Getting Started with MTConnect:

Monitoring Your Shop Floor – What's In It For You?

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Background

One of the top trends in manufacturing plants today is the need and desire to have a better understanding of what is happening on the shop floor. The most productive and efficient manufacturers are actively monitoring their shop floors, not to be "Big Brother" looking over the shoulder of the machine operator, but rather to obtain additional information that can help the machine operator and the plant to be more productive. Numerous manufacturers that have implemented machine monitoring have seen a 20% improvement in Overall Equipment Effectiveness (OEE) in just ten weeks, with a significant Return on Investment (ROI) from their initial investment in six months or less.

Historically, the challenge in monitoring a shop floor has been that each vendor of a machine tool or piece of manufacturing equipment would speak a unique "language", making the shop floor like a version of the United Nations with no translators. Without a common language, it was extremely difficult to get information out of a machine tool or piece of manufacturing equipment, and it was too expensive to maintain monitoring unless the manufacturer was very large and had lots of money to spend on software translators and custom solutions.

All of this has changed with the introduction of a new shop floor standard called MTConnect. MTConnect is the tool that translates the information obtained from a given machine tool or piece of manufacturing equipment into a common language. This common language is based on Internet standards and makes it very easy for software companies to write software applications that can easily monitor the shop floor and perform many other types of analyses. In other words, MTConnect is the "Bluetooth" of manufacturing. As such, MTConnect is not an application but rather a common translator that allows any machine in a plant to easily talk to software applications, such as a shop floor monitoring protocol, so that manufacturers know what is happening on the shop floor and can use that information to make changes to be more productive. As stated in *Modern Machine Shop*, when MTConnect is combined with a shop floor monitoring application, tremendous productivity gains in manufacturing are achieved.

Objective

The purpose of this document is to demonstrate the tangible benefits of monitoring a manufacturing plant, and of using the open and royalty-free standard called MTConnect as the way to get information off the shop floor.

Factory floor data is a modern day resource that can and must be gathered and used by decision-makers of all kinds within a manufacturing organization. Very much like underground natural resources such as oil, coal and natural gas, it's been there forever, just waiting to be extracted from deep inside each machine. This factory floor data can be mined by using a software and/or hardware system of agents and adapters. The data is then sent to applications where they are refined and prepared for consumption by various departments of the organization. Once the data is unlocked in a manufacturing environment, an organization can implement an endless number of improvements across several domains (e.g. quality improvement, data analysis, software development, process engineering, personnel, etc.) This capacity alone should make machine monitoring an attractive option for any manufacturer. With this new data, an organization can be assured that what it is doing is correct, can make changes to process when required, and can envision new opportunities that might otherwise have passed by unnoticed.

Quite often, shop owners assume that MTConnect is intended only for CNC type machines, but that is not the case. In the past, the different proprietary applications operating the various machines in a plant made it very difficult and expensive for some shops to enable their equipment for data collection. This was especially true for plants with different types of machines from different manufacturers. In particular, older "legacy" machines have proven to be challenging to monitor in real time. With MTConnect, simple sensors can be attached to any machine to allow monitoring and collect data in any one of several ways. Because the data is converted to XML format, the standard way to share information on the Internet, a manufacturer is able to integrate its machine data with just about any application, including MS Excel, MS Access, ERP Systems, Web pages, etc. In addition, as legacy machines are phased out and new machines replace them, the monitoring process remains the same. With MTConnect in place, there is no need to seek out or integrate a new hardware/software solution to monitor the new machines. Importantly, an increasing number of industrial equipment manufacturers are offering MTConnect connectivity as an option.

This white paper discusses a number of issues to be considered when determining what the tangible business benefits of machine monitoring are, and describes what adopters of MTConnect have already experienced. It also provides preparation for discussions with internal stakeholders or external third-party solution providers, and hopefully assists in

removing any barriers to MTConnect adoption. This guide does not address third-party vendor-specific requirements for implementing software or hardware applications that use data conforming to the MTConnect standard.

Neither will vendor-specific hardware or software solutions be highlighted in this white paper. Only guidelines and benefits that should be evaluated by anyone considering the implementation of MTConnect on their production floor are discussed.

