Evidence Book

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Project: FPL Remote Switching Device

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Abstract

This project aims to improve how Florida Power & Light handles fuse switches for safety. When something touches the power line or too much current is flowing through the lines, a fuse will pop open to stop the flow of electricity down the line. Following a request from our project sponsors, we are creating a solution to make closing the switch much easier and quicker.

Our project is focused on creating a new device to close fuse switches that would replace the traditional stick that pushes them closed. We aim for a solution that is easier to use, can be controlled remotely, is portable, and holds multiple fuses. It is not just for Florida Power and Light but also for other utility companies.

Our results include a device that can close the switches remotely to restore power. Stakeholders, like Florida Power and Light/NextEra Energy, Professors Dr. McConomy and Dr. Hooker, and the FAMU-FSU College of Engineering, can look forward to a safer and more efficient solution. The new device aims to change the way utility companies manage fuse switches, benefiting both primary and secondary markets.

Disclaimer

The information presented in this report is based on the research, analysis, and findings conducted by Team 304 for the FPL Remote Switching Device project. While every effort has been made to ensure the accuracy and reliability of the information provided, we acknowledge that certain factors, such as evolving technologies and industry standards, may impact the applicability of our recommendations. Readers are advised to exercise their own judgment and discretion when considering the insights and suggestions presented in this report. Team 304 and its members are not liable for any consequences arising from the use or interpretation of the information contained herein.

Acknowledgment

The completion of this project represents the culmination of dedicated efforts and valuable advice from many individuals. We would like to express our sincere gratitude to Dr. Shayne McConomy and Dr. Jerris Hooker, for their guidance, mentorship, and encouragement, throughout this experiment. Their knowledge, feedback, and constructive criticism have been instrumental in shaping the direction and quality of this project.

Furthermore, we extend our appreciation to the FAMU FSU College of Engineering for providing a conducive environment and resources that were essential for conducting our project. Our peers and colleagues involved with the University also contributed to the findings in our project.

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Notation

FPL	Florida Power and Light
SCADA	Supervisory Control and Data Acquisition
OSHA	Occupational Safety and Health Administration
KVA	Kilovolts
IEEE	Institute of Electrical and Electronics Engineers
SCAMPER	Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse

Chapter One: EML 4551

Project Scope

Description:

Create a system that can be used to close a utility cutout fuse switch from the ground.

Goals:

Have a new solution for switch reclosing that is less physically intensive than using the standard hook stick method, but still be as versatile and easy to use.

Primary Market:

Florida Power and Light

Secondary Market:

Other utility companies

Assumptions:

Assume that this device or other solution is to be able to be carried to the point at which it will be used by a linesman of average physical capabilities .

Stakeholders:

Our stakeholders include Florida Power and Light/NextEra Energy, Senior Design professors Dr. McConomy and Dr. Hooker, and the FAMU-FSU College of Engineering.

Customer Needs

To determine the needs for our design, Team 304 developed a set of questions to interview the project's advisors, Kyle Bush, Rodney Roberts, Teodoro Gonzales, Olugbenga Anubi Fang Peng, and Doreen Ayafor. These questions were designed based on the project scope and what the team agreed to be important characteristics to how the product should function. The questions and their respective answers were communicated via email. Table 1 below shows the questions asked to the advisors as well as their answers and interpreted needs.

By asking questions about what the issues are with the current device that is used and what features it has that are beneficial, we were able to focus on the problem that needs to be solved. Rather than focusing on making the old device better, we can keep our minds open to a new design that could be completely different.

Table 1: Interpreted Customer Needs

Question/Prompt	Customer Statement	Interpreted Need
How high does the product need to reach?	The barrel fuse is located between 30 and 40 feet depending on the pole.	The product needs to be able to extend to very high distances and accurately be controlled to attach to the barrel fuse
Does the product have to be portable?		The vehicle can be recovered in under 85 seconds.
Will the Product have to be put through harsh conditions?	Yes the finished product should be able robust enough to go through muddy water and harsh conditions in the event of a hurricane, or if a utility pole is in a non accessible area	The product is highly durable and robust, capable of functioning effectively even when exposed to challenging conditions, including muddy water and harsh weather conditions.
Question/Prompt	**Customer Statement**	**Interpreted Need**

Will the product need to open and close switches?	The process for opening live switches is not involved with this project, only closing/reclosing.	The device gives the user enough leverage to apply the upward force necessary to close the switch
Can the switches themselves be redesigned to implement automated closing?	The switches can be redesigned but ideally, the device can interact with industry standard switches.	The end of the device is capable of latching on to industry standard switches.
Does the product need to be retractable to fit in places for transport?	Because it needs to fit into the FPL work truck it has to be as efficient as possible with space.	The device is space efficient and can fit into a standard 8 foot long truck bed
Can we innovate the previous prototypes used at other colleges for this design?	Yes, we highly encourage you to be as creative as possible to add on to the design that Auburn University created.	The existing prototypes can be expanded on to create a more effective version that puts less strain on the lineman using it.
Can the product be attached to the fuse switch and manually?	Yes, we are open to this but there are products on the market that do this already. However, if you can find a way to make it more efficient then explore that option.	Research current products on the market and consider the positives and negatives of having a remote switch attached to the pole.
Do we have to worry about phase clearances between power lines?	Yes, safety is the number one priority, but the power lines are a good distance away from the switch.	Be cautious of prototypes that can interfere with the high-voltage power lines.
Will the product have to be used for both opening and closing the fuse switch?	No, we will only be using this device for closing the fuse.	The design will not have to hook or grab the fuse, but just push it into the catch.

After posing our questions during the meeting with the FPL representatives, we were able to understand the needs of the device thoroughly. There were some features that were non-negotiable, like the height that it must reach and the size limits. The device needs to fit into the truck bed that the workers take to the sites, and it needs to reach the height where the fuse switches are located. The idea of the switches being redesigned to have the closing be automated is not something that's off the table, however it would require new switches be implemented in all areas where there are overhead lines. This would mean the issue with the current design would persist until the company has the ability to replace all their switches that are in the field with the new design. From this, we determined that the solution will be designed to interact with the industry standard switches.

This project is one that has been posed to other capstone groups at other universities in the past, so there are previous students' solutions that FPL has given our group access to. Exploring other prototypes from the previous groups and building on them to create a more robust and efficient final design is a path that is very realistic for our group as well. One of the biggest takeaways from speaking with Kyle Bush was him mentioning to avoid adding weight to the end of the current design because of the inability to have control over it.

Functional Decomposition

Functional decomposition is an approach used to break down detailed processes into much smaller tasks and understand in the most simple way what a product must do. Unlike task analysis, it doesn't involve a step-by-step sequence. Instead, it begins with the task that the product aims to accomplish. In this case, functional decomposition is being applied in order to redesign the device that is used to close overhead fuse switches in storm restoration situations. It doesn't suggest specific solutions or elements, but reveals how the different subsystems interact to create the solution that solves the problem. Functional decomposition can also reveal features that can be implemented to improve an area that wasn't initially considered, enhancing the overall project.

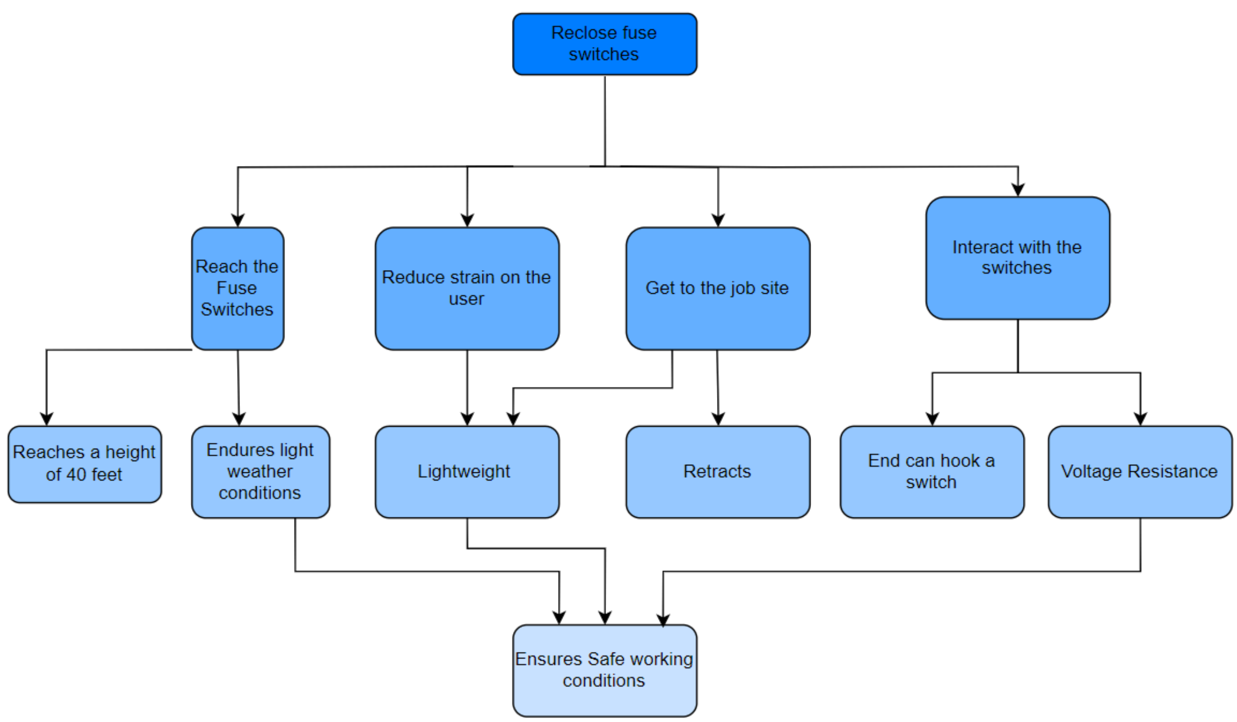


Figure 1: Functional Decomposition Flow Chart

After initial discussions with our sponsors establishing the scope of this project, we were able to determine the projects' preliminary requirements. With these requirements defined, we translated them to set an upper limit of specifications as to not limit the possibilities of the design. We concluded that any design with a retractable length of greater than 15 feet and anything excessively heavy to be unreasonable for any design capable of fulfilling our sponsors' needs. In doing this, we limit extravagant time expenditures without compromising overall design potential.

