Michigan Technological University

Manufacturing and Mechanical Engineering Department

AIST Steel Curriculum Development Grant – Year-End Report

Team Leaders

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Team Members of Industry 4.0 Consulting

1. Nicole Andress, Cybersecurity System and Network Security
2. Ewan Beyer, Cybersecurity System and Network Security
3. Matt Vongphachanh, Senior, Mechanical Engineering Technology
4. Matt Gagnon, Senior, Mechanical Engineering Technology
5. Ethan Nass, Senior, Mechanical Engineering Technology

Figure 1 *Industry 4.0 Consulting Team.*

All of the team members are registered as Senior Design, being brought on to work with AME Enterprise as consultants. Ewan Beyer and Nicole Andress specifically were brought on for consulting in order to bring Cybersecurity and Network Security concepts into the Foundry. The hope was that these two consultants would also help to further a project started in the prior year by the enterprise known as the Arduino project.

Project Summary

Project Goals

MMET seeks to better utilize the MSE pilot-scale metal/steel processing facility by updating the sensors and data collection capabilities to better align with the Industry 4.0. *Note that the equipment for steel casting, rolling, forging, stamping, and additive manufacturing already exists and is operational. This proposal seeks to instrument the equipment for use by a wider range of disciplines on campus.* Analysis of process (big) data with techniques such as machine learning will help produce highly capable manufacturing and mechanical engineering technology engineers for the steel industry.

Project Details

The current metal/steel processing facility at Michigan Tech is a fully operational and functional processing facility, however, it does not meet Industry 4.0 standards. To implement Industry 4.0 technologies and practices a project team was formed through AME, where a team of students were tasked to select a process and update it with Industry 4.0 capable technology. The student team met with the advisors on a bi-weekly basis throughout the academic year.

The process chosen to introduce Industry 4.0 technology was the metal melt and casting line. To improve the process, temperature measurement for the melt and molds were identified as being important to automatically collect for process improvement. The current metal melt and casting line has the following temperature measurement instrumentation:

- Manual melt temperature measurement track with a DigiTemp – Heraeus temperature display
- Mold thermocouple temperature measurement – pushes data wirelessly to cloud
- Spectrometer – connected to a stand-alone computer

Figure 2 *Melt temperature measurement and casting line mold set up with wired thermocouples*

The goal of this effort was to automatically collect and log this data to a central computer, as opposed to collecting data manually or having data stored on local non-networked computers. While trying to better align the facilities with current Industry 4.0 practices, other considerations are: ease of use, maximize efficiency, better process reliability/repeatability, and improved overall safety. By making improvements with these considerations in mind, a more beneficial learning environment for Tech students can be created.

To introduce Industry 4.0 technologies to the metal melt/casting line, three areas (Figure 3) were identified to upgrade with sensors that automatically log data during the melting and casting process:

1. Melt temperature measurement with wireless connection
2. Mold temperature measurement with thermocouples and wireless recording
3. Video recording of the entire process