Note: For the balance of this white paper, the terms "Device" and "Devices" will be used to describe any machine tool or other piece, or multiple pieces, of industrial process equipment on the shop floor.

This white paper has been prepared by a working group whose members are listed below. These organizations were selected to be a mix of MTConnect software and hardware solution providers, as well as end-users who have real-life experience with MTConnect at their manufacturing facilities.

- Memex Automation Inc. (Chair)
- General Dynamics – OTS
- Scytec Consulting Inc.
- MacKintok Inc.
- Connecticut Center for Advanced Technology, Inc. (CCAT)
- Task Force Tips
- Remmele Engineering, Inc.
- System Insights, Inc.
- Virtual Photons Electrons, LLC (Co-Chair)

Who Will Benefit from this White Paper

An ever-increasing percentage of companies are recognizing that the possibility of garnering shop floor data from their manufacturing assets exists today, but are unsure of the net business benefits associated with financing and undertaking a project to implement the standard. It is the purpose of this white paper to introduce companies to some of the tangible benefits associated with monitoring shop floor assets utilizing MTConnect, with a view to generating the necessary impetus to move from thought to action.

As the common and universal way to extract information from manufacturing equipment and transfer it to a shop floor monitoring software application, the MTConnect open and royalty-free standard have enabled dramatic improvements in equipment utilization. Companies are achieving concrete savings in both time and money.

So, who will benefit?

- Production benefits from having visibility of operations and increased efficiency.
- CEO's benefit from increased profitability of their manufacturing operations.
- Engineers benefit from having access to a significant amount of data about their machining processes.
- Operators benefit from being able to communicate better with the machine and all stakeholders affected by the machines.

What is MTConnect?

MTConnect is an open, extensible, and royalty-free standard protocol suitable for use with any type or manufacturing device. As an open standard, MTConnect is based on proven, well defined and commercially available Internet technologies. The MTConnect protocol is based on HTTP and XML (Extensible Mark-Up Language, the underlying language of most web sites).

An important aspect of MTConnect is its extensibility. This property means that MTConnect was designed such that items can be added and monitored dynamically, and so that the protocol is not locked to a specific and static set of monitoring items. This capacity means greater flexibility for both shop floor monitoring and accommodating the changing needs of manufacturing companies.

Why MTConnect versus a Proprietary Protocol?

Prior to MTConnect, each shop floor would implement their own, proprietary machine monitoring protocol to connect the Internet to the wide variety of manufacturing devices on the shop floor. What is a protocol? A protocol is defined as the common set of rules and instructions that both devices and applications use when they communicate. MTConnect is a protocol that can be thought of as the "Bluetooth of manufacturing". In the same way that people expect their phones and cars to support Bluetooth, makers of manufacturing equipment are now expected to support MTConnect.

The true value of MTConnect-enabled manufacturing equipment is sometimes misunderstood by the end-users. Unlike a proprietary connection, MTConnect allows both ease of integration and "future-proof" decision-making. When a proprietary mechanism is used to monitor the shop floor, the end-user is 100% locked in to that particular software solution, both in the present, and in the future. When MTConnect is used to monitor the shop floor, the end-user is no longer locked into one particular machine or software. The manufacturer can swap out various MTConnect-enabled shop floor monitoring solutions at any time and never have to change the equipment in the plant. This is a big win that saves a manufacturer time and money, both at that precise moment, and in the future.

Another advantage of MTConnect is that multiple applications can access data from MTConnect-enabled manufacturing devices simultaneously. This flexibility distinguishes MTConnect from most proprietary installations, where a given port is locked in to a single application. From a financial perspective, it is typically less expensive to MTConnect-enable a piece of manufacturing equipment than it is to install a proprietary connection. The greatest advantage is achieved when enabling the shop floor equipment is taken as the first step, and selecting the shop floor monitoring software is taken as the second.