During meetings with our sponsors to determine the customer needs we were able to understand the root task that needs to be accomplished; to close fuse switches that are being replaced or have been opened. This starts with our device being able to reach the fuse switches by arriving at the job site. Poles can be located in areas with vegetation and no road access, so it is necessary that the device can be transported to the location of the poles. The fuse switches are located at the top of the poles that can be up to 40 feet high, and the design will have to reach these heights to close them. Oftentimes, the switches need to be replaced as a result of storm conditions, so the design must be able to handle some weather conditions so it can be used for storm restoration. The sponsors and subject matter experts also expressed how physically strenuous the current method of closing the switches is because of the lack of leverage over the end of the pole that is 40 feet away when fully extended. Due to this, we want to use leverage more efficiently to make the device easier to control for the user.

By having a solution that is retractable, we create a more compact and easy to transport package that can still reach switches that are relatively high to perform operations on them. Our solution must be able to endure light weather, including some wind and rain in order to reach the site at which work is being done and perform operations in the field. Our solution should use leverage, so we can close the switch while reducing strain on those using our device. Our solution should be lightweight so it can be easy to transport and carry to a site where work is being done, while still being durable enough to endure some weather conditions. Our device should have some level of voltage resistance so that the operators of the device are working under safe conditions. Our device shall also have a hook attached to the end so that it can reach the switch and interact with it in order to perform reclosing.

Connection to Systems

The main systems in the project can be ranked by the number of functions they connect to. By looking at the cross reference table, the most important systems are the ones that allow the device to reach the fuse switches and reduce the strain on the user. The functions that fall within reaching the fuse switches include getting to the height of the switches, enduring the weather, and hooking the switch itself. To reduce the strain on the user, the device must resist a level of voltage, be lightweight and take advantage of leverage. The systems with slightly less importance in terms of functions are arriving at the job site and interacting with the switch. This does not mean these systems are not important, but rather that there are less tasks required for this system to function as intended.

Smart Integration

There are multiple functions that overlap between other systems, which only signifies their importance. The device being lightweight would reduce the strain on the user, but it would also make the device easier to transport to the job site and likely very efficient as a result.

Enduring light weather conditions would allow the device to reach the fuse switches, but it would also allow for easier transport to the job site and reduce strain on the user because it may not need to be stored in a heavy case or be constantly maintained.

Action and Outcome

Figure 1 shows the primary systems of the project. Each system has subordinate functions that allow for the system to operate. Consider subordinate functions as actions and primary systems as the actions' outcomes. To reach the fuse switches, the device must reach the heights that the fuse switches are located at and endure the conditions of the surrounding area. To ease the strain on the operator of the device, the device must take advantage of leverage and be lightweight. The device also needs to arrive at the job site, and so it must be light and small enough to fit into the work trucks that will transport it to the site. Lastly, to interact with the switches, it must hook the switch and have some level of voltage resistance.

Functional Resolution

Implementing a design that makes reclosing switches easier and more efficient is influenced by many factors. By breaking down the main task into reaching the switch, reducing the strain on the user, interacting with the switch, and arriving at the site, and then breaking each of those down into smaller tasks, the process for the design becomes much more approachable. This is because there are no restrictions on potential designs, and the design team can focus on the functions that need to be accomplished and use creativity to approach the project.

Target Summary

Targets

Reach: The device can reach switches that are at a height up to 40 feet.

Collapsibility: The device can collapse to under 8 feet in length.

Lightweight: The device weighs no more than 40 pounds.

Reduces Strain: The force required to keep the end of the stick in place when at a 60 degree angle with the ground is reduced by at least 20%.

Withstands weather: The material repels water and the electrical connections are protected from water falling from above.

Closing the switch: The device can apply 5 pounds of force necessary to close the fuse switch.

User approval: At least 7 out of 10 users agree that the device is easier to use than the current method of closing the switches.

Method of Validation

Reach: We can use a measuring device to ensure that the device can reach a switch at a height of up to 40 feet.

Collapsibility**:** We can again use a measuring device to ensure that the device is under 8 feet long.

Lightweight**:** We can use a weight measuring device to make sure the device weighs less than 40 pounds.

Reduces strain**:** To measure the moment, we will take the weight of our stick, and calculate its center of mass, and the length of the stick when reaching a vertical height of 40 feet at an angle of 60 degrees from the ground, which is 46.18 feet. We will also take these values from the current hookstick and calculate the moments, and make sure ours is less than 80% of what the current solution is.

Withstands weather**:** We can mimic light rain conditions with a spray bottle, and if our conductors are properly protected, then they will work after the device is sprayed.

Closing the Switch: We can again use a force measuring device to measure the force the device is using when closing the switch.

Derivation of Targets

Reach**:** We have determined that our device must have a vertical reach of up to 40 feet since that is the maximum height of the switches that we are working with according to our sponsors.

Collapsibility: Our device must collapse down to a length of under 8 feet long. This length was selected since it is one that will reasonably fit in the truck bed of a Ford F-150, which FPL uses as their work vehicle.

Lightweight**:** Our device may have to be carried up to 100 yards to a pole before it is being put into use. This means that a single person must be able to reasonably carry it this far. Because of this, we have determined that we want our device to weigh 40 pounds or less, since that is a weight we have reasonably determined to be around the limit for an average person to carry this distance.

Reduces strain**:** Our project was given to us because FPL wants to reduce strain on their workers while using hooksticks. Because of this, we have to make enough difference to the necessary moment to perform the task of closing the switch. The maximum angle and height we will have to use to close the switch is 60 degrees and 40 feet, and the difference in force to feel a definite difference is 20%.

Withstands weather**:** Our device will be used often after inclement weather, when there have been a lot of outages. Because of this, there may often be light rain still when our device is being used. For our device to be implemented successfully in the field, it must be able to withstand these conditions.

Discussion of Measurement

The tool that we will need to validate our first target which is "Reach" will be a laser measurer. The second tool we will use to measure our second target which is collapsibility will be a tape measure.

Our next tool that we will use to measure how lightweight our design will be is a scale. Next we will do some mathematical calculations to ensure that our design is reducing strain on the user. To measure how our design will endure light weather we will use a spray bottle representing rain that has a certain amount of water inside.

For our final target we will be using some sort of force measurement device to ensure that enough force can be applied to close the switch.

Critical Targets

Reach**:** The device will offer robotic aid to the user in extending the "Hookstick" to a maximum height of 40 feet to reach the fuses.

Portability: The device will be able to fit in the 8-foot bed of a standard work truck and be carried at least 100 yards to the work site.

Fuse Switch Closing**:** The device will give the user enough leverage in order to close the fuse switch.

Durability**:** The device must be robust and durable enough to function effectively after being transported, on challenging terrain, and in inclement weather.

High-Voltage Resistance**:** The device must have some level of voltage resistance as to keep the user safe, and not interfere with the high-voltage power lines.

Summary of Catalog

Appendix A: Target Catalog offers a complete list of targets and metrics dictating the groups' project. These targets and metrics were derived from the group's functional decomposition charts' lowest tier. The interpreted needs of the sponsor were also considered.

These defined targets and metrics shall be met in order to propagate the successful development, implementation, and operation of the product. A few of these targets and metrics were unconditional and therefore not open to interpretive definition. One such example of this is our needed length or ***reach***. The fuse switch will always be 35 to 40 feet above the ground, meaning the final product must conform to and be capable of achieving this metric.

Given the innate nature of the design method, the groups targets and metrics are expected to change due simply to the iterative nature of the process. As the project progresses, it is feasible to anticipate targets and metrics changing based on the needs, direction, and findings of the project. This is especially the case as a prototype is brought to a real world application and tested. We intend this catalog to serve as a guideline to begin the design process but not as a binding manual that discourages the limitation of innovation.

Concept Generation

Concept Generation overview

Concept generation is perhaps the first major milestone of the design process as the decisions made here ultimately impact the entire direction of the project. Generating such a massive list of concepts is no easy task but is necessary to give innovative concepts a much greater chance of formation. We utilized a plethora of methods and tools to aid and inspire our concept generation. These methods include Brainstorming, Reverse brainstorming, SCAMPER, crap shoot, and synectics.

Brainstorming is a technique that inspires creative thinking amongst a group of people. The intent is to devise new ideas and solve problems creatively by encouraging new paths of thinking and collectively generate solutions. This is accomplished by creating an environment that promotes free thinking and voiced thoughts/concepts without judgment; which fosters an open and innovative space for concept generation. Reverse brainstorming, SCAMPER, and crap shoot are all derived concepts of brainstorming.

In a typical brainstorming session, we considered solutions to the problem at hand; meaning we spent time generating solutions with the end goal in mind. Reverse brainstorming, however, considers the root of the problem. Rather than reacting to the problem and finding a solution, we consider how to remedy the root of the problem such that a solution is no longer required; Thus we define an entirely new solution.

The SCAMPER method is a mnemonic that represents another process we utilized. It is also a derivation of brainstorming and stands for Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse. By taking previously synthesized concepts and applying

SCAMPER, we were able to generate concepts that were either a better version of a previous idea or a completely new idea. This is because the premise of SCAMPER is to treat whole concepts as sectioned parts; once we have several concepts broken into even more partial concepts, we can combine the partial concepts from several different ideas to generate an entirely new concept.

The method of crap shoot is possibly the most traditional brainstorming method we used. Synonymous with derivations such as the random ideation method, the crap shoot method is simply conceptualizing the first thoughts that come to mind when considering the project as a whole. While this method may seem trivial, it produces and promotes out-of-the-box thinking; which is the epiphany of brainstorming.

The last notable method we utilized is synectics, which incorporates problem analogies to create and validate solutions in a seemingly unrelated environment. By doing this, we stimulate creative out of the box thinking that energizes the team and creates a fun carefree environment while still generating results.