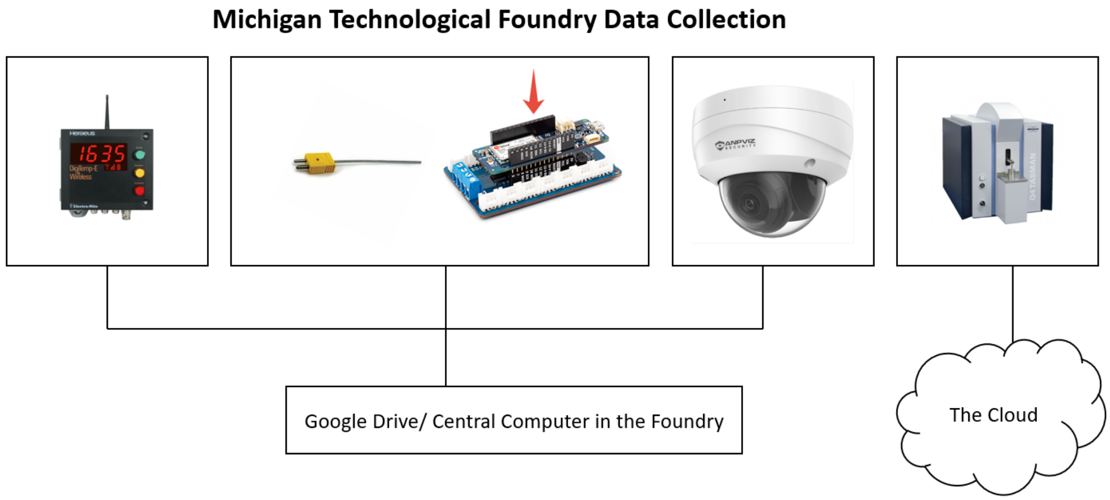

Figure 3 *Four areas of the casting line identified for collecting and processing data*

The first task this team assisted with was with the Heraeus DigiTemp; a device purchased in year one of this project. The device is designed to create wireless tracking of data as manual temperature readings are taken. When installed, this device was not able to track heat temperatures wirelessly as designed due to some minor components missing during the initial setup. Industry 4.0 Consulting provided the knowledge to troubleshoot and resolve the connectivity issues by documenting two methods in which this tool can be used; server device control and wired network. With server device control, it would track data and transfer it to the cloud. This method was not a viable option for the Foundry, however the second method was. With a wired network in the Foundry, a router is used as traffic control to transfer data between the DigiTemp and a computer. Before this wired network could be put in place, conduit needed to be installed first as protection from the environment. A third party company called Erico was hired into the Foundry for the installation of the conduit. With the conduit in place, cables installed, data now has a way to transfer to a computer. (Figure 4) Will show what the DigiTemp looks like below.

Figure 4 *Wireless temperature display module working, and wireless probe*

The second improvement brought to the casting line was the continuation of the Arduino project started in the prior year. At the beginning of this year, the Arduino was able to track four temperature readings locally to a computer, but was not capable of creating a log of temperatures. This device was also not able to push data wirelessly to a database. Industry 4.0 Consulting was able to redesign that original build by upgrading some of the parts to make it capable of wireless transmission of data. This upgrade consisted of using an Ardunio MKR 1010 and a MKR 1000. These two boards are designed to be built into IoT devices capable of collecting and transmitting data to a database. The group thoroughly investigated and determined that utilizing the Arduino cloud would allow for not only collecting data transmitted by the Arduino, but also accommodate use of the built-in remote control of the Arduino during the temperature collection process. This control can be used from either a phone or from a computer. Collecting and tracking the temperatures of Foundry molds used during casting fulfilled a critical request by the Foundry team as a teaching point. Figure 5 below shows how the new Arduino works from a thermocouple touching a temperature, which is then taken in by the thermocouple amplifier, gathered and organized by the Arduino, then pushed to the cloud. This upgrade made it possible so that the Arduino not only gathers four, but now seven temperatures in a sitting, every tenth of a second.

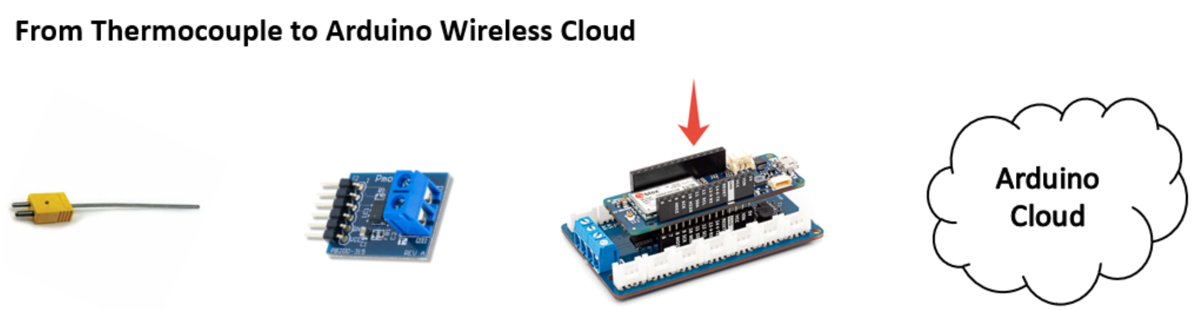

Figure 5 *Mold temperature recording process with an Arduino microprocessor with wireless capabilities*

