MTM Robotics 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 Robotics’ facility is located near Paine Field in Mukilteo, WA and consists of a 10,000 ft² design and manufacturing facility with a ETL panel shop and fully capable machine shop. MTM Robotics 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 Robotics’ 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 Robotics 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.
Company Info

• **Mission Statement and Philosophy**
  » MTM Robotics delivers high-quality automated portable machines to the aerospace industry which enable faster time to market for our customers.
  » MTM Robotics’s philosophy is to collaborate with our customers to develop new product technologies and share the success of bringing matured products to market.

• **Background Information**
  » Located near Paine Field in Mukilteo, WA
  » 10,000 ft² design and manufacturing facility
  » ETL panel shop and fully capable machine shop
  » Facility also manufactures tooling components used in the fabrication of composite airplane parts

• **Staff**
  » 5 Management (corporate, financial, project management)
  » 7 Mechanical Engineers
  » 3 Electrical Engineers
  » 10 Software Engineers (embedded, desktop, LabVIEW, and enterprise)
  » 3 Machinists
  » 3 Electricians / Electronic Technicians
  » 4 Assembly Technicians
  » 3 System Test
Portable Automated Assembly Systems

**Jig / Templates**
- Fast
- Flexible for manufacturing

**Light Automation**
- Simple low cost machines
- Integrates into existing manufacturing plans
- Manufacturing flexibility
- Allows concurrent work
- Reduced part handling
- Reduced flow time
- Many simple vs. one complex machine
- Drill multiple holes simultaneously

**Large machine tool**
- High capital and infrastructure costs
- Machine complexity increased due to large airplane structure
- Only one hole at a time
- Large permanent floor space required
- Concurrent work not allowed due to machine stay out zones.
- Late part arrivals and rework difficult to accommodate.
- High maintenance cost

- Setup time
- Not as much automation as required by some facilities (drill only).

PROPERTY OF MOBILE TOOL MANAGEMENT
Flextrack Technology

• Flexible to conform to various airplane contours
• Integral rack provides positioning along rail.
• Custom lengths
Current Boeing Mini Flextrack orders through Competitive Bid “WIN” over other Flextrack suppliers

- Boeing 777 Fuselage
  - 2 MFT’s in Production since 2012

- Boeing 787 Horizontal Stabilizer
  - 2 MFT’s in Production 2014

- Boeing 747 Fuselage
  - 14 MFT’s in Production 2014

- Lockheed C130J Wings
  - 2 MFT’s in Production 2014

Mini Flex Track system

- Fully Automated Drill / Countersink operation.
- Meets or exceeds Boeing hole quality specifications.
- NC Programmable Datasets for drilling wing beams and fuselage laps and bulkheads.
- Multiple machines on a single flextrack rail with coordinated operations for efficient management of machine operations.
- Replace manual drilling operations increasing speed and quality to replace template drilling
**Vacuum track**
- System only uses one vacuum track for easier loading and cost reduction.
- Configurable to any length
- Vacuum rail is stiffer to accommodate higher reaction forces
- 6” wide vacuum cups for higher reaction forces.
- Integrated vacuum sensors, monitored by machine controller

**Carriage**
- Generic X &Y positioning robot.
- Modular design: Any array of end effectors can be loaded for different tasks (drilling, inspection, sealing, riveting, fastening….etc)
- Onboard controller - needs no control cabinet and umbilical is very small.
- Entire system runs of stand 110V plug-in
- USB and Ethernet connections.
- Run from onboard touch screen pendant or remotely from PC.
- Increased y-axis travel (8 inches)

**End Effectors**
- Generic interface allows for different end effectors for varying production capabilities.
- Reversible – can be loaded to carriage in either direction
- Light Duty (on the right in picture) designed for smaller than 5/16” diameter holes. Uses a pneumatic drill motor with ranges from 20k to 3,500 RPM. Collet interface for tool holders.
- Heavy Duty (on the left in picture) fully electric spindle for controlled feeds and speeds with HSK 32A tool interface. Up to 7/16” diameter holes in Aluminum.
Mini Flextrack Portable Automation