Generated Concepts

1. Robot that will climb the extendo pole and close the fuse switch. The motor will be battery powered and the device will directly attach to the already existing extendo pole
2. Drone that will hover and have a robotic arm to close fuse switch
3. Magnetic ports that can attract the ends of the fuse switch into the right spot to close
4. Redesign fuses to close automatically with a motor or actuator using electricity from the actual pole*

5. Redesign fuses to close automatically using a motor or actuator using an external battery provided by the linemen
6. Robot that drives power lines using hooked wheels inspecting and closing switches with robotic arm
7. Tripod system that can leverage the pole like a telescope mount
8. clamping robot with four wheels that climbs power pole and closes switch
9. Change the orientation of the fuse switch catch to face down to make closing easier
10. Wire the fuse switch down to the bottom of the pole to make closing occur at shoulder level
11. A three legged device with a motor powered wheel that can extend the pole and support it. It will have a way to manipulate the legs of tripod to adjust for terrain
12. A two legged device with motor powered wheels that can extend the pole and support it*
13. Vehicle bumper mounted robot arm that extends to close switch*
14. A vertical extendo stick with an arm at the end that attaches directly to the utility pole that can be lined up with the fuse switch and allow the user to only adjust the rotation of the device and the arm at the end.
15. A three legged device that can be placed directly under the switch with a remote controlled arm that can extend upwards and manuever the arm
16. A device that attaches around the utility pole and climbs to a reasonable height and extends an arm to close the switch
17. Voltage resistance inflatable material that can be filled up with compressed air to extend and close the switch
18. Portable Scissor lift to raise the user to the height of the fuse switch

19. Install a series of steps on the pole for the user to climb and close the switch
20. An extendo stick that has a bridge-like attachment so it can be rested against the pole while in use, similar to a pool cue bridge*
21. A collapsible stick that is powered by a piston and can be extended under the fuse to push it into place, works similarly to the arm of an excavator
22. A tripod system with a spring loaded wheel that can be extended using tent-like pin and slot system in the legs
23. The mount that holds the fuse switch has a pulley built in and the stick has a rope end that can loop it and be pulled on to close the switch.
24. A jet pack that the user can wear and propel themselves up to fuse switch to close it
25. Implement a rope and pulley at the top of each pole to help extend the current extendo stick to its full length closer to the fuse
26. Redesign the fuse switch to be at the top of the pole and have a more pronounced hook that a drone can easily hook and pull
27. The fuse switch is redesigned to be a smart device that break the circuit in the event of shorting, but can also be connected by bluetooth to a device that the linesman carry to troubleshoot
28. Drone that will hover with a fixed hookstick to close the switch.
29. Robot that climbs the pole with a robotic arm to close the switch.
30. Robot that climbs the pole with a fixed arm to close the switch.
31. Electromagnet fixed to the switch that can be activated.
32. Drone with an electromagnet strong enough to be activated and close the switch.

33. Robot that climbs the pole with an electromagnet that is strong enough to activate at the top and close the switch.
34. Redesign switch so that there is a motor that can be activated to close it at the bottom of the switch.
35. Redesign the hookstick to have a tripod at the button and a second stick attached to a hinge at the top so one direction of movement is fixed.*
36. Use the previous design, but have a belt running up the stick, and have the belt be withdrawn with a motor to close the switch.
37. Redesign the switch to have a motor connected to it and connect the motor to SCADA with a status. Allow SCADA to have control of the motor to close the switch.
38. Redesign the switch to be connected to a hand-crank at the bottom of the pole which can be used to close the switch.
39. Redesign the hookstick so that it is the same as solution 35, but use a hand-crank instead of an electric motor.
40. Have aliens use a very small hookstick while standing on a flying saucer to close the switch.
41. Coat a hawk's beak in an insulator and train it to close the switch.
42. Hire a convict with an insulated glove to close the switch by climbing a ladder.
43. Train monkeys with insulated gloves to climb the pole and close the switch.
44. Give the workers steroids so they are stronger and less affected by the stresses of using the current hookstick design.
45. Redesign the fuse so that the loop is bigger and thus, easier to hook

46. Redesign the fuses so that they are curved. When they blow, instead of swinging down, they will swing inward slightly. The top point of contact will be on the top curved side and the hook directly on the end to provide a more natural closing motion as well as a smaller range of motion
47. Train an army of squirrels to close the switch. 401k and personal protective equipment must be provided.
48. Design a robotic extendo pole with a tripod. When the tripod opens, it will anchor itself into the ground by pneumatic hooks. The pole can then be extended and controlled by remote joystick.
49. Design an apparatus that will use magnets that act as a gravitational maglock. When the fuse needs to be broken to prevent line overload, the magnets will disengage. We can then re-power the magnets to attract the fuse back into position. The fuse must be on guides.
50. Design an apparatus that utilizes a cable to pull the fuse back into position. The fuse will be on guides to accomplish this. The cable will be fixed to the pole as would a flag mast rope.
51. Design an apparatus of revolving fuses (think revolver cylinder). When one blows, it will slide down in its chamber. Once it is deemed safe to reconnect, the springs inside the cylinder will re-engage the fuse. If the fuse is bad, the cylinder will rotate to a new fuse
52. A stick that is supported with a wider base, extends straight in the air and uses a piston powered arm to extend and close the switch
53. Two extendable legs with rack and pinion gears to extend that support the weight of a stick while the end can be maneuvered

54. Two extendable legs that can extend with hydraulics while the butt of the stick is planted in the ground to move the end of the stick around
55. Two extendable legs that can extend using a pin and groove system similar to a tent setup
56. A stick that collapses like a tent pole and can be supported by extendable bipod legs
57. Tripod like system with linear actuator legs that holds onto the stick and allows the point of leverage to move
58. A redesign of the fuse switch that allows it to magnetically attach to the pole so the point of contact is easier to reach
59. A voice activated fuse switch that closes when the user yells "CLOSE CIRCUIT"
60. A set of robotic stilts that the user can lift themselves to within reach of the fuse switch
61. A slimmer and more lightweight stick that collapses like a tent pole with a V shaped catch on the end to close the switch with.
62. Give the workers lifetime gym memberships so they can get stronger and traditional fuse switching won't be so much of a strain on their bodies.
63. Remake extendo stick so that it is carbon fiber, it will have more rigidity and be more lightweight and have nearly double the strength to weight ratio
64. Utilize the Auburn concept with one spherical joint, stakes in the foot pedals, and a hand held remote control to adjust the legs.
65. A linear screw acutator design that will extend the pole use a motor at the base of the pole.
66. A single pole and cylinder attachment to the extendo pole that will allow the user to maneuver the pole with more ease because the distance to the fulcrum is greater.

67. A system that leans against the utility pole with a cylindrical joint through a pole that can be maneuvered through user power..
68. A system that leans against the utility pole with a cylindrical joint through a pole that is motor assisted and can maneuver through user power.

Fidelity Concept Selection Method and Tools

From the above list of concepts generated, the following 8 were pre-selected as showing the most promise. This was accomplished by a series of eliminations in tiered selection format. To elaborate, this means we took our 68 concepts and created 34 groups of two. Whichever concept from each group was selected advanced to the next tier and so on until the following 8 fidelity concepts were chosen.

Medium Fidelity Concepts: (5 selections)

1. Design a robotic extendo pole with a tripod. When the tripod opens, it will anchor itself into the ground by pneumatic hooks. The pole can then be extended and controlled by remote joystick.
2. Design an apparatus that will use magnets that act as a gravitational maglock. When the fuse needs to be broken to prevent line overload, the magnets will disengage. We can

then re-power the magnets to attract the fuse back into position. The fuse must be on guides.

3. The fuse switch is redesigned to be a smart device that break the circuit in the event of shorting, but can also be connected by bluetooth to a device that the linesman carry to troubleshoot
4. Redesign the hookstick to have a tripod at the button and a second stick attached to a hinge at the top so one direction of movement is fixed
5. Design an apparatus that utilizes a cable to pull the fuse back into position. The fuse will be on guides to accomplish this. The cable will be fixed to the pole as would a flag mast rope.

High Fidelity Concepts: (3 selections)

1. Design an apparatus of revolving fuses (think revolver cylinder). When one blows, it will slide down in its chamber. Once it is deemed safe to reconnect, the springs inside the cylinder will re-engage the fuse. If the fuse is bad, the cylinder will rotate to a new fuse
2. Utilize the Auburn concept with one spherical joint, stakes in the foot pedals, and a hand held remote control to adjust the legs.
3. A three legged device with a motor powered wheel that can extend the pole and support it. It will have a way to manipulate the legs of tripod to adjust for terrain

Codes and Standards

The utility industry is heavily regulated by codes and standards and as a result, there are many guidelines that the group must stay within when designing a new device to close the fuse switches.

There are regulations on the distances that each phase of cable must be from each other and this will rule out some of the possible designs where the switch is being moved closer to the top of the pole. This also prevents some solutions where drones or devices closing the switch from above would not be able to access the fuse switch because of interference with other lines.

OSHA also regulates the distance that a linesman can safely work on a power line with the shortest being 1 meter for lines between 0 and 75 kVA and increasing as the line becomes more powerful. This regulation is only for trained linesmen, and there are separate guidelines for civilians.

For overhead lines between 0 and 50 kVA, there must be at least 10 feet of distance between the line and the area that can be accessed by civilians, and the distance increases as the line becomes more powerful. This rules out designs where the fuses are moved to lower access points.

OSHA also regulates the stick to be tested at 75kV per foot of length for at least 1 minute to ensure safety of the users. This must be taken into account when selecting the material of the device.

Concept Selection

After generating a mix of 8 high-fidelity and medium-fidelity concepts, the team needed to select a final design that was most suitable to the project's scope and met the majority of the customer needs. Firstly, the list of selected concepts were renamed and included with their descriptions in Table 2. The team conducted several concept selection analyses including: binary pairwise comparison, house of quality, pugh charts, and the analytical hierarchy process. After completing the concept selection process, the team agreed with the results and chose Display, as the final concept.

Table 2: *Selected Concepts for Concept Selection*

Concept Name	Original Concept #	Description
Revolver	51	Design an apparatus of revolving fuses (think revolver cylinder). When one blows, it will slide down in its chamber. Once it is deemed safe to reconnect, the springs inside the cylinder will re-engage the fuse. If the fuse is bad, the cylinder will rotate to a new fuse
Upgraded Auburn	64	Utilize the Auburn concept with one spherical joint, stakes in the foot pedals, and a hand held remote control to adjust the legs.
Tripod	11	A three legged device with a motor powered wheel that can extend the pole and support it. It will have a way to manipulate the legs of tripod to adjust for terrain
Cable Pull	50	Design an apparatus that utilizes a cable to pull the fuse back into position. The fuse will be on guides to accomplish this. The cable will be fixed to the pole as would a flag mast rope.
Upgraded Hookstick	35	Redesign the hookstick to have a tripod at the button and a second stick attached to a hinge at the top so one direction of movement is fixed
Smart Fuse	27	The fuse switch is redesigned to be a smart device that break the circuit in the event of shorting, but can also be connected by

		bluetooth to a device that the linesman carry to troubleshoot
Magfuse	49	Design an apparatus that will use magnets that act as a gravitational maglock. When the fuse needs to be broken to prevent line overload, the magnets will disengage. We can then re-power the magnets to attract the fuse back into position. The fuse must be on guides.
Pneumatic Pole	48	Design a robotic extendo pole with a tripod. When the tripod opens, it will anchor itself into the ground by pneumatic hooks. The pole can then be extended and controlled by remote joystick.