SECTION II – Uses of Data Obtained via MTConnect

There is essentially no limit to how companies can benefit from the data obtained via MTConnect from the shop floor. This information can be used to improve operations, track production, and justify decisions that affect plant operations. Some of the more common uses for shop floor data are:

- Production Dashboard or Monitor
- Alerts

- Equipment Availability and Usage
- Overall Equipment Effectiveness
- Production Reporting/Tracking
- Energy Conservation
- Mobile: Anywhere, Anytime Access to Plant Floor Information
- Quality and Statistical Process Control
- Data mining
- Genealogy
- Security

Each of these uses is addressed in detail in the following sections.

Production Dashboard or Monitor

A dashboard is a real-time overview display showing the current state of each machine in a manufacturing plant. The dashboard provides a high level view of the production facility and can identify problems on the shop floor requiring attention, or it may focus in the detailed functioning of specific devices. Typically, a dashboard takes the form of a display on a monitor or TV screen that may be placed on the shop floor itself, or in the offices of workers monitoring quality assurance, operations, maintenance, or production; i.e. wherever the end-user decides that the data has value. The dashboard can convey machine state information at various levels of detail, including Running, Idle, and Failed (Green/Yellow/Red), or any other data item of interest. Many software systems also provide a "drill down" feature to the dashboard to allow access to additional details on a specific machine. This information may appear on secondary screens dedicated to that machine or group of machines, or even customized graphical layouts designed for intuitive quick viewing.

Alerts

Alerts are notifications of changes on the shop floor that require the attention of management or maintenance, etc. Typically, alerts provide immediate identification of issues associated with a malfunctioning machine and its related processes. These can

include actual problems or pending problems that must be addressed to avoid a process interruption. Examples include: 1) Machine Down due to a specific fault or alarm; 2) Parts Running Low – Additional parts required; 3) Filters becoming clogged – Maintenance required; and 4) Irregular Activity while a machine is running. By tracking this information in real-time and enabling Alerts, managers can react quickly and send a notification via email, text message, or tweet to the appropriate people. Alerts can eliminate any unplanned downtime, which leads to a higher throughput and profitability.

Equipment Availability and Usage

Equipment availability and usage is a property of each machine that describes how effectively it is being utilized. A set of machine states is typically pre-defined based on machine and process requirements. The machine is then monitored by the data collection system, and the time that the machine is in each state is then accumulated and reported. These reports typically provide the data displayed based on multiple parameters, such as Real-Time, Hourly, Daily, Weekly, Monthly, Shift, Operation, Part, etc. Report formats vary, but usually are presented either in table format, bar charts, or line charts.

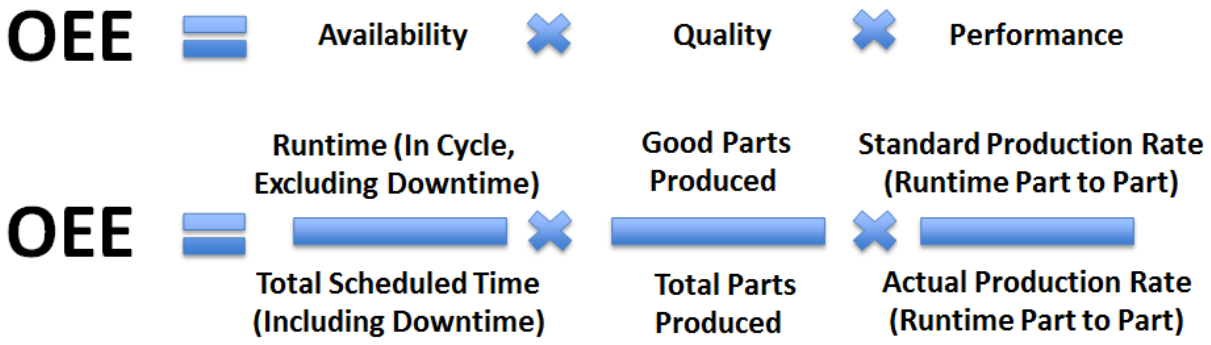
Machine Utilization is an effective parameter with which to evaluate the overall effectiveness of projects or operational changes aimed at incrementally improving the productivity on the shop floor. It is not cost-effective to have expensive equipment and their operators sitting idle for long periods of time. Machine Utilization values clearly show the amount of time parts spend in each state over time, allowing the operator to determine which devices have additional capacity available. Additional capacity means that more jobs can be taken on to generate additional revenue. By implementing interactive evaluations of machine utilization, capacity can be increased in a continuous manner.

