THE TRUE BUSINESS IMPACT OF IIOT TECHNOLOGY

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ABSTRACT
The concept of the Industrial Internet of Things (IIoT), has gained significant momentum in the industry recently, heralding a variety of associated solutions and values. Most of these unfortunately represent little more than desperate marketing stories from legacy providers, or unsubstantiated promises from exploitative startups, triggering significant needless investment in narrowly focused, often bespoke technologies, that ultimately represent unnecessary deployment and ongoing ownership costs.

INTRODUCTION
In this paper, we expose the pitfalls and opportunities in the choice of IIoT solution technology, at the device and machine level, the manufacturing execution management system (MES) layer, and enterprise business systems layer. The effect of a simple initial decision can influence the scale of investment by an order of magnitude or more.

Key words: AI, IIoT, CFX, IPC, Smart, Industry 4.0

AIMS OF AN IIoT-DRIVEN SMART FACTORY
With many companies trying to offer their bespoke IIoT solutions in the market today, we are often told that we are yet to learn how so much data can bring so much value. While the modern analysis of the vast patterns of data will surely bring an unprecedented value, we should not forget our decades of experience of business, management and engineering challenges. There is a well understood list of key criteria for the success of a manufacturing business that everyone involved in manufacturing should already instinctively know. Though prioritizations differ, these principles are fundamental to the business of manufacturing, and so should be treated as the benchmark against which to judge the value and effectiveness of Smart factory technology. The list of aims includes:

Manufacturing Differentiation Metrics:
- On-time delivery
- Zero-defect quality and product reliability
- Shorter product introduction
- Higher-mix with retained high productivity
- Fast response to demand changes
- Zero-waste supply-chain costs
- Minimized material-on-hand
- Proof of conformance and compliance
- Traceability of all operations and materials
- Minimal scrap / waste
- Maximum energy efficiency

Any form of change in manufacturing represents risk and cost before any value and benefit can be achieved. A great degree of confidence in any solution or technology is required before any investment should be approved. Initially, it is the more progressive companies that lead the way forward, facing potential benefits and consequences of their decisions. For others however, there is the increasing gap with their peers, which represents a growing challenge to catch-up.

Smart technology can be more easily understood when it enhances the existing decision-making processes currently made by humans. It is inevitable that the digitalization of decision-making will involve the modification or reinvention of existing legacy practices, so there is a degree of open-mindedness required. The technology is there to enhance the decision-making, rather than criticize it. The more information that is available at the instant a decision is made, the better that decision will be. As experience of assisted decision-making is acquired, the more trusted the suggestions will become, no longer requiring human agreement. This progressively frees the human element to work at a higher level.

Industry 4.0 is more of a business related goal than simply being a technology. The intent of the so-called “revolution” is to bring the manufacturer and customer closer together in terms of distance, time or preferably both. It has been an alarming statistic that for some time, the transportation of products from assembly factory to the customer, has far exceeded the cost of actual manufacture. A modest cost saving in the product distribution network drives opportunity for investment in automation for more flexible local manufacturing, contributing significant additional profit. Manufacturing close to the customer requires the business to respond very quickly to changes in delivery demand patterns, without the accumulation of buffer stock that was once the distribution network. The cost savings implementing this practice include warehousing and transportation, but more significantly, the reduction of investment in stock and the associated risk of depreciation, especially towards end of life. The impact of Smart manufacturing practices are founded upon proven market trends going back many years, and is being demanded more and more by customers. The traditional equation however for mass production, is that as variation increases, leading to high-mix and small lot sizes, the more productivity inevitably declines. The extreme case, “Build to Order” is at the opposite end of the spectrum to mass production efficiency. Industry 4.0 seems to be asking the impossible, that we get close to being able to build to order, yet retain mass production efficiency. In order to achieve this, there has to be a revolution in manufacturing technology.