House of Quality

Prior to the creation of the house of quality, a binary pairwise comparison of the customer needs was completed. Each of the needs were compared against the others and the need which was deemed of higher importance was given a 1, while the other was given a 0. Summing the rows of this matrix resulted in the importance weight factor matrix of our customer needs. This binary pairwise comparison can be seen below in Appendix A, Table A-1. Our most important need was determined to be “Interacts with the fuse switch and was given a weight factor of 7, while our least important need was “the device is lightweight” and was given a 0 for importance.

The house of quality was created next. On the leftmost axis, the customer requirements were listed, while the engineering characteristics were listed on the top axis. Going through the chart, each engineering characteristic was ranked depending on its level of contribution to fulfilling the customer requirement. The engineering characteristic relationship was measured as weakly, moderately, or strongly related to the customer requirement. Using the importance weight factor matrix along with the values now assigned to the chart, each engineering characteristic was given a ranking of importance. The most important characteristic for our product was determined to be reducing the strain on the user, while the least important was reaching the fuse switch.

The purpose of ranking our project's engineering characteristics is to eliminate the less important ones, helping to simplify our concept selection process. We decided to eliminate some of these based on their relative weight percentages. If any of the characteristics had a lower relative weight percentage than the total average of the relative weights, it was eliminated from our process. This left 5 remaining engineering characteristics to be used in the creation of the pugh charts. The house of quality is shown below in Table 3.

Table 3: *House of Quality*

House of Quality					
		Engineering Characteristics			
Improvement Direction		↑			
Units		ft	lbs	n/a	n/a
Customer Requirements	Importance Weight Factor	Reaches the fuse switches	Reduces strain on the user	Gets to the job site	Interacts with the switches
Reaches 40 feet	5	9	3		9
Endures weather conditions	3		1	9	3
The product must be collapsible	2	3	9	9	
Interacts' with the fuse switch	7	9	9		9
Reduces the force needed to reach the switch with the stick.	2	3	9		9
The device can resist voltage	5		1		9
It does not interfere with other power lines	3	3			9
The device is lightweight	1	9	9	9	3
Raw score	533	138	131	54	210
Relative Weight %		25.9	24.6	10.1	39.4
Rank Order		3	8	6	6

Pugh Chart

Team 304 used the Pugh charts to whittle down the number of concepts. These decisions were made based on the important engineering characteristics determined in the House of Quality. The Pugh charts are used to compare the selected concepts to a datum. The chart uses (+), (-), or (S) to dictate if a concept is better, worse, or satisfactory when it is compared to the datum. The chart uses a (+) symbol to dictate if an engineering characteristic has a more positive effect on the product when compared to the datum. The (-) symbol determines if the concept characteristic is worse than the respective datum. The (S) symbol, satisfactory, is used to represent that the concept is equivalent in function of the engineering characteristic when compared to the datum.

The datum selected for the first iteration Pugh chart is the current method of closing the fuse switch, which uses a device called an extendo pole which reaches to the fuse switch on a utility pole. The three concepts that proved to have the lowest total, shown in red in Table 4, were then excluded from the concept selection process. The remaining three concepts moved onto the second iteration of the Pugh chart. Most of the three concepts had similar results, so the engineering characteristic which had the greatest effect on the results was the product being collapsable. The concepts which received a better rating were deemed to possess a more productive method of making closing a fuse switch easier. Those concepts used one or more methods of closing the fuse switch, having the variability of concepts allows for different ways of attacking the problem. Fuse switch extendo concept made for a good datum for iteration two because it received a score of 8 in the first iteration of the Pugh chart. This was the median of the results, so it offered room for improvement when compared to the other concepts.

Table 4: *Pugh Chart: Iteration 1*

Pugh Chart: Iteration 1									
Engineering Characteristic	Fuse Switch Extendo Pole	**Concepts**							
		Pneumatic Pole	Magfuse	Smart Fuse	Upgraded Hookstick	Cable Pull	Revolver	Upgraded Auburn	Tripod
Reaches 40 feet	Datum	+	+	-	+	+	+	+	+
Endures weather conditions		+	+	S	S	+	+	+	+
The product must be collapsible		+	-	+	-	+	+	+	-
Interacts' with the fuse switch		+	+	+	S	+	+	+	S
Reduces the force needed to reach the switch with the stick.		+	+	+	S	+	+	+	S
The device can resist voltage		+	S	+	S	-	+	S	S
It does not interfere with other power lines		-	S	-	S	-	-	S	S
The device is lightweight		+	-	+	-	+	+	S	S
Plus (+)		7	4	5	1	6	7	5	2
Satisfactory (S)		0	2	1	5	0	0	3	5
Minus (-)		1	2	2	2	2	1	0	1
		12	6	7	3	8	12	13	7

In the second iteration of the Pugh chart, the Pneumatic pole is only satisfactory and no longer provides benefit through its ability to be collapsed, which leaves one sole design idea with the highest score. The Upgraded Auburn design's score remained the same, but because it provides benefits over the Cable pull design as well, it had the best score in the second iteration. Although it loses a benefit in the collapsibility in this iteration, it makes up for that by not interfering with power lines as much as the Cable pull.

Table 5: *Pugh Chart: Iteration 2*

Pugh Chart: Iteration 2				
Engineering Characteristic	Cable Pull	**Concepts**		
		Pneumatic Pole	Revolver	Upgraded Auburn
Reaches 40 feet	Datum	+	+	+
Endures weather conditions		+	+	+
The product must be collapsible		S	+	S
Interacts' with the fuse switch		+	+	+
Reduces the force needed to reach the switch with the stick.		+	+	+
The device can resist voltage		+	+	S
It does not interfere with other power lines		+	-	+
The device is lightweight		-	+	S
Plus (+)		6	7	5
Satisfactory (S)		1	0	3
Minus (-)		1	1	0
		11	12	13

Analytical Hierarchy Process (AHP)

The analytical Hierarchy Process quantifies the importance of a variety of criteria, and justifies decisions that the group makes. Characteristics that are deemed highly relevant in the house of quality were compared against each other to assign numerical values to signify the importance of each characteristic. Using the Comparison Criteria Matrix, the group assigned ascending values to quantify how important specific features are to the overall design. 1

represents equal importance between the two, 3 indicates slightly more important, 5 being moderately more important, 7 demonstrates significantly more important, and 9 can be shown through evidence as being extremely more important. If the value in the matrix is the inverse, it shows that the opposite of one of these designations is true. When each row of the matrix is averaged, we can create a normalized version of the previously mentioned matrix, which is shown in Table 6. This matrix provides the weighted importance of each criteria, which will then be used to determine the final design in the last stage of the Analytical Hierarchy Process.

Table 6: *Normalized Comparison Criteria Matrix*

Normalized Criteria Comparison Matrix									
Customer Needs	1. Reaches 40 feet	2. Endures weather conditions	3. The product must be collapsible	4. 'Interacts' with the fuse switch	5. Reduces the force needed to reach the switch with the stick.	6. The device can resist voltage	7. It does not interfere with other power lines	8. The device is lightweight	**Criteria Weight**
1. Reaches 40 feet	0.104275287	0.160771704	0.192307692	0.064516129	0.173110214	0.379075057	0.225225225	0.178571429	0.184731592
2. Endures weather conditions	0.034410845	0.053590568	0.115384615	0.064516129	0.057703405	0.025018954	0.024774775	0.107142857	0.060317768
3. The product must be collapsible	0.020855057	0.017684887	0.038461538	0.064516129	0.057703405	0.025018954	0.024774775	0.035714286	0.035591129
4. 'Interacts' with the fuse switch	0.729927007	0.375133976	0.346153846	0.460829493	0.403923832	0.227445034	0.525525526	0.25	0.414867339
5. Reduces the force needed to reach the switch with the stick.	0.034410845	0.053590568	0.038461538	0.064516129	0.057703405	0.025018954	0.075075075	0.107142857	0.056989921
6. The device can resist voltage	0.020855057	0.160771704	0.115384615	0.152073733	0.173110214	0.075815011	0.024774775	0.178571429	0.112669567
7. It does not interfere with other power lines	0.034410845	0.160771704	0.115384615	0.064516129	0.057703405	0.227445034	0.075075075	0.107142857	0.105306208
8. The device is lightweight	0.020855057	0.017684887	0.038461538	0.064516129	0.019042123	0.015163002	0.024774775	0.035714286	0.029526475
Sum	1	1	1	1	1	1	1	1	1

To ensure the validity of the rated importance of the engineering characteristics, a consistency check was conducted and proved to support the calculated results. The initial Criteria Comparison matrix and the consistency check are shown in Appendix B, Tables B-1 and B-2. From the normalized chart we determined that “Interact with the fuse switch” and “Reaches 40 feet” are of the highest importance and should be reflected in the final design choice moving forward. These characteristics are critical to our customers' needs and our key goal of being able to easily close the fuse switch.

In our Pugh Chart iterations, we narrowed the design concepts down to three: the Pneumatic pole, the Revolver, and the Upgraded Auburn design. All three designs were compared between each other in relation to each of the individual engineering characteristics. The same rating scale from the Criteria Comparison matrix was used for each of these individual comparisons. Each of these were normalized in the same fashion and given consistency checks, all of which can be found in Appendix B. Similar to the Criteria Weights found in the Criteria Comparison, a Design Alternative Priority was found from the averages of each characteristic matrix. These values were compiled into the Final Rating Matrix shown in Table 7. These rows show how well the design idea fulfills the engineering characteristic, the higher the value the better it performs and vice versa.

Table 7: *Final Rating Matrix*

Final Rating Matrix					
	Pneumatic pole	Upgraded Auburn	Revolver		Criteria Weights {W}
Reaches 40 feet	0.125	0.125	0.125		0.136
Endures Weather conditions	0.125	0.125	0.063		0.054
Collapsibility	0.125	0.016	0.344		0.029
Interacts with fuse switch	0.125	0.125	0.125		0.346
Reduces force on user	0.125	0.234	0.125		0.071
Voltage resistance	0.125	0.125	0.125		0.059
Doesn't interfere with power lines	0.125	0.234	0.125		0.536
Lightweight	0.125	0.234	0.016		0.008

Following the assignment of the Design Alternative Priorities into the Final Rating Matrix, the said matrix was multiplied by the Criteria Weights Matrix, the table to the right of the Final Rating Matrix, and placed within Table 8 below. The Alternative Value chart shows the overall rating for each concept with the higher value representing the best design concept.

