions providers can still assist the business with technical needs. The business will need to access data scientists and trusted business partners to help leverage the insights gained from their data. The business will rely on insights and analytics for competitive advantage and new business.

This maturity index is adopted from the Bsquare IIoT Maturity Index (Bsquare, 2017) and the Digital & IIoT Maturity index developed by Hitachi.

3. Manufacturing sectors were categorized within the maturity index based on secondary research and the expertise of the Roadmap Project Team:

**Most Mature:**

- Chemical
- Primary Metal
- Transportation Equipment

**Maturing/Developing:**

- Food
• Plastics and Rubber Products
• Fabricated Metal Products
• Machinery

**Least Mature:**

• Beverage and Tobacco Product
• Textile Mills
• Textile Product Mills
• Apparel
• Leather and Allied Product
• Wood Product
• Paper
• Printing and Related Support
• Petroleum and Coal Products
• Nonmetallic Mineral Product
• Computer and Electronic Product
• Electrical Equipment, Appliance, and Component
• Furniture and Related Product
• Miscellaneous Manufacturing

4. The top five manufacturing sectors that are thought to receive the most economic benefit of each IIoT application segment are as follows:

**Operating Efficiency/Operations Optimization**

1. Primary Metal Manufacturing
2. Fabricated Metal Product Manufacturing
3. Food Manufacturing
4. Machinery Manufacturing
5. Transportation Equipment Manufacturing
6. All Other Manufacturing Sectors
Predictive Maintenance

1. Fabricated Metal Product Manufacturing
2. Primary Metal Manufacturing
3. Machinery Manufacturing
4. Transportation Equipment Manufacturing
5. Chemical Manufacturing
6. All Other Manufacturing Sectors

Inventory Control/Inventory Optimization

1. Fabricated Metal Product Manufacturing
2. Machinery Manufacturing
3. Transportation Equipment Manufacturing
4. Plastics and Rubber Products Manufacturing
5. Food Manufacturing
6. All Other Manufacturing Sectors

Occupational Safety/Health and Safety

1. Fabricated Metal Product Manufacturing
2. Primary Metal Manufacturing
3. Transportation Equipment Manufacturing
4. Chemical Manufacturing
5. Plastics and Rubber Products Manufacturing
6. All Other Manufacturing Sectors

5. Manufacturing industries identified as most mature would receive their share of 50% of the potential economic impact per IIoT application segment based on their percent of total gross regional product; maturing or developing industries, 30%; and all other manufacturing industries, 20%.
6. The U.S. gross domestic product (GDP) is 17% of the world’s GDP, while Northeast Ohio’s manufacturing gross regional product is 2% of the U.S. GDP.

8.2 Voice of the Customer Interview Questionnaires

8.2.1 Demand Side (IIoT Implementation): Seeker VoC Questions

Organization’s Background

- How many years has your organization been in business?
- How long has your organization been exploring the potential impact and implementation of digital manufacturing?
- How many employees does your organization have and approximately what is the amount of annual sales?
  - Sales:
    - <$50 million
    - $50 million - $200 million
    - >$200 million
  - Employees
    - <50
    - 50 - 250
    - >250
- What is your business footprint?
  - Locations in Northeast Ohio?
  - Locations in the state of Ohio?
  - Within the USA?
  - Globally?
- How would you characterize your type of manufacturing?
  - Discrete manufacturing?
  - Process control/continuous?
  - Combination of both discrete and process control?
- What market segments do you serve with your products?
• Plastics and Rubber Products
• Fabricated Metal Product
• Machinery
• Computer and Electronic Product
• Transportation Equipment
• Chemical
• Primary Metals
• Petroleum and Coal Products
• Food
• Nonmetallic Mineral Product
• Other

• Have you created a digital transformation plan for your business operations?
• Why did your organization embark on the IIoT transformation of the business/institution?
  • Response to customer-driven needs
  • Strategic decision to improve business; also using for competitive advantage
• What are your expectations for business growth by implementing IIoT-related services?
• What is your expected ROI from the implementation of your Digital Transformation Plan into your operations. How do you measure value?
• Do you use OEE internally?
• How does your organization go to market?
  • External/Internal Sales Channels (including social media)?
  • Distribution Partners?
  • Business Reps?
  • Network Partnership?
  • Word of Mouth?
• What exhibitions and conferences are important to your business and which do you attend regularly?
General IoT/IIoT Knowledge

- Are you familiar with **Internet of Things** (IoT) and the **Industrial Internet of Things** (IIoT) and potential impact on your business?
  - Digitization of the operations
  - Impact on business culture
  - Impact on the organizational composition
  - Impact on technology (both product and process)
  - Potential new insights
  - Potential addition of new business models

- Why are you compelled to implement IIoT into your operation?
  - Competitive pressure
  - Customer request
  - Opportunity to improve business performance and efficiency
  - Opportunity to expand business in new direction
  - Will the implementation of IIoT put you in a better position to take market share and add new market presence and/or is this necessary to maintain your business standing in the marketplace?