SYSTEM COMPONENTS

Modular Assemblies

End Effector Assembly

Fastener Torque Assembly

Y-Axis Drive & Clamp Axis Drive

Fastener Delivery System

Vacuum Rail Assembly

Lubricant Reservoir and Pump

Retractable Stabilizer Foot

X-Axis Drive and user interfaces

PROPERTY OF MOBILE TOOL MANAGEMENT
Mini Flextrack Portable Automation

FULLY ASSEMBLED SYSTEM
HD Mini Flextrack with Temporary Fastener Installation Module
Concept Frame and Wing one-up drilling

- **Application** – Frame drilling and Wing Drilling
- **Materials:** Gr / Gr or Gr / Ti
- **Drill / countersink up to 7/16” diameter fasteners**
- **Apply sealant to countersunk hole (method 1)**
- **Feed Lock bolts and Hi-locks diameter fasteners**
- **Adjacent hole clamp-up**

PROPERTY OF MOBILE TOOL MANAGEMENT
Loading Carts
Rails
Crawlers
Modular / Portable Two Rail Mini Flextrack for Fuselage Join

X-axis = limited by rail length
Y-axis = currently 2 versions are available
- Long 900 mm
- Long 700 mm
A-axis = +/- 3 degrees
Z-axis = 20 mm

Flexible vacuum rail directly mounted on the structure

Rail A: 7 kg
X-Module Passive side: 9 kg
X-Module Driving side: 13 kg
Y-Module: 14 kg
ADU End-effector module: 2 kg
Rail B: 7 kg
Modular / Portable Two Rail Mini Flextrack for Fuselage Join

1 operator per system
Required one action at a time

Rail installation = 60 s (2 rail)

2. Passive X-carriage = 20 s

Active X-carriage + air supply = 20s

Y-Module = 25s

Energy connection
air + electric = 1min 30s

System ready

Turn on + Initialization = 35s

MTM ROBOTICS
A common interface allows installation of different module. The machine operating system is upgradable to control different end-effector module.
• ADU Setitech ST 1200:

This solution will not allow a full complete monitoring process (the LFT does not control feed and speed)
• Optional solution: Electrical spindle (more information chapter 9.1.2 electrical spindle)

This electrical spindle allows a monitoring of the complete process and adjustment of all drilling parameter (speed, feed following the stack-up and the material, tool break …)
Future Expansion of the Two Rail Mini Flextrack

- Modular Suction Cup with Rollers Eliminating need for Second Rail.
- Modular Y-Axis with lengths up to 47”
- Modular Sealant and Fastener Insertion system can include Drill System for Drill / Install or stand alone Fastener Install Only
- Modular Fastener Carriage with Capacity of 1,000 Final Fasteners for Multiple Diameters (Determined by Customer Need)
- Fastener Carriage that follows the Fastener Insertion system along the X - Rail
Future Hybrid Two Rail Mini Flextrack
Future Hybrid Two Rail Mini Flextrack
Future Hybrid Two Rail Mini Flextrack
Future Hybrid Two Rail Mini Flextrack
Future Hybrid Two Rail Mini Flextrack
Future Hybrid Two Rail Mini Flextrack
MTM Robotics System

X-Axis

Y-Axis

Z-Axis

A-Axis

Rear Foot stabilizes assembly during Nosepiece clamp

Clamping Nosepiece

Skin
Multi-Function End Effector

Hole Probe verifies:
• Hole diameter
• Countersink diameter
• Stack thickness

Vision System

Motorized Drill Spindle
2kW with integral drive electronics

Fastener Installation Tool
accepts fastener from tube

Sealant Applicator
applies sealant to fastener head

HSK-32 tooling

Chip Exhaust

Clamping Nosepiece
• Clamps to OML
• Sensors feedback normality information
• Load cell measures clamp force / drilling force

Dimensions: ~ 16” x 16” x 14”
Weight: ~38 lbs
Multi-Function End Effector

Linear guides for End Effector Shuttle
Curved Guides for A-Axis

Compartment:
- Electronics
- Shuttle drive
- A-Axis drive
Multi Function End Effector

- **Dimensions:** ~ 24” x 24” x 24”
- **Weight:** ~150 lbs with Fasteners

**Motorized Drill Spindle**
- 2kW with integral drive electronics
- Through bit coolant capable

**Hole Probe** verifies:
- Hole diameter
- Countersink diameter
- Stack thickness

**Vision System for Capturing datums**

**Clamping Nosepiece**
- Clamps to OML
- Sensors feedback normality information
- Load cell measures clamp force / drilling force

**Fastener carriage and Delivery system**

**Torque tool for Temporary Fastener installation**

**Shuttle selects function**
Robot MFEE Anatomy

- BACK PLATE
- CLAMP ASSEMBLY
- FRONT PLATE
- NOSE PIECE
- C-FRAME
- C-FRAME CLAMP
- TURRET
MFEE Benefits & Features

- Unique integrated controls system is highly flexible for robotic applications
  - Reduced cabling from main control system
  - Reduced size of robot dressing package – cables and piping
  - Reduces the size of control panels
- Modular design of turret allows for multiple drilling and fastening options without major chassis modifications
- MFEE can be operational when not connected to the primary cell controls
MFEE Benefits & Features
Mobile Tool Management
Mini Track Floor Beam Drill
777 Freighter Stub beam hardware
Lightweight Modular Gantry

PROPERTY OF MOBILE TOOL MANAGEMENT
Lightweight Modular Gantry
Lightweight Modular Gantry
Lightweight Modular Gantry

PROPERTY OF MOBILE TOOL MANAGEMENT
Lightweight Modular Gantry
Lightweight Modular Gantry
Lightweight Modular Gantry
Lightweight Modular Gantry

6 axis drilling machine:

- X
- Y
- Z (Drilling)
- Z (Clamping)

Overhaul dimension:

- 1900mm
- 450mm
- 800mm

Total weight: around 50 kg
A common interface allows installation of different modules. The machine operating system is upgradable to control different end-effector modules.
7.2.2  

**Energy requirement:**

Electric supply:
- supply #1: main power supply
  - input power: Universal AC: 85-264VAC, 1-phase 50/60Hz, 15A-30A
  - Output power: 48VDC or 90VDC

7.2.3  

**Velocity**

X and Y velocity: Max 8 inches/second (203 mm/second)

7.2.4  

**Positioning system**

Accuracy: Based on test holes are located within 0.3mm of their required position, measured relative to the nearest or chosen datum point.
<table>
<thead>
<tr>
<th>Drilling Process Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>One shot operation</strong></td>
</tr>
<tr>
<td><strong>Countersink Repeatability depth</strong></td>
</tr>
<tr>
<td><strong>Position Accuracy</strong></td>
</tr>
<tr>
<td><strong>Tool change time</strong></td>
</tr>
<tr>
<td><strong>Typical ALUMINIUM drilling parameters</strong></td>
</tr>
<tr>
<td><strong>Inches/Minute-Aluminium</strong></td>
</tr>
<tr>
<td><strong>Inches/Rotation-Aluminium</strong></td>
</tr>
<tr>
<td><strong>RPM-Aluminium</strong></td>
</tr>
<tr>
<td><strong>Estimated time hole to hole</strong></td>
</tr>
<tr>
<td><strong>Hole-to-hole’ cycle time</strong></td>
</tr>
<tr>
<td><strong>Diameter = 8 mm</strong></td>
</tr>
<tr>
<td><strong>Thickness = 9mm</strong></td>
</tr>
</tbody>
</table>

- **Yes : Drill + Countersink**
- ±0.05 mm
- 0.3mm
- 15s
- **31.2**
- **0.006**
- **5200**
- **8 seconds**
End Effector nosepiece sensors
And A-axis normality motion

Load cell—measures clamping force as well as drill force feedback

Normalizing nosepiece—Measures A and B axis normalization
Compensates for A axis

Counteraxial to hard-stop tool holder

A-Axis Drive Motor
A-Axis Motion
A-Axis and B-Axis Nose Piece with sensors

Integrated load cell
Three LVDT sensors that provide feedback on A-Axis and B-Axis orientation relative to the work surface
Lightweight Modular Gantry