Table 8: *Alternative Value*

Concept	Alternative Value
Pneumatic Pole	0.080
Upgraded Auburn	0.084
Revolver	0.083

Following the values in the table above, the ideal concept to move forward with is the Upgraded Auburn design to complete the assigned functions of the device and best serve the end user.

Final Selection

Team 304's final selection is the Upgraded Auburn design, which was concept number 64 on the Concept Generation assignment. This decision was made after having the highest alternative value (Table 8) using the values obtained from AHP and scoring above the datum in both iterations of the Pugh chart on Table 5. This concept demonstrates the best fit for the needs of the customer and fulfilling the expectations of the project scope, and will be the idea that our group will build upon.

Chapter Two: EML 4552

Restated Project Definition and Scope

Description:

Create a system that can be used to close a utility cutout fuse switch from the ground. The current method of closing the fuse switches is very strenuous for the user and not time efficient.

Goals:

Have a new solution for switch reclosing that is less physically intensive than using the standard hook stick method, but still be as versatile and easy to use.

Primary Market:

Florida Power and Light and NextEra Energy

Secondary Market:

Other utility companies

Assumptions:

Assume that this device or other solution is to be able to be carried to the point at which it will be used by a linesman of average physical capabilities .

Stakeholders:

Our stakeholders include Florida Power and Light/NextEra Energy, Senior Design professors Dr. McConomy and Dr. Hooker, and the FAMU-FSU College of Engineering.

Results

Functionality Testing

The mechanism can move smoothly and accurately rotates the track system for the fuse to be engaged. When disengaged, the fuse becomes shortened and hangs further forward at an angle, with the hook at the top for easier removal.

The mechanism that was tested was composed of 3D printed PLA, which ensures that a machined part or a cast part will move much more smoothly.

Durability Testing

The prototype that was created during the experiments was a proof of concept design that ensured the mechanism moves as intended. The device to be implemented will be created using machined metals and fiberglass insulation. It is anticipated that these materials will provide the durability necessary to last and withstand these conditions.

The device should ideally be able to withstand hurricane force winds and rain, because if it does not, then it proves to be less reliable in those conditions than the current industry standard.

Safety Testing

The final design should be able to contain a fire and not allow it to propagate and endanger animals or workers.

It should also be able to prevent arcing from occurring while the power is being restored. The device being attached using the insulator will presumably prevent this from happening but it must be absolutely certain that it will not happen.

Dealing with high voltage, the electromagnetic field must also not interfere with the microcontrollers, which is not anticipated to be an issue.

Discussion

Throughout the duration of our project, Team 304 has consistently exhibited a strong dedication to innovation and collaboration in the development of the FPL Remote Switching Device. Our team's commitment to understanding and addressing customer requirements, as shown by our analysis of customer statements and interpreted needs, has played a pivotal role in shaping our design process.

The selection of the Remote Switching Device revolver design, by comprehensive concept selection analyses and criteria evaluation, shows our team's strategic decision making strengths and focus on delivering a solution that optimally serves end users. Looking forward, we recommend maintaining a continued emphasis on user-friendly design, portability, and robustness to ensure the device's efficacy in adverse weather conditions, as emphasized by customer feedback.

Furthermore, exploring avenues for integration with smart grid technologies and remote control capabilities, stands to further elevate the device's utility and efficiency in the evolving landscape of utility operations. By remaining adaptable, responsive to customer needs, and receptive to technological advancements, our team firmly believes that future pursuits of remote switching devices for utility companies hold the promise of yielding greater advancements in safety, reliability, and operational efficiency.

Conclusion

The project proves that a mechanism can be used to engage, disengage, and hold multiple fuses. This is an important development for the utility industry because it can provide a new way to ensure reliability. Most power companies are becoming more reliable by trying to automate the process of examining the lines before replacing the fuse, but this provides a way to automate the replacement as well. Reliability is of utmost importance for a utility company because loss of power can cause significant safety hazards and economic consequences for hospitals, offices, and other types of businesses. Becoming more reliable means becoming more profitable

Further testing can also help to understand exactly how large a device can be at the top of the pole, potentially allowing for more fuses to be held inside the housing. This can lead to further changes in the materials used, to ensure a lightweight and compact device.

The experiment also provides much room for improvement, because eventually the device can be integrated into the SCADA smart grid, which means it could be controlled remotely from a control center, which could be the future of the utility industry.

Future Work

Considering that the design that was presented was mostly a proof of concept design, there is much future work to be done. Having a working mechanism that can engage and disengage the fuse proves that the design can work, but for it to be implemented there are a couple things that must be improved.

The housing of the design can be made from a similar steel to the one used for overhead transformers, but it must be machined to fit the revolver inside. The cover for the compartment with a water resistant edge will also be made so that rain can flow over the top of the design with no damage to the internal electrics.

With the mechanism made, there is a possibility for 4 or more fuses to be contained within the revolver device, so more calculations must be done to compute the most fuses that can be supported by the brackets. The only limiting factor would be the weight of the revolver.

Another area for future improvement would be eventually connecting our device to the SCADA system that FPL uses to monitor the grid. With the capability to control the device from a remote control center, the entire process could be automated with a monitoring system that uses Artificial Intelligence to ensure that the conditions are safe before reclosing.

References

IEEE Std C37.42-2008. (2008, May). IEEE Standard Design Tests for High-Voltage (>1000 V) Fuses and Accessories. IEEE Power Engineering Society. Piscataway, NJ, USA: IEEE.

Occupational Safety and Health Administration. (1994, January 31). Federal Register / Vol. 59, No. 19 / Monday, January 31, 1994 / Notices. Retrieved from https://www.osha.gov/laws-regs/federalregister/1994-01-31

Appendix

Code of Conduct

Mission Statement:

Team 303 aspires to accomplish all project goals with exceptional dedication, innovation, and punctuality. The team will meet and exceed all expectations of the project in all facets. The apex of team 303's success is governed by the integrity, accountability, and communication skills of each individual.

Outside Obligations (Excluding Senior Design):

Jacob Ray

Company obligations MON,WED 9AM-11AM, 4PM-8PM & TUE,THU 9AM-1PM

University obligations MON, WED 2PM-315PM & FRI 3:30PM-5:30PM

Christian Perez

Company obligations MON 3PM-6PM, TUES 1PM-2:30PM, WED 9AM-3PM, THU 12PM-3PM

Nicholas Grant

University obligations MON 8AM-9:15AM, TUES 11AM-12:15PM, WED 8AM-9:15AM, 5:30PM-8PM & FRI 8:15AM-10:45AM

Team Roles:

Jacob Ray

Primary Role: Prototype Design Engineer

Secondary Role: Organizational Aid

The Prototype Engineer is responsible for designing and testing 3D CAD models and producing physical prototypes. This role is also tasked with organizing meetings and reviewing documents for conciseness and format.

Nicholas Grant

Primary Role: Dynamics Engineer

Secondary Role: Mathematician

The Dynamics Engineer is responsible for all matters related to control systems and robotics. This role is also tasked with any mathematical calculations required.

Christian Perez

Primary Role: Materials Engineer

Secondary Role: Quality Control

The Materials Engineer is responsible for material design, selection, and maintaining all matters of materials science. This role is also tasked with ensuring the quality of all produced deliverables.

Communication:

Our modes of communication will include Microsoft Teams, Text Message, and Email. When in-person meetings are not possible, Microsoft Teams is to be used. Text Messaging and Calling will be used in situations where Microsoft Teams is unavailable/unnecessary. Email will be used for formal communication with team members, sponsors, and subject matter experts.

Dress Code

Classroom Attire

Casual; Environmentally conscious/socially appropriate attire.

Presentation and Professional Events

Business casual; Dress shoes, pants, and belts with a button-up shirt or polo shirt.

Attendance Policy:

The group will meet at least twice per week to work on assignments or discuss a plan for future assignments. Attendance of group meetings is required. Absences will be excused if the reason is justifiable, or 24 hours of notice is provided. If a group member is absent from a meeting without notice or the reasoning is not justified, that member must bring refreshments to the next team meeting. Three absences from group meetings will result in a formal discussion with all group members about punctuality and attendance. Four or more absences will result in a meeting with Dr. McConomy.

Group Notification Procedure:

The team will communicate primarily through Microsoft Teams. Organization of team meetings, important team memos, all files, and remote meetings will be channeled through Microsoft Teams.

Meeting Etiquette Standards:

Members are expected to maintain an appropriate appearance for meetings with Dr. McConomy, the TA's, the sponsor, etc. They are also expected to refrain from using inappropriate language and be courteous to others.

Procedure Prior to Meetings with Dr. McConomy or TA's:

Do any relevant background research or preparation. Create a set of questions and points that need to be addressed.

Procedure to Contact Dr. McConomy:

If an issue between group members arises, the group members should have a civil conversation without accusing others or becoming defensive. A plan of action should be created to ease and prevent further conflict and if the plan is not followed or the conflicts continue, then Dr. McConomy will be consulted.

Preferred Outcomes of Meetings with Dr. McConomy:

Create a plan of action that includes disciplinary measures if violated.

Amendment Procedure:

This document can be amended with a formal team vote. This vote will require a majority vote (4 of 6 members) and all members must sign the amendment. The amendment will be included as an attached appendix to this document. All necessary parties will be notified of the amendment and will receive a copy of the new document.

Statement of Understanding:

I hereby express my comprehension of the Code of Conduct and commit myself to fulfill all requirements detailed in The Code of Conduct. I understand that all procedures outlaid in The Code of Conduct are expected of each member. I understand that The Code of Conduct is subject to change. Signing this document is a binding agreement to adhere to the standards detailed above.