- What are your expectations for implementing IIoT into your operations?
  - Increase Revenue
  - Increase Operating Profit
  - Increase Operating Cash
  - Reduce Operating Cost
  - New product direction
  - Are you convinced it is possible to achieve an acceptable ROI from the implementation of IIoT? How would you measure the value in your ROI calculation?

- Are you familiar with Digital Maturity? If so, how would you rate your organization’s level of maturity?
  - Immature: Not ready for IIoT without major overhaul (Lack the IT infrastructure)
• Developing: We are working on it but not there yet (Some IT infrastructure but not “data” savvy)
• Nearly Ready: We will be ready with a little assistance (Most IT infrastructure and some data skills)
• Mature: Ready to go (We have a robust IT infrastructure and skilled data resource – data scientists)

IIoT Business Transformation
• Do you have a strategic planning process and does your strategic plan include operational improvement initiatives? Does it also include a digital transformation strategy?
• Are your IIoT efforts part of an ongoing evolution of your business?
  • Do you currently consider your organization to be a lean manufacturing enterprise?
  • Have you recently updated your ERP system and are you adding new functional modules to your capabilities?
  • Will your implementation efforts reflect an incremental improvement on the operations or does IIoT represent a major pivot in the business strategy?
• How do you plan to implement your Digital Transformation Strategy?
  • Are you establishing a comprehensive Digital Transformation Plan?
  • Or, are you taking a stepping-stone approach by exploring specific use cases and implementing pilot projects first?
  • Are you familiar with Digital Maturity? If so, how would you rate your level of maturity?
• Describe your existing digital infrastructure:
  • Do you have both an IT (information technology) and OT (operational technology) function established?
  • Are all your critical machines/control systems connected to a data highway and reporting their real-time status?
  • What is the mix between legacy and new machines and how many of those legacy machines need to be instrumented?
  • Are you collecting data from all the sensors that you think can provide valuable insight into the operations?
• Do you have a “historian” function with enough data handling capacity to support the continuous data streams coming from all the critical machines and controllers that comprise the operations and from real-time inputs that will be coming from all the operators?

• Do you have the staff to support your application interface, IoT hardware, software, data analytics, data comms/aggregation and cybersecurity needs?

• Do you have the staff to support the “operation, care and feeding” of the IIoT system?

IIoT Implementation Assistance

• What IIoT Application Areas do you need assistance with?
  • Operating Efficiency?
  • Product Quality?
  • Predictive Maintenance?
  • Supply Chain Management?
  • Inventory Control (in-house inventory management)?
  • Occupational/worker Safety?

• Do you have enough knowledge and staff to implement an IIoT system?

• What kind of help are you looking for to aid you in the IIoT transformation of your business?

• IoT Solutions Partner (IoT SP): An end user-facing organization that has established a comprehensive network of IoT domain experts in hardware, firmware, software, connectivity, data analytics and vertical market applications. The organization assists in new business model definition and provides total integration of customer-specific IoT solutions. An IoT SP offers some combination of elements from hardware to data analytics expertise and not necessarily the “whole package.”

• IoT Systems Integrators (SI): A company that stitches solutions together, providing hardware installation and software field deployment, IoT security and access control management, IoT system provisioning and configuration, field deployment, training services, system maintenance and support
• **Manufacturing Execution System Vendor (MES):** A company that provides “out-of-the-box” and “canned” hardware and software products for integrated IoT solutions typically comprising smart devices, connectivity hardware and software, cloud interface, and application software.

• **Enterprise Security Company (ESC):** A company having expertise in any aspect of the software, hardware and best practices related to protecting the IoT system (i.e., smart connected devices, communications, cloud services and application interfaces) from nefarious activities

• **Testing, Certification and Registration Providers (TCR):** Organizations that validate the functionality, performance, compliance and security of the products and services that utilize smart devices and systems

• **Consultant (CON):** An expert or experienced professional having a background in any of the subject areas vital to the successful implementation of an IIoT system

**Training and Skills Development**

• Do you provide technical training for your employees and/or customers?
  • Internally developed training
  • Training in conjunction with an academic institution

• Do you provide technical training to your clientele?

