Digital Advanced Manufacturing System - Connected Enterprise

FANUC is pleased to provide the following concept overview for an integrated manufacturing learning system based on the principles of the Industrial Internet of Things (IIoT) and Digital Manufacturing.

Goals as communicated by Lorain County Community College

• Provide Learning Opportunities for Lorain County Community College Students to prepare them for rewarding careers in Advanced Manufacturing.
• Showcase Lorain County Community College’s leading education position in the disciplines of advanced manufacturing and Digital Manufacturing technologies to Industrial Partners, Current Students and Potential Students.
• Provide an adaptable learning system that can be modified and upgraded as technology advances and / or needs change.
• Establish an authentic industrial manufacturing process, unique to Lorain County Community College, utilizing industrial grade technology that produces a relatable production part, customized to each Lorain County Community College visitor, which can be retained by the visitor and used to build Lorain County Community College brand.
• Create a platform that can deliver Digital Manufacturing opportunities across multiple Lorain County Community College programs.
• Implement a system that can be quickly and cost effectively supported and serviced.
• Establish a solution that includes technology that can strengthen pathway from high schools.

Project Summary

IST (a valued Lorain County Community College partner for many years), in collaboration with FANUC (the global leader in CNC controls and advanced automation for manufacturing), and Rockwell Automation (the world’s largest company dedicated to industrial automation and information) proposes to partner with Lorain County Community College to implement a one-of-a-kind integrated manufacturing learning system built on proven cutting edge technology and featuring the concepts of digital manufacturing.

To follow is a summary of the proposed system and related processes, along with key student learning deliverables.

Line Summary

The flexible manufacturing line will be initially designed to machine and engrave a custom USB Flash Drive enclosure and insert the USB pcb and related components into the enclosure, producing a fully functional, custom to the individual customer, USB Flash Drive. Integrating today’s lean manufacturing principles of make-to-order production and single piece flow, each individual enclosure will be custom engraved “as ordered” by the customer and could include such information as the customer’s name, the name of their organization, their logo and / or Lorain County Community College’s logo and contact information.
Featuring the most advanced aspects of digital manufacturing the line will be controlled and monitored using one of several Rockwell Automation Allen-Bradley Programmable Logic Controllers (PLC’s). Rockwell Automation Allen-Bradley Human Machine Interfaces (HMI’s), located at each manufacturing operation, will deliver real-time data including throughput, cycle-time, reject rates, performance to standard, uptime, preventive maintenance information and more.

Utilizing innovative IIoT technology, line performance will be monitored at the point of production, for pertinent production data that could be monitored via a tablet computer or on a computer screen in a classroom located any distance from the production line.

Finally, all production data can be collected in real time and exported via a CSV file for use in analysis and predictive analytics producing learning opportunities consistent with the principles of IIoT and digital manufacturing.
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Digital Manufacturing Line:
**Shared Resource for Industry & Education**

- Fanuc Robodrill CNC vertical machining center
- Laser Engraving Cell
- Assembly Cell
- Packaging Cell
- Robot mounted 3D printing
- Exploring Robotic Welding
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Digital Manufacturing Line:  
**Shared Resource for Industry & Education**

- FANUC α-D14MiA5 Robodrill CNC vertical machining center
- Manual or integrated robot load/unload

- 14 tool turret
- X-axis travel (longitudinal movement of table) – 500mm (19.685 inches)
- Y-axis travel (cross movement of saddle) – 400mm (15.748 inches)
- Z-axis travel (vertical movement of spindle head) – 330mm (13.7795 inches)
- Series 31i-Model B5 Control Unit
- Maximum of 5 axes
- 10,000 RPM spindle
- Dedicated door on right side of machine for robot allows unrestricted access through front door for manual operation.
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Digital Manufacturing Line:
Shared Resource for Industry & Education

- FANUC Fenceless CERT carts with integrated iRVision
- Allen Bradley GuardLogix PLC
- Allen Bradley SafeZone safety laser scanners
- PanelView Human Machine Interfaces with un-tethered mobile HMI applications
- Conveyors with Allen Bradley variable frequency drives
- Ethernet/IP communications
- RFID tracking and barcode tracking
- Carts are on wheels so that they can be used independently or mixed and matched in what sequence needed.