I, Christian Perez, understand. //SIGNED// 19 SEP 2023

I, Nicholas Grant, understand. //SIGNED// 19 SEP 2023

I, Jacob Ray, understand. //SIGNED// 19 SEP 2023

Functional Decomposition Charts

Table 9: Function Chart

	Major Systems				
Minor Functions	Reach the fuse switches	Reduce strain on the user	Gets to the job site	Interact with the switches	**Total**
Retracts	X		X		2
Endures light weather	X				1
Uses leverage		X			1
Lightweight		X	X		2
Voltage resistance		X		X	2
End can hook a switch	X			X	2
Total	3	3	2	2	

Target Catalog

Table 10: Targets Catalog

Functions	Targets	Metrics
Reach	40 [Feet]	Distance
Collapsibility	≤ 8 [Feet]	Length
Lightweight	40.0 [lbs]	Weight
Reduces Strain	≤ 80% of previous design [%]	Moment
Withstands Weather	± 0.05 [Miles]	Distance
Closing the Switch	>50 [Newtons]	Force

Operation Manual

1. Connect the following circuit

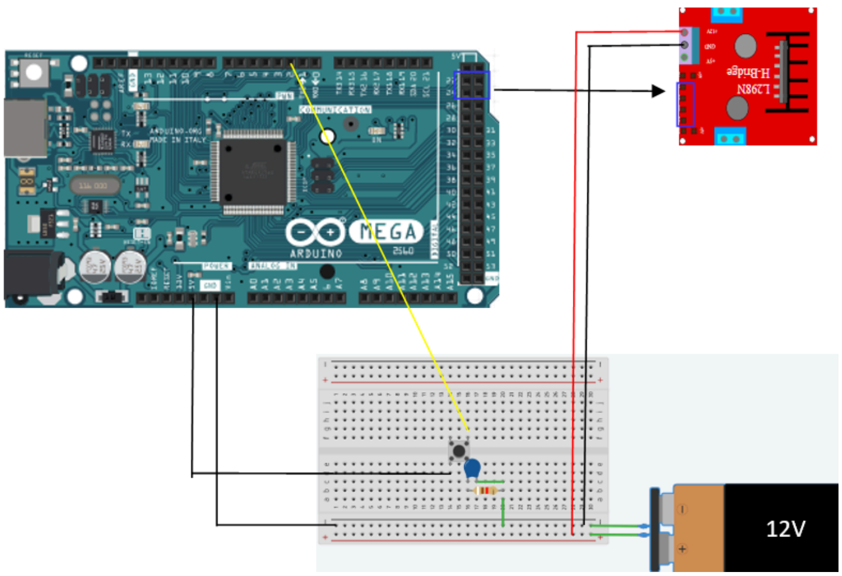


Figure 2: Circuit Diagram

Use a 12 volt power supply to connect to the breadboard. The 5V supply in the Arduino goes to the bottom left leg of the button. The top right leg of the Arduino is connected to pin 2 of the Arduino. The bottom right leg of the button is connected to a 10Kohm resistor and 1uF capacitor, which are both connected to ground. The ground of the Arduino is connected to the negative rail of the breadboard. Digital pins 22-25 of the arduino are connected to the L298N motor driver in that order. Connect the 12V and ground ports of the L298N driver to the positive and negative rails of the arduino respectively. Connect the motor driver to the motor, With the top right port having A, the top left having A-, the bottom right having B-, and the bottom left having B. A phase is black, A- is green, B phase is red, and B- is blue.

2. Upload the following code:
    a. Open the Arduino IDE

b. Include the AccelStepper library

c. Use the following code:

```
#include <AccelStepper.h>
#include <MultiStepper.h>


//initialize variables

int currentPosition = 0;
int desiredPosition = 0;
int counter = 1;
int state = 0;
int buttonState = 0;          //sets up state of the putton to
0
const int buttonPin = 2;      //sets the button pin to 2
const int ledPin = 13;        //sets LED pin to pin 13


//declare step order
int fullSteps[4] = {0b1, 0b1000, 0b10, 0b100};


void setup() {
  DDRA = 0xFF; //using port A as output
  pinMode(buttonPin, INPUT);  //takes input from the button
pin
  pinMode(ledPin, OUTPUT);    //sets ledpin to output
}

void loop() {
  buttonState = digitalRead(buttonPin);
  switch(state) {
    case 0:
      if((buttonState == HIGH) && ((counter % 3) != 0)){  //if
button is pressed and counter is not divisible by 3, enter
loop
        currentPosition = 0;
```

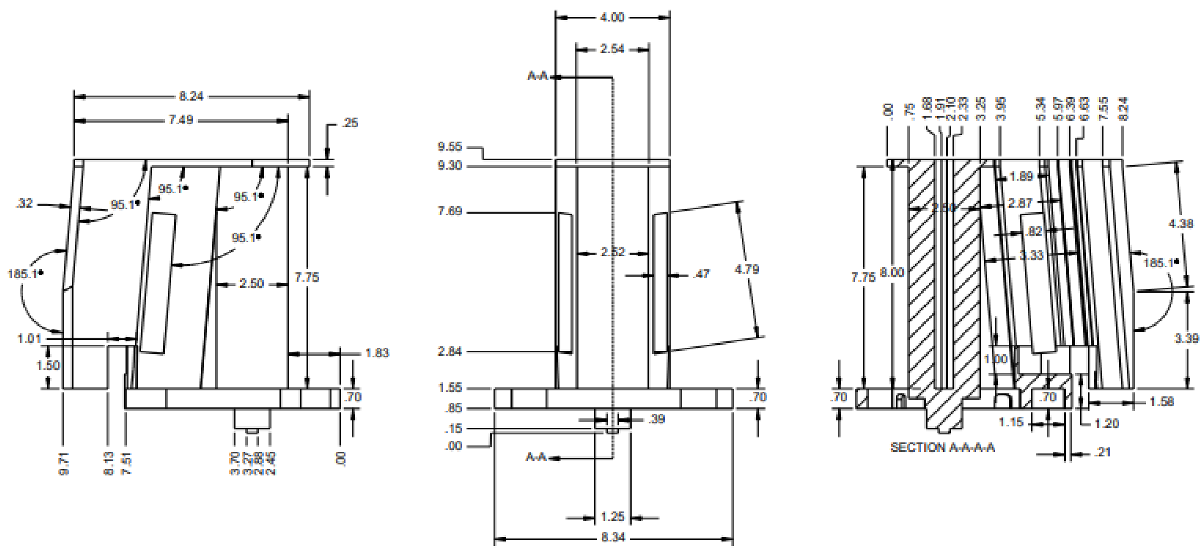
```
        desiredPosition = 67;          //set desired position
to 67 to drive motor
        digitalWrite(ledPin, HIGH);    //checks to see if
button input is read
        counter++;                     //iterate counter
        state = 1;                     //move to state 1

        }
      else if((buttonState == HIGH) && ((counter % 3) == 0))
{    //if button counter is divisible by 3, rotate 66 steps
        currentPosition = 0;
        desiredPosition = 66;           //set desired position
to 66 to drive motor
        digitalWrite(ledPin, HIGH);     //checks to see if
button input is read
        counter++;                      //iterate counter
        state = 2;                      //move to state 2

      }
      else {
    // turn LED off:
    digitalWrite(ledPin, LOW);
    }

    break;


    case 1:
      if(currentPosition == 67){   //reset state to inert (0)
after rotating 67 steps
        state = 0;
      }
    break;

    case 2:
      if(currentPosition == 66){    //reset state to inert (0)
after rotating 66 steps
        state = 0;
      }
    break;
```

```
  }

if(currentPosition < desiredPosition){  //drive motor to
desired postion
  currentPosition++;                    //if motor is not at
the desired position, move forward
  PORTA = fullSteps[currentPosition % 4];
  delay(30);
  state=0;
}
else if(currentPosition = desiredPosition){

  state=0;
}
else{

  state=0;
}
}
```

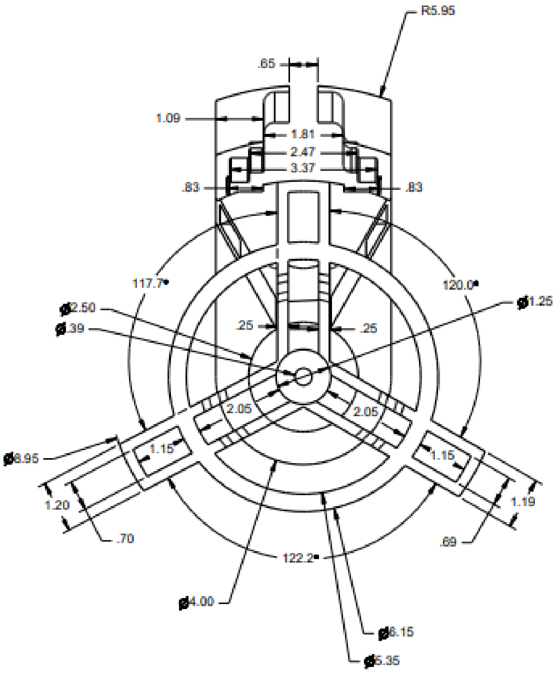
3. Turn on the power supply, set it to 12V, and press the button. The motor will turn about 120 degrees.

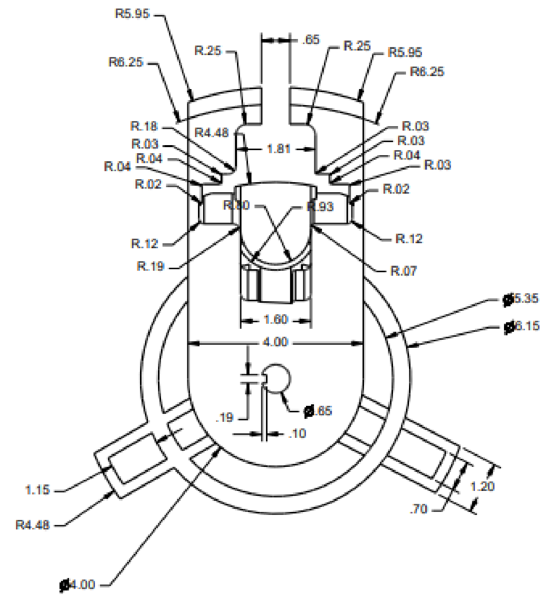
4. Fuse will engage and and device will be ready to replace fuse when triggered

Engineering Drawings



Part Name:	Material:	Finish:	
Revolver	Aluminum	Remove Sharp Edges	
Revision:	DWG. No.:	Drawn By:	Page No.:
5.0	1501	J. Ray	1