• What Skills Training and Workforce development needs does your organization have and how do you address them?

**Blockchain Implementation**

• On a scale of 1-5 (5 highest), what is your understanding of blockchain and its potential value proposition?
  • (If score 3 or higher) On a scale of 1-5 (5 highest), what is your view of the applicability of blockchain to your business?

• Does your organization have an active blockchain-related project in place? (Yes/No)

• Do you need help implementing a blockchain network? (Yes/No)

**8.2.2 Demand Side (IIoT Implementation): Solver VoC Questions**

**Organization’s Background**
• How many years has your organization been involved with industrial automation and how many years have you been providing IIoT related services?

• How many employees does your organization have and approximately what is the amount of annual sales?
  • Sales:
    • <$50 million
    • $50 million - $200 million
    • >$200 million
  • Employees
    • <50
    • 50 - 250
    • >250

• What is your business footprint?
  • Locations in Northeast Ohio?
  • Locations in the state of Ohio?
  • Within the USA?
  • Globally?

• Does your organization have a Digital Transformation Plan and what is your estimated maturity?
  • Operational implementation of IoT
  • Customer services implementation of IoT/IIoT

• Why did your organization embark on the IIoT transformation of the business/institution?
  • Response to customer-driven needs
  • Strategic decision to improve business

• What are your expectations for business growth by providing IIoT-related services?

• What is your expected ROI from the implementation of your Digital Transformation Plan into your operations? How do you measure value?

• How does your organization go to market?
• External/Internal Sales Channels (including social media)?
• Distribution Partners?
• Business Reps?
• Network Partnership?
• Word of Mouth?

Organization’s Services

• Are you able to assist your clientele with their organization’s Digital Transformation Plan/IIoT Implementation Plan?
  • Formal planning process?
  • Site visit audit process?

• Do you maintain a library of use cases and case studies that you share with your clients?

• Which of the following descriptions best characterizes your **IIoT supply chain** capability?

  • **IoT Solutions Partner (IoT SP):** An end user-facing organization that has established a comprehensive network of IoT domain experts in hardware, firmware, software, connectivity, data analytics and vertical market applications. The organization assists in new business model definition and provides total integration of customer-specific IoT solutions. An IoT SP offers some combination of elements from hardware to data analytics expertise and not necessarily the “whole package.”

  • **IoT Systems Integrators (SI):** A company that stitches solutions together, providing hardware installation and software field deployment, IoT security and access control management, IoT system provisioning and configuration, field deployment, training services, system maintenance and support

  • **Manufacturing Execution System Vendor (MES)/Manufacturing Operations Management (MOM):** A company that provides “out-of-the-box” and “canned” hardware and software products for integrated IoT solutions typically comprising smart devices, connectivity hardware and software, cloud interface, and application software.
• **Enterprise Security Company (ESC):** A company having expertise in any aspect of the software, hardware and best practices related to protecting the IoT system (i.e., smart connected devices, communications, cloud services and application interfaces) from nefarious activities

• **Testing, Certification and Registration Providers (TCR):** Organizations that validate the functionality, performance, compliance and security of the products and services that utilize smart devices and systems

• **Consultant (CON):** An expert or experienced professional having a background in any of the subject areas vital to the successful implementation of an IIoT system

Organization’s Capabilities

• Do you have experience with the different types of manufacturing?
  • Discrete manufacturing?
  • Process control?
  • Combination of both discrete and process control?

• Which of the following descriptions best characterizes your IIoT-related Technical capabilities?
  • **Application Level**
    • Augmented Behavior/Visual Interface
    • Advanced Analytics/Deep Learning
    • Data Reduction/Basic Analytics
    • Digital Twin
  • **Systems Level**
    • Data presentation platforms/distribution
    • Data processing
    • Database platforms
    • Middleware
    • Network/Device management
    • Cloud/Local server data storage
• **Communications Level**
  • Session Protocols
  • Network/Transport Protocols
  • Data Link Protocols
  • Edge Gateway

• **Smart Device Level**
  • Smart Device OEM
  • Smart Device Components
  • Smart Device Development/Simulation
  • Smart Device Manufacturing

• **Cybersecurity**
  • End User Level
  • System Level
  • Communications Level
  • Smart Device Level
  • System Security Simulation

• Which of your organization’s technical capabilities do you consider world-class and which technical capability/s set/s your organization apart from your competition?