The third improvement made during this project included the installation of cameras in the Foundry. Alongside the request on the part of the Foundry to collect temperature readings, was the request for visual reference data that matched those temperature readings as a teaching point in the Foundry class setting. The challenge that AME enterprise had to face last year was that of a legal issue. Due to University policy, if cameras are installed anywhere on campus they must be installed by IT. Once installed, these cameras will be used for surveillance purposes only, and controlled by IT. Unfortunately that meant that if cameras were installed, none of the data would be able to be used for research purposes. To resolve this challenge, Industry 4.0 Consulting contacted Brian Cadwell, Chief of campus police, to discuss viable options. With the permission of Public Safety, Industry 4.0 Consulting was able to install cameras for the sole purpose of research only. To ensure clarity of the purpose of the camera, signage was created to be posted near the cameras indicating that they were not for surveillance purposes. and an agreement was signed between the Foundry and Brian stating that permission was granted to use cameras in the Foundry.

Figure 6 *Cameras were installed in order to track the heating and pouring process.*

The fourth improvement included overcoming challenges surrounding the Foundry Spectrometer. The Spectrometer is a vital piece of equipment that is used in the Foundry to test the purity of metal samples poured on the casting line. When an engineer is melting and mixing samples, use of the Spectrometer ensures that the correct sample is being made. The machine starts off by burning into the sample to create a vapor. Then it applies high level light beams into the vapor, causing the light to reflect and bounce off of the metal fragments gathered in the vapor. This machine is capable of analyzing the metal sample based on how the light reflects off of the fragments, therefore creating data on what was mixed in that sample. The Spectrometer can be viewed in Figure 8. The challenge with this machine is that it was attached to a computer that ran the operating system Windows 7. The Cybersecurity consultants were able to provide cybersecurity training to the Foundry staff that helped them understand that there are hundreds of methods that can be used to hack into a vulnerable operating system like Windows 7. It was important to get this computer on a modern operating system in order to protect the data that is stored on this computer prior to gaining access to the internet with the school. After further analysis of this computer, it was also brought to light that the only way to get data off of the computer, created by the Spectrometer, would be to print off the data. Due to this challenge, the Cybersecurity consultants provided training to the Foundry staff on the Cybersecurity C.I.A Triad model.

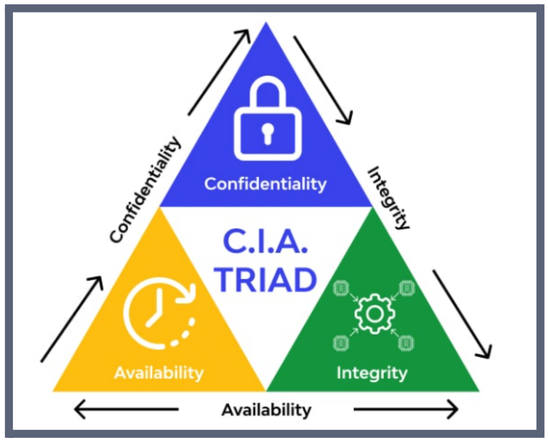

Figure 7 *The C.I.A Triad model.*

The Cybersecurity Triad C.I.A model is a concept that all Network Engineers and those of the Cybersecurity field knows well. The first part of this model is C, for Confidentiality. Confidentially refers to protecting information on a device, service, or product from unauthorized users. The next part of this model is I, for Integrity. To ensure Integrity of a service, product, or computer network, means to promise users of said service that the users data is handled by a trustworthy source. This means to protect user data from being damaged, hacked, or accidentally altered by unauthorized users. The final piece of the model is A, for Availability. No matter how high security is on a network or device, if a user cannot access the data they are supposed to have access to, then the service is not providing what it promised.