Note that the robot shown in the picture is the smallest robot FANUC available. The proposed system includes the largest FANUC robot that will fit on the CERT cart.
Robot Mounted 3D Printing
FANUC has agreed to donate a prototype 3d printing head and integrated control software to enable one of our LR mate robot to be capable of 6-axis 3D printing for demonstration and research purposes.
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Digital Manufacturing Line: Shared Resource for Industry & Education

- Laser Engraving Cell
- LNA MP2 Diode Pumped, Solid State (DPSS) galvanometer laser engraving system
- Suited for marking plastics, anodized aluminum and hard metals such as titanium, stainless steel and carbides.

**BEAM SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Mode of operation:</th>
<th>Pulsed</th>
</tr>
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<tbody>
<tr>
<td>Typical pulse width:</td>
<td>3 ns</td>
</tr>
<tr>
<td>Pulse energy:</td>
<td>0.08 mJ</td>
</tr>
<tr>
<td>Peak Power:</td>
<td>Up to 30 kW</td>
</tr>
<tr>
<td>Beam Quality:</td>
<td>&lt;1.5 M²</td>
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<tr>
<td>Main Wavelength:</td>
<td>1064 nm</td>
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</table>
### Example Production Process (subject to Lorain County Community College feedback):

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Equipment &amp; Software</th>
<th>Learning Objectives</th>
</tr>
</thead>
</table>
| Customer enters custom order information (name, font, logo, etc.) into HMI. Data is retrieved by PC, formatted for Laser engraving process and sent to PLC. | Rockwell Automation Allen Bradley Master Control Panel including an Industrial Computer, RSLogix, PLC, Safety PLC (monitors safety for all cells) all within one enclosure on a stand-alone pedestal. | • Human Machine Interface  
  • Production Planning and Scheduling  
  • Introduction to Automation  
  • Human Machine Interface-programing, operation and troubleshooting (including un-tethered/mobile HMI applications)  
  • PLC Networking & Related-operate and maintain.  
  ControlLogix Fundamentals, programming and Troubleshooting. Micro850 Configuration, Programming, and Troubleshooting  
  • Ethernet /IP and industrial switches.  
  • Industry Certifications-ControlLogix Maintainer Certificate |
| Production technician enters raw material and production data into HMI.        | All software including FactoryTalk and Panelview Plus 7.0, allowing untethered networking via Bluetooth or WiFi for review and operation via Laptop, PC, Tablet or Mobile Phone. Studio 5000 toolkit enabling offline monitoring, access and programming via laptop or PLC. |                                                                                                                                                    |
| Robot retrieves enclosure raw material and delivers to machining operation     | FANUC LR Mate 200iD/7L Robot with R-30iB Controller                                  | • Robot Operation including power up, jogging, fault recovery, production operation execution, creation, modification and execution of teach pendant programs and program backup and restoration.  
  • Offline Robotic Simulation, cell design, testing and modification.  
  • Related Industry Certifications |
| CNC Robodrill machines enclosure                                               | FANUC ROBODRILL α-D14MiA5 with FANUC CNC Controller - High Speed, High Efficiency Compact Machining Center  
  2 base sizes for customizing enclosure style for USB. | • Industrial machining, CNC Programming and Networking, Setup, Setting Verification, Tool selection, tool and equipment maintenance.  
  • Related Industry Certifications |
<table>
<thead>
<tr>
<th>Task</th>
<th>Machine &amp; Equipment</th>
<th>Training Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robot retrieves machined enclosure and places on Variable Frequency Drive Conveyor</td>
<td>Allen-Bradley Variable Frequency Drive Conveyor</td>
<td>• Principles, operation and maintenance of Industrial VFD Conveyors</td>
</tr>
<tr>
<td>Conveyor delivers enclosure to Quality Control Cell #1. Using vision technology, part dimensions are checked to specification and part is either accepted or rejected.</td>
<td>iRVision 2D Guidance Hardware &amp; Software&lt;br&gt;This would all be in one station, the laser would be included in the same process.</td>
<td>• Vision equipment and software overview&lt;br&gt;• Vision Setup including camera setup, calibration, and vision process&lt;br&gt;• TPP programming for vision&lt;br&gt;• Troubleshooting&lt;br&gt;• Related Industry Certifications</td>
</tr>
<tr>
<td>Robot places enclosure in fixture custom content is etched onto enclosure utilizing a Laser Etching Unit mounted on a FANUC Robot Arm</td>
<td>LNA MP2 DPSS All-in-One Laser marking system mounted onto FANUC LR Mate 200iD/7L Robot with R-30iB Controller. &lt;br&gt;Rockwell Automation Panelview HMI</td>
<td>• Laser Engraving programming, vector images, raster images, power, pulses, feed rates, networking and safety.&lt;br&gt;• Photonics (laser cutting, etching, joining) barcode etching optional</td>
</tr>
<tr>
<td>Robot places enclosure onto Variable Frequency Drive conveyor which delivers enclosure to Assembly Cell</td>
<td>Allen-Bradley Variable Frequency Drive Conveyor</td>
<td>• Functional safety application- Light Curtains, Safety Relays, E-stop and other Physical Safety Components , GuardLogix Integrated Safety System- Configuration, Programming, and Troubleshooting&lt;br&gt;• AC and DC Drives&lt;br&gt;• Basic Motion Control, Kinetix 5500, 5700- Configuration, Programming, and Troubleshooting</td>
</tr>
<tr>
<td>Assembly Cell, utilizing a robot camera, retrieves USB printed circuit board and related hardware from material load magazine and inserts contents into custom enclosure.</td>
<td>FANUC LR Mate 200iD/7L Robot with R-30iB Controller&lt;br&gt;Rockwell Automation Panelview HMI</td>
<td>• Industrial Robotic Assembly, Kanban Systems, Inventory Feed Systems&lt;br&gt;• Motor Drive Conveyors</td>
</tr>
</tbody>
</table>
Robot places completed USB Flash Drive onto Variable Frequency Drive conveyor which delivers enclosure to assembly cell.