• Which of the following IIoT **Application Areas** have you provided solutions for?
  • Operating Efficiency?
  • Product Quality?
  • Predictive Maintenance?
  • Supply Chain Management (interaction with suppliers)?
  • Inventory Control (in-plant management of inventory)?
  • Occupational/worker safety?

• What recognized partnership programs/certifications does your organization have?

• What IIoT hardware manufacturers and software packages do you support?
• Are you able to address the needs of instrumenting legacy equipment as well as implementing new equipment/software installations?

• Would a membership in an IIoT Seeker/Solver match making (active) portal help drive demand in your business?

Training and Skills Development

• Do you provide technical training for your employees and/or customers?
  • Internally developed training;
  • Training in conjunction with an academic institution;

• Do you provide technical training to your clientele?

• What Skills Training and Workforce development needs does your organization have and how do you address them?

Blockchain Implementation

• On a scale of 1-5 (5 highest), what is your understanding of blockchain and its potential value proposition for you and your clients?
  • (If score 3 or higher) On a scale of 1-5 (5 highest), what is your view of the applicability of blockchain to your business?

• Does your organization have an active blockchain-related project in place? (Yes/No)

• Are you providing, or do you plan to provide, blockchain services/consulting? (Yes/No)

8.2.3 Supply Side (product innovation): Seeker VoC Questions

Organization’s Background

• How many years has your organization been involved with industrial automation and how many years have you been providing IIoT-enabled products?

• How many employees does your organization have and approximately what is the amount of annual sales?
  • Sales:
    • <$50 million
    • $50 million - $200 million
    • >$200 million
  • Employees
    • <50
• 50 - 250
• >250

• What is your business footprint?
  • Locations in Northeast Ohio?
  • Locations in the state of Ohio?
  • Within the USA?
  • Globally?)

• What types of manufacturing do you have experience with?
  • Discrete manufacturing?
  • Process control?
  • Combination of both discrete and process control?

• Does your organization have a Digital Transformation campaign specifically applied to product innovation?

• Why did your organization develop a Digital Transformation product campaign?
  • Response to customer-driven needs
  • Strategic decision to improve business

• What are your expectations for business growth by providing IIoT-enabled products?

• What is your expected sales growth from the implementation of your Digital Transformation product campaign?

• How does your organization go to market?
  • External/Internal Sales Channels (including social media)?
  • Distribution Partners?
  • Business Reps?
  • Network Partnership?
  • Word of Mouth?

Organization’s Assistance Needs

• What kind of Technical help are you looking for to aid you in the IIoT-related product innovation?
• **Application Level**
  - Augmented Behavior/Visual Interface
  - Advanced Analytics/Deep Learning
  - Data Reduction/Basic Analytics
  - Digital Twin

• **Systems Level**
  - Data presentation platforms/distribution
  - Data processing
  - Database platforms
  - Middleware
  - Network/Device management
  - Cloud/Local Server data storage

• **Communications Level**
  - Session Protocols
  - Network/Transport Protocols
  - Data Link Protocols
  - Edge Gateway

• **Smart Device Level**
  - Smart Device OEM
  - Smart Device Components
  - Smart Device Development/Simulation
  - Smart Device Manufacturing

• **Cybersecurity**
  - End User Level
  - System Level
  - Communications Level
  - Smart Device Level
• System Security Simulation

• Do you need assistance from IIoT Application Area subject matter experts to aid in your IIoT-related product innovation?
  • In Operating Efficiency?
  • In Product Quality?
  • In Predictive Maintenance?
  • In Supply Chain Management?
  • In Inventory Control?
  • In Occupational/Worker Safety?

Organization’s Supply Chain Support Needs

• Which of the following descriptions best characterize/s the type of IIoT supply chain company you are seeking to help with your Digital Transformation product campaign?