INDUSTRY 4.0 HAS FAILED

For over five years now, Industry 4.0 and Smart manufacturing have been popular buzz-words in the industry, inspiring a leap forward in performance and capability. Almost every company has promoted "Industry 4.0" related products. In reality, this was done in order to prevent the collapse of sales of existing products, technologies and solutions. No-one would sign off on a purchase order that was not future-proof. Unfortunately, every vendor had either a different story, or no story at all, to back up their Industry 4.0 claims. The main thrust of Industry 4.0 to date, has simply been a series of disparate marketing campaigns. This is evidenced by the continued decline of manufacturing productivity as reported in the German press over this period. Though Smart manufacturing appears to be gaining popularity quickly, the term Industry 4.0 has inevitably suffered, with many senior management leaders refusing now to entertain any related marketing messages, believing the meaning of it has diluted to a point at which it has no value in discussions.

Beneath the surface of Smart Manufacturing, no matter what it is called, a fundamental barrier exists, which has to be eliminated before any but the most affluent manufacturing companies can seriously consider Smart technologies. Looking around existing factory operations, it is clear that the quantity and quality of data gathered from production processes is very poor, added to which, the cost and volatility in the data collection process is very high. The issue is very simply that each manufacturer has a different set of data content, as well as different methodologies for sharing it. The situation is bad enough that simple reports cannot be completely trusted, nor used directly to make decisions. To make bespoke connections come up to the level where the data has value, is very expensive, which very few can afford, especially considering the many thousands of potential data connections needed. This single factor is the key barrier preventing true holistic Smart factory projects from getting started.

At best, current efforts have a very focused approach, limited to just one narrow area of the factory, usually with just one vendor. This has led many solution providers and customers to take a wrong turn, with expectations that putting data into the cloud will somehow magically create value. Though not without some merit, many of these solutions are just a slightly updated proprietary method to acquire existing data that was already available through other means. The data itself, since it is coming from individual machines, lacks any form of context, and so has very little value in isolation. Putting non-contextual data into a cloud environment means that linking the disparate elements in the "big data" environment will require extensive, almost impossible levels of processing, in order to deliver even a slight increase in value, unless tremendous engineering customization is employed to restructure the data in a contextually valuable manner.. The "digital landfill" that is subsequently created in the cloud is becoming increasingly expensive, with data volume increasing exponentially. The value however does not increase in most cases, as later on, most data is found to be unusable, unintelligible or irrelevant. This leads ultimately to project failure. This is something that companies feel that they have to do, but it is in almost every case, not the right thing to be doing.

THE REAL COST OF SMART FACTORIES

When starting to consider the costs of a Smart Factory project, thoughts immediately turn to the application software, with consideration of an off the shelf package, or set of packages, against the potential to develop solutions internally. On a pure cost basis however, it has been proven over and over again that investment in data connections is at least half of the total investment required, which can increase to over 80% of the entire project costs in some cases. These connection costs are up-front, occurring before any value can be returned, and so represents the most significant burden to practical Smart factory adoptions. This is also true of the follow-on costs of ownership and maintenance. With the arrival of IIoT, it is a natural assumption that this problem will be reduced, but in fact, that is not the case.

Legacy bespoke interfaces are in a sense quite simple to manage. Requirements are defined, an NDA drawn up between customer and supplier, the specification made, and software development undertaken, after which, weeks later, testing and deployment. The advantage of bespoke connections is that at least initially, the data content is fully defined. Each such connection is likely to come however with a price tag of several tens of thousands of dollars, meaning around thirty or so connections for each million dollars invested. For those few manufacturing operations that think they can afford these costs, studies were done to identify how many endpoints would potentially need to be connected to the Smart factory network. In many cases, the number coming back exceeded ten thousand. This put the potential price tag for Smart factory connections at around $300m. There are claims around the industry, especially from China, that certain companies have indeed spent this much in the development of their Smart factories. In such cases, the return on investment is quite unfathomable.

IIoT-based technology is heralded as bringing a change to this situation, but unfortunately, a change does not necessarily mean improvement. The nature of IIoT-based communication is that it is no longer data exchanged between one defined point and another. Using real IIoT means that all data is available to anyone and everyone within the Smart network. The machine vendors themselves therefore have to decide what data should be shared, with all vendors in isolation from each other. Though the cost of interface development is now no longer between the customer and machine vendor, the IIoT will now need to be translated and understood, alongside all other IIoT data sources, which are likely to have a completely different data schema, timing, format and meaning. This introduces the burden of middleware, which is specifically software that acts as a translator between all of the different data sources. Middleware solutions are complex, requiring continuous maintenance as the proprietary data from each source is updated. Such updates occur regularly as multiple uses of the data evolve. Discrepancies and inconsistencies then arise between applications. What has occurred, is that the costs that the legacy interfaces required for development has simply been moved to middleware, with an increased layer of complexity resulting in inconsistencies of data requiring additional costs to rectify. Many IIoT systems based on proprietary data are actually worse than the bespoke data connections they replaced. There certainly is no real business motivation to move toward this direction if the full scope of the Smart factory is to be considered. It takes some time for would-be Smart factory teams to realize this issue, and understand the true costs of the Smart factory either way. The usual result is authorization of only a very narrow and focused Smart application that has a reasonable price tag, yielding very little value and impact on the business. The end-point of most Smart factory projects are reached, to again become little more than a marketing story.

Consequences are ongoing even after projects have run aground. It is likely that each machine vendor, for each machine model they make, will be supporting more than thirty different bespoke formats, each slightly different, based on each of their significant customer's needs. There is a large overhead of cost associated with this, not only for the maintenance of the software, but also the application of all of the interfaces to newer versions and models of machines in the future. At the lower end of the data gathering spectrum, the story is similar, with many sensors, switches and other measurement or control devices, sending data through a mechanism, such as OPC or MT-Connect, that also need to continue to be supported, as well as the significant cost of maintenance for all of the middleware involved. This it the state of play for most factories attempting to implement Smart technology today.

Consequences extend beyond costs. Members of the IT teams involved in Smart factory projects fail to deliver on expectation. A significant amount of frustration is experienced, and a skepticism of solutions grows. The typical IT team represents a significant indirect cost to a manufacturing business, and there needs to be a tangible contribution. Team leaders naturally start to look internally to create solutions that are in their own control. The result is the growth of point-solutions, simple applications with bespoke data connections, grouped under the guise of Smart systems. There is little consideration of the original holistic business requirement, but rather defensive positions on legacy style systems adapted to appear Smart, little more than an internal marketing story. This positioning applies equally to internal IT solutions providers as well as most established commercial providers in the industry.

IIoT "PLUG & PLAY" STANDARD: THE IPC CONNECTED FACTORY EXCHANGE (CFX)

Amongst key industry thought leaders, the issues around IIoT-based communication technology, triggered movement towards new communication standards. With so many past standards failing to deliver the specific needs and complexities required by electronics manufacturing, a new approach was needed, one that would satisfy the modern demands for Industry 4.0, that completely avoided the costs of legacy and bespoke interfacing. With a mandate focused on the IIoT-based plug and play environment, the concept of CFX was launched, and was immediately very well received within the industry, by machine vendors, manufacturers and solution providers. Being an IPC standard, the content of CFX is consensus-based, representing all aspects of assembly manufacturing. Over the two years spent developing CFX, more than four hundred participating companies have been involved, developing and defining message content that represents non-proprietary, technology orientated design, to meet the most progressive requirements for Industry 4.0.

There are three distinct components of the CFX technology:

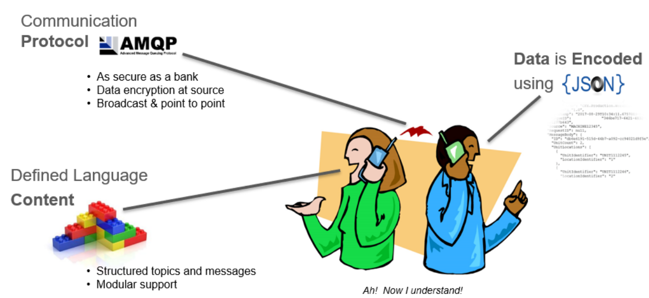

Figure 1. Components of the CFX standard

1. Communication Protocol: The AMQP v1.o protocol was chosen as the mechanism to transfer IIoT data from point to point. This is in itself an open standard developed by the banking industry for the purpose of secure, encrypted transactions across any network, and is widely in use in mission-critical areas. The unique aspect of AMQP v1.0 is that it provides two distinct data transfer mechanisms within one protocol. For general messages that convey information, a broadcast structure is used, whereby a broker is used to deliver messages reliably to any number of recipients. Where direct message exchange is required, data can also be sent point to point, using a request / response structure, such that commands can be immediately actioned and confirmed. No other protocol allows this duality of message types, yet is a critical requirement for manufacturing, as the data must be shared robustly without a drain on the resources of senders.
2. Data Encoding: The JSON format was chosen, as it is the most modern, efficient way to structure data messages, such that data can be read by humans as well as easily and simply parsed in software. The vast majority of modern software developers are very familiar with the JSON format, which is used in the majority of web-based systems today.
3. Defined Language Content: This is the most critical and unique element of CFX, which all other standards have not succeeded in delivering. CFX defines the precise

definition of data content, such that all data sent using CFX will use the exact same content and formats, no matter who or where it was generated, essentially plug and play. Though this creates quite a rigid requirement, it means that any receivers of CFX messages know exactly what the data represents without any need for translation or middleware. The flexibility required to support newer machines and processes is provided by the modular topic-based structure that CFX adopts, such that any machine, past, present or future, can be digitally modeled using selected relevant topics. The CFX standard is updated roughly twice per year, in order to expand the scope of manufacturing technologies to which it may be applied.

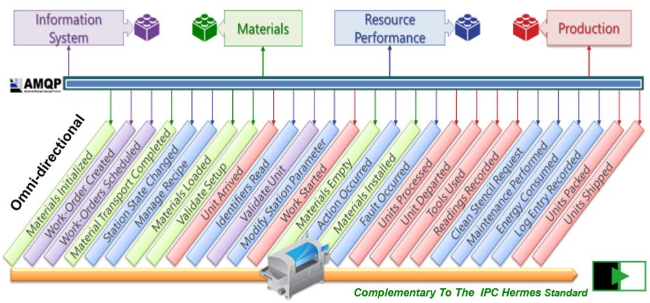

Figure 2. Example of CFX Messages

CFX topics and messages are clearly defined in the standard, each with sub-topics that progressively contain more technology specific details. This makes the selection of CFX messages simple and relevant, for any purpose from the simplest of dashboards, to the most complex analytics reporting and control systems. The top-level topics break down as follows:

- Production: Messages related to the movement and processing of production units, including all process information, measurements, test results, readings, tools used etc. A complete and detailed set of process traceability.
- Resource Performance: Messages related to the efficiency and productivity of machines and other processes, including details of state changes, such as down-time, maintenance events, setup procedures, and any other actions that happen that influence machine added-value versus non added-value activity.
- Materials: Messages that relate to all material utilization, including consumption, usage, spoilage, verification, scrap, and transportation. The messages together provide a complete and exact traceability of materials across the whole factory.
- Information System: Providing information about work-orders and schedules, the creation of unique production unit IDs, as well as measurements from non-production related sensors including energy consumption, temperature and humidity etc.

