Artificial Intelligence and Machine Learning in Consumer Products

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Abstract

Artificial intelligence (AI) and machine learning (ML) are emerging technologies in modern products. The Consumer Product Safety Commission (CPSC) is responsible for mitigating risks in consumer products. The organization needs to identify the presence of AI/ML in consumer products and any associated potential hazards. For this project, the WPI team's goal was to assist the CPSC by creating a methodology that could be utilized to identify AI/ML capable products. The project involved identifying the components of an AI/ML system and developing a screening process that can be used to determine AI/ML capability in consumer products. The CPSC now has a methodology to identify AI/ML capable products, allowing them to determine the impacts of AI/ML on the safety of consumer products.

B term

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WPI

Artificial Intelligence and Machine Learning: Changing Safety Concerns in Consumer Products

Artificial intelligence and machine learning are becoming more popular in products today, creating a need to better understand the technology and its relation to consumer products. The Consumer Product Safety Commission (CPSC) is a government agency charged with maintaining safety in consumer products. The agency needs to identify and assess artificial intelligence (AI) and machine learning (ML) in consumer products to ensure consumer safety.

The Consumer Product Safety Commission focuses on the mitigation of risks ranging from injury to death caused by consumer products. They are responsible for checking and reducing risks associated with thousands of common products. The CPSC uses incident reports of hazards caused by products to investigate whether these products are potentially harmful. They work on mandatory requirements and encourage the adoption of voluntary standards for a wide range of products and program areas.

Figure 1 shows common applications of AI technology as reflected by revenue.

This figure displays the array of fields that are taking advantage of AI and its capabilities. A common example of AI is self-driving cars that use AI to assess and navigate their environment[2]. Digital assistants for mobile devices, including Siri and Alexa, help users with certain tasks such as texting, calculating, and web browsing. Some appliances also use AI/ML to make products more efficient, such as smart refrigerators and ovens that can assist the user with monitoring and cooking food[3]. Since AI/ML products have a variety of uses, the CPSC wants to investigate the uses of AI/ML in these products in order to ensure functionality and safety.

The WPI team's work was the initial stage of a larger project to be conducted by the CPSC to investigate AI/ML and the impacts it has on consumer products. The overall project will study the components, functions, and impact of AI/ML in consumer products.

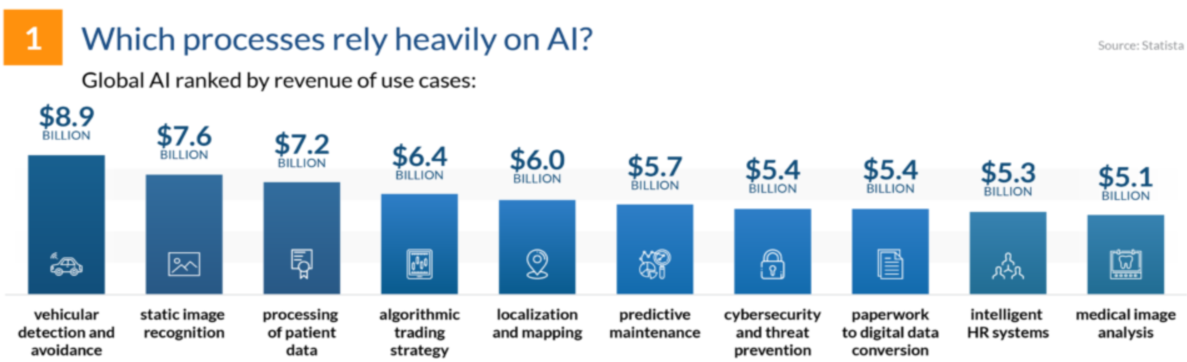


Figure 1: AI applications[1]

The scope of the WPI team's work included examining the components that make up an AI/ML system so that the CPSC can determine whether a product is AI/ML capable.

Throughout the course of this project, there were three main objectives:

1. **Create working definitions of AI and ML;**
2. **Identify the components involved in an AI/ML system;**
3. **Design a screening process to determine AI and ML capability in consumer products.**

The goal of these objectives was to help the CPSC to clearly define AI and ML and determine whether a product has the capability to incorporate AI or ML. It was critical to understand whether AI/ML could be present in a product so that the CPSC can later draw conclusions about potential physical hazards. In interviews with industry and academic AI/ML experts, many agreed that defining AI and machine learning is a difficult task. The research team created working definitions relating to this project so that the concepts of AI/ML could be better understood. Next, a screening process was created to identify whether a product is AI/ML capable. This system was designed so that CPSC employees can determine initially if a product is AI/ML capable and then proceed with studying the functions and impact of AI/ML in consumer products.

Examination of Artificial Intelligence and Machine Learning

Artificial intelligence and machine learning are fairly new concepts that are now becoming more widely utilized in modern technologically sophisticated products. Since there is limited information on AI/ML, it can be difficult to identify whether they exist in consumer products and what effects they may have on the functionality and safety of the products. The research team worked to create a methodology that can be used to identify AI/ML in consumer products, allowing the CPSC to investigate any potential hazards posed by the AI/ML.

This section discusses the concepts of AI/ML and examples of products that incorporate it. Hazards involved with electronic products and the ways companies test products will also be discussed. Finally, the role of the CPSC in consumer product safety will be explained.

How did Artificial Intelligence and Machine Learning Originate?

Artificial Intelligence (AI) is evident when a machine seems human-like and can imitate human behavior[4]. Machine Learning (ML) is defined by Stanford University as "the science of getting computers to act without being explicitly programmed"[5]. AI/ML was originally the brainchild of 20th century writers and artists. By the 1950s the idea of machines that could think was being considered by countless scientists, philosophers, and mathematicians. Since then, AI/ML has grown immensely. In 1997, world chess champion Gary Kasparov was defeated by IBM's Deep Blue artificial intelligence software. In the same year, Microsoft introduced a speech recognition system into Windows that used AI/ML as well. According to an article published by the Harvard University Graduate School of Arts and Sciences, AI/ML research has surpassed almost every goal that has been set for it and developments do not show any signs of slowing down[6].

What Are Artificial Intelligence and Machine Learning?

