Making Manufacturing Smart

Implementing the Industrial Internet of Things (IIoT) makes factories smart and confers a host of operational benefits.

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Manufacturing operations occupy a unique position in the automation technology landscape. Machinery and production automation systems need to be advanced enough to deliver high performance and integrated enough to provide economical operation, yet must be based on mature products and methodologies offering sufficient reliability.

“Cutting edge” technology can be employed, but “bleeding edge” technology is usually not warranted. How is the right balance achieved? In fact, why push for tightly integrated operational information and other advanced functionality if individual pieces are running “good enough”?

The main reason is because harvesting, processing and analyzing the correct data helps operational personnel make the best informed choices at their facilities, and enables management to optimize strategic plans throughout multiple locations. Simply put, advanced data analytics improves efficiency, reduces maintenance, and creates a safer work environment.

Fortunately, in recent years a number of device, communication, and software capabilities have developed in an interrelated manner—making it easier to extract and analyze manufacturing data. When combined effectively, they can elevate “business as usual” manufacturing to “smart” manufacturing. In fact, in many ways automated manufacturing is already smarter than one might expect.

Machinery and process plants commonly employ control systems with many types of sensors. While the highly touted Internet of Things (IoT) concept promises that one day all devices will become networked information providers, it turns out that the Industrial IoT (IIoT) already has countless sensors and other devices reporting data to higher level automation systems. Where the IoT is directed toward consumer convenience, the IIoT takes a laser focus on efficiency and safety.

Manufacturers such as Advantech offer a spectrum of hardware and software to facilitate gathering information from the lowest level sensor, or any machine, and routing it over a network to higher level automation, visualization, and information systems. Automation controllers pre-process and package the raw information from sensors and other field devices. These devices are the “things” in the IIoT.

Industrial wired and wireless networks, working in conjunction with the Internet and cloud services, are the superhighway for moving information. This information moves from field controllers to human machine interfaces (HMIs) located on the plant floor and in control rooms, and from the HMIs to front office PCs and out into the mobile world of smartphones and tablets.

Smart manufacturing is a powerful trend, building on readily available hardware and software to take production operations to the next level of performance. This White Paper will examine the reasons for implementing IIoT technologies, and will point out many enabling technologies and methods to make smart manufacturing a reality. It will also discuss how smart manufacturing benefits users in specific ways.

The Time to Implement the IIoT Is Now
Manufacturing businesses worldwide want to implement the IIoT to gather more data and improve operations. While these objectives have been present for many decades, it's now much more feasible to implement the IIoT because of the technology advancements as listed in Table 1 and expounded upon below.

Table 1: Why Implement The IIoT Now?

- Most new devices offer smart connectivity
- Methods exist to enable traditional devices to become smart
- Controllers are proficient at handling smart data
- Standardized wired and wireless Ethernet networks are economical, powerful, and pervasive
- Specific industrial networking formats are common
- Open interfaces and numerous drivers are available to facilitate economic integration
- Communication methods are suitable for private and public clouds
- Mobile visualization offers new ways to bring data to users
- Big Data harvested from the IIoT can be more easily analyzed
- Smart manufacturing adoption can occur in steps, with benefits realized along the way

In past years, devices and equipment typically offered minimal connectivity. One reason is that the technology and standards were not always in place, and another was just to cut costs by avoiding a niche connectivity option that few customers wanted. Sometimes a vendor might restrict connectivity to make their device more exclusive, or to avoid extra complications taking them away from their core business.

Those days are gone, and now connectivity is the “killer app” more often than not. Consumer devices such as phones, watches, appliances, and even sneakers are commonly able to connect and interact with each other. Similarly, industrial devices have moved from awkward and proprietary communication interfaces to standardized networks and protocols, often Ethernet-based. In today’s market, industrial manufacturing demands connectivity from most every device purchased. Even if the functionality is not immediately needed, it helps to future-proof investments.

For legacy devices using basic analog and digital signals, or maybe simple serial communications, there are modules that can boost this equipment up on to contemporary networks and protocols. In this way, end users can choose an upgrade path that preserves their existing system, yet provides value by making their “dumb” devices smart, leading to intelligent machinery.