Implementation of any new communication mechanism, requires development at each endpoint creating or receiving data. The IPC has created an open-source Software Development Kit (SDK) for CFX on a variety of platforms, such that most of the development work required for CFX implementation is avoided. One machine vendor claimed that they achieved CFX support for their machine within three hours, through the use of the SDK. As well as the huge cost and lead-time saving, this means that CFX can be very cost effectively retrofitted to older machines, even those which are no longer supported under normal conditions. Some machine vendors have stated that CFX will be made available on every machine that they have ever sold into the market. Such is the ease of use, using Linux, CFX has been incorporated into tools, such as soldering irons and torque wrenches. The SDK can also be used "in house" to provide connection to bespoke machines, such as functional testers and bespoke systems. For very old machines that do not possess any computing power to support CFX, there are commercially available solutions based on inexpensive hardware, such as the Raspberry Pi credit-card sized computer, which, with the addition of a similarly sized and priced IO board, can act as a CFX data generator at the machine itself, with sensors attached to the legacy equipment as required, the SDK embedded, and Engineering services to provide a turnkey service. Internal IT engineering are of course free to develop their own endpoint solutions for such machines.

When we revisit the barrier for entry into Smart manufacturing, the use of CFX provides a revolutionary solution in itself, comprising all of the required data, freely available for any aspect of Industry 4.0. As CFX is provided as a native standard interface from each machine, the vendor has only one interface to support and maintain. For IT teams and solution providers, applications using CFX are interoperable through the single CFX interface. Machines from many vendors now connect to a variety of software applications, each with the absolute minimum cost of ownership, minimum risk of issues, and maximum opportunity to utilize data. Instead of the majority of R&D resources being spent on interface creation, support and maintenance, all effort can now be focused on the next generation of Smart factory applications

IT SECURITY & THE SHOP-FLOOR

Though extensive measures will typically have been taken to protect the IT network against cyber-attacks from outside the network, problems are just as likely to come from within, as most production machines now have the ability to connect to the internet. Where sensitive products are being made, IT teams insist that there has to be no electrical or other physical connection between the strictly managed company IT network, and what takes place on the shop-floor. For this reason, the Smart connected factory represents an impossibility. Sharing of data between machines and devices on the shop-floor is restricted to a local "OT" network which has no outside connection, and no connection to the main IT system.

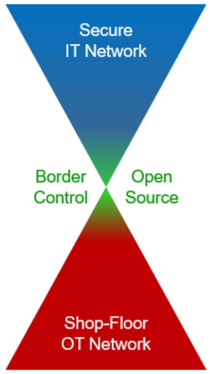

Figure 3. The CFX Open Source Border Control

Uniquely with CFX, a secure bridge may be developed and used to connect a single border-control device in between both network systems. On the IT side, there is the company-sanctioned security policy, and on the other, the connection to the factory floor, which as a default will have a complete block of any and all network activity. Nothing whatsoever can pass through the border control device, except CFX data through one port. Software on the border control device provides monitoring of all aspects of the data stream, blocking any unrecognized activity. In the case of CFX, this is simple to achieve, as CFX is the only standard that is based on fixed data content definition, such that all data can be specifically authenticated against the standard. Both the CFX SDK and the AMQP v1.0 host software packages are open source, so the code can be scrutinized by the IT team, who can incorporate it into their own border control software, with no dependencies on third parties for the security of the network. The breakthrough that this approach represents is very significant for Smart manufacturing in sensitive operations.