Artificial intelligence and machine learning are powerful tools in the hands of any product designer. Most people have heard of these technologies but it is important to have a foundational understanding of what they are. The intelligence of a machine is determined by its ability to process information and act rationally in a manner that resembles human reasoning[4]. If a device can analyze data and make decisions on its own, it is considered to be artificially intelligent. An important subcategory of AI is machine learning (ML), where a machine can interpret given data and then improve its ability to perform specific tasks based on that data. The implementation of ML creates a machine that can model information and gain experience to improve over time. For example, mobile browsers use ML technology to collect data about a computer user's searches in order to provide more relevant information in future searches.

"Artificial intelligence (AI) applications are utilized to simulate human intelligence for either solving a problem or making a decision"[7]. The appeal of using AI in products is the use of simple problem solving and basic data processing for applications such as speech to text, autonomous movement, and other complex tasks. Machine learning (ML) is a similar tool, as it is a type of AI that is more suited towards taking in data and gaining experience from it[8]. Machine learning can perform tasks well, provided that the algorithm that guides the machine is trained properly with appropriate data. The system uses training data to learn how to process information, and is then tested for performance. Based on the results of the test data set, the ML program updates the algorithm in an attempt to do a better job on the next set of data. *Figure 2* illustrates the process.

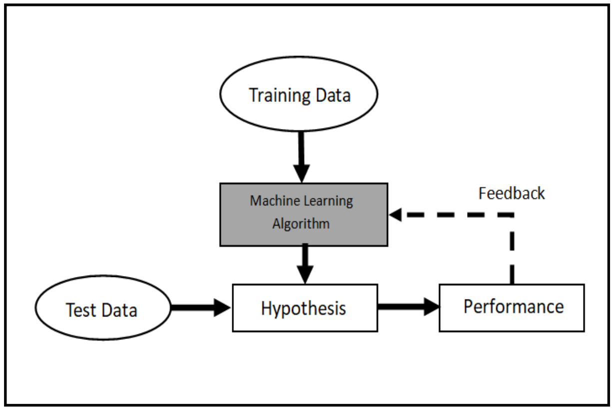


Figure 2: Machine learning diagram[9]

What Products Use AI/ML?

Many products incorporate artificial intelligence and machine learning technology in order to make them safer or more user-friendly. A recent application is self-driving cars that use AI/ML to gather information about their environment and allow them to navigate appropriately[11]. Vacuuming robots use AI/ML to scan the area around them using sensors and respond to their environment by avoiding obstacles when moving. Another product field where AI/ML may be present is in micromobility devices such as an e-bike or scooter *(Figure 3)* that can be used by consumers as a method of transportation[12].

The position, route, speed, and other data regarding the use of the e-bike or e-scooter can be collected by the company that owns the scooter at any time. The on board technology may be dedicated to collecting the data and processing it for transmission, a possible indicator of machine learning components. All of these products are made more efficient through the use of AI/ML. As electronic consumer products continue to evolve, AI/ML will become increasingly prominent and vital for such products. But, like all new and innovative technology, there will be problems.

Figure 3 : Micromobilty - electric scooter[13]

What Are Some Potential Physical Hazards?

Any electronic or mechanical product has the potential to be hazardous to the consumer. Electronic and electromechanical devices can be subject to problems such as malfunction, wear, or fragmentation[14]. These issues could possibly harm a user, and AI/ML products are not excluded from these risks because they too are electronic devices. Examples of these physical hazards could include chemical exposure, fire, or electrocution.

Chemical exposure in electronic products is an issue that is often overlooked. Many devices contain chemicals in batteries, components, paints, and stickers that could be harmful to users if not regulated. Electronic products can have the tendency to catch on fire if a circuit is broken, shorted, or if the battery is damaged. A damaged battery can sometimes lead to fires and even explosions in extreme cases. If the pressure in a battery is high enough, it could cause the electronic product to burst[15] . Electrocution is also a physical hazard of any electronic device[16]. Electric shock can occur if there are any faulty appliances, damaged cords, or if the device is in contact with water. All electronic products, including those that incorporate AI/ML, have the capability of causing physical harm to an individual.

Examination of Artificial Intelligence and Machine Learning

How Do Companies Test Electronic Products?

Prior to releasing an electronic product, companies must go through a standard safety testing process to ensure that their product is safe. These safety tests can vary based on what type of product is being designed. For example, a medical device needs to follow the requirements specified by the Food and Drug Administration (FDA). These requirements can include water resistance, backup systems, and impact regulations. Other products have requirements for their given field that organizations like the Consumer Product Safety Commission can regulate.

A great deal of safety testing is done by third party independent testing companies not affiliated with the CPSC or the manufacturer, such as Underwriters Labs. An example of a test done by these companies is a brake test conducted by putting a vehicle on a slanted surface and holding it there for a prolonged time to see whether or not it slides down. Another common test is a drop test that measures how a device breaks when it hits the ground; if it shatters into sharp pieces it will fail the test. Other tests determine the flammability of products by igniting them and observing how it burns. These tests are conducted to ensure that once a product is released to market it will be safe for consumers to operate. Whether it be a bicycle helmet or an ATV, the CPSC must be able to assess its safety.

What Are Unique Hazards of AI/ML?

As previously stated, AI/ML can share common hazards with general electronics since they are all electronic products. However, since AI/ML is a newly developed technology, it can add more potential for problems. When an artificially intelligent machine is responsible for making decisions, new risks may be created that have not yet been considered. For example, most electronic products are turned on and off by a human user. A product that incorporates AI/ML could have a feature that determines when to power the device. This technology could potentially induce additional hazards that need to be investigated. The CPSC is one of the leading organizations responsible for assessing the safety of consumer products, and the team's work will assist the CPSC in identifying hazards with AI/ML devices.

A visual representation of Artificial Intelligence [31]

What is the Purpose of the CPSC?

The CPSC's mission is to promote the safety of consumer products by addressing "unreasonable risks." The Consumer Product Safety Commission was formed in 1972 through the enactment of the Consumer Product Safety Act[17]. The Commission is an independent agency of the US government, and they report directly to Congress and the office of the President. The CPSC goes about their mission by primarily issuing product recalls and fines. Since their formation almost 50 years ago, the CPSC has been responsible for the recall of over 7,000 products[18].

The CPSC's role in the government is to monitor and regulate products produced for the market, often leading to increased regulation on what companies are able to manufacture and introduce to the marketplace. It is the responsibility of the CPSC to conduct research on products and identify possibly fatal or harmful issues in order to prevent injury. If a product is determined to be hazardous, the CPSC may advise the manufacturing company to issue a product recall. Some of the more successful recalls were the recall of faulty pool drainage systems that entrapped people and led to drowning[19], as well as the recall of many infant cribs that posed hazards to young children and infants[20]. Since its inception, the CPSC has dealt with physical hazards. However, today a lot of the effort put into product design is in the software of electronic devices including technology such as AI and ML. This new technology creates a product area in which the CPSC does not have an extensive level of regulatory experience. However, it is still the responsibility of the CPSC to ensure that the increasingly common use of artificial intelligence and machine learning does not turn out to be a safety hazard for consumers.