**Connecting Islands to the Mainland**

Many production plants consist of “islands of automation”. Often, there are many automated skids or systems with minimal interaction among them, even though taken as a whole they form a production line. Sometimes these systems have been assembled and grown up over a long period of time. What they have in common, though, is that each island is operated by one or more controllers. Industrial controllers have more than enough power to perform some data processing, but may not share common communication protocols.
Fortunately, there are many flavors of “gateways” or “bridges” available. These can take the form of dedicated configurable devices, or PCs running various drivers and communication software. These gateways can translate pertinent information from existing systems into a suitable format for higher level integration.

When disparate controllers and the systems they control are capable of being connected, some huge informational advances can be achieved. Such systems can be interconnected to supervisory alarming and historian systems, consolidating key information from a whole production line into a few effective displays or reports.

For many operations, when subsystems are integrated in this way, it is possible to achieve a transfer of upstream and downstream information and improve the production flow. Or, when production goes down it is possible to use the integrated information to identify and eliminate the root cause, promoting overall equipment effectiveness (OEE) tracking. These are just a few of the benefits of a connected factory. As TechRadar.com puts it, “In the wider economy, the IIoT is critical in reducing unplanned downtime of production facilities and plants.”

Network Standards Enable Integration

Standardized networking methods are a key driver towards making a factory smart. Of course, the rising prominence of Ethernet variants in the commercial and industrial arenas has been important, as vendors can easily and economically leverage wired and wireless versions of Ethernet for industrial components. However there are also many well-established industrial networking technologies, such as DeviceNet, CAN and IO-Link to name a few. Every industrial network tends to have some path or method to interconnect with Ethernet. There are enough options such that an optimal solution can be found for any given situation.

While the networking method makes the connection, it is important to remember that the communication protocols require equal attention. These protocols define the “language” that devices speak. Just as there are several common and established networking methods, so it is with protocols.

For industrial applications, some of the major players in the Ethernet world are EtherNet/IP, Modbus TCP/IP and Profinet. There are other protocols optimized for specialized applications and industries, such as for power equipment or motion control. The takeaway is that while there is not one protocol to rule them all, there are certainly several open protocols in common use.

Moving Information to the Next Level

Assuming that technical and cost barriers are overcome for gathering information in a smart factory, what are the next steps? The first is typically to make the information visible to operators and managers so that they can make informed decisions. This used to mean tabular lists or printouts of numbers, but information presented in this manner is difficult for people to process. That is why so many variants of graphical display software and HMI packages have been developed.
Earlier generation HMIs used to just reside locally to their associated factory processes. Today’s HMIs use networking, the Internet, and public or private cloud services to extend their reach to wherever users are. Instead of just a single machine, production line, or factory being coordinated—it is now possible to manage multiple factories across the world in a more organized manner.

The Internet and cloud services are ideal for publishing smart manufacturing information to laptops, tablets, and smartphones, putting the information directly in user’s hands. Many visualization software packages have features specifically adapted to mobile device operation. It has become especially prevalent and useful for mobile devices to present a streamlined “dashboard” view which shows only the most important information in an easy-to-read format.

End user expectations from HMI packages have soared, due to consumer familiarity with high performance home computers, phones, and tablets. The graphics must be informative and must also look good and easy to use. HMI’s that take advantage of multi-touch swipe and zoom gestures position themselves that much close to the everyday user. Fortunately, browser-based products like Advantech’s Webacces are available that offer a familiar user experience, are easily extendable to all types of devices, and are able to publish the information conveniently over the Internet.

But the smart factory is about much more than just dishing out pretty graphics. At the factory level, the proper flow of status and command information is crucial for manufacturing execution systems (MES) that strive to track and record the production of finished goods. At an even higher level, data is required for enterprise resource planning (ERP) and business logistics systems to be effective.

A real opportunity exists when all of the Big Data can be harvested from many IIoT sources, and then effectively analyzed to reveal inefficiencies that can be overcome or trends that can be intelligently re-vectored. Gathering enough of the right information can enable users to make discoveries that would be otherwise impossible. Besides just improved throughput, IndustryWeek.com points that benefits can be found in material costs, energy efficiencies, labor costs, maintenance costs, and the cost of adverse quality².

Keep in mind that implementing smart manufacturing is not an all-or-nothing proposition. If fact, adopting smart technologies and methods can (and often should be) carried out in steps. This reduces the initial cost, and allows an organization to determine which pieces of the smart factory yield the most benefit for their situation.