TURNING DATA INTO VALUE: CONTEXTUALIZATION

Now that CFX has revolutionized the way in which raw data is made available and shared across the IIoT network, the focus moves to the next stage of Smart factory development, which is how to utilize the data to create value. The simple type of search, for example using tools such as Google, is not sufficient when dealing with manufacturing data. Though there is a huge potential to find out previously unknown facts about influences and effects on production quality and performance, the values will depend on how clever the analytics software is, but more fundamentally, how much potential value exists within the data itself. Take the example of a machine stopping, perhaps due to no product arriving to be processed. The machine message can only say something such as "no product". There is no amount of statistics that can practically use this data without contextualization with other events that contributed to this scenario. The reason for the "no product" is most likely due to a related upstream issue, which could be caused by a breakdown of a different machine, a material issue, schedule issue, or in fact any one of many different other reasons. Unless the real cause is known, there is very limited value from statistical analysis of the originally reported stop condition without a core understanding of how that data element can be linked to any other. Using IIoT-driven contextualized data, several orders of magnitude of continuous needless computing power for analytics is avoided, as well as significantly reduced data storage requirements, in order to gain the same value from analysis. The IIoT-based MES layer identifies these relationships based on knowledge of the live production configurations, product design and production data, materials flow and status, tool utilization and many others. This process takes the usable value of data reported from around 20% in the case of raw data, to nearly 100% for contextualized. Performing the contextualization of process data as it happens, means that trillions of repeated cycles of analytics can be avoided, without loss of detail, gaining greater value, saving significant cost and time taken to achieve results. The sheer volume of data storage required is also reduced significantly through contextualization, with the removal of data duplication and redundancy.

THE THREE LAYER MODEL:

Taking a look at Industry 4.0 holistically makes it immediately clear that there is no single Industry 4.0 solution, and that interoperability of machines and applications is the key. The three layer model illustrates how original data, both raw and contextualized, is utilized in different ways throughout the hierarchy of manufacturing.

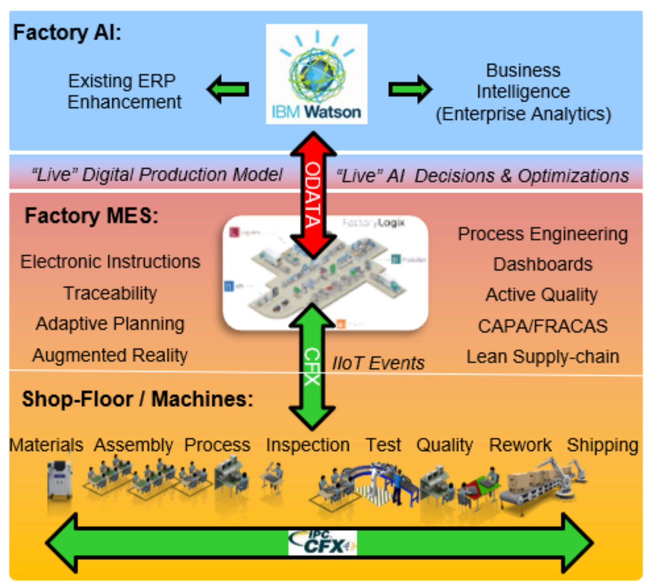

Figure 4. The Three Layer Industry 4.0 Model

Layer #1: IoT Infrastructure (Edge)

The term "Edge computing" can be misleading. In general, the term is used to describe the processing of data, the result of which is sent from one domain to another, typically out to the cloud. "Machine learning" is the term used for functionality, usually analysis, of a narrow range of data focused around a specific machine or technology type. The result of the machine learning is then sent from the machine to the outside world. The more data available for machine learning, the more value can be added from analysis. An example is the analysis of a 3D x-ray image. The machine learning algorithm will search through the image, detecting any deviations, comparing what it sees against what it expects. The learning aspect is simply the ability to adjust the search and detection parameters based on the results from past performance, for example where an issue was flagged by the software, but subsequently became a "no fault found". The raw data used by machine learning is often proprietary and very large, so this processing is usually seen inside or close to the machine itself, and is asynchronous to the line operation.