The CPSC focuses on physical safety hazards such as fire, shock, and impact. It reduces risk by looking at data regarding common sources of hazards and investigating potentially hazardous products. Various program areas differ in their level of assessment, such as fire safety's focus on small ignition sources in residential areas or the electrical engineering area's focus on shock and burn hazards. While these are key foci of the commission, these same program areas have limited information when it comes to identifying artificial intelligence in a system, or determining whether the device is capable of such features. It is currently difficult for the CPSC to investigate products that may incorporate AI/ML technology, so they need a method to determine which AI/ML products are safe for consumers.

A Visual Representation of Consumer Products[32]

Strategies Used to Assess AI/ML in Consumer Products

The goal of this project was to assist the Consumer Product Safety Commission (CPSC) by creating a methodology used to determine whether a consumer product may be artificial intelligence and/or machine learning capable. This process involved creating working definitions of AI/ML and identifying the components of an AI/ML system. The team began by collecting data about AI/ML through research and interviews to gain as much information about the technology as possible. A screening process was created to allow the CPSC to identify products that could incorporate AI/ML. Thus this project contributed to a carefully defined understanding of the concepts of artificial intelligence and machine learning and their potential existence in consumer products.

The Four-Phase Approach

The project was the first portion of a larger project conducted by the CPSC. The CPSC's project follows a four-phase plan: Identification, Implications, Impact, and Iterations of AI and machine learning within consumer products. Phase 1, Identification, was the stage of determining whether a specific product is capable of incorporating AI or ML based on its components. Identifying AI/ML capability is crucial, as it allows the CPSC to know whether the product should be further studied for functions and impacts of AI/ML. Phase 2 focuses on the implications or possible consequences of AI/ML, in which the potential functions of the AI/ML in a product would be investigated. This process will allow the CPSC to study the purpose of the AI/ML in a product and the effects it may have on the product's capabilities. Following the completion of phase 2, phase 3 will focus on the potential impacts of AI/ML in consumer products such as smart watches and appliances and whether any potential physical hazards exist as a result of the AI/ML. Some of the potential hazards include electric shock, fire, and impact hazards. Lastly, phase 4 will consider the iterations of the AI/ML and predict how the behavior of a product may change over time. The four-phase approach is outlined in *Figure 4.*

The goal for this project was to complete Phase 1, giving the CPSC a methodology for determining whether a product is AI/ML capable. The project had three objectives to be accomplished for Phase 1:

1. **Create working definitions of AI and ML**
2. **Identify the components involved in an AI/ML system**
3. **Design a screening process to determine AI and ML capability in consumer products**

Figure 5 shows the process of the project.

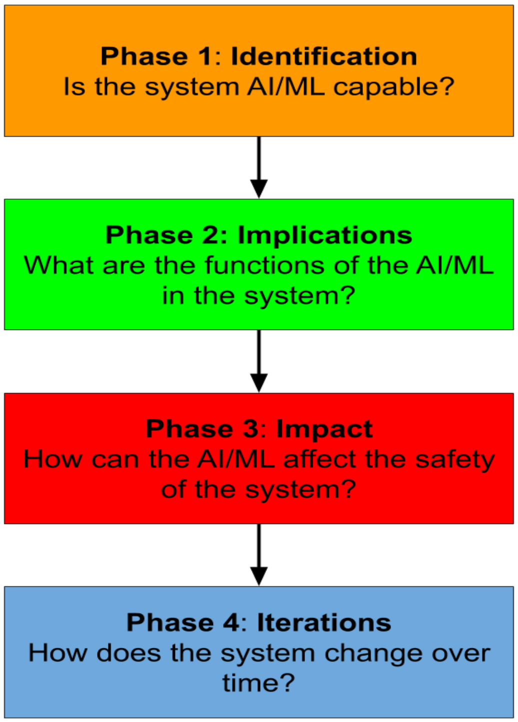


Figure 4: Four-Phase Approach

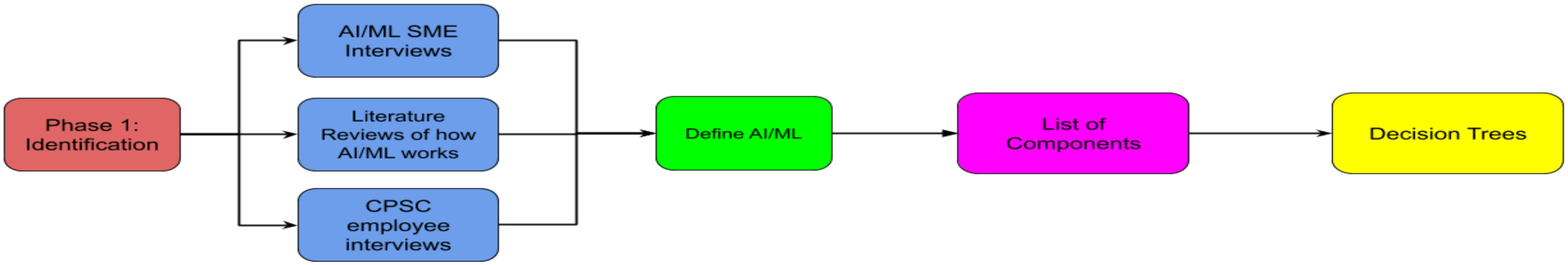


Figure 5: WPI Project Methods Flow Chart

Defining AI and ML

Interviews were used to gather general information regarding artificial intelligence, machine learning, and the CPSC. A list of questions was developed for discussion points during the interviews (Supplementary Materials: Appendix A). The goal of these interviews was to find out how each professional defined artificial intelligence and machine learning and what they would look for in products to identify an AI/ML capable system. Interviews were conducted with eight AI/ML experts in both academia and industry to obtain varied perspectives on AI and ML, including Computer Science professors at WPI and subject matter experts such as Nevin Taylor, a chief technology officer at the CPSC. The group received a broad range of answers that they were able to compare and cross reference to find the most general and widely accepted definition.