When analyzing the Spectrometer computer, this product was not very easily accessible for users. Users were not allowed to use USB drives on this computer due to Michigan Tech IT protocols for securing critical data, particularly on outdated and vulnerable operating systems like Windows 7. Confidentiality was not ensured on this computer as well, as there were no passwords to protect any of the data. The Foundry staff had years of data stored on this computer, that if lost, would leave them without valuable teaching research. Finally, there was no promise of Integrity on this device. If a malicious actor were to approach this computer, press the spacebar on the computer keyboard to login, they would have full access to years of research data without restriction.

In order to solve the major challenge behind the Spectrometer, Industry 4.0 Consultants were granted permission to upgrade the computer and work with IT to get this computer compliant. The second part of this solution was to upgrade the Spectrometer software and database to be 64-bit compliant so that a modern operating system could be installed. The final part of this project solution was to ensure Integrity of the data on the computer by having user accounts that separate the students from the staff data. This solution not only meets the guidelines of the C.I.A Triad model, but also made this machine compliant with Michigan Tech IT. The efforts of the Industry 4.0 Consultants provided connectivity and security of the research data collected through the Spectrometer, as well as the ability for backup data to be stored externally.

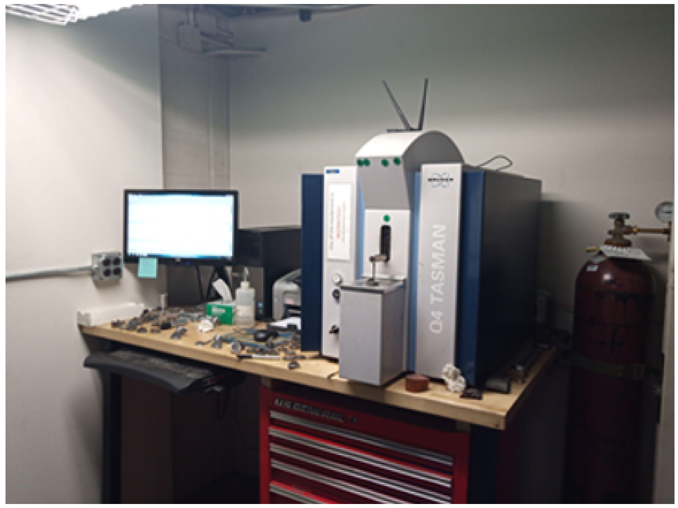

Figure 8 *The Foundry Spectrometer.*

The final part of this project was to solve the challenge in terms of how to actually integrate Industry 4.0 concepts into Michigan Tech's Foundry. There are now five data gathering devices, which would be two cameras, the DigiTemp, Arduino, and the Spectrometer. Implementing Industry 4.0 meant that there needed to be a way to collect all the data to one location. In order to do this, the consultants needed to create highways for data to travel from these devices. This required installation of a computer network within the Foundry. The challenge the team ran into while designing this mini network was that this environment deals with hot metal, and the Foundry is a huge cement room. So the first task was to have a third party service install conduit highways to protect network cables from the environment. Once all the devices were attached with network cables, all of the cables were brought to the middle of the room and plugged into a centralized network router attached to the computer in the middle of the room.

