# Targets

## Functions and Targets/Metrics

The previously outlined functional decomposition was performed to identify four major subsystems with 14 functions that must be accomplished to achieve the key goals of the project. The four main subsystems of the “Rockwell Automation Manufacturing for STEM Engagement” system are Manufacture, Educate, Control, and Support. The 14 functions generated fit into one or more of the four subsystem categories. To determine the success of the identified functions, specific values were set for the design criteria to meet. The targets are numerical values to quantify the success of each function, followed by the metric, which is the physical quantity being described by applied to the target. The validation method for each target is also outlined below.

## Method of Validation

The project aims to educate and engage students in manufacturing engineering through an automated demonstration. To ensure the system’s success, the performance must be thoroughly validated. This will be done using a variety of testing methods that are outlined below and applied strategically to each target and metric. The testing methods used to verify each specific target are noted in later sections.

*Performance testing* will be used to assess the capabilities of the system specifically regarding speed, stability, and accuracy. This involves a variety of targeted techniques including *load testing*, which evaluates how the system behaves under the expected load of the linear actuator. It is also vital to employ *stress testing* that will push the system beyond its specified limit to ensure it can handle potential extreme conditions and recover from failures related to them. This may include excess force and improper user interaction. *Endurance testing* will assess degradation of the system over time, as it should be built from industrial hardened devices that withstand the effects of time.

Many derived targets and metrics relate to time and require the use of *production speed testing*. This will quantity how long a manufacturing step or process takes under typical and peak load conditions. It ensures that the system can handle user requests efficiently.

One of the most integral methods of validation is *safety testing*. Given the young, non-technical audience, it is important that the device is as finger safe as possible. *Functional safety testing* will be used to evaluate the automated steps in the system, and *mechanical safety testing* will assess the design for any hazards in physical components, like sharp edges or structural integrity. Similarly, it is important to evaluate how user-friendly the system is in general. This includes testing the level of automation and requirement of user interaction through *usability testing*.

Several tools will be used to measure our targets and metrics. A timer will be used to measure any time-related functions. A load cell will be used for functions where the amount of force applied needs to be determined. A rep counter will be used for functions that need tracking of physical quantities. A protractor will be used for functions where angles need to be measured. A ruler will be used for functions where distance needs to be measured. Lastly, a scale will be used for functions where weight needs to be measured,

## Derivation of Targets and Metrics

For each function generated in functional decomposition, the corresponding targets and metrics were set through extensive research and discussion among the design team. A few other necessary functions were also determined and are listed at the bottom of Table NUMBER in Appendix NUMBER. A thorough explanation of each target and metric is given in later sections.

The manufacture subsystem had three functions, all of which had targets set based on the materials included in a typical button pin set (Amazon, 2020). It was noted that when determining a press fit force, the equation below should be used (Savvy Calculator, 2023).

The linear force required to successfully produce a button pin is roughly 150lbs, which allowed the assembly target to be set.

The educate subsystem had its function targets set based on an existing button maker distributed by Tecre (Tecre, 2015). All versions of this button maker allow for around 200 buttons to be produced per hour. This equates to roughly 20 seconds to produce one button. The design team determined that this was a good reference, but too low of a time to also accomplish the educate functions. For that reason, the target was set at 60-90s with at least 4 automated steps that display update messages to the user.

All functions under control were evaluated based on the current sensors in use and typical Rockwell sensor to determine a response time of under 100ms required. The failure and error rates were set to ensure customer satisfaction.

The support targets and metrics were derived in communication with Rockwell Automation to understand who they want to market the product to and how it will be transported. The outside functions were found to be necessary for the success of the project based on sponsor needs as well, and the engineers in communication with the design team directed the specific values of the targets.

## Manufacture Targets and Metrics

The manufacture subsystem is a vital part of the overall system. Manufacturing is defined as the process of turning raw materials into finished goods. One of the key goals of this project is to teach an audience about the manufacturing process. This subsystem holds all functions related to producing a button pin. The subsystem has three primary functions: receiving raw button pin materials, assembling the button pin, and outputting the completed pin to the user. By going through each function, the audience will gain a better understanding of the critical steps in the manufacturing process. To ensure the manufacture subsystem is effective, targets and metrics were identified for each function

To produce a button pin, the system must first receive the raw materials. The metric chosen for this function is the number of pieces received, with four pieces being the target value. The target value was derived from the number of required materials to make a completed button. This function will ensure that all necessary materials are accounted for before the manufacturing process begins. The metric will be tested by how many pieces of each material are detected by the system before manufacturing starts. To validate the data, team members will conduct counts of the physical quantities and compare them to values output by the system.

The following function in the subsystem is to assemble the button pin with the given raw materials. To form a button, these materials must be pressed together. The metric identified for this function is the amount of linear force applied during the pressing process. The target value for this function is at least 150 pounds of force. This will ensure that all the components are securely combined to prevent faulty or damaged buttons. *Load testing* will be performed, and the metric will be tested through multiple test runs of the pressing process. It will be validated by hand calculations and load cell measurements taken during these runs by the design team.