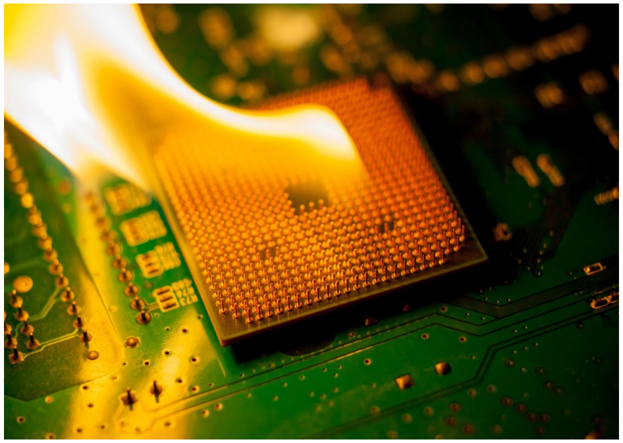
Ten CPSC employees were also interviewed to gain understanding of the products they work on and how they conduct investigations. Employees from a wide variety of program areas were interviewed, including fire, electrical, Internet of Things (IoT) and e-mobility. They spoke about the specific hazards dealt with in each program area, along with the CPSC's process for identifying and investigating potentially hazardous products. The outline of the questions that were asked in these respective interviews appears in the Supplementary Materials file.

A literature review was utilized to enable the team to better assess how AI/ML technology works and how to identify it in consumer products. Information relating to the definitions of AI and ML and their components was gathered to increase the understanding of AI/ML concepts. Scholarly journals and research reports about how to define AI/ML were also studied.

Additionally, a survey was given to CPSC employees designed to assess how they felt about the prevalence of AI/ML in their respective program areas. The survey was conducted through Google Forms, a format that allowed the respondents to remain anonymous. This survey was conducted voluntarily, so respondents were able to answer whichever questions they felt comfortable answering. The questions asked in the survey were also asked of the interview subjects at the CPSC. The survey was achieved by open written responses, and 34 responses were obtained (See survey in Supplementary Materials: Appendix A). The responses gave insight into the opinions of the CPSC employees on AI and ML and how it might affect their program areas.

Development of the Project Deliverable

Once all of the necessary information was gathered, working definitions of AI and ML were created (Supplementary Materials: Appendix C). AI and ML are general concepts and are difficult to define, so project terminology was developed in order to avoid confusion. These definitions helped to clarify the terms AI and ML as they are used throughout documents given to the CPSC. Working definitions of physical harm, safety, and hazard were also created for use in later phases of the overall project. To create the screening process for AI/ML capability, the components of an AI/ML capable system were identified and researched. These components were described in a detailed table consisting of a list of the components and relevant examples, which will be shown in the AI and ML components sections. A series of questions was also developed that the CPSC could ask when investigating a product for AI/ML capability. These questions were presented in the form of a decision tree, which will be discussed in the decision trees section. Separate decision trees were developed for AI and ML, as they have different components and may need to be investigated separately. Using these decision trees, the CPSC can form a conclusion as to whether a product is AI/ML capable.



Fire Hazard in Electronic Devices [33]

CPSC Employees Anticipate Growth of AI/ML in Consumer Products

A survey was given to CPSC employees designed to assess how these employees felt about the prevalence of AI in their respective product fields (Supplementary Materials: Appendix A). The survey found that the large majority of CPSC employees agree that there is a likelihood that AI or ML is already, or will soon be, utilized in products in their program areas. This opinion is reflected in *Figure 6,* showing the responses from the interviews as well as a questionnaire sent to CPSC staff.

This survey was conducted voluntarily and received 34 survey responses. The pie chart also includes 4 responses received from interviews with CPSC employees as the same questions were asked of them. There were scenarios where the respondents either did not have an answer, or gave an answer that was unrelated or a misinterpretation of the question asked. These were determined as the respondents were asked to elaborate on the questions. The conclusion drawn from these responses is that most CPSC professional employees believe that AI and/or ML are either currently or will be in their program area.

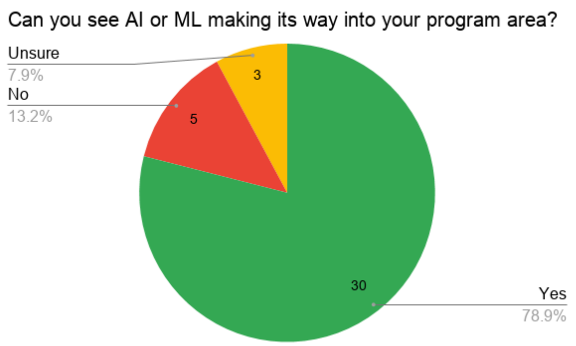


Figure 6: Graph of survey and interview responses (n = 38)

Working Definitions for Project Purposes

It is important to establish working definitions for both artificial intelligence and machine learning for this project. This terminology was arrived upon through research and interviews with subject matter experts (SMEs).

Artificial Intelligence (AI):

Artificial intelligence is a field of computer science that allows a system to interact with its environment in a manner that resembles human decision-making. An AI system processes information to provide an output based on the given input. It can be used in a system's role to assess information and aggregate answers or in a support role to assure successful operations.

Machine Learning (ML):

Machine learning is the process of a system gaining knowledge or experience from given data and improving its performance over time without being explicitly programmed. It involves monitoring information to assess outputs, measuring to find differences or adaptations, and creating a comparative or temporal model to characterize outcomes.

These terms are working definitions, but by no means definitive definitions of either term as both wordings are open to debate within the scientific community. Interviewees stated that AI and ML as topics are not currently well defined and many people have conflicting opinions on how AI and ML are related. When asked to define AI, the research team saw a wide range of answers from experts, however there were some commonalities that appeared. Most of the definitions of artificial intelligence compare the actions to that of a human or to human intelligence. The full interview reports can be found in the Supplementary Materials: Appendix B.

The terms were also developed based on literature reviews. Research provided a better understanding of AI and ML systems in general and identified four primary components in any AI or ML system.

An AI Capable System Must Contain Four Main Components

In order for a device to be capable of incorporating AI/ML technology, it must contain certain components: a data source, an algorithm, computational capability, and a connection. *Table 1A-C* is a description of the components along with a few of the most common examples. The full table can be found in Supplementary Materials: Appendix D.