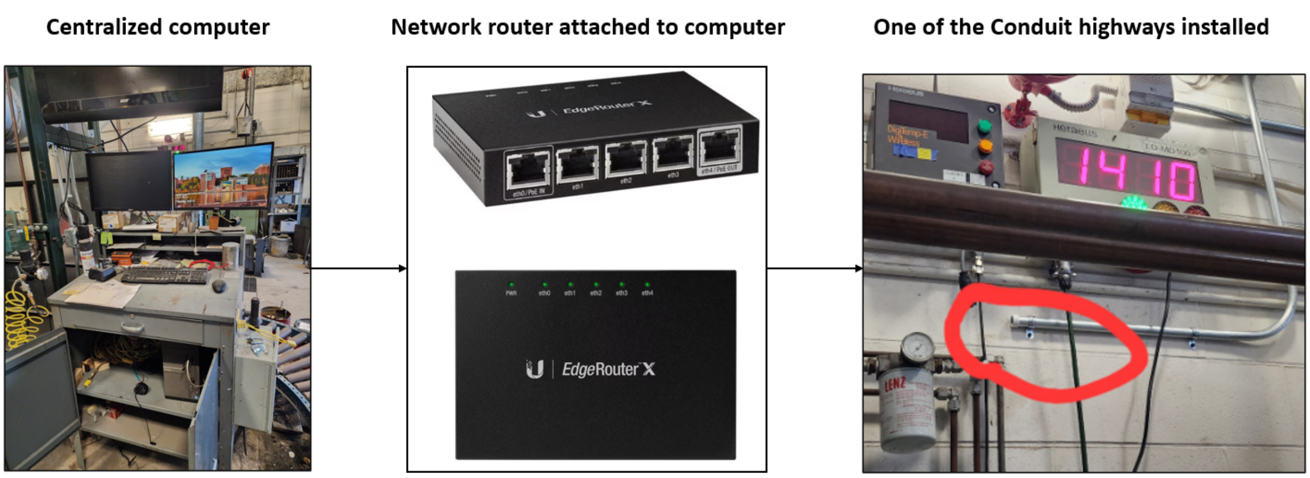

Figure 9 *Network installation used to gather data.*

Current Project Status

At the end of the second semester, the students have the following completed tasks.

1. A Heraeus Digitemp-E Wireless temperature module and Qube wireless probe transmitter installed correctly and wired up to transmit data. The modules are now able to communicate, and have the ability to send data to the main computer through the computer network installed.
2. Two IoT capable Arduino microprocessors were purchased to work with previously purchased thermocouple modules. The unit will eventually allow 16 thermocouple units capable of monitoring temperatures at a rate of 10 Hz. An Electrical Engineer will be needed to correct faulty wires and to design the bus to ensure a stable final product.
3. Foundry has been granted legal use of cameras in order to add visual data to their temperature readings.
4. Spectrometer's computer have been replaced with a newer model, and the Bruker software has been upgraded to be compatible with modern operating systems. This device has been granted Michigan Tech IT's approval to have access to the internet. Currently still awaiting for the installation to be completed by IT.

Project Expenses

Project expenses for the 2021-2023 academic years are listed in Table 1.

Table 1 Equipment Expenses for Industry 4.0 Project

Industry 4.0 Budget			
	Michigan Tech Grant	Expenses	
Year 1	$10,000.00	$722.36	$9,277.64
Year 2	$10,000.00	$14,066.37	-$4,066.37
TOTAL	$20,000.00	$14,788.73	$5,211.27

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Future Project Plan

Once the students return to campus, this project will resume for one more year. Since the equipment has been purchased and installed, there are now two remaining tasks to complete. The first project that needs to be completed is the Arduino project. Currently there are seven thermocouples running, which means half of the device is up and working. Once complete the tool will need to undergo testing to ensure product stability. The second task that needs to be addressed is that Foundry staff are looking to have all of the data synchronized together. This task will need the assistance of a programmer that has an in-depth knowledge of coding infrastructure, and will need months to complete this task. If these two tasks are completed, there are two more tasks that could be completed in order to integrate more Industry 4.0 concepts into the Foundry.

Upon completion of the upgrade to the casting line, two other processes have been identified for future Industry 4.0 upgrades.

1. Moisture sensor addition on the Green Sand Mixer
2. Extrusion Press sensor upgrade

These projects will be further discussed once the initial project has been completed.

Dissemination of Results

Staff that assisted with project: Dr. Nathir A. Rawashdeh, Dr.Vinh Nguyen, Dale Dewald, Russell Stein
Project Schedule: Fall 2022 to Spring 2023
Student Participation: Undergraduate Students Nicole Andress, Ewan Beyer, Matt Vongphachanh, Matt Gagnon, and Ethan Nass.
Steel Plant Interaction: No Steel Plant Interaction was done this academic year. Next academic year, once the team is able to record data, project mentor Jesse Gelbaugh will be consulted.
Project Duration: Year two is complete. Year three will start September 2023 and end May 2024.