SMART CONNECTED OPERATIONS

Capturing the Business Value of the Industrial IoT

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SECTION 1

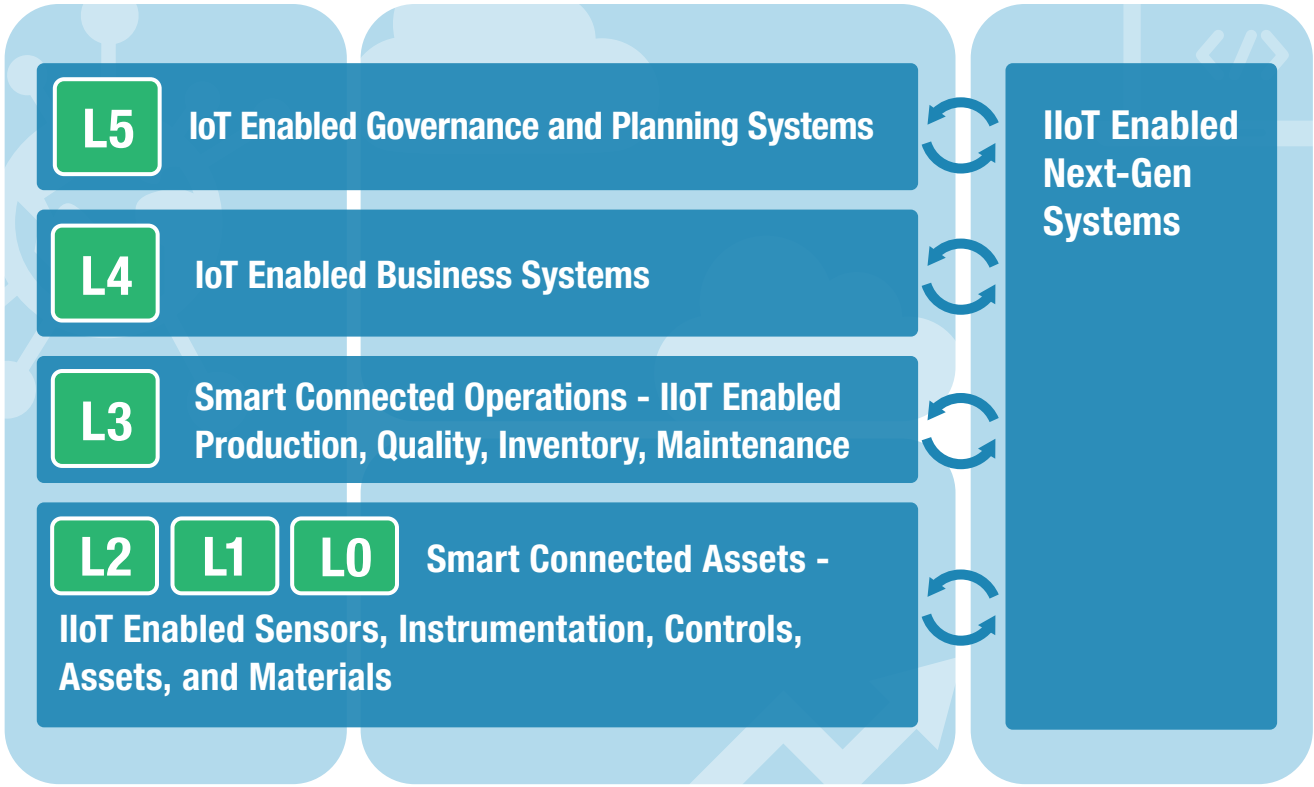
Introduction, Research Demographics, Industry Drivers, Challenges

Introduction

Smart Connected Operations is a future looking vision that describes what the factory or production line of the future will look like. It will involve Industrial Internet of Things (IIoT) enabled MOM applications integrated with IIoT enabled assets and IIoT enabled business systems. It is an elemental part of creating the Smart Connected Enterprise and is often where companies have breaks in the strands of the digital thread.

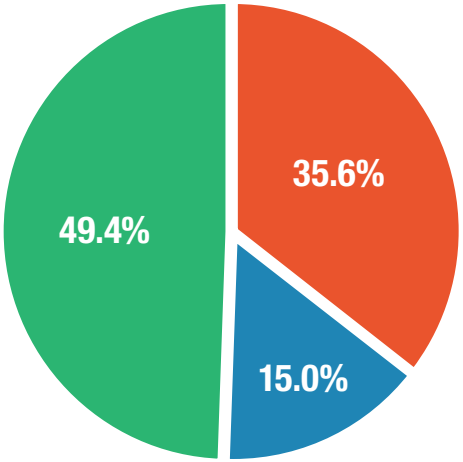
In moving towards this vision, both solution providers and manufacturing organizations are going to have to up the game when it comes to investing in IIoT. These investments will include the creation of new organizations that bring together IT, OT, and business leaders, new technologies that enable connectivity, cloud, big data analytics, and the development of new applications, along with the foresight to see that small pilot projects today could transform entire industries tomorrow.

SMART CONNECTED ENTERPRISE



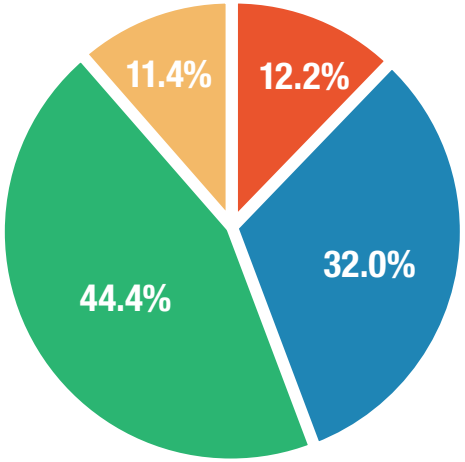
Research Demographics

The survey data presented in this eBook is based on over 500 respondents to LNS Research's Manufacturing Operations Management (MOM) online survey. Respondents have participated in this research to access the resulting research reports and come from a broad range of industries, geographies, and company sizes. Respondents have shared insights on business objectives, challenges, the maturity of leadership and business process capabilities, the use of technology, and performance in operational and financial metrics.