The first component is a data source, used by a device to collect input. An AI system relies on some form of input to be processed. In many electronic devices, sensors are used as the source of data. A sensor is a device that collects input data that can be processed by the system[22]. There are many different types of sensors that are used for various applications in electronic products. An infrared or ultrasonic proximity sensor detects the presence of an object that passes in front of it and is commonly used in high-end automobiles for parking assistance and collision avoidance. Temperature sensors found in air conditioning systems can detect changes in the temperature of the environment to allow optimal heating or cooling. Microphones and photoelectric (sound and light) sensors are also used to collect data necessary to the function of a device[23]. Another sensor seen in collision avoidance systems is an accelerometer that measures the rate of change of the velocity of an object. Gyro sensors can measure angular velocity and are found in mobile devices and airplanes. These sensors and many others can be used to collect data and are essential components of an AI capable system.

Component	Description	Examples
Data Source	A common form of a data source is a sensor. Sensors are electronic devices that quantify the state or changes in the state of the outside en-	
Proximity (Infrared) sensor	Devices that utilize fields, beams or light to detect a presence or movement. These devices may identify ambient light, speed, proximi-	Security camera, automatic lights, obstacle detection, motion trackers
Temperature sensor	A device that detects the temperature in a specific area. Typically used to display the current temperature of the area, or controls the device after reaching a specified temperature.	Overheat detection in phones, refrigerator regulator, 3D printers, high end soldering irons

Table 1A: AI Component List for Data Source

An algorithm is a set of instructions designed to perform a specific task. This can be a simple process, such as multiplying two numbers, or a complex operation, such as playing a compressed video file[24]. AI and ML algorithms are difficult components to identify, but there is a way to separate an AI algorithm from a standard robotic process. In terms of algorithms, what needs to be identified is whether or not the system makes decisions on its own. In order to identify AI, it is helpful to explain what is not AI. A type of system that is often confused with AI is robotic process automation (RPA). RPA systems are programmed to repeat the same task based only on input from devices such as a timer[25]. The simplest way to look for the difference between an AI algorithm and an RPA is to identify whether the product is making a decision from one or multiple inputs. In slightly more technical terms someone would try to identify whether the code uses "if" statements. Looking for an "if" statement is somewhat of a simplification, but it is a good way to easily identify complex AI algorithms since such algorithms will take advantage of many "if" statements. Another way to identify AI algorithms is to think of whether the system could be broken down to a decision tree. If the system is entirely RPA based, a decision tree will not work but, if the system has to make decisions and those decisions are not made by a human hitting a button, then that system uses an AI algorithm.

To get a better idea of AI algorithms, some examples of an AI algorithm should be provided. As a starter, one could consider an automatic vacuum robot. These devices are known for making decisions when they collide with walls and will change their course when encountering an object. If these were using RPA, they would perform the same action repeatedly such as going straight for 30 seconds then turning right. This would not be considered AI, as the device is not making a decision and is only following simple steps. An example of a system that does not use an AI algorithm would be a timed light which would turn on for 1 second then turn off for 1 second and repeat until the system is turned off. This is a good example of an RPA, as the actions are simple and there is no decision being made by the device as it follows simple instructions without any deviation.

Another component of a system that may incorporate AI is computational capability. In order for a device to perform computations, it must contain a central processing unit (CPU). A CPU is the main processor in any computerized system[26]. The operations of a CPU in a system are to fetch, decode, execute, and write back. The processor first fetches the instructions from program memory. That information is decoded so that other parts of the CPU can continue the operation. The instructions are then executed to perform the desired operation. Finally, the CPU writes back to send the output to the memory after the operation is performed.

A CPU may be found in a number of different forms[26]. Most modern processors are microprocessors, a processor that is implemented on a single chip. A microcontroller is a small computer that contains a CPU and is used in many electronic products. CPUs are often used as embedded processors, meaning that the processor controls the mechanical or electrical functions of a physical device. In an electronic product, data must be taken in from sensors and processed through a CPU in

Algorithms	The software or code in a system that allows for the device to make decisions.	
Decision making	The act of a product or AI system making choices autonomously.	Decision tree, linear regression[21]
Computation	Computation usually requires a central processing unit (CPU). A CPU manipulates data collected from sensors to	
Microcontroller	Small computer designed to read and respond to input.	Remote control devices, appliances
Microprocessor	A processor that is stored and implemented on a single chip. Nearly all modern processors are microprocessors.	Systems that incorporate an on-board computer

Table 1B: AI Components List for Algorithms and Computation order for the product to be capable of incorporating AI.

The next component of an AI capable system is a connection. Connection refers to the linkage through networks that allows for the flow of information throughout the system. Most systems are connected either through data busing or the Internet of Things (IoT). A data bus is a physical component consisting of either a connector or set of wires that transports data to and from the system's memory or processor[27]. In an IoT connected device, data is collected by the device and sent to the cloud[28]. Information is then processed in a data center and stored or sent back to the device. Data busing and IoT connection enables a system to send and receive information to be processed and is a necessary component for AI capability.

A System Must Have All Four Components to be AI Capable

In order for a product to be AI capable, it has to incorporate all four components: data source, algorithm, computation, and connection. Without all four components present, the system could not be classified as AI capable. Each component is an essential aspect to an AI capable system. AI first needs to have a source of data, whether by manual input into a software, or by sensors. Once the data has been collected, a processor then runs the algorithm to determine what to do with the given information. Depending on the algorithm, the device generates an output based on the given input by the sensors. Connection allows the information to be linked throughout the entire system.

Connection	The linkage through networks that allows for the flow of information throughout the system.	
Data bus	An electronic point to point connection for the purpose of transferring binary code through a system.	Computers
Internet of Things (IoT)	A group of connected products that send data to the cloud to be processed. Information is then sent back to	Smart watches, smart appliances, home security systems

Table 1C: AI Components List for Connection

An ML Capable System Must Include Three Main Components

Just as a system must contain specific components to be considered AI capable, an ML capable system also has a minimum set of components. The three components of an ML capable device are monitoring, measuring, and modeling. *Table 2* describes these components.

A system that incorporates ML must monitor, measure, and model data that has been given to the ML process. First, the system monitors outputs. ML improves answers that have been previously produced, so it must observe a generated output. For example, machine learning could be used to improve the process of making cookies. In order for the ML to compare the cookies, batches of cookies must first be made. The cookies would be considered the output in this example, so ML monitors the output by taking in generated answers.

The next ML component is measuring. When an ML system measures, it observes differences within the data. Any adaptations, or changes in the outcome, are analyzed so that an accurate model can be created. For example, image processing uses machine learning to find any differences between the observed images to decipher the content of the image.