Allen-Bradley Variable Frequency Drive Conveyor

• Principles, operation and maintenance of VFD Conveyors

Quality Control using vision technology, part dimensions are checked to specification and part is either accepted or rejected.

• Quality Control
• Vision Systems

Conforming Parts advance to Packaging Cell. Parts are packaged by a robot. Packaging and custom contents are identified using RFID technology and read via fixed machine or hand-held RFID reader.

FANUC LR Mate 200iD/7L Robot with R-30iB Controller
Rockwell Automation Panelview HMI
Rockwell Automation RFID Technology Kit (Variety of Tags, Imprinter, etc.)

• Industrial Packaging Operations
• Related Industry Certifications
• RFID Technology

Packaged USB Flash Drive delivered by production line directly to customer or to finished goods inventory.

• Product Delivery

Summary
The process noted above achieves all of the digital manufacturing and IIoT learning objectives communicated by Lorain County Community College while doing so in a fashion that is truly unique to Lorain County Community College. Further, the industrial nature of the manufacturing cells provide authentic learning experiences for students.

The products produced by the manufacturing system (USB Drives) are consistent Lorain County Community College’s focus on technology and the fact that each individual USB Drive is fully custom and unique to each Lorain County Community College visitor will result not just in a memorable experience for the visitor but will leave them with a product that will remind them of their visit each time they use it.

The end result of this partnership, as stated, is a Lorain County Community College - controlled flexible manufacturing process unlike anything currently operating in an educational facility. As a leader in technical education Lorain County Community College is the state-of-the-art training institution. We view this project as a significant step into the future, and one that maintains Lorain County Community College leadership position in the field.
Modular Flexibility
The unique modular design makes this system well-suited as a shared resource for industry and education use:

- Support R&D projects
- Support production line design / small scale production runs
- Provide credit & non-credit training and certification to employees and the general public.
- Provide capstone / work-based learning projects to students

The various robots cells are moveable, so they can be used individually or easily moved into whatever combination or sequence is needed. Integrated vision systems allow the robots to adapt to variations in part, fixture, and conveyor placement.

The modular nature of these robots will also make it possible to move them close enough together to be used in multi-arm coordinated motion applications.

Credit Courses
This system is needed to replace LCCC’s old CIM system for teaching the following credit automation courses:

- AETC 111 – Robotics and Automated Manufacturing
- AETC 121 – Programmable Logic Controllers
- AETC 211 – Workcell Interfacing
- AETC 223 – Programmable Logic Controllers II
- AETC 231 – Flexible Manufacturing Systems
- AETC 221 – Automated Systems Troubleshooting
- Plus additional courses that are still to be developed

Industrial Accreditation
With this system Lorain County Community College will be able to:

- offer manufacturer accredited certification training levels 1 - 3.
- become a FANUC Authorized Satellite Training Center (F.A.S.T.)

![Diagram of course levels and certifications](image-url)
RoboGuide Software
Another benefit of this Digital Advanced Manufacturing System is that it can be modeled, programmed, and simulated offline using RoboGuide Software.