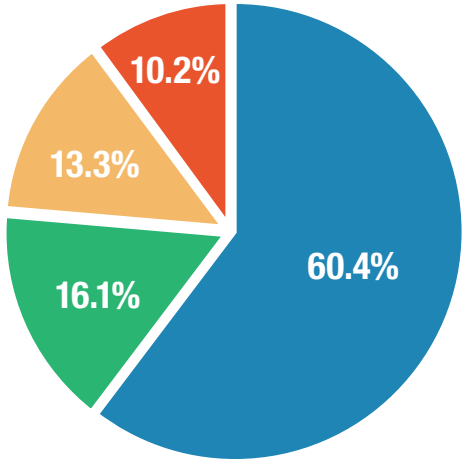
COLOR BY COMPANY REVENUE

- Small: $0 - $250MM
- Medium: $250MM - $1BB
- Large: $1BB+



COLOR BY HQ LOCATION

- North America
- Europe
- Rest of the World
- Asia / Pacific



COLOR BY INDUSTRY

- Discrete Manufacturing
- F&B / CPG
- Life Sciences
- Process Manufacturing

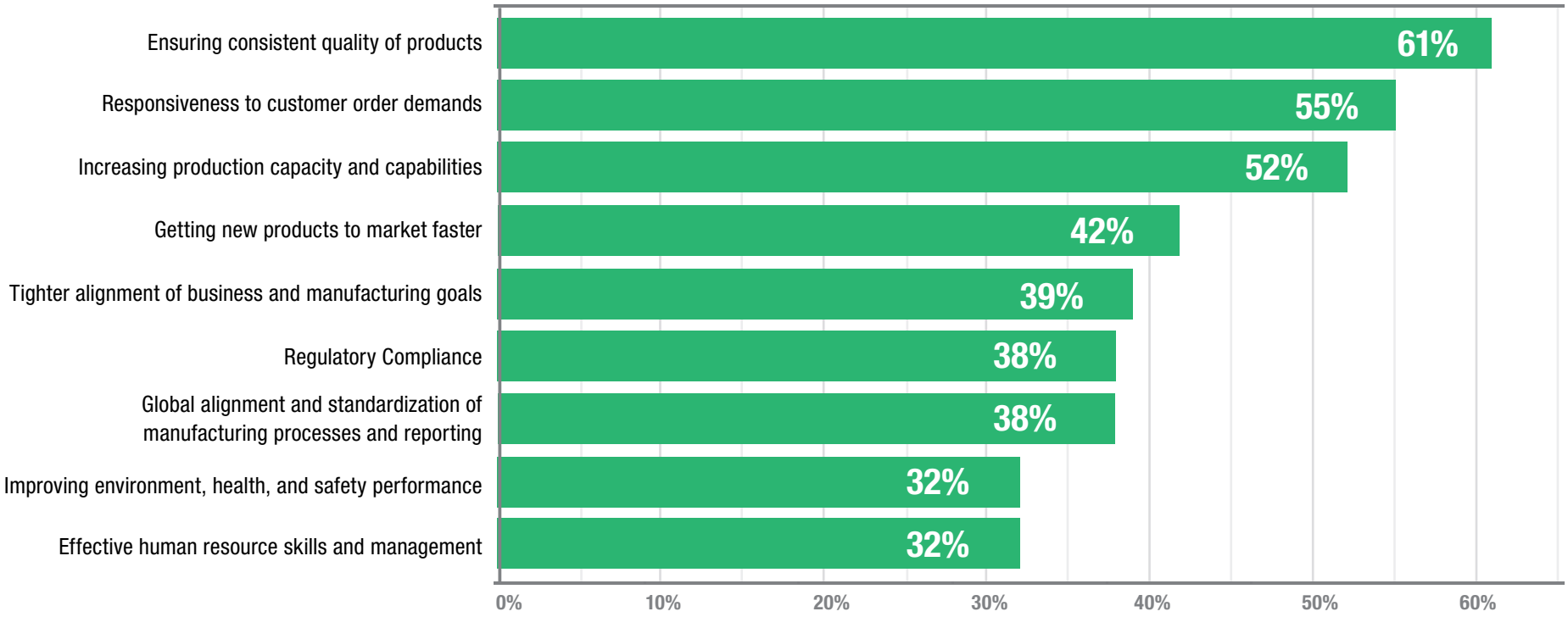
Industry Drivers

The top strategic objectives in the manufacturing industry have remained consistent for years, with many centered on serving customers. Industrial companies want to deliver customers high quality products, and deliver them on time. They also want to be able to increase production capabilities and quickly introduce new products to the marketplace.

Over time it is likely that these customer focused objectives will remain at the top of the priority list. In fact, being customer focused may even become more important as IIoT technology innovation continues to enable Smart Connected Products and move traditional manufacturers from delivering traditional products like cars or jet engines to IIoT enabled Products as a Service (PaaS) like on-demand transportation or thrust.

Manufacturers continue to focus on delivering value to customers.

Top Operational Objectives



Industry Challenges

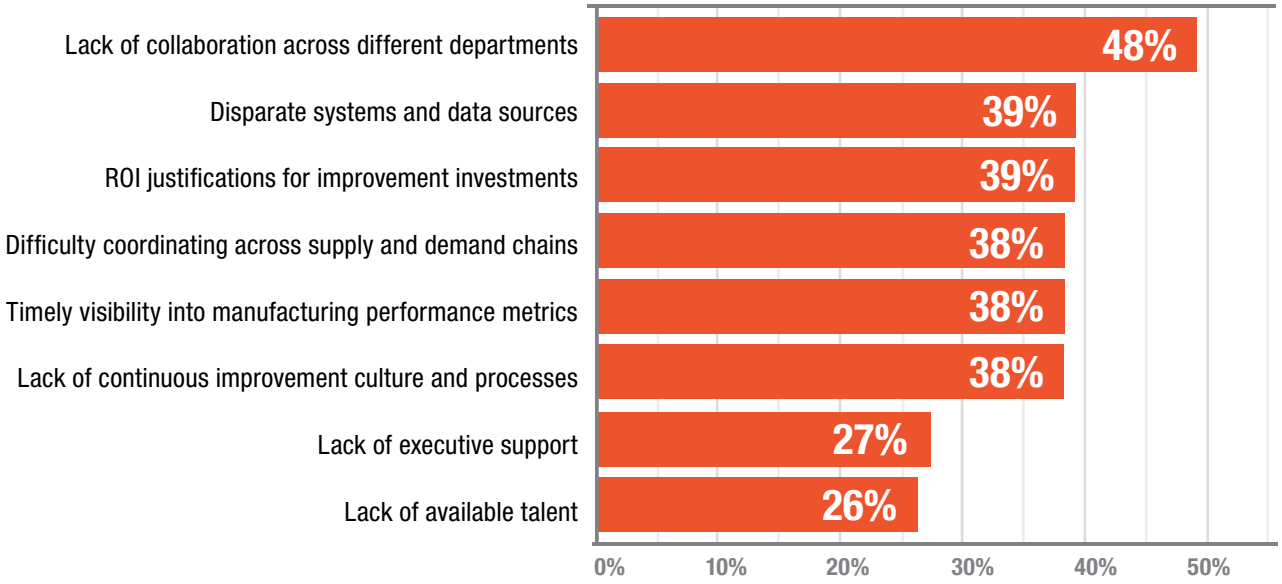
The challenges that manufacturers face with achieving objectives span people, processes, and technology. This is informative in the sense that all three of these capabilities are highly dependent on each other for success, and a shortcoming in any one area can jeopardize the whole system. Without strong and well established leadership and culture, robust process architecture and change management, and new technology with a clear ROI, any manufacturing organization will struggle to be world class and achieve business objectives.

It is also worth noting that just as objectives have remained consistent over time, so have the challenges in achieving them. Unfortunately, using traditional technology approaches has often left manufacturers coming up short and attempting to solve the same problems in the same way over and over again while expecting a different result. It is no wonder that the past decade has left many wanting when it comes to manufacturing software.

As will be discussed in the rest of this eBook, just as IIoT technologies are transforming the products manufacturers are delivering, they are also transforming the information and operational technologies used to enable these solutions, and will hopefully provide new approaches to achieve these objectives with greater success. In fact, we can begin to consider people, processes, and technology in the context of the IIoT. In this new paradigm both people and processes can be considered as things along side more traditional "things" like sensors, instrumentation, materials, and assets.

The top challenges in manufacturing span people, processes, and technology.

Top Operational Challenges



In this new IIoT paradigm the distinction between people, processes, and traditional "things" like sensors, instrumentation, materials, and assets, will melt away as new cyber-physical systems are created.

SECTION 2

IT–OT Convergence and Adoption of Industrial IoT Platform

What Is the Industrial IoT?

The Internet of Things (IoT) refers to the network of networks encompassing the use of standard Internet Protocol (IP) technologies to connect people, processes, and "things" to enable new cyber-physical systems.

Traditionally the Internet has been understood as the distributed and open network of computers using standard IP technologies. As the use of mobile technologies has increased over the past decades the connection (or inclusion) of people to the Internet has become commonplace and ubiquitous.