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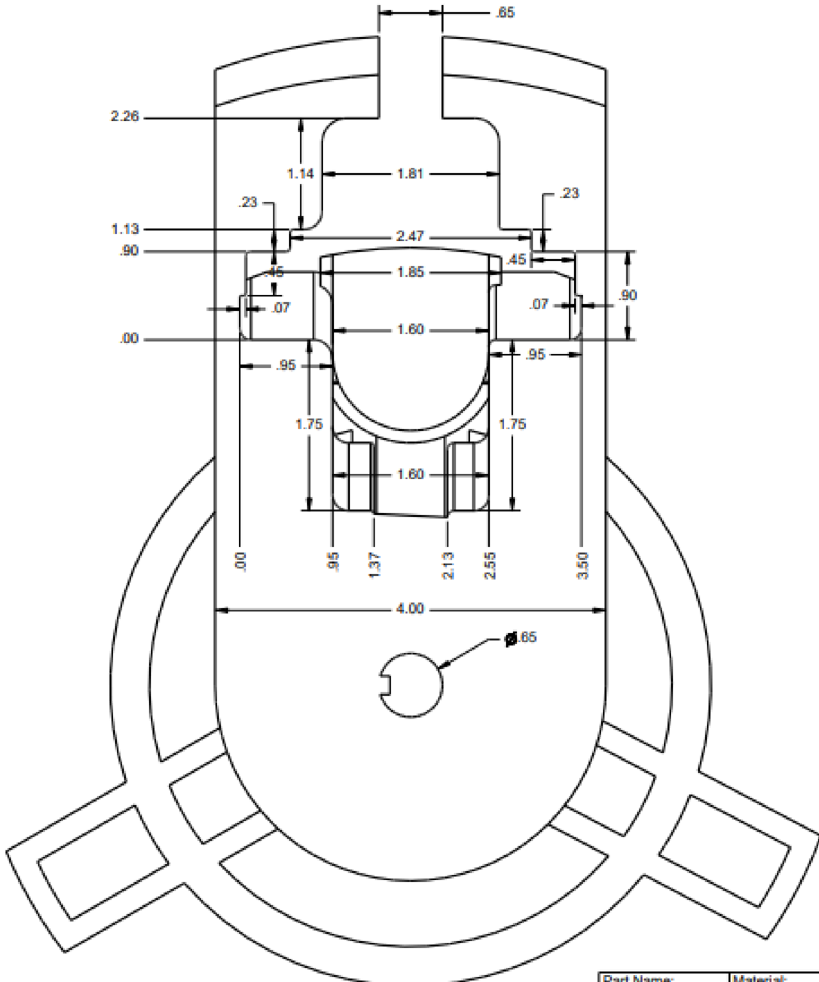
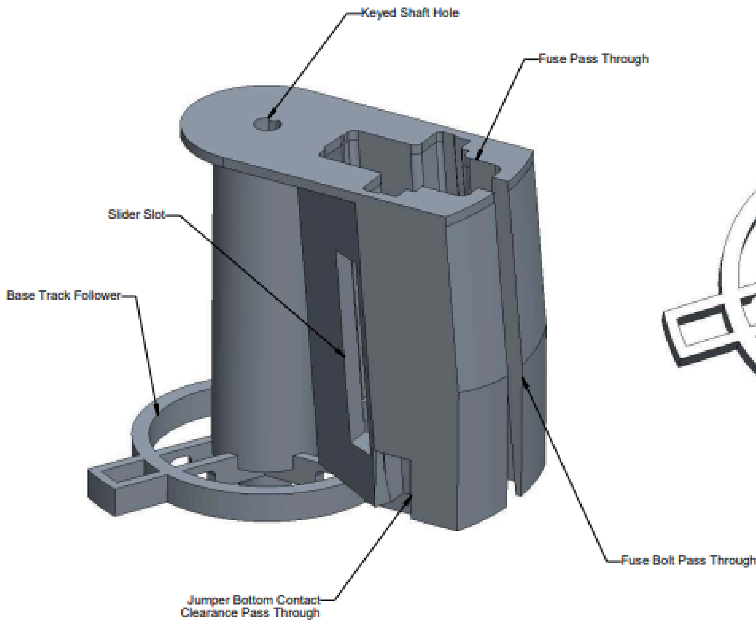
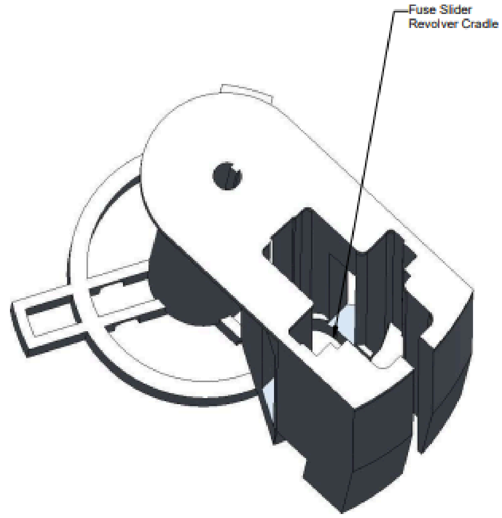
Revolver	Aluminum	Remove Sharp Edges	
Revision:	DWG. No.:	Drawn By:	Page No.:
5.0	1501	J. Ray	2



Part Name:	Material:	Finish:	
Revolver	Aluminum	Remove Sharp Edges	
Revision:	DWG. No.:	Drawn By:	Page No.:
5.0	1501	J. Ray	3





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Revision:	DWG. No.:	Drawn By:	Page No.:
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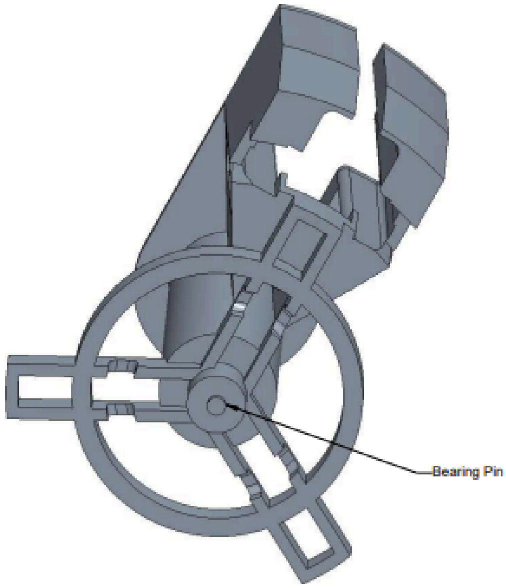

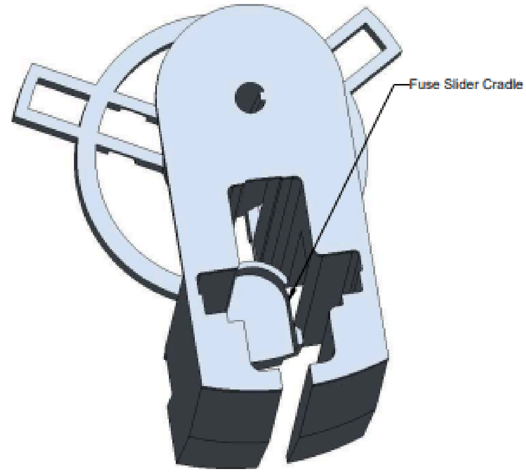

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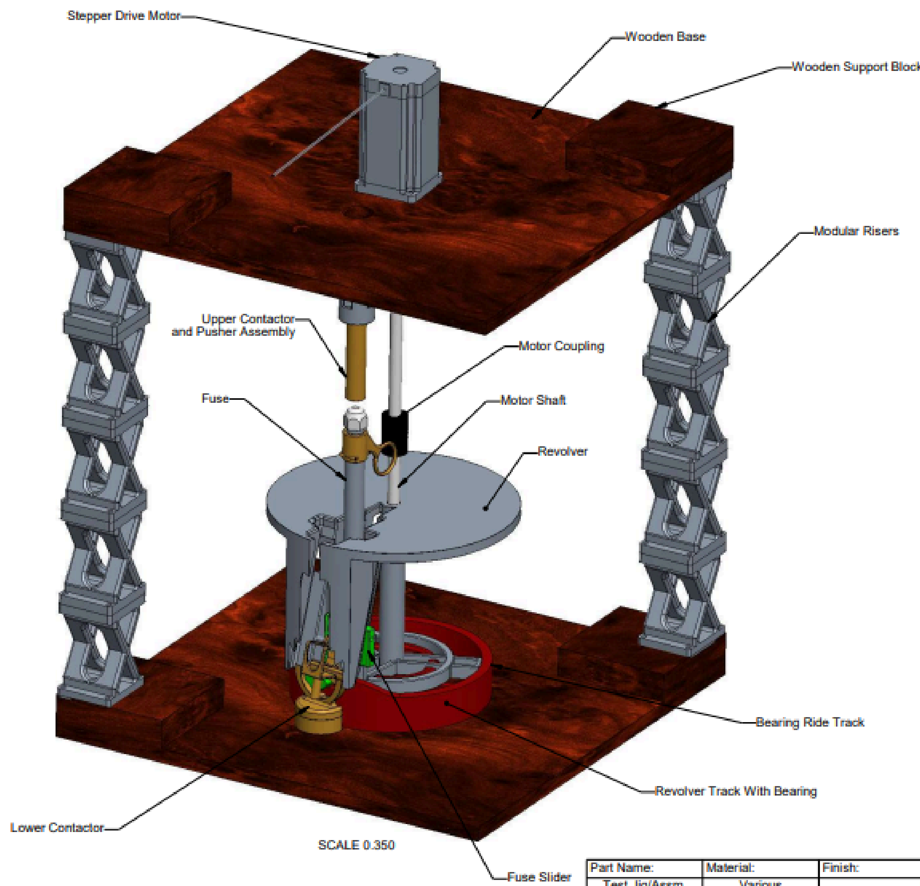