• Cloud Hosting Provider (CHP): A cloud hosting service provider that supplies the software and hardware (SaaS, Paas and/or Iaas) required to interface with the cloud

• Independent Software Vendor (ISV): A software/firmware producer that is not owned or controlled by a hardware manufacturer; a company whose primary function is to develop and distribute software for imbedded intelligence

• Independent Firmware Vendor (IFV): A firmware producer that is not owned or controlled by a hardware manufacturer; a company whose primary function is to develop and distribute embedded software and/or code firmware for embedded intelligence, cloud and mobile apps

• Network Equipment Provider (NEP): A company that sells products and services to communication service providers such as fixed or mobile operators, as well as to enterprise customers

• Device OEM: A company that produces a highly integrated device (usually includes hardware, software and communications) and equipment that may be marketed by another manufacturer

• Original Design Manufacturer (ODM): A company that designs and manufactures products as specified and eventually rebrands by another firm for sale
• **Design and Engineering Service**: A multidisciplinary company that can design several aspects of a smart device, including electronics, controls (both software and firmware), hardware, communications, packaging, design for manufacturability, design for human factors and cybersecurity

• **Contract Electronics Manufacturer (CEM) or Electronics Manufacturing Service Provider (EMS)**: A company that designs, tests, manufactures, distributes and provides return/repair services for electronic components and assemblies for original equipment manufacturers (OEMs)

• **Chip Vendors (CV)**: Designers and suppliers of specifically purposed, highly integrated chips for embedded systems

• **Software Intellectual Property (IP) Vendors**: Firms that have IPs that can be licensed for use within the ecosystem of IoT – examples of such uses include data analytics, edge computing platforms, motor control algorithms used in microcontrollers, and security and encryption

• **Engineered Materials Developer & Supplier (EMD)**: A company that develops advanced materials that support the creation and commercial viability of smart devices (for example, sensors and packaging) and/or the supply of newly developed material

• **Fabrication Machine Builder/Integrator (FMB)**: Any company involved with the integration of new processes used in the advanced fabrication of highly functional and low-cost smart devices, including, for example, integrated roll-to-roll machines with continuous in-process printing of electronics and IC component placement and new form factors for highly integrated packaging

• **Testing, Certification and Registration Providers (TCR)**: Organizations that validate the functionality, performance, compliance and security of the products and services that utilize smart devices and systems

• **Smart Systems Research Institutions (R&D)**: Any institution that sponsors IoT-related development programs (hardware- or software-based) that deal with the product or processes for smart devices, communications, data gathering and storage, data analytics and market vertical applications
• **Consultant (CON):** An expert or experienced professional with a background in any of the subject areas vital to the successful implementation of the IIoT system

Training and Skills Development

• Do you provide technical training for your employees and/or customers?
  - Internally developed training
  - Training in conjunction with an academic institution

• Do you provide technical training to your clientele?

• What Skills Training and Workforce development needs does your organization have and how do you address them?

Blockchain Implementation

• On a scale of 1-5 (5 highest), what is your understanding of blockchain and its potential value proposition?
  - (If score 3 or higher) On a scale of 1-5 (5 highest), what is your view of the applicability of blockchain to your business?

• Does your organization have an active blockchain-related project in place? (Yes/No)

• Do you need help implementing a blockchain network?

8.2.4 **Supply Side (product innovation): Solver VoC Questions**

Organization’s Background

• How many years has your organization been involved with industrial automation and how many years have you been providing IIoT-related services?

• How many employees does your organization have and approximately what is the amount of annual sales?
  - Sales:
    - <$50 million
    - $50 million - $200 million
    - >$200 million
  - Employees
    - <50
• 50 - 250
• >250

• What is your business footprint?
  • Locations in Northeast Ohio?
  • Locations in the state of Ohio?
  • Within the USA?
  • Globally)?

• Have you identified a set of services that you can provide to assist your customers in their Digital Transformation related product innovation efforts?

• Have you created a digital transformation plan for you own business operations?

• Why did your organization embark on the IIoT transformation of the business/institution?
  • Response to customer-driven needs
  • Strategic decision to improve business

• What are your expectations for business growth by providing IIoT-related services?

• What is your expected ROI from the implementation of your Digital Transformation Plan into your operations? How do you measure value?

• How does your organization go to market?
  • External/Internal Sales Channels (including social media)?
  • Distribution Partners?
  • Business Reps?
  • Network Partnership?
  • Word of Mouth?

• What exhibitions and conferences are important to your business and which do you attend regularly?

Organization’s Services

• Are you able to assist your customers with their organization’s Digital Transformation/IIoT Product Innovation Plan?
  • Formal planning process?
• Product digital twin/simulation exercise?

• Do you maintain a library of use cases and case studies that you share with your customers?

• Which of the following descriptions best characterize/s your Industrial Internet of Things (IIoT) supply chain capability?