Machine Downtime is a parameter that can be used to determine the root cause(s) for lost production time. Data can be collected from the machine to assess each non-productive machine state. Furthermore, the Machine Downtime Analysis can be divided into Planned and Unplanned Downtime. The Unplanned Downtime can then be segregated into specific causes for production losses. Once the causes of production losses are identified, projects can be undertaken to eliminate or reduce these unplanned downtimes. By tracking machine downtime, it is much easier to determine if scheduled maintenance or other activities do indeed minimize it.

Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) combines Machine Utilization information with quality measurements to provide a tool to compare the end-to-end effectiveness of any process or machining operation with its designed capacity. OEE is used to measure how a production operation changes with time, determines the impact of changes made on the shop floor, and compares the effectiveness of different processes or machines.

Mathematically, OEE is the product of three ratios expressed as a percentage, and aggregated plant-wide OEE = capacity utilization.



Customers who have implemented OEE utilizing MTConnect typically experience an **increase in Capacity Utilization (CU)** of 30% plant-wide, a minimum increase of 11% and a maximum increase of 110%. The tracking of OEE has a considerable financial impact in that a 10% increase in CU generates a 21% increase in **I**ncome **F**rom **O**perations ("**IFO**"). IFO is defined as operating income, EBITDA. An example is shown in the figure below.

ABC Co	Company Performance Prior to OEE	Plus 10% CU	Plus 20% CU
Revenue	$ 10,000,000	$ 10,000,000	$ 10,000,000
COGS	$ 7,577,465	$ 7,323,099	$ 7,068,732
SGA	$ 1,211,268	$ 1,211,268	$ 1,211,268
EBITDA	$ 1,211,268	$ 1,465,634	$ 1,720,000

Note: **CU** = Capacity Utilization **COGS** = Cost of Goods Sold **SGA** = Sales, General, Admin. **EBITDA** = Earnings Before Interest, Taxes, Depreciation, Amortization.

Production Reporting/Tracking

MTConnect allows production data to be gathered directly from the machines and transferred to software applications that can analyze the data. For example, various applications can monitor production levels, manage product flow through the production process, track inventory and raw material queues, and monitor many other aspects of the shop floor. Examination of these results can then be used to increase the effectiveness of lean and just-in-time practices, thereby optimizing the utilization of high-value assets and personnel. Reports on production can be provided in "near real-time" or periodically, and displayed in multiple parameters such as Hourly, Daily, Weekly, Monthly, Shift, Operation, Part, etc. Once again, the data can be presented in a variety of formats, such as tables, bar charts, or line charts. Drill-down capabilities can provide a detailed analysis of production data associated with individual machines, operators, work orders, shifts, parts, and production lots.

Visualization of Maintenance Tracking, Problem Resolution and Planning

Maintenance issues typically fall into two categories – reactive, such as Machine/Process Faults, and proactive, such as Preventative Maintenance. The use of MTConnect and the appropriate software application can help resolve issues in both categories. With respect to the Machine/Process Faults, alerts and real-time dashboards can be used to advise maintenance teams immediately of problems on the shop floor. With respect to Preventative Maintenance, plans are often based strictly on calendar time (monthly, quarterly, or annual) with no consideration of actual production status or machine usage. By measuring operating times or number of operations directly from the devices, information is gained that permits more effective management of preventative maintenance schedules. Many times, early identification of an issue or change in the plant can prevent the development of more significant problems.

For example, consider a manufacturing company whose President received an email alert whenever an E-Stop occurred anywhere in the plant. When an E-Stop occurred, the ceramic bearings and spindles of the machines would often be damaged. The spindles alone ranged in cost from $30,000 to $100,000, and the unexpected E-Stops were taking a heavy financial toll on the company. By receiving email alerts about E-Stops, the President could then immediately notify those responsible for performing a real-time analysis and determining why they were happening. The lessons the company learned were then rapidly applied in order to minimize the number of times E-Stops happened in the future.

The MTConnect protocol monitors the status of equipment in real-time and quickly alerts operators and maintenance personnel of potential problems or needs. In addition, MTConnect can be used to link the monitoring software to networked corrective action solutions. If a web-based portal is used, it is easy to connect the staff to other network locations of information that will help to guide them through the necessary corrective actions, and document that the process was done correctly. Often when performing a maintenance or setup procedure, technicians have to decide what to do next based on the status of the machine. MTConnect can provide the visual feedback needed to facilitate the decision-making process and ensure the machine is fixed or set up properly. Images, graphics and data representing the current state of the machine can be displayed based on real-time notifications and data streams, taking the guesswork out of whether a procedural step was performed correctly. As a result, technicians gain valuable confidence and assurance that they performed their jobs accurately. Self-adjusting procedures by the machine itself, including corrective actions based on real-time data are possible with MTConnect. With the machine acknowledging its previous corrective actions, this can assist the workers in their decision making, if a previously acknowledged corrective action is displayed on the screen. Further analysis on human actions in real-time can be visually represented to identify weaknesses in equipment, components, or processes.

Energy Conservation

Manufacturing is among the most energy-intensive human activities since the industrial revolution. Energy industrial consumption has been monitored and has been traditionally viewed simply as a "bill to be paid". Today, manufacturing accounts for almost 30 % of all greenhouse gas emissions in the United States, and the costs of energy generation are increasing on average by 10% per annum. Thus, companies are seeking strategies for energy usage optimization with an eye to decreasing both costs and pollution. However, there has been a wide gap between monitoring energy consumption and actually correlating that data to the operational activities in a factory. With MTConnect, every kilowatt spent on a particular machine, part, work order or client, can be tagged in real-time. In addition, infrastructure items like pumps, chillers, air compressors, HVAC and lighting can be monitored to provide a complete view of a plants energy consumption.

For example, one manufacturer in the Midwest U.S. was able to obtain dramatic energy savings by monitoring its plant's energy usage and demand patterns, turning energy costs into a controllable operating expense. This case study will be presented in a session on MTConenct.org on how MTConnect implementation can quantify Energy Performance Indicators (EPIs) and Return on Investment.

MTConnect also reduces the cost of implementing test standards such as the Baseline Energy Consumption (BEC) standard for machine tools. The BEC metric is a standard measure of the energy consumption of machine tools. Applications of BEC include estimating the approximate energy requirements of operating a machine tool to manufacture a specific part, comparing the energy requirements of two machine tools that are being applied in similar activities, and performing Return-on-Investment calculations to justify energy efficiency improvements in machine tool and machining technologies. MTConnect makes it possible to develop standardized testing tools since the data collected from different types of machine tools will be in the same format. It is then easy to apply the same set of test tools to data obtained from different types of equipment.

Mobile: Anywhere, Anytime Access to Shop Floor Information

Personal communication devices, ranging from mobile phones to tablets, are changing the way people access and interact with information. MTConnect enables seamless, ubiquitous collection of information from the shop floor because it greatly simplifies the integration of disparate types of devices and data sources. Since MTConnect is an Internet-based standard, MTConnect acquired data can be applied to existing Web-based paradigms and frameworks, including those operating on mobile phones and other personal communication devices. This capacity can radically change how people consume data pertaining to the manufacturing shop floor, enabling remote access and visibility into the plant from virtually anywhere in the world. Such immediacy has the potential to radically decrease response times to problems, increase communication across complex supply chains, and reduce the cost of integrating geographically distributed manufacturing enterprises.

Quality and Statistical Process Control

Statistical Process Control (SPC) applications can use MT Connect-enabled Machine Utilization information to more accurately collect information and predict when quality issues might occur. These applications also can proactively determine when adjustments and tool changes should occur to prevent problems. During precision manufacturing, even a prolonged loading time between cycles can significantly affect part quality. With real-time machine utilization data, this effect of loading time can be accounted for. MTConnect-enabled SPC can improve the effectiveness of quality management systems, both by highlighting wasted effort and by helping to focus resources where they are needed. MTConnect also permits the tracking availability and usage of quality monitoring equipment, such as CMM, jigs, fixtures, and gauges, potentially facilitating more effective equipment utilization even in the Quality Assurance lab.

Data Mining

The large amount of data a manufacturing facility produces presents a challenge to any attempt to identify factors that could improve a manufacturing process. Data mining is a technology that can be used to analyze vast amounts of data and identify inherent knowledge structures within that data. One can then extract information regarding every variable in every step of a manufacturing process, and this information can in turn be used for process improvement and model development. Considering the large number of variables and sheer volume of data generated by a manufacturing plant in most situations, data mining may be the *only* practical analysis solution available. Data mining combines powerful computing techniques, with machine learning and statistical analysis to achieve this goal. Computing techniques assure the fast handling of large data volumes; machine learning is used for 'knowledge discovery' or the creation of knowledge structures; and statistical methods are used to ensure that knowledge structures are fully optimized.

Examples of analyses that can be performed with data mining include:

- Associating alarms with phenomena occurring immediately prior to the alarm
- Determining sources of poor quality in a manufacturing supply chain
- Identifying sources of high energy expenditures

With respect to data mining methods, techniques exist that can consume every type of data, from unstructured to highly structured, from low to high dimensional, and from sparse to

dense. These techniques can be applied to most aspects of the manufacturing process, from development to delivery of the final product, and everything in between. Specific aspects include:

- Maintenance
- Materials planning
- Process optimization
- Scheduling
- Fault detection
- Operator impact

For the most efficient and effective implementation of data mining, the extracted data must be presented in a common structure, a process facilitated by MTConnect. In addition, with the use of a standard data interface, MTConnect allows the seamless integration of analysis tools from external parties into the analysis structure of the organization. The time needed for the staging and Extract, Transform, Load (ETL) segments of any integration project will thus be minimized. MTConnect can ensure that analyses performed on vast data sets collected across disparate equipment, facilities, and even countries, are completely consistent with each other.

Genealogy

An increasing number of companies are requiring cradle-to-grave part tracking. The "cradle" is the date when a part is completed and the "grave" is the date the part is otherwise disposed of. Cradle-to-grave part tracking is quite common with medical devices. Some companies are starting to track parts prior to the cradle, going back to which piece of manufacturing equipment actually created the part, and all of the actions performed by manufacturing equipment during part creation. A single machine tool can generate a lot of data during the creation of a part. With MTConnect, all of this creation data can be stored in a database so that if a part fails, a company can not only determine which manufacturer created the part, but they can also go all the way back to the actual manufacturing process and run analytics to detect anomalies in the part production process. This precision tracking can reduce the expenses associated with large product recalls.

Security

MTConnect is secure because it is a read only protocol whose function is passive data collection. The benefit of this restriction from a security standpoint is that it is impossible for MTConnect to make a change to any manufacturing device since the protocol can only ask for information. In other words, MTConnect can never instruct a machine tool or manufacturing device to take an action. The MTConnect Institute does recommend that all data be encrypted whether they are "in flight" on the network or "at rest" on the disk drive. Encryption is a basic security step that any manufacturer should insist upon.

SECTION III – MTConnect Technical Overview

MTConnect Specifications

For further technical information on MTConnect, please visit MTConnect.org

Connecting a Device to a Network

For detailed information on how to MTConnect-enable devices on the shop or plant floor, please refer to "Getting Started with MTConnect – Connectivity Guide", located at MTConnect.org The Connectivity Guide will answer most technical questions regarding what is involved in making manufacturing equipment MTConnect-enabled or ready. The Connectivity Guide can be viewed as a companion document to this white paper and is intended for those individuals who want to understand the specific steps in MTConnect-enabling their plant or shop floor manufacturing equipment.

SECTION IV – Comments, Questions or Suggestions

Any questions or comments on this white paper should be sent to a Dave Edstrom at DEdstrom@MTConnect.org. Dave will share your comments, questions or suggestions with the authors of this white paper and reply back to you. The goal of the MTConnect Institute is to continually improve this white paper to make it as useful as possible to those manufacturers who want to understand the benefits of monitoring their shop or plant floor using MTConnect. Through its open standard and royalty-free protocol, MTConnect is the ideal way to forge a common connection among multiple different manufacturing devices.