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Revision:	DWG. No.:	Drawn By:	Page No.:
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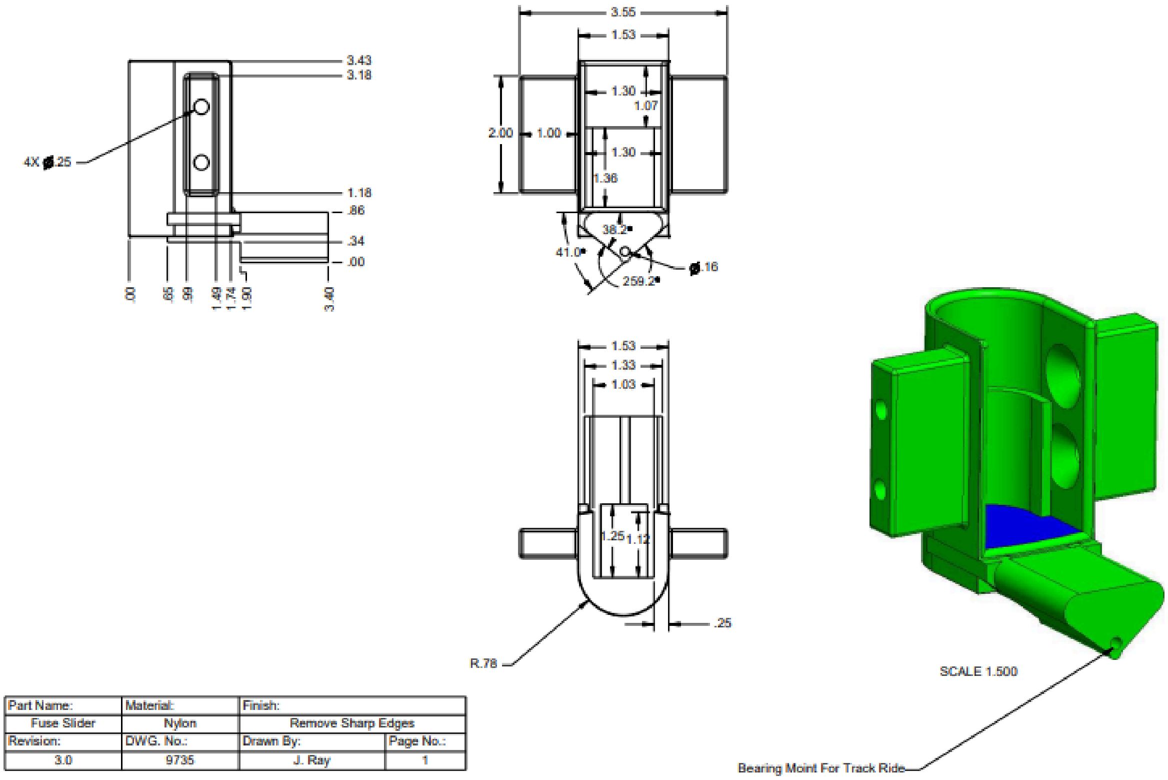

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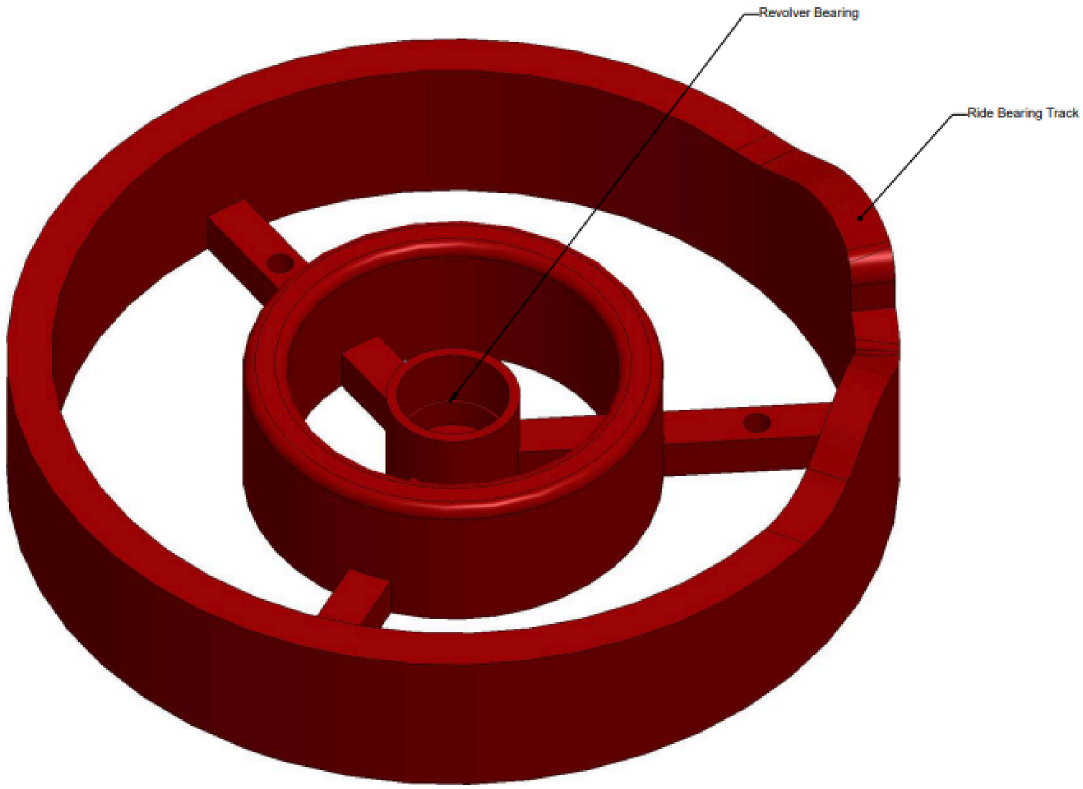

SCALE 1.500

Part Name:	Material:	Finish:	
Revolver Track	Delrin	Remove Sharp Edges	
Revision:	DWG. No.:	Drawn By:	Page No.:
4.0	1476	J. Ray	1

Risk Assessment

Figure 3: Risk Assessment

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Hooker	Phone #: (850) 410-6463	Dept.: EE	Start Date: 24 Nov 2023	Revision number: 1
Project: 304-FPL Remote Switching			Location(s): FAMU-FSU college of Engineering	
Team member(s): Andrew Lois (ACL), Jacob Ray (JR), Nicholas Haynes (NH), Nick Grant (NG), SirDarius Lomack (SL), and Christian Perez (CP)			Phone #: JR: 386-292-6107 NG: 561-401-2705 ACL: 561-568-5172 CP: 786-300-5812 NH: 770-940-9214 SL: 754-242-2792	Email: ACL: acl20c@fsu.edu JR: jdr18b@fsu.edu SL: skl19b@fsu.edu NG: nhg19@fsu.edu CP: cperez5@fsu.edu NH: ngh19b@fsu.edu

Experiment Steps	**Location**	**Person assigned**	**Identify hazards or potential failure points**	**Control method**	**PPE**	**List proper method of hazardous waste disposal, if any.**	**Residual Risk**	**Specific rules based on the residual risk**
Prototyping, Assembly, Testing	FAMU-FSU college of Engineering	All Team Members	Physical/Slip, Trips, Falls Hazard Loose wires, spools, parts, bolts, boxes could cause tripping, falling, and fall injuries.	Properly organize workspaces to avoid loose parts.	Slip resistant close-toed shoes, awareness	N/A	HAZARD: 1 CONSEQ:A Residual: Low	N/A
Prototyping, Assembly, Testing	FSU college of	All Team Members	Physical Hazard Heavy parts during moving	Instruct workers to carefully move heavy parts and have a plan	Impact/Cut resistant gloves	N/A	HAZARD: 1 CONSEQ: A	N/A

			power supplies could cause electrical shock					
All	FSU college of Engineering	All Team Members	Slips/Trips/Falls Hazard Use of oils or other fluids as well as general use of shared spaces could lead to slipping on wet floors or tripping over objects left out could cause fall damage	Workers should wear slip resistant shoes and always be aware of their surroundings	Slip resistant close-toed shoes	N/A	HAZARD: 1 CONSEQ: A Residual: Low	N/A
All	FSU college of Engineering	All Team Members	Biological Hazards In any industrial or shared space, mishaps that cause bleeding or other body fluids or injuries that cause oneself to bleed increases exposure to sickness, diseases, and other ailments	Any instances of bodily injury should be assessed, and necessary sanitation will be done	Gloves, Hand sanitizer	N/A	HAZARD: 1 CONSEQ: A Residual: Low	N/A
Prototyping, Assembly, Testing, storage	FSU college	All Team	Crushing Hazards	Make sure workers have a	Awareness, proper	N/A	HAZARD: 1	N/A

	of Enginee ring	Member s	Heavy parts moved in/out of storage or assembly areas pose the risk of falling on extremities or other body parts. These parts can crush the body or extremities	firm grip on parts when moving them and ask for help if they need it.	lifting form		CONSEQ: B Residual: Low	
Prototyping, Assembly, Testing	FSU college of Enginee ring	All Team Member s	Entanglement Hazards Use of or testing parts, motors, and equipment poses the risk of entanglement of hair, clothing, and extremities. This can cause ripping, lacerations, pinching, or crushing of body parts, skin, and extremities	Secure loose hair and make sure all body parts and clothing are clear of the motor's operation.	Awarene ss, well fitting clothing, hair-ties	N/A	HAZARD: 1 CONSEQ: B Residual: Low	N/A
Prototyping, Assembly, Testing	FSU college of Enginee ring	All Team Member s	Physical/Burn Hazard Use of equipment such as 3D printers	Be aware of hot parts and use proper PPE when moving them.	Awarene ss, heat resistant gloves	N/A	HAZARD: 2 CONSEQ: B Residual:	N/A

			and machining equipment or tools that generate heat such as motors can cause burns on the skin and body				Low Med	
ALL	FSU college of Enginee ring	All Team Member s	Chemical Hazard Use of a shared space or industrial setting poses the risk of unknown substances and chemicals that can irritate the body, skin, eyes, and respiratory system	Make sure to clean stations of substances before and after use. Make sure workers are aware of their surroundings.	Awarene ss, chemical washing station	N/A	HAZARD: 2 CONSEQ: B Residual: Low Med	N/A
Prototyping, Assembly, Testing	FSU college of Enginee ring	All Team Member s	Strike Hazards Use of power tools during project or high energy release mishaps may cause objects to fly at high velocities and strike people	Workers will wear hardhats and protective glasses when working with tools of any kind	OHSA certified impact safety glasses	N/A	HAZARD: 2 CONSEQ: B Residual: Low Med	N/A
Prototyping, Assembly, Testing	FSU college	All Team	Vibration Hazards	Make sure workers are	Vibration , impact	N/A	HAZARD: 2	N/A

	of Engineering	Members	Use of power tools, or close proximity to other Vibration producing objects may cause nerve damage or desensitized extremities	aware of the dangers of the tools they are using and are properly trained on how to use them.	resistant gloves		CONSEQ: B Residual: Low Med	
Prototyping, Assembly, Testing	FSU college of Engineering	All Team Members	High Energy/Physical Hazards Use of tools, machinery, pneumatics, electrical systems that have the capability to use and store high amounts of energy may rapidly deteriorate or explode. This may cause burns, blunt force trauma, and many other severe injuries	Only certified workers can operate heavy machinery to ensure there is no misuse, and workers will always wear proper PPE	Vibration, impact, electrical, fire resistant gloves	N/A	HAZARD: 2 CONSEQ: C Residual: Low Med	N/A