
Introduction



MOBILE | **TOOL**
MANAGEMENT

Mobile Tool Management, Inc. (MTM) delivers high-quality automated portable tools and software systems to the aerospace industry which enable faster time to market for our customers. Our philosophy is to collaborate with our customers to develop new product technologies that are targeted to the customer's needs. MTM's facility is located near Paine Field in Mukilteo, WA and consists of a 10,000 ft² design and manufacturing facility with a UL panel shop and fully capable machine shop. MTM carries a full host of engineering and management staff to execute system solutions, including mechanical, electrical, and software engineering personnel as well as project management staff.

MTM's core capabilities include:

- Full turn-key manufacturing of portable automated machine systems
- Design, development, and support of automated and networked machines and tools
- Machine and system mechanical design, implementation, and deployment
- Machine control software development with intuitive human interfaces
- Factory-wide software designs and implementations for orchestration of manufacturing processes
- Development of factory-wide resource management tools, including resource reservations and positioning
- Software solutions for process and quality control, deployed on the customer's enterprise network
- Software systems to close the loop between manufacturing plans and manufactured product

MTM has been in business since 2003 and has delivered more than 40 manufacturing system deployments which have been comprised of machines, tools, machine software, enterprise software, and deployment support. Our systems have been deployed globally in the United States (Washington, South Carolina, Georgia, and Salt Lake City), Japan, UK, France, and Italy.

MTM delivers complete manufacturing solutions from top to bottom—enterprise to the factory floor.

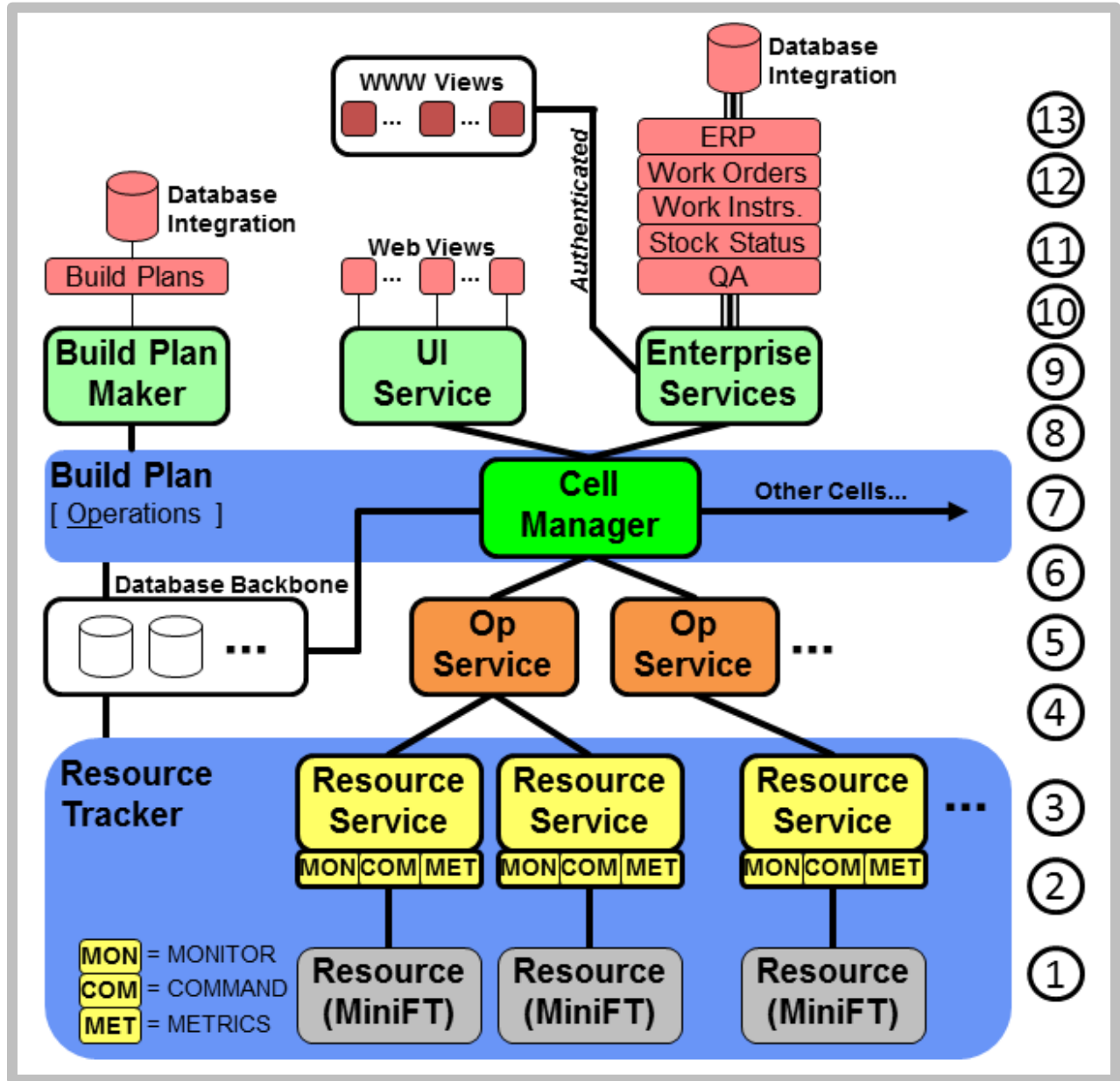
This document describes MTM's "Serenity Software Suite", a collection of distributed software products and optional custom-tailored hardware products which enable the creation, deployment, and monitoring of complete manufacturing systems in any industry.

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Serenity Software Suite – Overview

The **Serenity Software Suite ("Serenity")** is a collection of software services that enables complete vertical software visibility for manufacturing environments (e-Manufacturing). This suite of software enables digitization and consumption of build plans as well as command and tracking of manufacturing resources such as Mini FlexTracks. Serenity Suite provides dashboard monitoring features at all levels throughout the factory: from the floor all the way to the corporate enterprise network. Referring to the following figure entitled "Serenity Software Suite, Major Components" and working up the numbered layers, the features and benefits include:

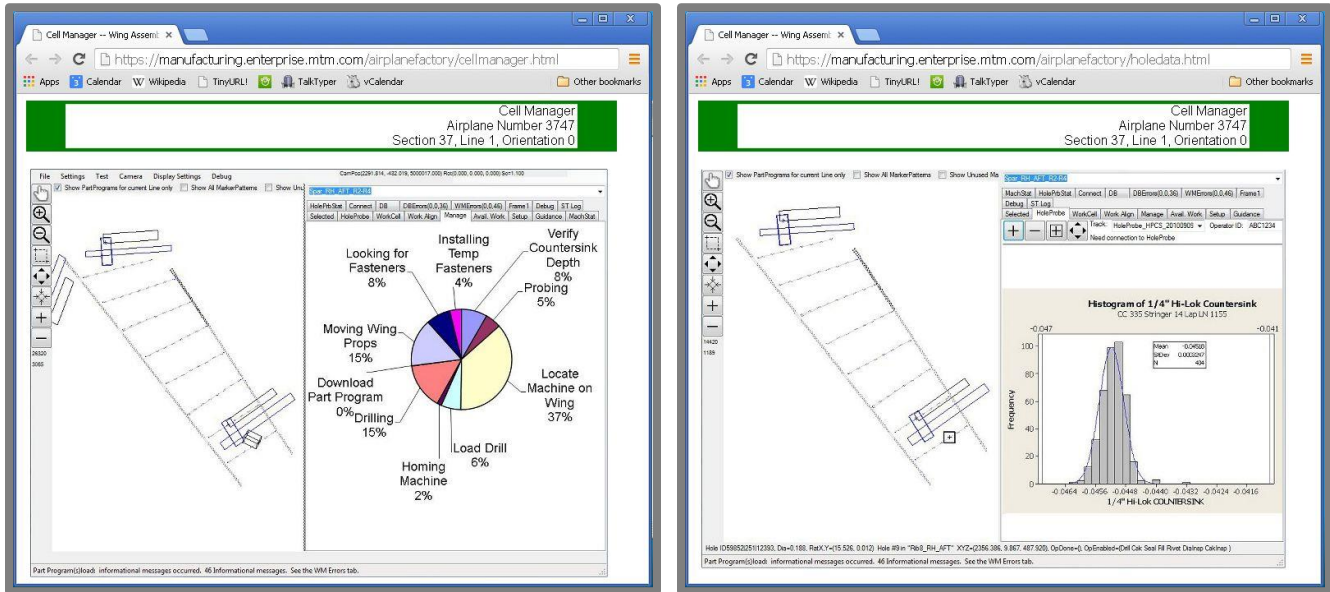
- **Network-enabled Mini FlexTracks (MFTs) [1-2]** are machines which have built-in networking hardware and software components for connecting them to your factory Ethernet or wireless network. Beyond physical connection to your network, MFTs are registered onto the Serenity network through two software components: 1) "Resource Services", and 2) the "Resource Tracker". Both of these software components are discussed below.
- **Resource Services [3]** are gateways that enable MFTs to be on the Serenity network. These software services translate between the MFT-specific communication protocol and the Serenity backbone protocol. Resource Services can have three components: monitor (MON), command (COM), and metrics (MET):
 - **Monitor and Command** features provide status and control of MFTs. For example, MFT motion and programming commands, MFT status and condition, and MFT physical location.
 - **Metrics** receive real-time data from the MFTs. This data captures the duration of MFT operations for both automated events and manual operations involved in MFT setup. Metrics can be real-time or historical, and rendered in any browser in many formats (e.g. pie charts, Pareto charts, histograms, etc.). Example metrics for a MFT include NC/Part Program execution time, hole-to-hole cycle time, tool-change time, human setup times, machine down-time, inspection times, etc.
- **The Resource Tracker [3]** provides a network database for tracking MFT machines, NC/Part Programs, drill processes, and tools. It maintains characteristics of MFT machines such as physical availability, operational status, and physical locations. It provides NC/Part Program management, including entry, selection, delivery, and maintenance of the digital NC/Part Programs. This digital asset management is also applied to drill process information and machine tool databases. The Resource Tracker gets information direct from the MFT machines, from NC/Part Program software applications, and from tool database sources. As a result, the following features are offered:
 - **NC/Part Program Process Management** is achieved since NC/Part programs and hole/stack processes are derived from the Enterprise network and database using company-native CAD tools. These manufacturing production files are fully version-controlled and maintained within Serenity's databases which can be linked to the Enterprise database infrastructure. Final delivery of NC/Part Programs to MFTs is managed through this controlled path.
 - **Tool Traceability** is achieved with a tool database component to perform tool selection verification, storage of gauging information about tools, and activity logging to track tool lifetime usage.
- **Operations Services [4,5]** are upstream from Resource Services and they represent the sequence of build instructions needed to complete a particular subassembly within the Build Plan.
- **The Cell Manager [6,7]** orchestrates Op Services and it is the main consumer of the digitized Build Plan. This structure allows one Cell Manager to be a peer or parent of other Cell Managers (e.g. many cells within one factory, many factories [cells] across multiple geographic sites, etc.). The Cell Manager also maintains historical data for post-production and trend analysis. Finally, as a manager of database information, the Cell Manager can be aligned with your database technologies (MS SQL Server, Oracle MySQL, NoSQL, etc.).
- **Coordination of Multiple Mini FlexTracks (MFTs) [1-7]** is made possible by deployment and planning of multiple Op Services in conjunction with orchestration from the Cell Manager. This allows multiple MFT machines to be deployed in parallel, simultaneous operation to increase manufacturing efficiency and production rates.
- **Web service technology [3-11]** is used for Serenity backbone communication and for user views from Web browsers. This allows for easy access to the system: a Web browser is all that is needed.
- **User Interface (UI) Views [9-11]** are browser-based portals for accessing all of Serenity. Because of the magnitude and scope of a complete manufacturing system, specific instances of UI Views are typically developed to match your manufacturing needs. Secure access and permissions are controlled through user roles and Web-based authentication procedures as dictated by the customer.
- **Enterprise Services [8-12]** represent the interface to your existing corporate and manufacturing network infrastructure. Because Serenity is based on Web technology and services, integration with your enterprise network can be transparent and aligned with modern trends in network operability. Software service adapters reduce vendor-specific dependencies when interfacing with your pre-existing enterprise resources.
- **Online Assistance and Maintenance [13]** can be employed due to the web technologies employed within Serenity. With proper access roles granted for support, this feature allows for remote monitoring of controller status and error messages, debugging of performance issues with real-time response, live remote training assistance, and remote monitoring of energy usage through the addition of energy metrics monitoring.



Serenity Software Suite, Major Components

Serenity Software Suite – Mini FlexTrack Gallery

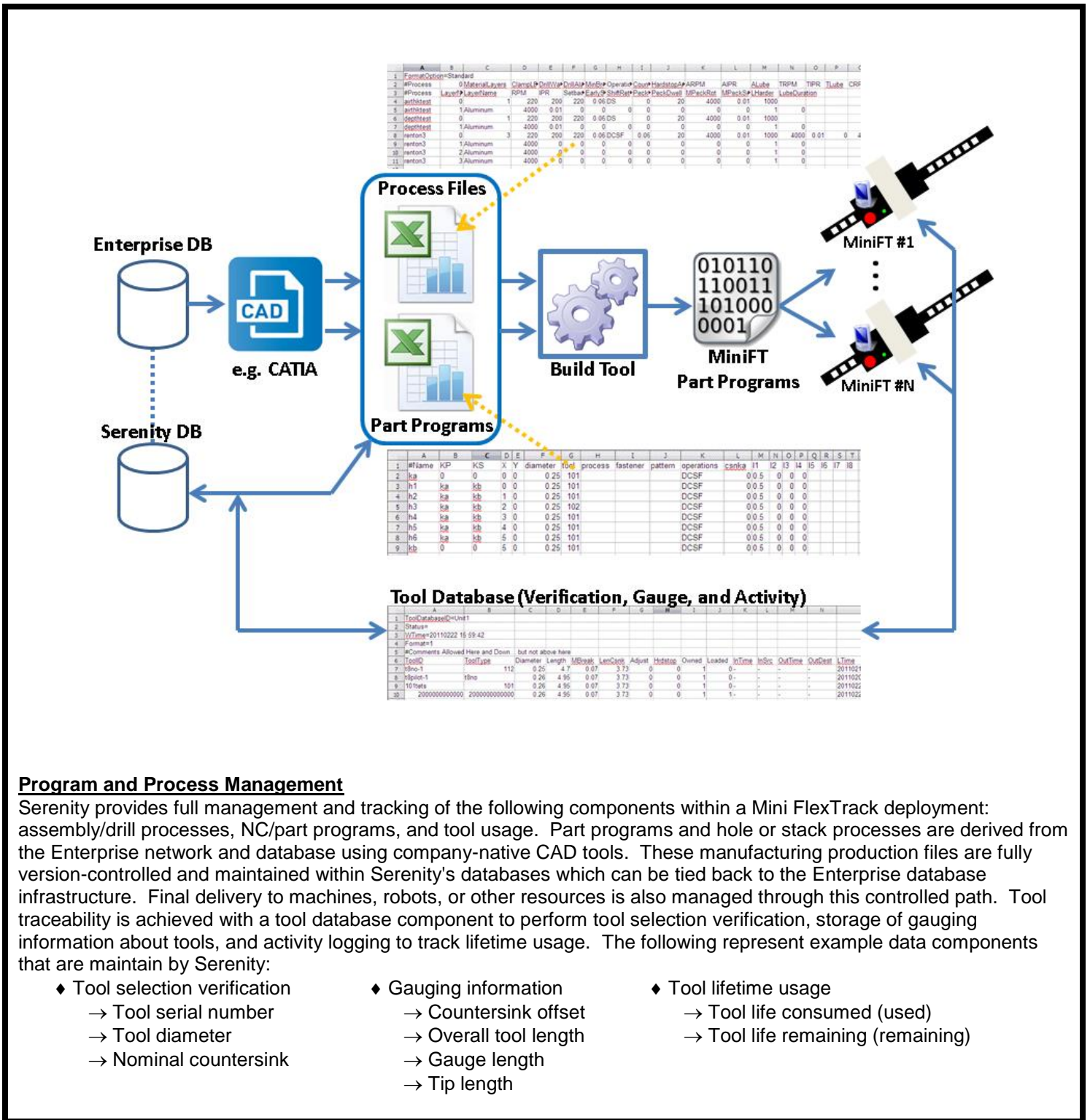
Although Serenity can support a wide range of machines, robots, tools, and resources from any vendor, this gallery shows examples for deployments which are focused on Mini FlexTrack support. This gallery shows just a few example components and features that can comprise the Serenity Software Suite when deployed to support Mini FlexTrack machines.



Example Web Views

This shows an example airplane wing manufacturing work cell. The image on the left shows a visual representation of the work piece (the wing) along with data from Metric Services shown as a pie chart visualization (displaying manufacturing time spent on steps such as setup, operations, calibrations, etc.). The image on the right is similar, but it shows a histogram of historical manufacturing quality assurance data for hole probe measurements which can be recorded on the fly during manufacturing.

Serenity Software Suite – Mini FlexTrack Gallery, Continued

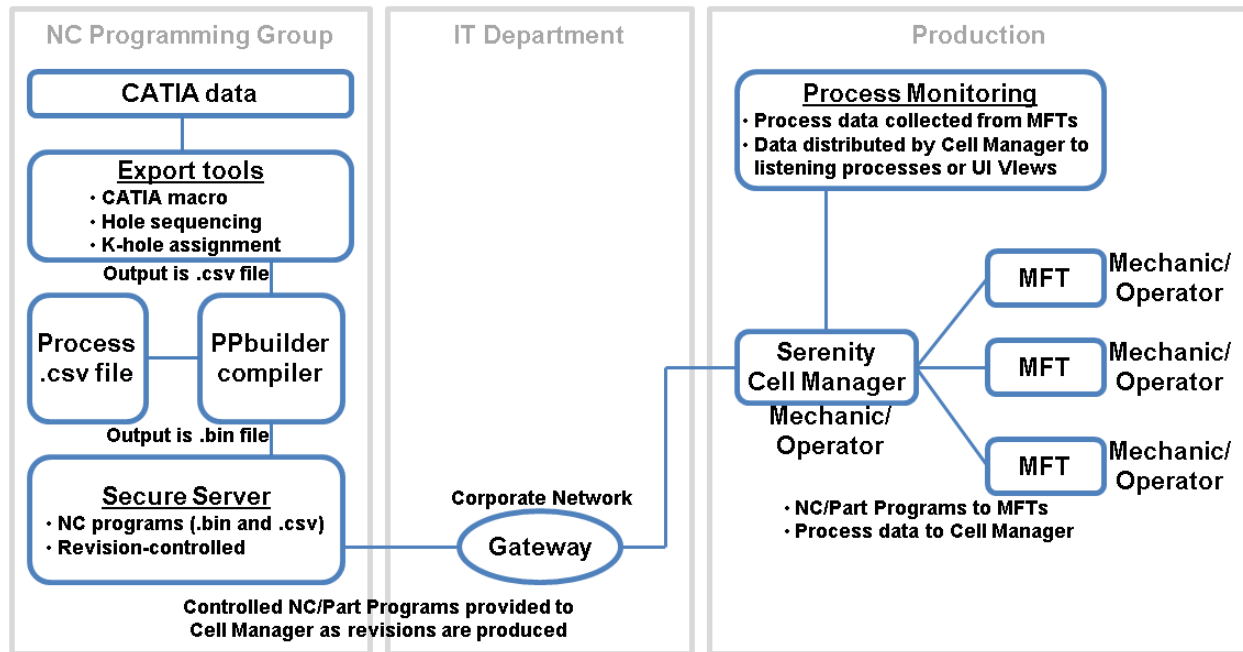


Program and Process Management

Serenity provides full management and tracking of the following components within a Mini FlexTrack deployment: assembly/drill processes, NC/part programs, and tool usage. Part programs and hole or stack processes are derived from the Enterprise network and database using company-native CAD tools. These manufacturing production files are fully version-controlled and maintained within Serenity's databases which can be tied back to the Enterprise database infrastructure. Final delivery to machines, robots, or other resources is also managed through this controlled path. Tool traceability is achieved with a tool database component to perform tool selection verification, storage of gauging information about tools, and activity logging to track lifetime usage. The following represent example data components that are maintain by Serenity:

- ◆ Tool selection verification
 - Tool serial number
 - Tool diameter
 - Nominal countersink
- ◆ Gauging information
 - Countersink offset
 - Overall tool length
 - Gauge length
 - Tip length
- ◆ Tool lifetime usage
 - Tool life consumed (used)
 - Tool life remaining (remaining)

Serenity Software Suite – Mini FlexTrack Gallery, Continued



NC/Part Program development and machine process monitoring

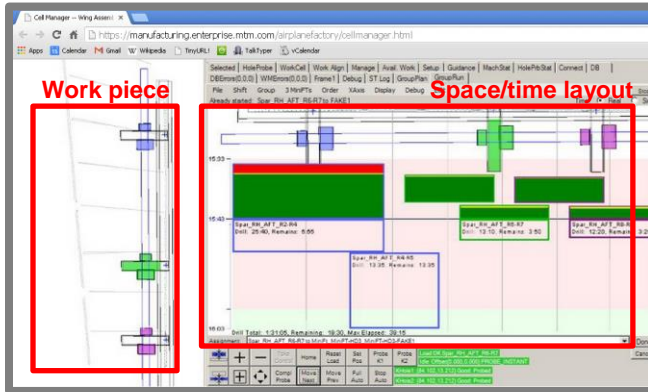
Serenity provides an interface with CAD/CAM departments and software tools to facilitate NC/part programming of Mini FlexTracks. This includes post-processor development, NC programming for first articles and follow-on runs, as well as the ability to produce NC programs off-line.

Using a combination of MFT software tools and Serenity components, the customer can perform NC programming with CATIA V5 / DELMIA V5 software. MTM can accommodate customer programming experts to organize meetings and reviews of programming solutions for validation. MTM provides example programs and all documentation regarding the machine and process capabilities (e.g. characteristics of motion axes, control limits, etc.)--the documentation set describes all sub-routines and how G and M codes are used.

Additionally, key process and machine parameters can be made available over the Serenity infrastructure when MFTs are deployed. Examples of such parameters include:

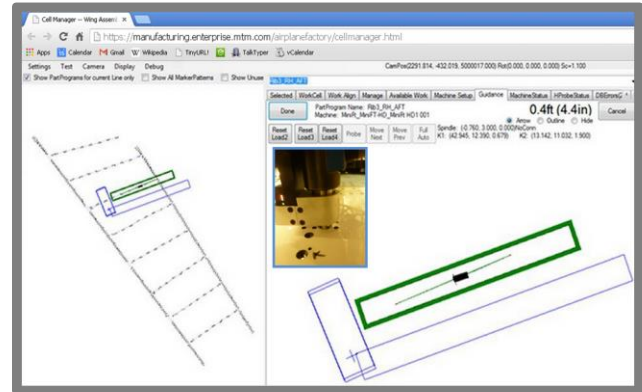
- Current NC/Part Program being referenced
- End effector type
- Position of the system on or around the work piece
- Live action feedback
- End effector currently used (e.g. Automated Drill Unit [ADU], fastener insertion, torque-down, etc.)
- Quantity of holes drilled and remaining quantity of holes to drill
- Estimated time remaining and time consumed for the current drilling operation
- Process control (start, pause, restart, etc.)
- Remaining time until manual control or intervention

Serenity Software Suite – Mini FlexTrack Gallery, Continued



(a)

Part program division, machine delegation, time/sequence planning, and collision avoidance can be seen here in the view of the work piece (left) and the deployment map which shows spatial layout and time slots (right).



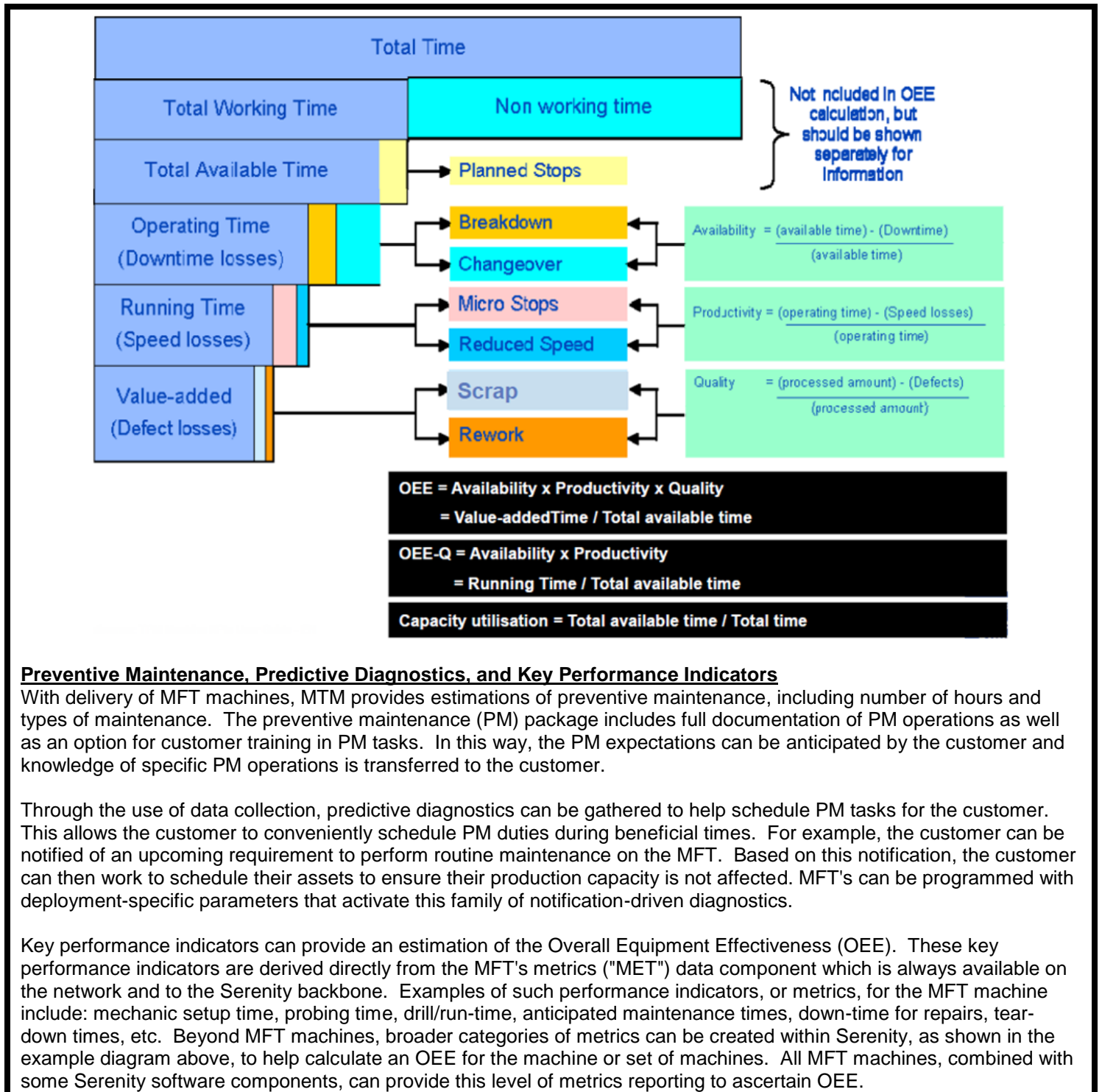
(b)

Machine placement aids: example here shows green work envelope of machine to ensure all hole locations within a part program can be reached after placement. Also shown is an optional live video feed of the drilling end effector for visual feedback.

Coordination of Multiple Machines

Serenity provides features for manufacturing planning when using multiple Mini FlexTracks. This includes part program division and machine delegation, machine placement aids, time and sequence planning, and collision avoidance. Division of the work piece into sections allows specific Mini FlexTracks to work in defined zones based on part program extents. This feature maximizes machine capacity on a work piece by allowing machines to operate in parallel to increase production rates. Additionally, these operation zones can accommodate unique manufacturing requirements like keep-out zones. Machine placement aids help reduce setup times by automatically guiding the Mini FlexTrack into its work position or by providing spatial feedback to a human operator that reduces setup times. Time and sequence planning can be performed automatically with a scheduler using spatial inputs about the work piece and predicted completion times for jobs in each zone. Finally, with the known operational extents of the machines, Serenity can pre-plan to ensure no machine collisions. Additional layers of safety are also incorporated at the machine level to prevent collisions through the use of sensors onboard the Mini FlexTrack -- this low-level collision system also reports upstream to the Serenity backbone. Thus, Mini FlexTracks operating under Serenity benefit from two-way collision avoidance features at both the planning stage and the operational stage.

Serenity Software Suite – Mini FlexTrack Gallery, Continued



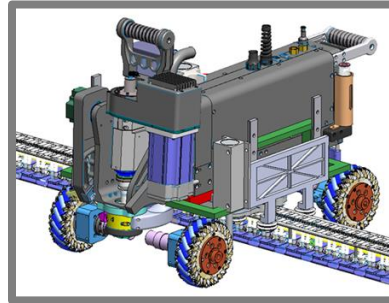
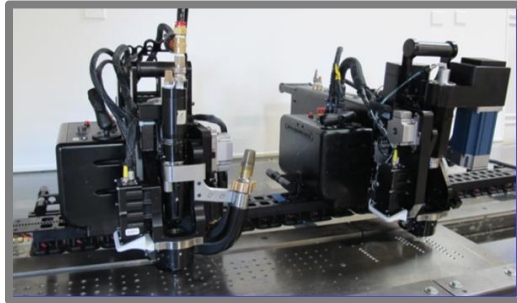
Preventive Maintenance, Predictive Diagnostics, and Key Performance Indicators

With delivery of MFT machines, MTM provides estimations of preventive maintenance, including number of hours and types of maintenance. The preventive maintenance (PM) package includes full documentation of PM operations as well as an option for customer training in PM tasks. In this way, the PM expectations can be anticipated by the customer and knowledge of specific PM operations is transferred to the customer.

Through the use of data collection, predictive diagnostics can be gathered to help schedule PM tasks for the customer. This allows the customer to conveniently schedule PM duties during beneficial times. For example, the customer can be notified of an upcoming requirement to perform routine maintenance on the MFT. Based on this notification, the customer can then work to schedule their assets to ensure their production capacity is not affected. MFT's can be programmed with deployment-specific parameters that activate this family of notification-driven diagnostics.

Key performance indicators can provide an estimation of the Overall Equipment Effectiveness (OEE). These key performance indicators are derived directly from the MFT's metrics ("MET") data component which is always available on the network and to the Serenity backbone. Examples of such performance indicators, or metrics, for the MFT machine include: mechanic setup time, probing time, drill/run-time, anticipated maintenance times, down-time for repairs, tear-down times, etc. Beyond MFT machines, broader categories of metrics can be created within Serenity, as shown in the example diagram above, to help calculate an OEE for the machine or set of machines. All MFT machines, combined with some Serenity software components, can provide this level of metrics reporting to ascertain OEE.

Serenity Software Suite – Mini FlexTrack Gallery, Continued



Mini FlexTrack Machine Resources: Image on the left shows Mini FlexTrack machines available as catalog items which are capable of material processing as portable CNC platforms. The machine on the right is a robotic crawler platform that can carry Mini FlexTrack machines or it can be adapted to carry factory resources such as hand tools, consumable stock items, etc. for resource delivery on the factory floor. Both Mini FlexTracks and Crawlers can be tracked as resources within the work cell and factory.