The last function of the subsystem is to output the completed button to the user. The identified metric for this function is the time taken for the completed button to be transferred from the pressing stage to the safe zone. The target range for this metric for this step is 0-20 seconds. This ensures that the user receives their button promptly and observes the result of the manufacturing process. This metric will be tested through *production speed testing* with multiple system test runs and validated by measuring the amount of time it takes for each run, with adjustments when necessary.

## Educate Targets and Metrics

The educate subsystem was previously identified as an integral component of the system’s success with three corresponding functions. A key goal of the project is user engagement and interaction, meaning it is important that the system functions at a pace quick enough to hold attention, but slow enough to follow each manufacturing step. The system needs to engage the user, while resembling a realistic manufacturing process and adequately displaying it to the audience.

To ensure the user is engaged, the production rate was selected as the metric evaluated. This is the time taken to complete one personalized button pin. A target of 60-90s was set, as the product should not take much longer than one minute to avoid redirection of the young audience’s attention. This metric will be tested with *production speed testing* by completing a series of button pins on the machine and recording the time from the first user interaction to the output of the final product. To validate the data, the test engineer will conduct the testing with an additional team member acting as the operator.

For the system to resemble a realistic manufacturing process, *usability testing* will be employed. The metric for evaluation is the quantity of automated steps. The target was set at a minimum of four automated steps including the reception of raw materials, assembly of the top components, assembly of the button top to the button back, and outputting of the final product. To validate the data, the test engineer will record the number of manufacturing steps that are completed automatically and confirm the results with the design team.

The system must display the manufacturing process to the user, meaning that it is visually appealing and easy to understand. The chosen metric is the quantity of update messages displayed to the user through the human machine interface (HMI). This will be validated by the test engineer through *usability testing* done with several different people acting as the operator, including members of the design team and sponsors as well as non-technical users.

## Control Targets and Metrics

The control subsystem is designed to manage the system's responses to both user interactions and internal automated processes through coding. For our design to operate effectively, the code must accurately execute inputs to automate the manufacturing process. Each of the following functions are vital for the overall control and efficiency of the system, ensuring it operates effectively within its designed parameters.

The first key function is actuating upon user input, which ensures that any user commands are executed within one second. This rapid response is crucial for maintaining user trust and operational efficiency, allowing the system to remain interactive and responsive. The target was set at less than 1s and will use internal *performance testing* imbedded in the code to print the total time from interaction with the user to execution of a step. This will be done multiple times, and the values will be recorded and validated by the test engineer.

The receiving sensor information function is responsible for the collection and initial processing of data from various sensors. This data is crucial for the subsequent decision-making processes, with a target to complete this task in less than 100 milliseconds. This swift response allows the system to adapt quickly to changing conditions and maintain a high level of performance accuracy. The *performance testing* will be done identically to the previous function and involve internal code to print the reaction time.

The third function, operates by given computer data, focuses on how well the system adheres to the predefined algorithms and commands. The system aims to have a failure rate of less than 2 percent in executing these commands, ensuring reliability in the automated decisions it makes. The test engineer will conduct *stress testing* to push the system beyond typical conditions and ensure this does not cause failure.

Another critical function is halting in response to error or user override, where the system needs to safely and efficiently pause operations. The mean time between errors should be less than 10 minutes, reflecting the system’s ability to run smoothly over prolonged periods without significant issues. *Performance testing* will allow an internal counter to mark each known failure and save the data for the test engineer.

Lastly, the stopping upon completion function ensures that the system can cease all operations within 30 seconds of completing a task or detecting a critical operational error. This capability is vital for preventing unnecessary resource use and ensuring the system's longevity.

## Support Targets and Metrics

The support subsystem is another critical component of the success of our overall system, and it will utilize three corresponding functions. The primary focus of the design team is making the system safer and ensuring it produces a good button pin. The system must be able to meet certain safety metrics while also being easily transportable and accurate in creating this product.

The first function is that the device maintains its rigidity. To prioritize safety as previously mentioned, the design team narrowed its focus on the reduction of the frame deflection angle. This angle is what was decided to be the metric of the function, and the target range that it will fall into will be less than 3°. After identifying this issue in the initial testing of the device, it was decided that to make the system safer for children, the deflection angle that the device would undergo due to the linear actuator would need to be constrained. This will be *load tested* by attempting to find the lowest force that must be applied by the linear actuator that may reduce the deflection angle.

The second support function is that the device will align the materials accurately. This function will ensure that the materials used to assemble the button pin can make a product that is as close to perfect as possible. The metric to be used for this function is the conveyor belt’s position accuracy. The conveyor belt in this system is immensely crucial to the product. It moves the materials across the system and is responsible for putting the pieces directly underneath the linear actuator so that the pin may be pressed down upon. The target range for this metric must be small to have the most accurate placement possible for the product, which has been outlined as a range between 0 and 3 millimeters. This will be *performance tested* through a series of trials beginning with the conveyor belt at various locations.