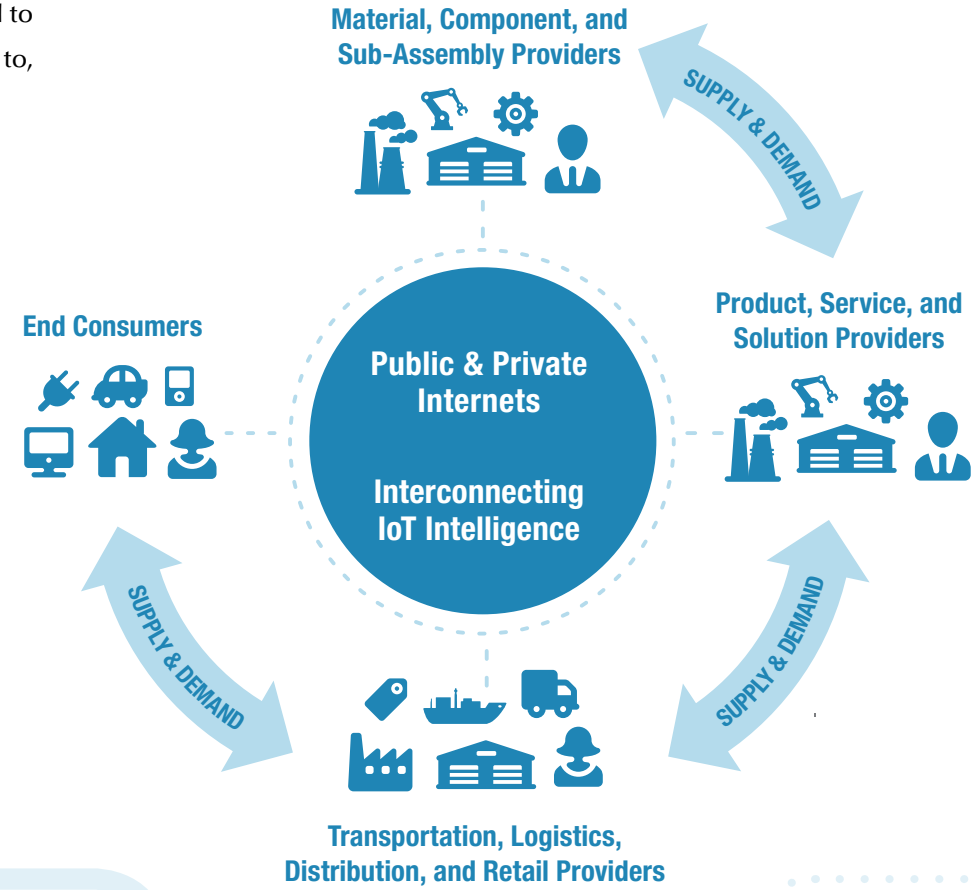
Over the past several years, and increasingly in the future (some estimate 50 billion connected things by 2020), physical things connected to the Internet will be the dominating force, including but not limited to, new IP enabled:

- **Devices**
- **Sensors**
- **Instrumentation**
- **Materials**
- **Mobile and Fixed Assets**
- **Products**

The Industrial Internet of Things (IIoT) should be understood as a subset of the broader IoT, where the people, processes, and things are primarily engaged in the production of physical goods and maintenance of physical assets.

Because of the legacy automation technology (also referred to as operational technology) and information technologies today, much of which are based on proprietary communication protocols, the emerging technologies, challenges, and use cases of the IIoT are unique to many other areas of IoT and demand special attention.

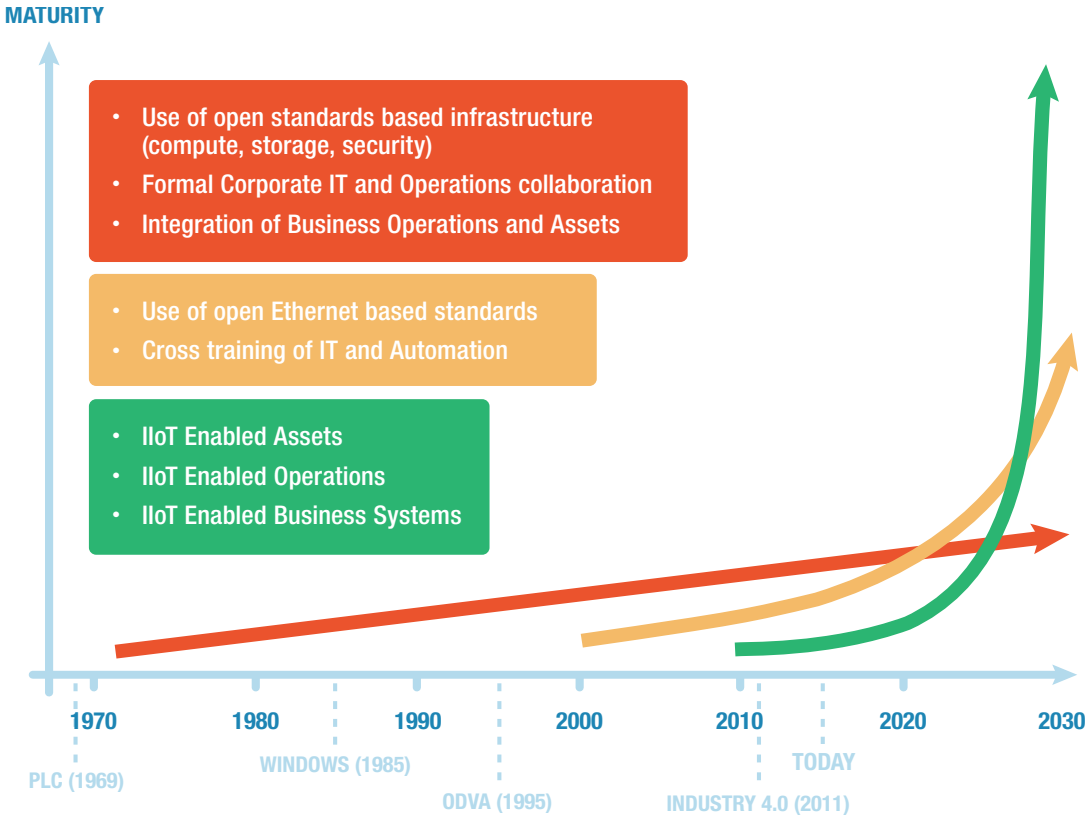
IoT for Extended Manufacturing Enterprise Value Chains



IT–OT Convergence

It is not uncommon to hear in manufacturing circles that there is nothing new when it comes to the IoT, or "machine-to-machine" (m2m). A prevailing belief is that the industry has already been engaged in IoT and m2m for many years and all of these "buzz words" are just re-characterizations of existing trends that are long-standing and ongoing; namely IT-OT convergence.

LNS Research is clearly not in agreement with these nay-sayers and there is much evidence pointing to the contrary. It is true that the trend of IT-OT convergence has existed for as long as IT and OT have been around. But it is also true that the way in which these technologies are converging is changing, as is the pace at which this is occuring.



In the early days, IT-OT convergence could be understood mainly in the context of moving from proprietary systems and a complete separation of IT and OT professionals, to beginning to use Microsoft technology on the shop floor and enabling collaboration between IT and OT groups.

As organizations and technology changed in the early 2000s, the original manifestation of IT-OT convergence continued, but new realizations emerged, namely the convergence of plant and enterprise networks through the use of Ethernet on the shop floor and cross training of personnel.