• **Cloud Hosting Provider (CHP):** A cloud hosting service provider that supplies the software and hardware (SaaS, PaaS and/or IaaS) required to interface with the cloud

• **Independent Software Vendor (ISV):** A software/firmware producer that is not owned or controlled by a hardware manufacturer; a company whose primary function is to develop and distribute software for embedded intelligence

• **Independent Firmware Vendor (IFV):** A firmware producer that is not owned or controlled by a hardware manufacturer; a company whose primary function is to develop and distribute embedded software and/or code firmware for embedded intelligence, cloud and mobile apps

• **Network Equipment Provider (NEP):** A company that sells products and services to communication service providers such as fixed or mobile operators, as well as to enterprise customers

• **Device OEM:** A company that produces a highly integrated device (usually includes hardware, software and communications) and equipment that may be marketed by another manufacturer

• **Original Design Manufacturer (ODM):** A company that designs and manufactures products as specified and eventually rebrands by another firm for sale

• **Design and Engineering Service:** A multidisciplinary company that can design several aspects of a smart device, including electronics, controls (both software and firmware), hardware, communications, packaging, design for manufacturability, design for human factors and cybersecurity

• **Contract Electronics Manufacturer (CEM) or Electronics Manufacturing Service Provider (EMS):** A company that designs, tests, manufactures, distributes and provides return/repair services for electronic components and assemblies for original equipment manufacturers (OEMs)
• **Chip Vendors (CV):** Designers and suppliers of specifically purpose, highly integrated chips for embedded systems

• **Software Intellectual Property (IP) Vendors:** Firms that have IPs that can be licensed for use within the ecosystem of IoT – examples of such uses include data analytics, edge computing platforms, motor control algorithms used in microcontrollers, and security and encryption

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• **Smart Systems Research Institutions (R&D):** Any institution that sponsors IoT-related development programs (hardware- or software-based) that deal with the product or processes for smart devices, communications, data gathering and storage, data analytics and market vertical applications
  - **Consultant (CON):** An expert or experienced professional with a background in any of the subject areas vital to the successful implementation of the IIoT system

Organization’s Capabilities

• Do you have experience with the different types of manufacturing?
  - Discrete manufacturing?
  - Process control?
• Combination of both discrete and process control?

• Which of the following descriptions best characterize/s your IIoT-related *Technical* capabilities?

  • **Application Level**
    - Augmented Behavior/Visual Interface
    - Advanced Analytics/Deep Learning
    - Data Reduction/Basic Analytics
    - Digital Twin

  • **Systems Level**
    - Data presentation platforms/distribution
    - Data processing
    - Database platforms
    - Middleware
    - Network/Device management
    - Cloud/Local server data storage

  • **Communications Level**
    - Session Protocols
    - Network/Transport Protocols
    - Data Link Protocols
    - Edge Gateway

  • **Smart Device Level**
    - Smart Device OEM
    - Smart Device Components
    - Smart Device Development/Simulation
    - Smart Device Manufacturing

  • **Cybersecurity**
    - End User Level
    - System Level
• Communications Level
• Smart Device Level
• System Security Simulation

• Which of your organization’s technical capabilities do you consider world-class and which technical capability/s set/s your organization apart from your competition?

• Which of the following IIoT Application Areas have you provided solutions for?
  • Operating Efficiency?
  • Product Quality?
  • Predictive Maintenance?
  • Supply Chain Management (interaction with suppliers)?
  • Inventory Control (in-plant management of inventory)?
  • Occupational/Worker Safety?

• What recognized partnership programs/certifications does your organization have?

• What IIoT hardware manufacturers and software packages do you support?

• Are you able to address the needs of instrumenting legacy equipment as well as implementing new equipment/software installations?

• Would a membership in an IIoT Seeker/Solver match making (active) portal help drive demand in your business?

Training and Skills Development

• Do you provide technical training for your employees and/or customers?
  • Internally developed training;
  • Training in conjunction with an academic institution;

• Do you provide technical training to your clientele?

• What Skills Training and Workforce development needs does your organization have and how do you address them?

Blockchain Implementation

• On a scale of 1-5 (5 highest), what is your understanding of blockchain and its potential value proposition for you and your clients?
  • (If score 3 or higher), On a scale of 1-5 (5 highest), what is your view of the applicability of blockchain to your business?
• Does your organization have an active blockchain-related project in place? (Yes/No)
• Are you providing, or do you plan to provide, blockchain services/consulting? (Yes/No)
9 REFERENCES


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