Lastly, the device will be able to be assembled with ease. The company sponsor, Rockwell Automation, wants the device to be able to be easily transported from location to location to increase the educational reach of the device. The metric to be used for this specific function is the time spent unpacking and setting up the device, and the target attempted to be accomplished is under 30min. The product in general is aimed to be assembled and disassembled by a user that is not an engineer and has no technical background. *Usability testing* will be employed to repeatedly test how quickly the device can be put together using a specific set of instructions.

## Targets and Metrics Outside of Functions

In addition to functions within the manufacture, educate, control, and support subsystems, three outside functions were identified to ensure the system meets its key goals. These functions include storage for the button pin materials, system longevity, and ease of transport. Each of these functions contributes to the reliability and usability of the system. Targets and metrics have been established for these functions so that practical needs are met, and the system can operate efficiently.

The first additional function is the storage of the button pin materials. This function ensures that the raw materials are stored securely and readily available when the manufacturing process starts. The metric identified for this function is the number of pieces that can be stored. The target range for this metric is 10-15 pieces for each material. This ensures that the system can operate and complete multiple buttons before needing a restock of materials. The metric will be tested by the number of pieces that can be stored without causing a delay in the manufacturing process. Test runs of the system will validate the metric to determine how long the system can operate before needing a restock.

The following function is the overall longevity of the system. This ensures that the system can operate reliably over extended periods of time with minimal maintenance. The metric identified for this function is its service life. The target for this metric is that the system should last at least ten years before requiring major maintenance. This means that the system will remain durable and functional with minimal breakdowns. The metric will use *endurance testing* with continuous runs of the system and will be validated by stress tests to assess wear and tear over time. The individual components will also be analyzed to ensure they are adequately industrially hardened.

The last function is the ease of transportation. The system is expected to travel globally, and this function will ensure that it can be moved efficiently from different locations. The metric for this function is weight. The target for this metric is to be less than 30 pounds. This ensures that anyone can move the system without it being too heavy. *Mechanical safety testing* will be performed by a variety of individuals moving the system to various locations in the College of Engineering, and the results will be validated by fatigue levels.

## Summary of Critical Targets and Metrics

Upon completion of the targets and metrics catalog, the design team evaluated the results to extract the most critical ones, which are displayed in Table NUMBER below.

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| Critical Targets and Metrics | | | | |
| Subsystem | **Function** | **Metric** | **Target** | **Unit** |
| Manufacture | Assembles Pin Button | Linear Force Applied | 150 < x | pounds (lbs) |
| Educate | Engage User | Production Rate | 60 < x < 90 | seconds(s) |
| Control | Receives Sensor Information | Response Time | x < 100 | milliseconds (ms) |
| Operates by Given Computer Data | Failure Rate | x < 2 | percent (%) |

To achieve success of the project, a button pin should be properly assembled for the user to keep. The completion of a personalized item for the user to take away is critical in ensuring the audience is engaged and more likely to retain aspects of the demonstration. Thus, the first critical target is applying a linear force of at least 150lbs. The button materials cannot be properly sealed together unless this force is applied, making it a critical metric in achieving all key goals of the project.

As previously mentioned, the physical result of the process is intended to maintain engagement and spark interest in the audience. Another critical target in ensuring this occurs is assembling the pin button in 60-90s. With this metric, the process is continuous and iterative like a typical industrial manufacturing process. The time is also short enough for the young audience to avoid boredom.

To successfully control the process, the system should receive all sensor information in less than 100ms. This allows the system to react quickly to any errors that may arise and begin correcting them. It also enables the user to have better control when operating the optimized process.

Finally, the system must operate by the given computer data. This is critical as it is the foundation of success in the project and what controls all manufacturing steps. The target of less than a 2% failure rate must be met to call the process optimized by the design team’s standards.

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| Subsystem | Function | Metric | Target | Unit |
| Manufacture | Receives Button Pin Materials | Number of Pieces | x = 4 | pieces |
| Assembles Pin Button | Linear Force Applied | 150 < x | pounds (lbs) |
| Output Button Pin | Output Step Time | 0 < x < 20 | seconds (s) |
| Educate | Engage User | Production Rate | 60 < x < 90 | seconds(s) |
| Resembles Realistic Manufacturing Process | Number of Automated Steps | 4 < x | steps |
| Displays Manufacturing Process | Number of Update Messages | 4 < x | messages |
| Control | Actuates Upon User Input | Response Time | x < 1 | seconds (s) |
| Receives Sensor Information | Response Time | x < 100 | milliseconds (ms) |
| Operates by Given Computer Data | Failure Rate | x < 2 | percent (%) |
| Halts in Response to Error or User Override | Mean Time Between Errors | 0 < x < 10 | minutes (min) |
| Stops Upon Completion | Reset Time | x < 30 | seconds (s) |
| Support | Maintains Rigidity | Frame Deflection Angle | x < 3 | degrees (°) |
| Aligns Materials Accurately | Conveyor Belt Position Accuracy | x < 3 | millimeters (mm) |
| Assembles with Ease | Time Spent Unpacking and Setting Up | x < 30 | minutes (min) |
| Other | Store Button Pin Materials | Number of Pieces | 10 < x < 15 | units |
| Operates with Longevity | Service Life | 10 < x | years |
| Transports with Ease | Weight | x < 30 | pounds (lbs) |

References

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