An ML system must also model information. The ML model characterizes the differences determined by the measuring component. When multiple outputs are being compared against each other, a comparative model is created. Modeling output that is being compared with previous outputs is considered a temporal model. Creating a model allows the system to learn from experience and improve its behavior over time. Once a model has been established, the system will continue to monitor and measure information to further develop the model.

The three components of machine learning can be explained with the cookie example. When baking a batch of cookies, it is likely that the person baking them would like the cookies to taste good. If baking cookies incorporated machine learning, the ML could be used to improve the quality of the cookies. First, the monitoring component would consider the batches of cookies as the output and observe their characteristics. The measuring component would find differences between the cookies to determine which batches are better. Using the information found through measuring, a model would be created that would describe how the baking process leads to the desired output. Over time, the cookies would continue to be monitored in order to improve the model and eventually result in the best cookies possible.

A System Must Have All Three ML Components to be ML Capable

In order for a system to be ML capable, it must have the following three components: monitoring, measuring, and modeling. The system first must be able to monitor the outputs to prepare for analysis. The measuring component then compares the data to determine the differences. Finally, the system models the data either in terms of comparative, differences between data, or temporal, the change over time. A system must monitor, model, and measure to be ML capable.

Decision Trees Can Be Used to Identify AI/ML Capable Devices

The goal of this phase was to identify the components that make up an AI/ML system

Component	Description	Examples
Monitoring	Distinctions	
Qualify	Assesses outputs to observe the given information.	A voice recognition tool that processes a user's speech.
Measuring	Differences	
Quantify	Analyze adaptations to find differences within the data.	An image processing application that finds the differences between two or more images.
Modeling	Differentials	
Characterize	Enables the system to Enlighten/Empower/Evolve so that it may improve over time.	A vacuuming robot that develops a model of the rooms it vacuums in order to navigate its environment.

Table 2: ML Components List

and to provide a methodology to determine whether a consumer product is AI/ML capable. To accomplish this task, AI and ML decision trees were created. A decision tree is a tool that shows the flow of questions and their consequences in a tree-like pattern. *Figures 7a and 7b* show the decision trees created to identify AI and ML capable systems. These decision trees are the product of the findings described above. To demonstrate the use of the decision tree, for example, consider a smoke detector. The device uses a sensor to collect information on the quality of the air in a building. A processor is used to analyze the information given by the sensors. An algorithm in the device tells the smoke detector whether the alarm should sound. Smoke detectors only go off when there is a hazardous amount of smoke being detected. Through the help of the sensors and processor, the algorithm decides when to set off the alarm. The system is linked together to enable the flow of data from each component. According to the decision tree, the smoke detector system would answer "Yes" to the AI questions. Therefore, a smoke detector is AI capable.

Another consumer product that could be analyzed in the decision tree is a standard refrigerator. When the door of the fridge is opened, a touch sensor enables a light to be turned on. The touch sensor in the fridge does not collect data to be analyzed by an algorithm to make a cognitive decision. The sensor only detects when the door is opened, closing the circuit to provide light to the fridge. Therefore, when assessed in the decision trees, a standard refrigerator does not have AI or ML capabilities.

An example of an ML capable system is a vacuuming robot. When applied to the ML decision tree, it was determined that due to the system changing its behavior over time, it must incorporate the three ML components. It first monitors by observing the room as it makes decisions to navigate its environment. The robot will locate objects around the room and remember their location. It then measures to find differences as it explores the room multiple times. If an object is in the same location every time, the robot will note that there are no differences in the object's location. The vacuuming robot creates a model by organizing the information found from monitoring and measuring and compares them against past iterations and information. Since the system is a loop, the robot continues to monitor and measure to build upon the created model. The vacuuming robot changing its behavior over time leads to the conclusion that the product is a machine learning capable system.

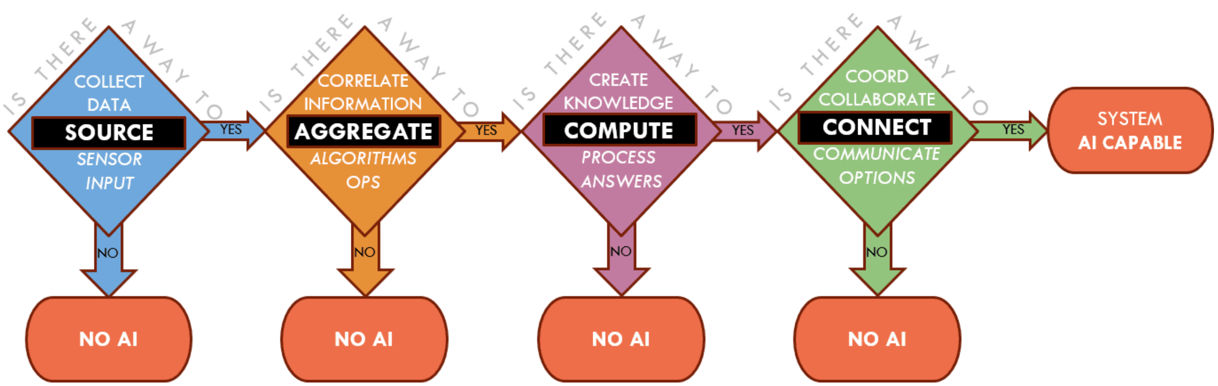


Figure 7a: AI Decision Tree

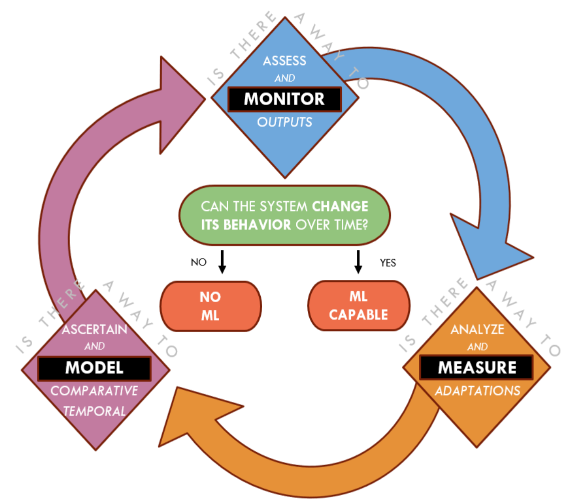


Figure 7b: ML Decision Tree

Key Findings of AI and ML

Functions of AI/ML May Vary Depending on the System

Some relevant information for Phase 2, the implications of an AI/ML system, has been collected throughout the project. Discussions with subject matter experts (SMEs) and CPSC employees revealed potential functions of AI and ML systems based on their components.

Interviewees and literature reviews identified the intended functions from a variety of AI systems, and the possible capabilities exhibited by any particular system. For one example, AI can be used within the medical field to analyze x-rays of patients using cameras to collect information in the form of images. This system then relays the images to the software and processes the data into concise data. The data allows the operator to identify any key problems that may be missed by a human eye. The function of the AI is to interpret the data collected and ensure the identification of problems. Another important function of AI would include the collision detection systems in most modern consumer vehicles and some micro mobility devices.

While AI experts assisted in providing information on AI and ML alone, the team gained additional information from employees of the CPSC to understand how some AI systems may function from the perspective of consumer safety. CPSC employees see some of the functionality of AI within portable generators that detect power levels or usage rates. AI components are also included in carbon monoxide detectors that use a variety of different atmospheric sensors to identify changes in the environment. Smart fridges incorporate temperature regulation and can be modified to show recipes based on the items within. There are many product areas that currently utilize AI/ML or may do so in the future. The functions studied will help the CPSC better evaluate the implications of AI/ML in consumer products.

AI/ML in Products Could Impact Consumer Safety

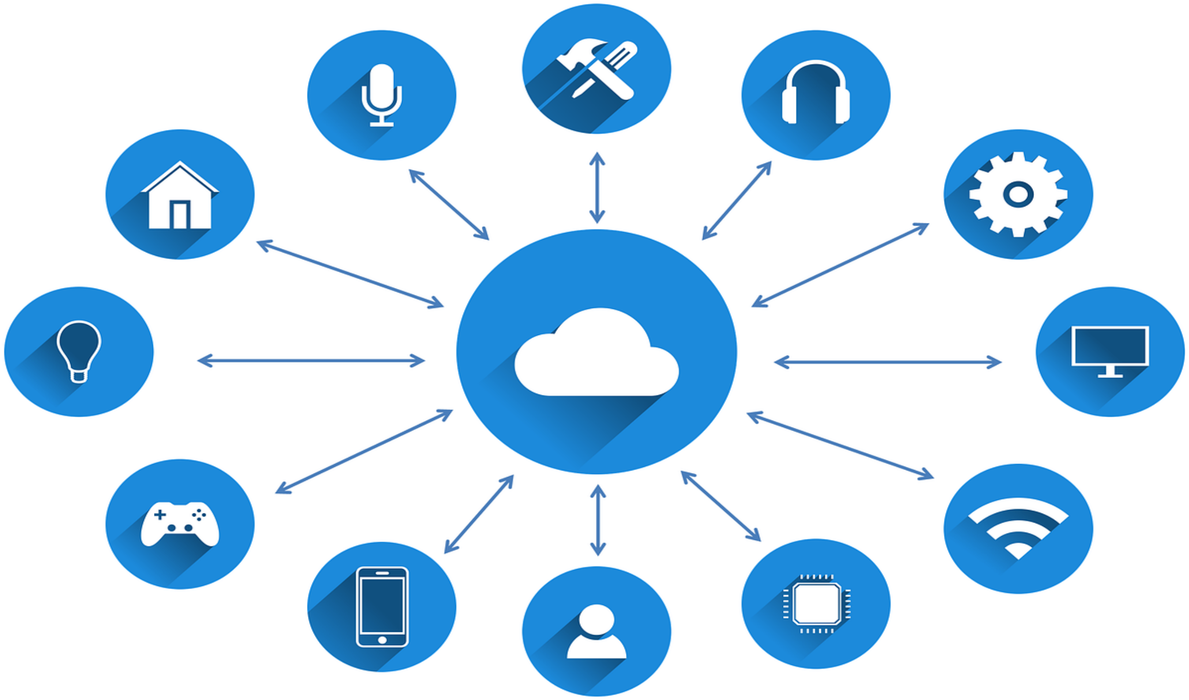
In addition to information relevant to Phase 2, some information on potential hazards of AI/ML in consumer products was collected that could give insight into Phase 3. While Phase 3 was not within the scope of the WPI team's project, information has been found relating to the terminology and types of potential hazards. Before investigating any hazards, it is important to cover the working definitions of hazards, physical harm, and safety created for this project. **Physical harm** relates to a source of bodily pain, injury, or cause of an illness suffered by an individual. **Safety** is the state of being protected in the sense that a person or object is protected from some danger or harm. Lastly, a **hazard** is a potential source or a situation that increases the likelihood of physical harm to an individual or group of individuals (Supplementary Materials: Appendix C). Examples of physical harm could include mechanical contact, hazardous energy release, exposure to hazardous chemicals, or other hazards from a product. These three definitions helped us to gain insight into potential hazards and identify whether anything found would be classified as such.

To explore more about hazards, literature reviews were utilized to understand hazards and common safety concerns. The main document examined was the CPSC's mid-term Volunteer Standards Tracking Activity Report[29]. This report holds a record of all voluntary standards and any significant changes over the past year. It covers standards for products ranging from additive manufacturing to window coverings. Based on this document, the CPSC's policies for AI and ML hazards would most likely relate to carbon monoxide alarms, some gas appliances, smoke alarms, some portable generators, connected smart devices, and self-balancing recreational vehicles. The document revealed program areas that may be more likely to incorporate AI/ML technology and the potential areas of study.

Based on interviews with the CPSC and AI experts, the team has been able to identify additional functions of AI/ML in consumer products and other ways they could cause potential hazards. Among the SME experts interviewed, a majority have expressed thoughts on functions that could also cause hazards. For example, an AI system that regulates battery power could discharge the battery if left unchecked, or an AI controlled temperature regulator could malfunction causing a false reading or worse. Another example includes a home automation system. Most of these devices record the events and changes in the surrounding environment and act based on the time of day and trends. Such a system could take in false data or react incorrectly to the wrong situation, causing problems within the household ranging from incorrectly locking doors to smoke detector alert failures. Additionally, these same issues could prove to be severe hazards if devices such as surgical machines malfunction while in the middle of an operation.

While interviewing SME helps with understanding how AI/ML can affect software, it is easier to understand hazards from the perspective of the CPSC employees as they deal with these issues daily. Based on the interviews conducted with the employees, the team learned about several common hazards that could be caused due to malfunctions of devices that incorporate AI and machine learning. The most common hazards the CPSC covers include fire, impact, and shock hazards. Fire hazards tend to be caused by malfunctions in the electrical circuits and overheated components. As for shock hazards, electronic devices can always create situations that result in an electric shock delivered to the user. Lastly are impact hazards, where fragile parts or moving objects could cause bruises or other physical injuries to the user. Devices that contain exposed moving parts of loose parts that could fly from the product could result in possible injuries. From our talks with CPSC employees we determined that the program areas that would be most likely to incorporate AI/ML in the future would be e-mobility, internet of things (IoT), gas grills, and wearables. Within the scope of Phase 3, a preliminary analysis of the most common hazards applicable to AI and machine learning has been established, and the team hopes the CPSC can develop this phase even further.

Representation of Smart Devices [34]



Internet of Things (IoT) Diagram [35]

The CPSC Can Now Identify AI/ML Capability

The primary goal of this project was to develop a methodology for the CPSC to identify artificial intelligence and machine learning in consumer products. To accomplish that task, working definitions of artificial intelligence and machine learning were created. The components of AI and ML capable systems were then identified and researched in detail. Finally, a decision tree was developed as a screening process along with supplementary materials to elaborate on the components of an AI/ML capable system. This screening process should be used in situations where AI/ML is a potential cause of a hazard. If an electronic product is found to be a source of a physical hazard and the cause of the hazard is not an obvious physical component, AI/ML may be present. The CPSC should then use the AI/ML screening process to determine the product's AI/ML capability. **The components list and decision trees provide a tool to enable CPSC examiners to identify AI/ML capability in consumer products** as a first step towards identifying the functionality and any potential hazards caused by the AI/ML, and thus enabling them to mitigate potential risks to the consumer.

Future Project Developments

Prior to the completion of the WPI team's project, the CPSC did not have established definitions of artificial intelligence or machine learning. These terms are difficult to define and often depend on the context. The CPSC may use the given definitions as needed when referring to AI and ML in future work. The organization should continue to develop the definitions of AI and ML as they gain more information and modify them as needed for specific applications.

The screening process given to the CPSC allows them to determine whether a product is AI/ML capable. Next, the **CPSC needs to study the functions of AI and ML in consumer products to find out if the product incorporates AI/ML.** Functional AI/ML is difficult to recognize in a product, as the major indicators of AI and ML would be located within the software. Since the CPSC cannot easily access software due to difficulty obtaining it from the manufacturer and may not have the resources to analyze code, other methods should be relied on to identify functional AI/ML. It is recommended that the CPSC look to establish categories of AI and ML functions. These functions could include navigation, such as GPS or autonomous movement, or safety assurance in situations such as automatic braking systems. By identifying AI/ML functions, the CPSC will be able to look at the behavior that the software causes and come to a conclusion about the usage of AI/ML.

It is recommended that the CPSC study the potential AI/ML in program areas that are most likely to incorporate AI/ML, including e-mobility, internet of things (IoT), gas grills, and wearables. Studying AI/ML components gave insight into potential functions of AI/ML in products, and discussions with CPSC employees helped to understand where AI/ML may be present in current and future program areas. Understanding of the functions of AI and ML systems will enable the CPSC to study the impact of AI/ML on the safety of consumer products.

Major Takeaways

AI/ML is increasing in popularity in consumer products and organizations like the CPSC are addressing issues that can be difficult and complex both to define and to fully comprehend. The components of an AI/ML capable system have been identified, and decision trees were made to determine AI/ML capability. Throughout the course of this project, the team has learned about AI/ML, how consumer safety is addressed, and professionalism. Team members learned professionalism and project management. Through the help of sponsors and advisors, knowledge regarding how to conduct Program Management Reviews (PMRs), presentations, and report writing was gained. The skills and experience gathered throughout this project will be essential for future careers.

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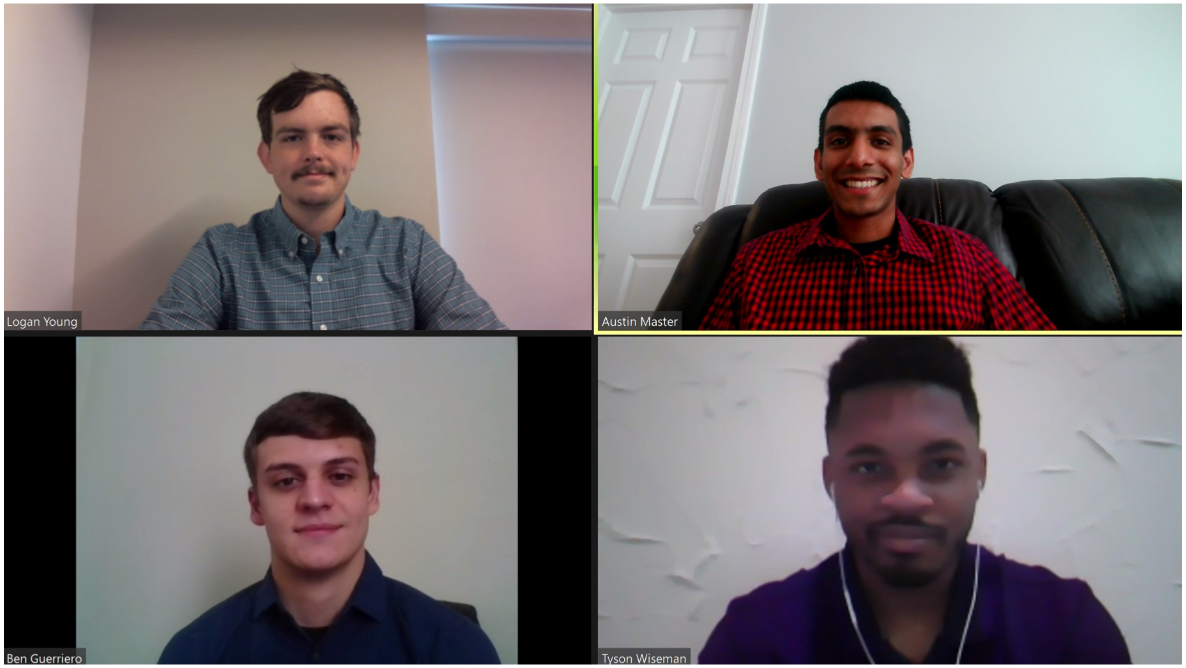

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