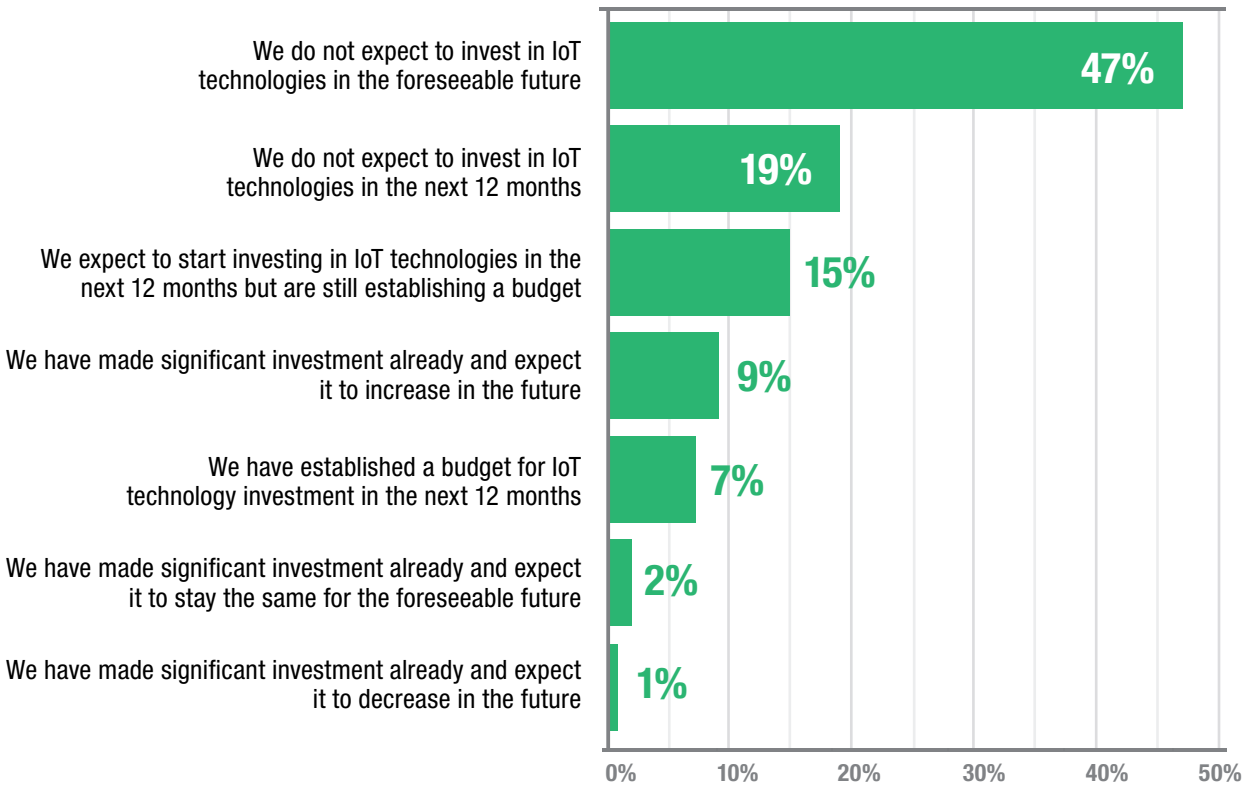
Today, both of these manifestations of IT-OT convergence continue at differing rates, but a new third paradigm has emerged and it is all around the IIoT. As more and more things are connected, and as more and more cyber-physical systems like Smart Connected Assets and Smart Connected Operations become a reality, industrial companies and the vendors serving them will be forced to innovate and deploy these new IT-OT technologies at a rate not before seen in the industrial sector.

OT, or Operational Technology, is a relatively new term describing the long standing process control and automation technologies supporting plant operations.

Adoption of IIoT

Since August of 2014 over 400 manufacturing executives have shared their plans on the adoption and nature of interaction with the IIoT in industry. Not surprisingly, the adoption of IIoT technology is still in the early adopter phase with 34% of companies currently investing or planning on investing in IIoT technologies over the next year. Clearly, the market is not yet in broad adoption and it is critical that these early adopters build clear business cases and make good on ROI goals in these first projects.

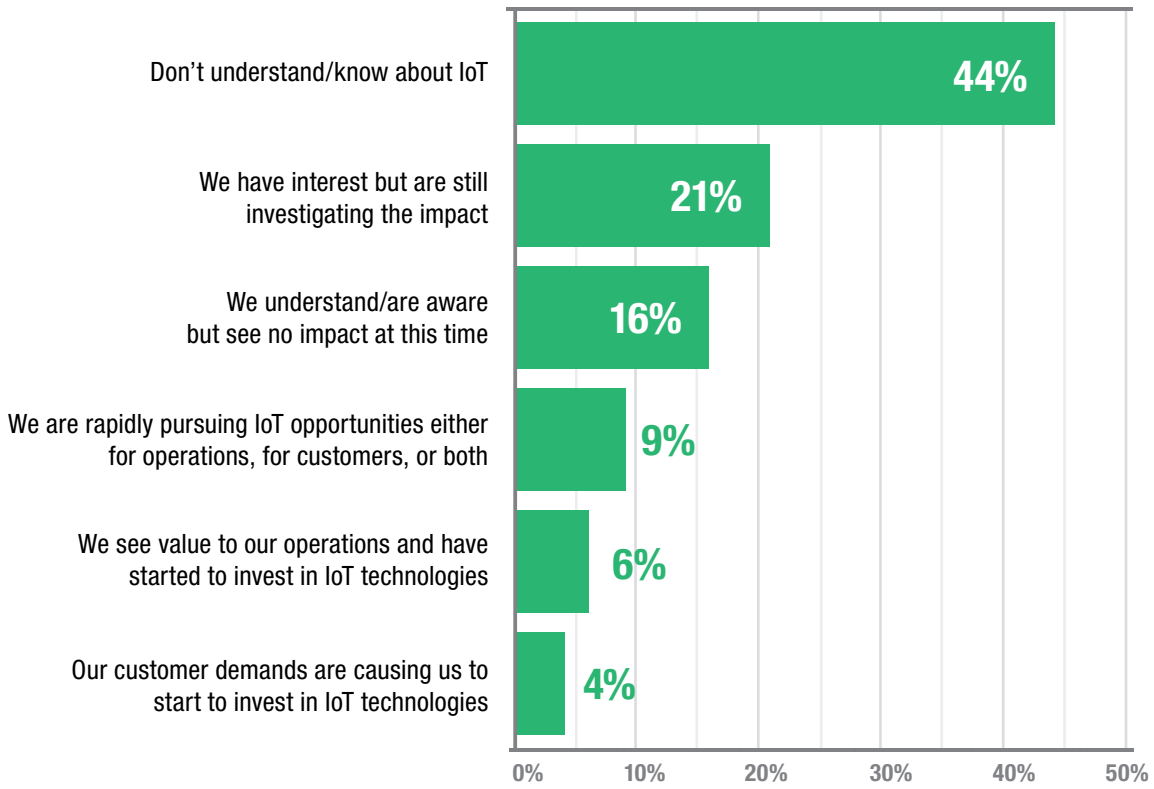
Adoption of IIoT



Impact of IIoT

When companies' understanding and impact of the IoT is examined, some additional interesting results emerge, especially on the connection of a lack of understanding of the IoT and the lack of adoption of IoT. In fact, the overlap is astounding between the 47% of the market that does not plan on investing in IoT in the foreseeable future and the 44% of the market that does not understand or know about the IoT. This result highlights the second major challenge facing broad adoption for IoT in manufacturing, namely rapid education of industry leaders that currently do not know or understand the IoT.

Impact of IIoT



Crossing the Chasm in IIoT

When these two major results on the adoption and education of IIoT are considered together, the adoption of IIoT fits the traditional model of technology adoption. The early market is currently testing the value of IIoT and needs to prove the value of the IIoT over the coming months and years. The mainstream still needs to be educated quickly to prompt adoption and cross the chasm, with the final 19% of the market that knows about the IIoT and still doesn't want to invest now bringing up the rear.

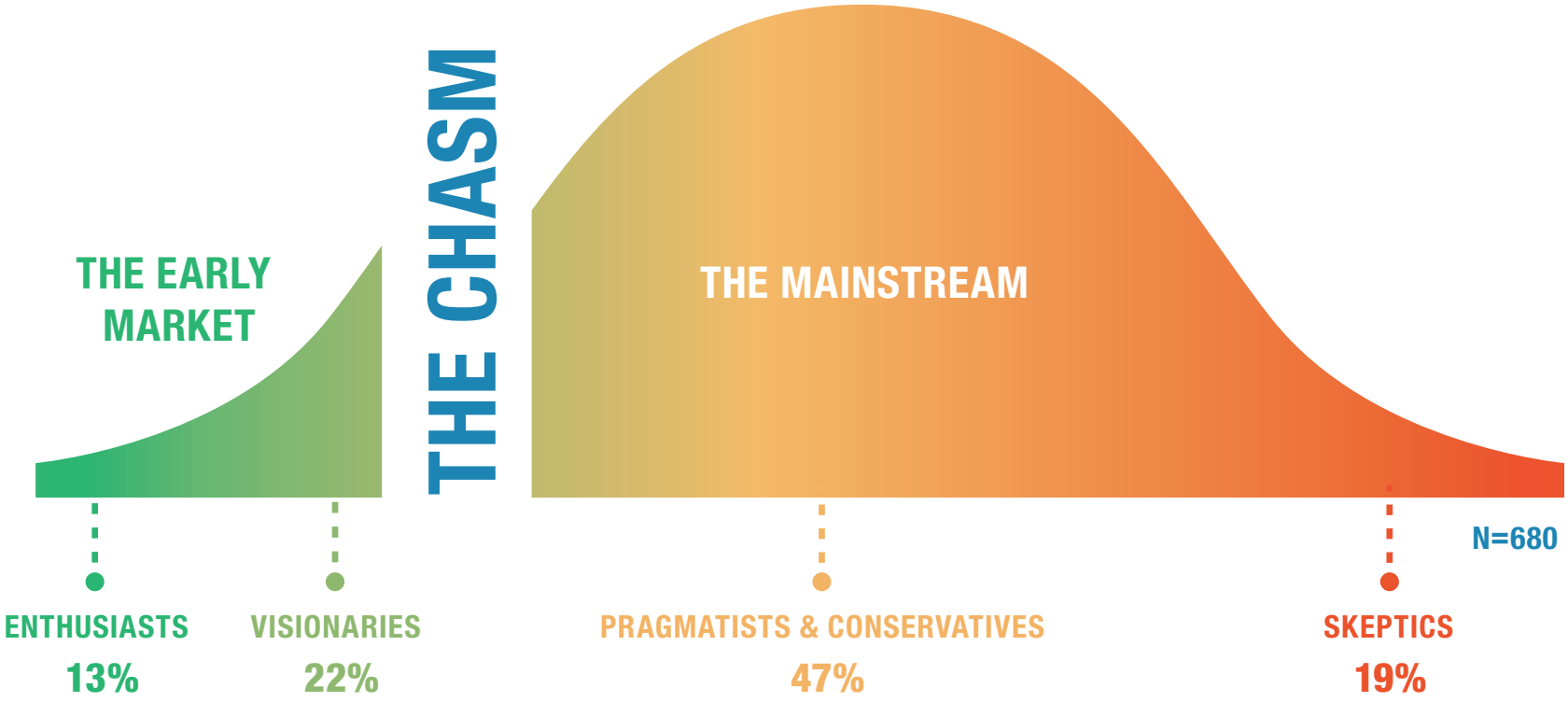
13% moving forward today

22% looking to pilot... important to get quick, demonstratable wins

47% still doesn't understand IIoT... important to quickly educate and motivate

19% knows and doesn't care

Crossing the Traditional Technology Chasm for the IIoT



SECTION 3

Transformation of Traditional Manufacturing System Architecture

Traditional Value Chain Technology Architecture

The Purdue or ISA95 reference architecture has been used in the manufacturing industry for decades to describe the different types of technology and business processes used across the enterprise.

At the top of the hierarchy are the decisions and business processes that are the most high level, like management system governance, supply chain planning, and product portfolio planning. At the bottom of the hierarchy is the physical world.

If over time the adoption of technology, use of standards, and degree of integration had grown homogeneously, the vision of shop floor to top floor integration would be much closer to reality. Unfortunately, every company has dramatically different levels of adoption and maturity across the different levels, with most companies having broad adoption in business systems and automation with limited adoption in between.

When this realty is coupled with the fact that real-time systems on plant networks collect data types and data at a pace that would overwhelm business systems, it becomes clear that without a dramatic step change in technology and architecture it is likely most companies will never achieve shop floor to top floor integration. Enter the IIoT Platform.

Unfortunately, every company has dramatically different levels of adoption and maturity across the architecture, often making top floor to shop floor integration impossible.

Industrial Internet of Things Platform

The Industrial Internet of Things Platform as defined by LNS Research is a future looking framework for categorizing the technology capabilities needed to deliver IIoT solutions like Smart Connected Assets, Operations, and Enterprise.

LNS Research sees four major buckets of capabilities making up the platform:

CONNECTIVITY includes the needed hardware and software for networking in the plant and at the enterprise, the standards for integrating machines, clouds, and applications, and the technology for quickly and efficiently managing devices, moving data, and triggering events.

CLOUD includes the use of all types of clouds across the enterprise to put computing and storage capabilities where they are most needed: at the edge, in the plant, at the enterprise, or outside the firewall.

BIG DATA ANALYTICS includes the use of a broad set of statistical and optimization tools to cleanse, monitor, and analyze both structured and unstructured data for enabling never before possible insights.

APPLICATION DEVELOPMENT includes the needed tools for quickly and easily creating new mashup software applications that leverage all other areas of the IIoT platform as well as quickly and easily moving existing legacy applications on top of the platform as well.

For the foreseeable future, the delivery of an IIoT Platform will come through an ecosystem of vendors, most likely being a combination of large and established IT vendors, large and established Automation vendors, System Integrators, and emerging IIoT startups.

However, the preeminence of the ecosystem in the IIoT space should not diminish the amount of innovation, speed, and aggressiveness many vendors are demonstrating in the development of IIoT platforms. Many vendors today have compelling offerings in two or three of the major requirements categories and it may not be long before some vendors move to have capabilities in all four.

Security is of utmost priority in industrial settings and is not called out as a separate part of the platform but instead built in fundamentally across it.

INDUSTRIAL INTERNET OF THINGS PLATFORM

CONNECTIVITY

- Network Infrastructure - Wired, Wifi, and Cellular
- Standards - Serial/ Proprietary > Ethernet/Open
- Machine 2 Machine/Data Acquisition - Embedded, Gateways, APIs, Web Services, OPCUA, Modbus TCP/IP, MQTT, etc.
- Device Management
- Complex Event Processing
- Alarms, Condition Based Monitoring
- Data Transport and Speed
- Security - Authentication, Access Control, Intrusion Detection/Prevention, Firewalls, Application Whitelisting, Antivirus/Spyware, Cryptography, Logging, Data Tagging, Compliance, etc.

CLOUD

- Private/Public/Hybrid
- IaaS - Compute, Storage, Network
- PaaS - Run Time, Queue, Traditional DB/DW | Data Historian | In-Memory Database | Hadoop/Data Lake
- SaaS - Traditional Enterprise Applications, Next-Gen IoT Enabled Applications
- Security - Authentication, Access Control, Configuration Management, Antivirus/Spyware, Cryptography, Logging, Data Tagging, Compliance

BIG DATA ANALYTICS

- Statistical Programming: R, SAS, SPSS
- Search, Text Mining, Data Exploration
- Analytics: Image/Video, Time Series, Geospatial, Predictive Modeling, Machine Learning, etc.
- Statistical Process Control
- Optimization and Simulation
- Metrics and KPIs
- Visualization

APPLICATION DEVELOPMENT

- Integrated Development Environment: JAVA, HTML5
- IIoT Data Model and Execution Engine
- Workflow and Business Logic Modeler
- Collaboration, Social
- Mobile
- Search
- Security - Authentication, Access Control, Configuration Management, Cryptography, Logging, Compliance

Smart Connected Enterprise

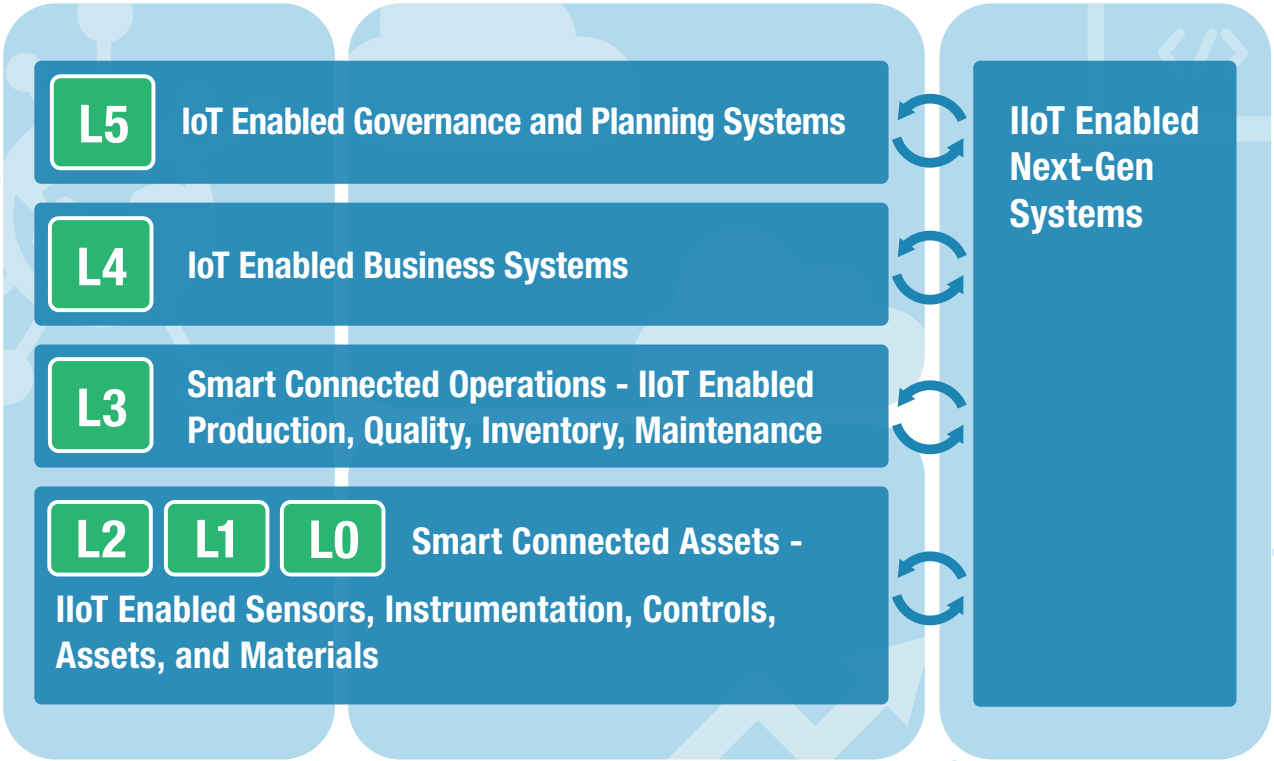
Legacy is the name of the game in manufacturing technology. Although manufacturing is hot and many new plants are being built to bring operations closer to the point of consumption, the biggest opportunity remains modernizing existing plants and assets.

As described above, shop floor to top floor integration has proven over the past 30+ years to be largely an intractable problem; the IIoT Platform will change this in two ways.

First, the traditional architecture will begin to converge and flatten as solution providers port or re-write existing applications to run on top of IIoT platforms. Moving forward, it is likely that there will be vendors talking much more about IoT enabled MOM, MES, sensors, instrumentation, controls, assets, and materials. This IoT enablement is what will trigger the emergence of "Smart Connected" Assets and Operations.

Second, the creation of IoT enabled next-generation systems will enable true shop floor to top floor integration and mashup applications by eliminating the dependency of unbroken integration between traditional systems and allowing for the flow of data to and from anywhere in ways that make sense given limitations of legacy systems and the use cases for new business models.

The combination of IIoT enabled legacy systems and IIoT enabled next-generation systems is the foundation for enabling the smart connected enterprise.



SECTION 4

Smart Connected Operations: IoT Enabled Production, Quality, Inventory, and Maintenance

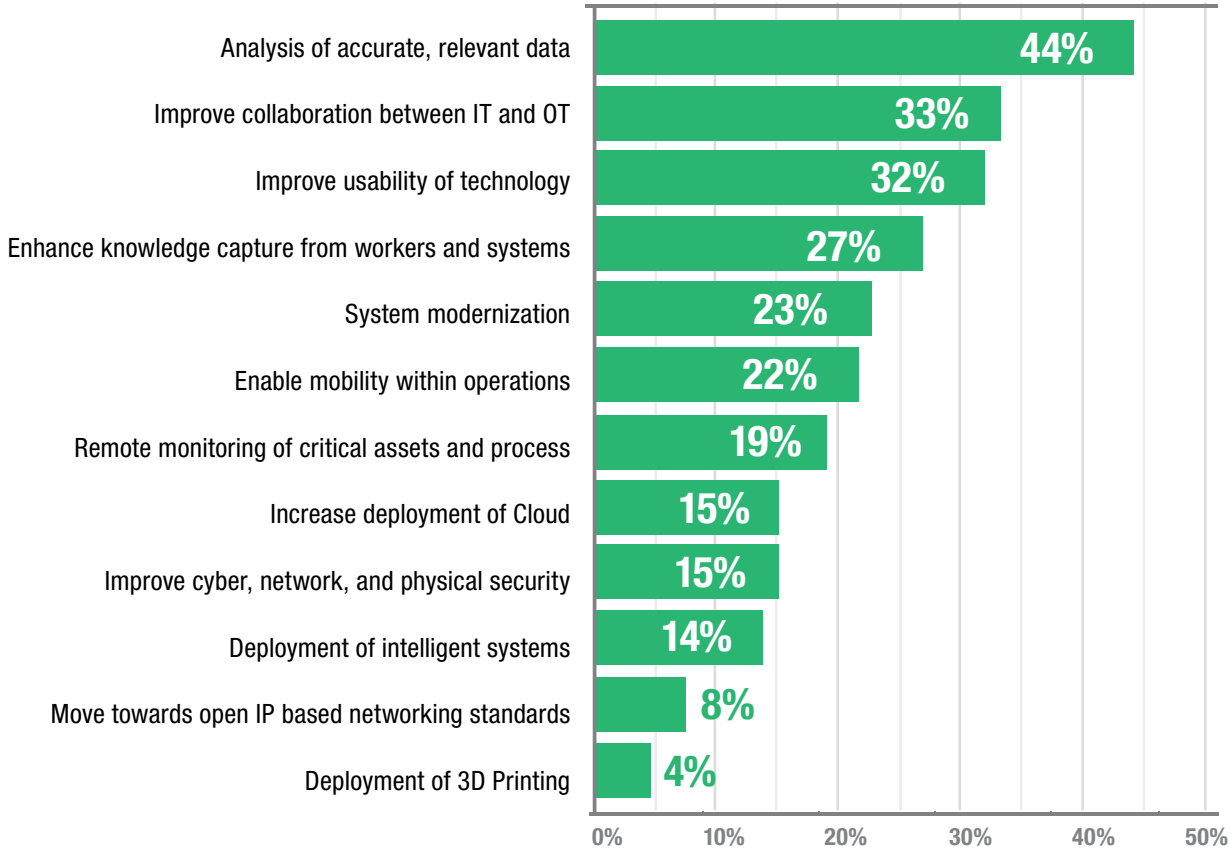
Strategic Objective for Operational Technology

When it comes to the top objectives manufacturers have today for operational technology, the number one is the analysis of accurate, relevant data for better decision making, followed closely by IT-OT collaboration and improving the usability of technology.

These goals clearly support many of the business objectives discussed earlier around supply chain efficiency and rapid new product development. These goals can also be thought of in context of many of the biggest gaps manufacturers have today, namely:

- **Effectively using manufacturing data (much of which never leaves the legacy application for analysis)**
- **Collaboration between IT and OT (which may not exist at all or can even be contentious)**
- **Lack of consumer grade qualities in manufacturing technology like mobility, search, and personalization**

Top Objectives for Operational Technology



Modernizing Legacy Systems

Since the publication of the MOM Best Practices Guide, LNS Research has been promoting the idea of a MOM Integration and Collaboration Platform. Rather than investing in separate applications with separate database structures, integration requirements, and user interfaces, a platform approach brings a common and standardized set of services for deploying MOM applications.

Over time MOM vendors have to a varying degree pursued this approach, but it is likely that as early adopters of IIoT enable their offerings by building in connectivity, cloud, big data analytics and application development the entire market will shift or be left behind. This move to IIoT enabled MOM applications will promote:

Increasing open IP standards based integration

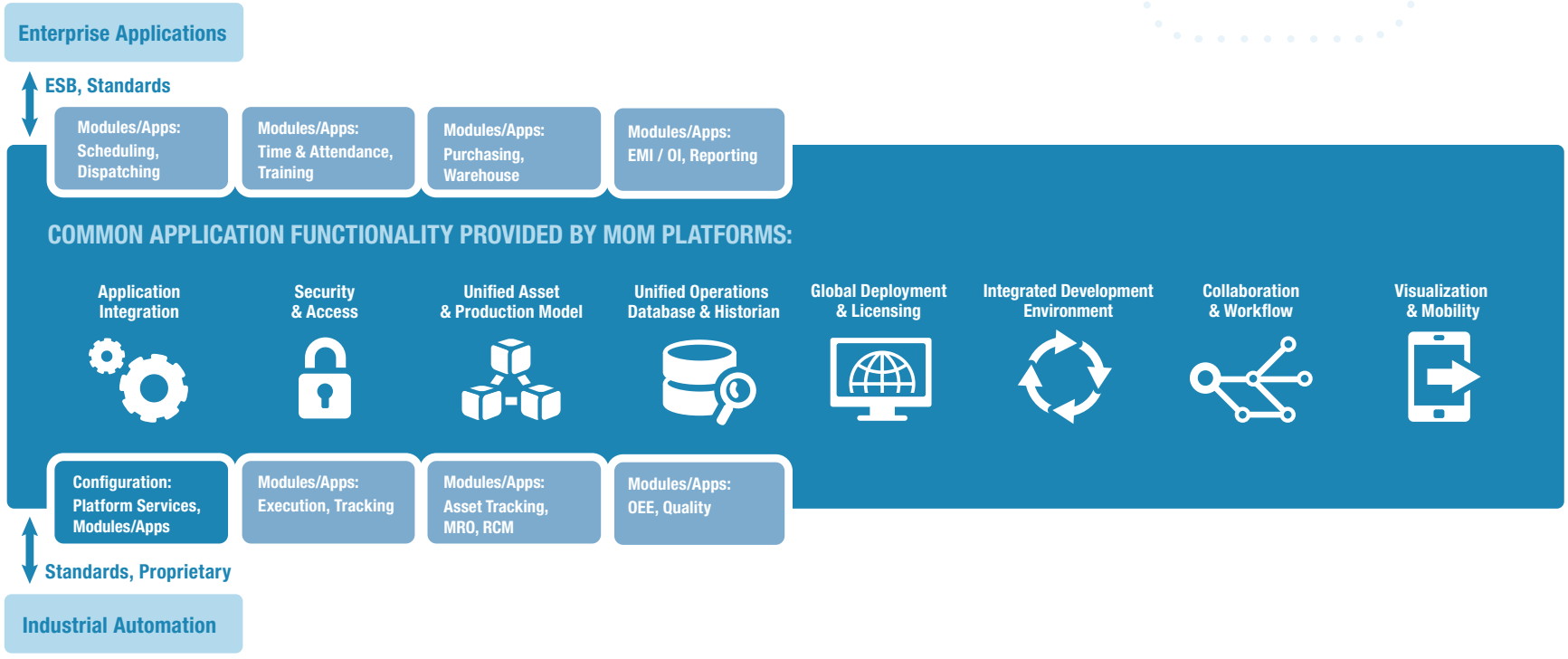
Increasing analytics and optimization at the edge

Increasing use of mobile, social (including video and collaboration), and cloud

Remote monitoring and access

Closed-loop business processes

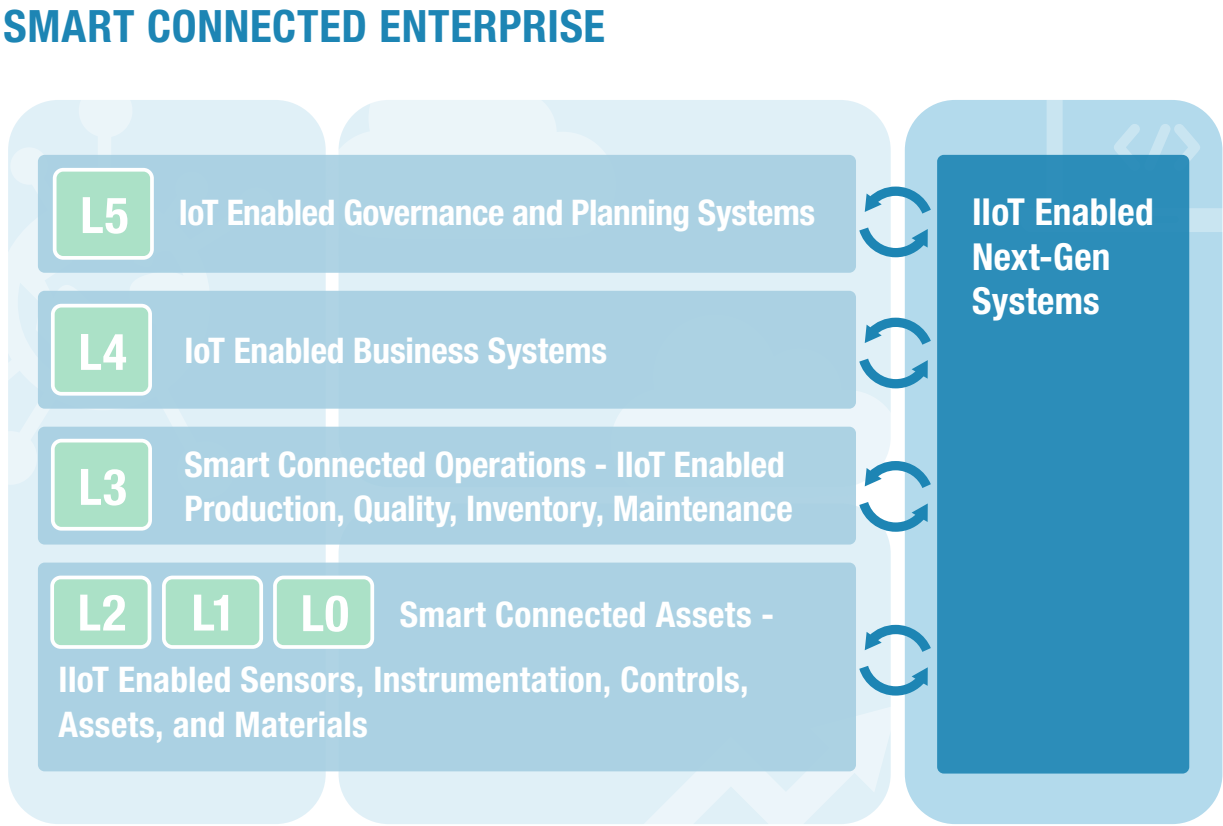
Future - Integration & Collaboration Platforms



Implementing Next-Gen IIoT Systems

IoT Enabled Next-Gen Systems include mashup applications that will be able to integrate data, people, workflows, and legacy systems with applications and Web services from outside the firewall. These Next-Gen systems will be able to break down traditional architectures by facilitating this integration with a "from anywhere to anywhere" approach that will eliminate the need for information to flow through systems in an unnatural way. This will allow for the development of specific use cases, including:

- **Shop floor to top floor mashup applications**
- **Traceability and genealogy systems (including serialization)**
- **New business model enablement, Smart Connected Products, Products as a Service (PaaS)**
- **Remote monitoring and access**
- **Closed-loop business processes**



Smart Connected Assets

Smart Connected Assets, as the name suggests, can sense and respond to internal and external environment as an intelligent agent. By IIoT enabling assets, companies can move from real-time control, to predictive control, and finally to autonomous control, where Smart Connected Assets are critical components of cyber-physical systems.

SMART CONNECTED ASSETS

Converged Sensors, Instrumentation, Controls, and Assets

REAL TIME → PREDICTIVE → AUTONOMOUS

AWARE OF AND CAN REACT TO:

Design and Configuration

Internal and External Operating Conditions

Past Performance

Predicted Future Failure

MRO Inventory (Internal and External)

Energy Use

Raw Material

Supplier Performance

Customer Requirements

Environmental Impact

Smart Connected Operations

The Smart Connected Operations concept is a future looking vision that describes what the factory or production line of the future will look like. It will involve IIoT enabled MOM applications integrated with IIoT enabled assets and IIoT enabled business systems. It is an integral part of creating the Smart Connected Enterprise and is often where companies have breaks in the strands of the digital thread.

Smart Connected Operations are aware of internal and external operating conditions, systems, and events as well as the traditional operations disciplines of quality, inventory, maintenance, and quality. As more and more systems, devices, sensors, assets, and people are connected more and more data will be collected that is both structured and unstructured, enabling new analytical techniques to provide previously undiscoverable results.

Over time, Smart Connected Operations will allow manufacturing organizations to move from providing just real-time data, to providing real-time data in context of operations with predictive analytics embedded, to eventually a true autonomous production environment, where production equipment can make decisions independent of human intervention in the context of real business conditions and objectives.

It should also be noted that creating a production environment that resembles Smart Connected Operations will be an incremental journey over many years given the degree of legacy dumb unconnected assets and operations in place today, but modernizing these systems will be critical for enabling many of the top current business goals, like changing business models to deliver services instead of products and creating a true flexible manufacturing environment with a lot size of one.

SMART CONNECTED OPERATIONS

Integrated Assets, Operations, and Business Systems

REAL TIME → PREDICTIVE → AUTONOMOUS

AWARE OF AND CAN REACT TO:

Plant, Asset and Product Design or Configuration 5, 8

Inventory levels and flow 1, 3, 4, 8, 12 **| Quality performance** 4, 9

Asset performance 5 **| Internal and External Operating Conditions**

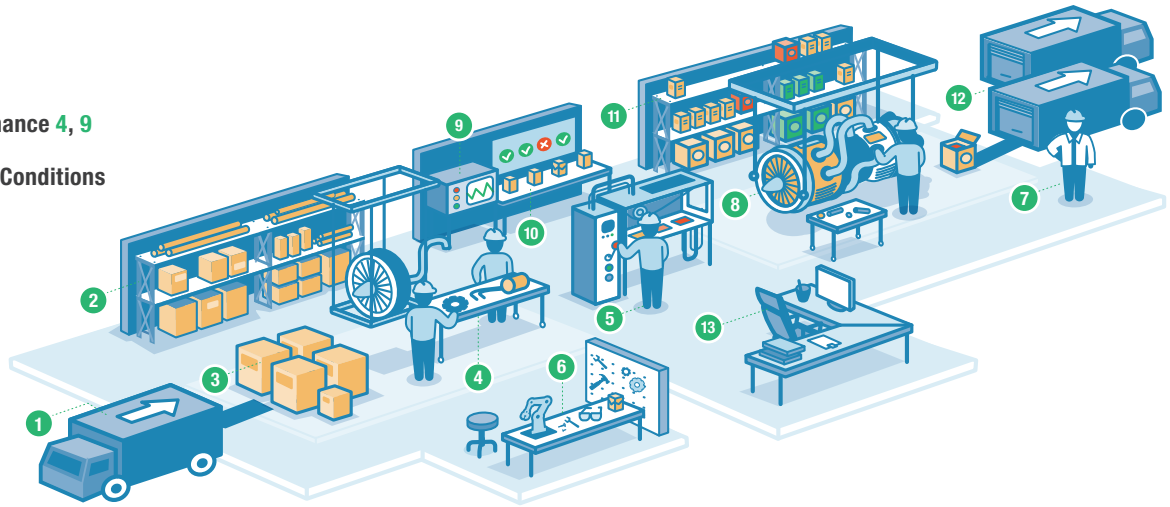
Supplier Performance 1

Customer Demands and Requirements 12

Environmental Impact | Energy Use

Mobile enabled employees with collaboration and optimal decision making 7, 13

Closed loop business process 13



SECTION 5

How to Drive ROI and Get Started with IIoT

IIoT Business Case Development

Business case development for IIoT technology has many advantages over other markets like Consumer, Healthcare, and others. In other industries, there is often a lack of an established business model, wherein the industrial setting demonstrable cost savings and operational efficiency alone can drive early investment. Below are four early business cases that make great starting points for investment:

ASSET VISIBILITY, RELIABILITY, AND, BENCHMARKING

Reduced down time, improved utilization, reduced MRO inventory, improved design

ENERGY VISIBILITY AND BENCHMARKING

Reduced energy costs, improved production efficiency, improved asset performance, improved design and commissioning

TRACEABILITY AND SERIALIZATION

Reduced scope and impact of adverse events, improved inventory and manufacturing performance

FLEXIBLE MANUFACTURING

Reduced lot size, increased customer responsiveness, increased asset utilization, increased production capacity

IIoT Pilot Project Examples

Although it is just a few years into a multi-decade journey with the IIoT, many companies have already jumped feet first into transforming operations. Four compelling current examples include:

CONNECTED CONSTRUCTION SITE: Real-time control, crash avoidance, remote monitoring of hundreds of cranes on world's largest construction site.

AUTONOMOUS MINING EQUIPMENT: Remote monitoring, real-time control, geospatial optimization.

DIGITAL OIL FIELD: Common data and optimization across exploration, well development, operations, and pipeline.

AUTONOMOUS AUTOMOTIVE CELL: Robots aware of and reacting to other robots, materials, design specifications, and mobile workers. No central programming or control.

LOT SIZE OF ONE: Electronics assembly where individual units are matched to specific orders. Production and assets react to work in process. No central programming or control.

SECTION 6

Summary & Recommendations

Summary and Recommendations

The IIoT is a transformative technology that will change the definition of IT-OT convergence, manufacturing system architecture, organizational structure, and business models. The development and deployment of IIoT technology will be incremental and part of a long term trend but the opportunity is here today. Companies that fail to properly educate themselves on the new technology as well as start to invest in pilot projects will likely lose any competitive advantage and even miss entire industry-wide changes that can happen in as fast as a few years.

- No single vendor today can deliver all the needed capabilities of an IIoT Platform, Smart Connected Asset, Operations, or Enterprise. It is important to build relationships with traditional IT vendors, OT vendors, System Integrators, and Next-Generation IIoT Startups.
- Vendor collaboration is critical for delivering on the vision of Smart Connected Assets, Operations, and Enterprise. Focus on vendors that have a strong partner strategy and are participating in industry consortiums.
- Most companies today lack the internal skillset and structure to effectively deploy new IIoT and IIoT enabled technology. Work on creating new manufacturing IT groups that bring together IT, OT, and business leaders.
- The time to start is now to capitalize on these new technologies in manufacturing.

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