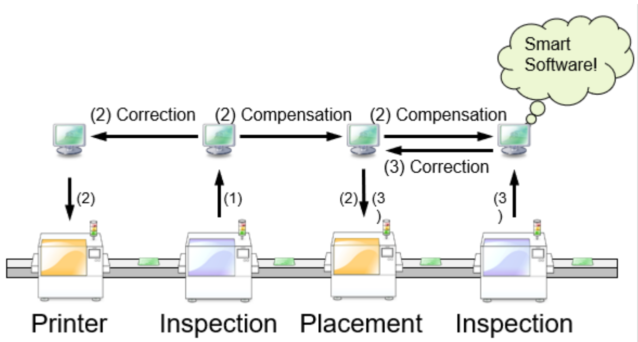

Figure 5. A typical closed loop example

"Closed-loops" are a wider application of machine learning, involving the exchange of data between two or more machines. The basic premise is that one machine later in the process, records and feeds back data related to the performance of preceding operations. On the detection of an issue or trend, correction parameters can be applied to the upstream machine, as well as parameters sent to downstream machines so as to reduce the severity of deviations detected. Closed-loop systems do not require defects to happen in order to work, any deviation can be tracked using techniques such as 6-sigma, such that defects are avoided. A typical closed-loop application consists, for example, of an inspection or test machine, sending data to the machine performing component placement or screen printing. In the case of deviation being detected in the placement of paste or components, the most likely cause is revealed through analysis of the pattern of results across the entire set of data for the individual PCB, as well as from the history of consecutively produced PCBs. CFX supports sophisticated machine to machine communication for closed-loop analysis and related machine learning algorithms.

Layer #2: The IIoT-based MES

A key element of CFX IIoT communication is that the content is factual, and does not include pre-defined calculations based on assumptions. The MES layer is free to build contextual value in any way that it likes, in fact in many different ways, depending on the various MES applications. The modern IIoT-based MES provides all of the expected functions, including digital manufacturing engineering with paperless documentation and Augmented Reality (AR), live execution management, near-term adaptive planning, Just in

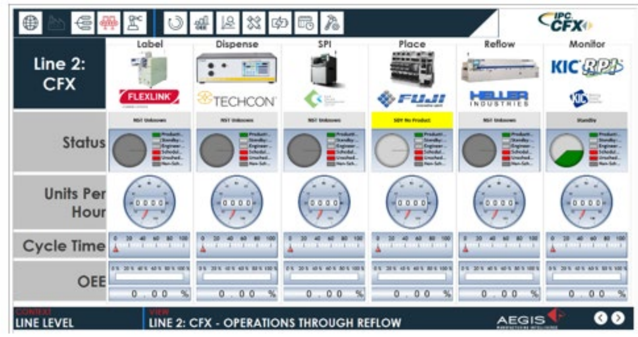

Figure 6. IIoT driven Dashboard

Time (JIT) material logistics and warehouse control, quality management including CAPA / FRACAS capabilities, as well as fully exact compliance, conformance and traceability of all materials and process data. Though all of these functions are familiar, the difference made by the IIoT-driven MES environment together with CFX, can increase productivity by two or four times in areas of high product mix, drive quality issues to zero-defect levels, as well as making the factory highly flexible and reactive to customer needs.

CFX messages are omni-directional, and so in turn, the IIoT-driven MES system provides information back from the factory layer to individual production machines and other stations. Vendors of such machines for example may choose to utilize information from other machines in the line, other lines in the factory, and from the factory layer which includes information about work-orders and material transportation logistics. Individual machines, or groups of machines in lines, are able then to perform further self-optimization based on, for example, the specific mix of products to come, or changes in the size, shape or supply-form of materials. Machine vendors are able to provide increased Industry 4.0 optimization on their machines through the use of CFX. This contributes to make CFX very robust in the industry.

The human operator, the most flexible asset in the factory, is also a key part of the digital factory. The IIoT-based MES layer supports the inclusion of human operators through the adoption of AR, directing the execution of complex step-by-step operation, without any specialist knowledge or training. Information from many sources, including the original product design is provided, based around dynamic and interactive work-instructions. AR technology promotes the ability for any operator to perform any assembly task, on any product, at any time. Having two hands free at all times greatly increases productivity. The most significant feature of AR is for human operators to be dynamically assigned to a wider range of tasks, across many different areas of the factory, including assembly, test, inspection, material logistics, quality control etc. all at a moment's notice.

Layer #3: AI

The focus of IIoT-based MES systems is on operational execution in all forms, supporting the real-time, live production environment. Manufacturing information provides greater value when used both in the live environment and for post-production analysis. The use of analytics software, whether on the shop-floor itself or in the cloud, driven by contextualized data, discovers patterns in data that reveal opportunities for improvement. These patterns can be related to design or production process limitations, as well as the effects of alternate or substituted materials. It is unlikely that the complex relationships involved would have been noticed in the live environment without the use of analytics. Areas of loss, waste and upcoming risk can be identified, so as to recognize optimization opportunities. A wide variety of Business Intelligence and other analytics systems exist today, which, though powerful, have been challenged by the lack of contextualized, consistent and reliable shop-floor data. Using standards such as ODATA, the IIoT-based MES can feed data to any kind of analytics system, integrating shop-floor data analysis together with live manufacturing management.

Analytics itself however is not the limit to which contextualized data can be utilized. Though it seems most software and analytics algorithms are referred to as "AI" today, true artificial intelligence is differentiated from other software algorithms in its ability to modify the algorithm itself to gain better results, rather than just the parameters initially provided. In order to do this, a flexible goal is set, a method of measuring success. Even the way of measuring success may be learned. The shipping of a defect-free product may be a first consideration, but how about measuring the reliability in the market versus the design intent? As intelligent software applications develop, such as IBM's Watson, we get to a layer beyond analytics, a layer which can augment the real-time operation of the factory. The factory management AI of the future will see everything, and make suggestions for operational improvements in real-time, executed by the MES layer. Though this is still manufacturing science fiction, the coming few years will turn this into fact, and those who are ready with qualified and contextualized data as part of their Smart factory operations, will have the opportunity to strongly differentiate themselves, through the application of AI at the core of manufacturing management.

AIMS OF AN IIOT-DRIVEN SMART FACTORY: ACHIEVED

While on the journey to reach the full potential of IIoT technology, based on CFX, the IIoT-driven MES, business analytics and AI, the direct impacts in terms of core business metrics are realized:

Market Differentiation Metrics:

- On-time delivery: 100%
- Zero defects: Achievable
- Product introduction: 8 days -> hours
- High-mix productivity: Increased 100%
- Response to demand changes: 1 month -> 1 day
- Supply-chain costs: Reduced by 75%
- Conformance and compliance: Assured
- Traceability of all operations: Exact, material & process
- Scrap / waste: Reduced by 80%
- Maximum energy efficiency: Increased by 5%

There are several new best practices, low-cost and low-risk actions that can be immediately taken as part of any initiative to get moving along the true practical Smart factory path.

- CFX IIoT Data Exchange: Adoption of the CFX interface factory-wide. Most key vendors already have CFX roadmaps, with many machines already supported. Vendors are also able to retro-fit CFX to older machines, and the CFX SDK can be easily utilized in bespoke machines or with simple inexpensive hardware, machines that have no interface capability.
- IIoT-based Digital MES: Building the context of information provided through CFX, and until all vendors are on board with CFX, existing legacy interfaces. Creating the interoperable environment for all MES related functionality immediately creates value from visibility, execution control, lean materials, quality management, paperless work-instructions with AR, adaptive planning and many more.
- True AI-based Factory Automation: The vision of the factory of the future can only be attained once the prior steps are in place, already creating value. The future is an exciting time, where AI-based software will deliver the ultimate business differentiation, an optimized, lights-out factory potential that automatically makes and delivers whatever the customer immediately needs.

It is vitally important that the right path towards Smart manufacturing is followed. Technologies should be chosen that represent building blocks towards the ultimate end-goal, each generating benefits along the way.