The time to implement the IIoT is now, and here are the specific components which make up a typical IIoT implementation in a manufacturing plant.
IIoT Building Blocks

Data flowing through the smart factory can be imagined as a pyramid structure as shown graphically in Figure 1, and as detailed in Figure 2.

Figure 1, OT/IT Integration for Smart Manufacturing. Data in a smart factory flows from machines to controllers and HMIs and from there to MES and ERP systems.
Figure 2. Smart Manufacturing Data Flow. The Industrial IoT facilitates data transfer from field devices to visualization platforms at operational and management levels.

Another good reference is ISA-95, which defines industrial automation interface concepts from the lowest (Level 0) to the highest (Level 4) level in terms of both functionality and immediacy. If “Level 0” is considered to be the actual physical process, then the smart manufacturing foundation begins at “Level 1” and consists of the sensors and field devices.

Table 2 lists the main IIoT building blocks and this section describes each piece and shows how they fit together.

Table 2: IIoT Building Blocks
- Smart sensors
- Network-capable I/O
- Controllers – PLCs, PACs, DDCs, Proprietary
- Network switches, media converters, routers, security
- Visualization, fixed location
- Visualization, mobile
- Business strategy systems

Traditional sensors were historically hardwired and offered only a single basic process signal, but today’s smart sensors are networked and provide additional process signals and device diagnostics. They can maintain on-board calibration data, and technicians can interact with these sensors remotely. Think of a flow transmitter that also provides temperature and pressure information, and can alarm when the data readings are suspect.
More advanced analyzers can simultaneously provide multiple sensed variables for complex parameters such as pH. Barcode readers and RFID tags are key ways to establish material tracking. Many other types of smart sensors and field devices are available, all capable of providing data to higher level systems.

**From Sensors to I/O and Controllers**

Many varieties of networked remote I/O modules are available to bring hardwired devices into a control system. Some styles are panel-mounted, while others can be installed in harsh areas. The main benefit of smart I/O is reduced field wiring, and the ability for designers to tailor the exact right product to the need (Figure 3).

![Figure 3, ADAM-6200. This smart I/O module has built-in web server capability, Ethernet connectivity and a built-in graphic control logic engine—making it a key building block for many IIoT implementations.](image)

Sometimes the issue is less about how to bring the data into the system, but more about how to transport it effectively to where it can be used. When it comes to the IIoT ecosystem, DesignNews.com says “Hardware manufacturers need to ask what can be done to simplify the connectivity stack from the field devices being measured up to the application level. It needs to be as easy as possible to connect devices and physical things at the edge of networks up through the application stack.”

Smart devices, whether they are I/O modules or sensors, often have the ability to communicate directly to higher level PC applications used for data analysis and other purposes. However, it is often most appropriate to gather these field devices into “Level 2” controllers, whether they be PLCs, PACs, DDCs, DCSs, or other designs. Some controller types are associated with specific processes or industries, but there are many examples of crossover applications. For example, even though a PLC is often considered for discrete manufacturing, there are times when it serves the role commonly filled by an HVAC DDC system.

Controllers are useful to perform pre-processing of data from field devices. Sometimes they will scale it, or will consolidate several pieces of information into a consistent context. For instance, a smart flow controller can be evaluated for flow alarm conditions only when it is expected to be running, and it can be monitored for on-board faults at all times.

**Networking Nuances**
Networking forms the backbone of smart manufacturing at all levels. When it comes to Ethernet, switches and routers are often used, as industrial suppliers have modified commercial Ethernet components to work in demanding factory environments. Wi-Fi Ethernet also finds applications in factory environments, usually for supporting flexible and often mobile HMI visualization.

There are two more networking concepts that exist in traditional networking, but are specially adapted and enhanced for the industrial IIoT market due to the critical nature of the factory environment. The first is fast-reacting redundancy, needed to keep I/O and smart devices online, especially devices that are being commanded to take actions affecting production processes. The second is security appliances capable of keeping the world (and hackers) out of the factory, while allowing the necessary data to securely flow in and out.

**The Highest Levels of Smart Manufacturing**

HMIs are “Level 2” systems that facilitate detailed plant operations. They can be PC-based running software, or a more dedicated hardware type. Plant networks supply HMIs with the information they need, either directly from field devices, or more commonly through I/O and controllers.