We are offering and quoting the available Fastener Delivery System that can store up to 80 temporary fasteners (see pictures below). This system is programmable to drill and install temporary fasteners per the part program at whatever the frequency the customer desires. Here under a drawing of temporary fastener on our Mini Flex Track drilling machine.
7.2.8 Controller Software

Software to control Mini Flex Track runs on a Windows 7 tablet, installed on a pendant control and it offers:

- Easily and friendly interface to load / control program
- Easily process to load program from server DNC server (Mini connected)

Software interface:
Main Screen For Homing
When the machine is turned on the program requires the user to home the machine before they can proceed.

- The operator can:
  - Home to standard features (Drill-Axis, Clamp-Axis, A-axis, Y-Axis, Z-Axis)
  - Home to optional features such as an RFID tag.
Mini Flextrack 777 Fuselage Circ Join Riveter
To be used after drilling with Mini Flextrack
Process –

Circ drilled with Mini Flextrack drilling machines

Strap, stringer splice, and shear ties are removed, deburred, faye surface sealed, and cleco’d back in place.

Drilling machines are either

A) Moved to a position where several straps are free to be riveted. After straps are riveted Mini Flextracks are moved over riveted areas allowing access to remaining straps.

B) Side machines are removed with quick disconnect rail segments and riveting machines are added on rail with quick disconnects.

Rivets are loaded into panel and rivet tape applied.

Circ riveter machines are loaded and riveting process begins
Fuselage Circ Join Riveter

Machine specifications –

• Machine estimated weight – 75 lbs + 6 lbs rivet gun
• Runs on same rail system as Mini Flextrack drilling equipment with same spacing
• BACR15FV7 & 8 Rivets
• 42” Y axis travel

PROPERTY OF MOBILE TOOL MANAGEMENT
Referring to the following figure entitled “Serenity Software Suite (S3) Major Components” and working up the numbered layers, S3 provides the following features and benefits:

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 which was recorded on the fly during manufacturing.
Serenity Software Suite (S³) – Overview

Web Enabled Communication Software for e-Manufacturing

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)

PROPERTY OF MOBILE TOOL MANAGEMENT
Serenity Software Suite

NC Programming Group
- CATIA data
- Export tools
  - CATIA macro
  - Hole sequencing
  - K-hole assignment
- Process .csv file
- PPbuilder compiler
  - Output is .bin file
- Secure Server
  - NC programs (.bin and .csv)
  - Revision-controlled

IT Department
- Corporate Network
- Gateway

Production
- Process Monitoring
  - Process data collected from MFTs
  - Data distributed by Cell Manager to listening processes or UI Views
- MFT
- Mechanic/Operator

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 Robotics can accommodate customer programming experts to organize meetings and reviews of programming solutions for validation. MTM Robotics 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

**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.

(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.
Preventive Maintenance, Predictive Diagnostics, and Key Performance Indicators

With delivery of MFT machines, MTM Robotics 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.

MTF’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.
Auto Hole Probe

- Single Shot Auto Hole Probe Measures:
  - Countersink Diameter
  - Hole Profile from Entrance to Exit at 0 deg and 90 deg
  - Stack Height
  - Calculates Grip Length
- Uses Standard Fed Max Gauge Probes.
- Portable Data Collection.
- Ethernet Connection to database.
- Reduces Measurement time from Minutes to Seconds.
- Excellent for Lab Environment researching Cutting Tools.
- Data saved to Text File for future use.
Auto Deburr

- Designed to search and auto detect the transition between Titanium and Composite.
- Release a deburr blade.
- Rotate 360 degrees and remove the burr on the Titanium.
- Benefits:
  - Eliminates the need to separate the two materials after drilling and deburring each hole
  - 6 systems in production on 787 in Charleston, SC
• Designed to automatically detect multi layered stacks of different material using thrust changes.
• Automatically change feeds and speeds during the drilling process by layers.
• 16 motors in production on 777 Empennage in Everett
• 12 motors in production on 777 Vertical Fin at Frederickson
• 4 motors in production on 787 in South Carolina