- The simulation using virtual robots that act just like the real thing. Programs can be transferred back and forth from between RoboGuide and the actual robots. Both the robot’s movement and application commands are simulated with this program.
- RoboGuide has CAD-to-path capabilities for making complex paths easier to program.
- RoboGuide also has the ability to simulate, test, and optimize new applications.
Additional Information

• FANUC ROBODRILL α-D14M/IA5 CNC Machining Center


• FANUC Robot Dual Check Safety (DCS).
  http://motioncontrolsrobotics.com/dcs-improves-stop-position-prediction/
  http://motioncontrolsrobotics.com/dual-check-safety-dcs-explained/

  http://lnalaser.com/dpss-laser-marking-system/
  video https://www.youtube.com/watch?v=ecbtq0DQd4k

Additional Options

The overall Digital Advanced Manufacturing System as described costs $512,489 with most of the costs from the ROBODRILL ($160,000) and the robot stations ($52,000 each). There are several other options for this system:

• Options for the ROBODRILL:
  o Tool length switch to make setting up new tools faster and easier. Also can be used to detect worn or broken tools during use – $2,330
  o Renshaw touch probe to make setting up new parts and fixtures faster and easier. Also can be used to measure workpiece coordinates or machining dimensions – $5,770
  o DDR-T 4th axis cradle allows fixture to be rotated allowing angled machining and machining of multiple sides of part without refixturing. (for X500) – $19,490
  o Operator panel with alphabet keys – $???

• FANUC Collaborative CR-4iA/L Robot. The new green collaborative FANUC robots are designed to be able to work near or in cooperation with a human operator. These robots meet safety requirements of ISO 10218-1:2011 and RIA/ANSI R15.06-2012. We would like upgrade at least one of the robots to a collaborative model to be able to work with and training this important technology. Price includes instructor Dual Check Safety and Collaborative robot training. http://www.fanuc.eu/tr/en/robots/robot-filter-page/collaborative-robots/collaborative-cr7ial – $8,426
Tool Length Switch (Option)

The tool length switch is used to detect worn or broken cutter.
It is installed on the table or jig.

Touch Probe (Option)

Touch probe makes it possible to measure workpiece coordinates or machining dimensions in condition of setting workpiece on the jig.
Possible to make cradle type jig easily

Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>for X300</th>
<th>for X500</th>
<th>for X700</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. load capacity *</td>
<td>45kg</td>
<td>100kg</td>
<td></td>
</tr>
<tr>
<td>Center height</td>
<td>200mm</td>
<td>260mm</td>
<td></td>
</tr>
<tr>
<td>Turn diameter</td>
<td>φ 310mm</td>
<td>φ 410mm</td>
<td></td>
</tr>
<tr>
<td>Clamp torque</td>
<td>700N • m</td>
<td>(DDR : 500N • m + Tail support : 200N • m)</td>
<td></td>
</tr>
</tbody>
</table>

* Including swing plate, work, and clamping device

Operator's panel (standard)

Operator's panel with alphabet keys (option)
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Digital Manufacturing Line: Shared Resource for Industry & Education

- FANUC CR-7iA/L collaborative robot
- 6 axis with 911 mm reach and a 7kg payload capacity
- Allows operators and robots to work in a shared space without any safety fencing in production.
- This robot can work in cooperation with a human operator (examples: parts assembly, work piece transfer).
Features
The FANUC compact collaborative robot line-up is a small, human arm sized six-axis 4kg-7kg payload robot with short, standard and long arm variants available. The collaborative robot can be wall or invert mounted to save floor space.

Three models are available for various reach/payload needs:
- FANUC Robot CR-4iA - short arm variant with 4kg payload
- FANUC Robot CR-7iA - standard arm with 7kg payload
- FANUC Robot CR-7iA/L - long arm variant with 7kg payload

Collaborative Operation
- The CR line-up of robots can operate in cooperation with or alongside humans in a shared workspace without safety fences or sensors.

Safety Function
- The collaborative robots stop safely in the event of contact with a human operator.
- The collaborative robots can be pushed out of the way at anytime with minimal force.
- The CR line-up is certified to meet the requirements of ISO 10218-1 for collaborative robots.

Intelligence and High Reliability
- Robot is immediately ready for use with on board solenoid operated air valves as standard equipment.
- Latest intelligent functions such as force sensing and iRVision (Integrated vision) are available.
- The FANUC collaborative robots are designed with the same high reliability as all FANUC robots.