These HMIs can be flexibly located in main control rooms, on machines, in maintenance and management locations, or elsewhere. More recently, it has become common to configure consumer-grade or industrial-grade tablets as HMIs and troubleshooting stations that can be carried around the factory.

One of the real game changes in HMI space over the past decade is the emergence of browser-based products like Advantech’s WebAccess. No longer are users tied to specialized hardware, or difficult software installations. Just as PCs and Ethernet successfully leveraged commercial technology into the industrial arena, browser-based products prospered by offering much the same end user experience as traditional software, but at a lower price point and requiring near-zero configuration on the end user’s device. These products are capable of providing an HMI interface anywhere within a facility, on all types of mobile devices, and throughout the world via the Internet. Not only that, but they can offer advanced features such as integration with Excel, Google Maps, and video streams.

Residing above HMIs are “Level 3” MES and “Level 4” ERP systems. These software-based systems typically run on servers located at a given production plant, or even far away in a corporate office. Software systems at each progressively higher level are typically less “real-time” than at lower levels. While MES and ERP systems are a subject of their own, they both require close integration with lower level sensor and control systems in order to be effective.

A comprehensive smart manufacturing solution built on an IIoT foundation is necessary to power operations and business management. These IIoT building blocks can be combined to create real-word applications to deliver specific benefits, as shown in the following example.

**Food and Bev Gets Smart**
Food and beverage manufacturers can find many ways to benefit from smart manufacturing. Their objectives are typically to improve product quality, reduce waste, track material usage and reduce costs (Figure 4).

Figure 4, Dairy Plant. Food and beverage facilities like this dairy plant can realize multiple benefits from IIoT implementations in the form of increased production, higher quality and more efficient energy use.

Bulk ingredients received and stored to silos, tanks or on pallets are scanned or keyed into a lot tracking system. The MES uses this information to dispatch ingredients to the processing equipment as needed (Figure 5).
Figure 5. Food and Bev. Food and beverage facilities implement MES solutions by gathering data from sensors and field devices via I/O, controllers and HMIs. Data from HMIs is then sent to MES platforms for analysis.

Quite often, material weight is logged into the system at the time they are received, and also when added into the process.

Most plants have one or more control rooms, but it is becoming more and more common to provide operators and maintenance technicians with tablets so they can walk around the process areas. The right browser-based software, like Advantech’s WebAccess, operated on a tablet—not only enables freedom of movement, but can extend the operator’s reach through the use of streaming video to monitor other plant areas. The actual production equipment may consist of one large site-built automation system, or many packaged pieces of equipment that are interconnected. In either case, there are one or more controllers interacting with field devices to keep operators informed.

Finished products are packaged for shipment to customers. The packaging equipment has its own controllers to operate the machinery, to perform check-weighing or product inspection, and to label the goods. Packaging equipment is often a multi-step process, and this equipment usually provides performance data in the form of speed or units per minute.

Any time there are multiple steps in a process, it is critical to identify which steps are the limiting throughput factor. Similarly, if there is a failure, then operators need information to point them to the root cause. Smart manufacturing will harvest all of the production key performance indicators, and use them to identify bottlenecks that can be improved, and will also facilitate troubleshooting.

At the highest level, data provided via smart manufacturing allows business operators to track, direct and optimize their raw material usage and productive output. Uptime and downtime can be analyzed, and inefficiencies identified and wiped out. Without the data provided by smart manufacturing systems, none of this is possible.

**Conclusion**

For today’s factory, superficial good looks aren’t enough to prove that things are running at their best. Instead, additional improvement opportunities must be actively sought to create a smart factory. One way to do this revolves around obtaining more operational data and putting it to work. Any process of improvement is based on quantitative analysis of measurements, and fortunately the IIoT opens up a whole new world of quantifiable data.

Connectivity is no longer a unique luxury, as it has instead become a baseline requirement. Intelligent machinery leads to a connected factory, which in turn provides the platform for smart manufacturing. Businesses everywhere want to leverage the IIoT in the most expedient way possible, and fortunately the technology is available now to make this happen.
The building blocks are smart devices, methods for making legacy equipment smarter, robust networking, and a wide variety of software—all of which are readily available to build into new facilities or integrate into existing operations. The widespread availability and ease-of-use of these enabling technologies allows end users to focus less on how to harvest the data, and concentrate more on improving operations.

References:
