WW-202420

Final Design Report

Southern Illinois University Carbondale
Saluki Engineering Company

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College of Engineering, Computing, Technology, and Mathematics

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Cover Letter (TD)

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Dear Senior Design Professors,

Our team is excited to share our final design report for Project WW-202420, a bicycle tow-behind electric weed eater. We have designed and engineered this project in collaboration with Patrick Work, owner of Bike Surgeon in Carterville, IL, and it will be used to help maintain the trails at Touch of Nature in Carbondale, IL. Our goal was to create an eco-friendly tool that makes trail maintenance quicker and easier.

This project's design and implementation has been completed at Southern Illinois University using a mix of on-campus fabrication and component selection. The design aims to reduce the manual labor needed for weed control by offering a compact, electric-powered alternative to traditional gas-powered tools. In this report, we've outlined our overall design, key features, and implementation process.

On behalf of the WW-202420 team, we extend gratitude to Patrick Work for his support and commitment to our team and project. If any questions arise, please reach out to me at taylor.demick@siu.edu.

Regards,

Taylor Demick
WW-202420 Representative

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1. Introduction and Considerations (CB)

Using the design outlined in our preliminary project proposal, out team has engineered a bicycle tow-behind electric weed eater that will promote easier and more efficient trail maintenance. Using Touch of Nature's trail system as an example of the current challenges in trail maintenance, regularly clearing weeds is essential to maintain comfort and accessibility for riders. Overgrowth, especially during warm and rainy seasons, leads to an increase in ticks, mites, and other hazards that discourage riders from using the trails. Currently, trail maintenance is performed manually, with individuals using weed eaters to clear trails on foot. This work quickly becomes tiring, as it can take up to two hours for one person to clear one mile of trail.

Recognizing the physical effort and time it takes to keep trails clear of overgrown weeds on foot, we have designed and implemented a solution that combines the convenience of biking with the power of Milwaukee weed-eating tools. Featuring dual weed-eating heads that trim the weeds on either side of the path as the rider bikes along, our design reduces the need for labor-intensive, manual clearing. The design also features a handlebar-mounted control device allowing users to wirelessly adjust motor speed while riding. For functionality on uneven terrain, the weed-eating heads feature a spring-and-rotation mechanism allowing them to retract and return to position when contacting natural obstacles. Our design offers an eco-friendly, efficient alternative for trail maintenance, enabling weed trimming without heavy machinery or excessive manpower.

We prioritized public health, safety, and welfare by designing a system that reduces operator fatigue and limits the likelihood of repetitive strain associated with handheld equipment. The handlebar-mounted wireless control further enhances rider safety by allowing adjustments without dismounting or reaching near moving parts. Globally and culturally, our design supports outdoor recreation and sustainable trail maintenance practices. Socially, it promotes volunteer-led trail upkeep by making maintenance more accessible. Environmentally, the design eliminates the need for gas-powered machinery, reducing emissions and promoting eco-friendly trail maintenance. Economically, our solution minimizes labor requirements and lowers long-term maintenance costs, offering an affordable alternative to large-scale equipment for park districts and conservation groups.

2. Design Implementation (ALL)

2.1 Problem Statement and Background (CB)

Our project's goal was to design and engineer a potential solution to the current challenges in trail maintenance. Using Touch of Nature's trail system as an example, regularly clearing weeds is essential to maintain comfort and accessibility for riders. Overgrowth, especially during warm and rainy seasons, leads to an increase in ticks, mites, and other hazards that discourage riders from using the trails. Currently, trail maintenance is performed manually, with individuals using weed eaters to clear trails on foot. This work quickly becomes tiring, as it can take up to two hours for one person to clear one mile of trail. To address this problem, our team has designed and engineered an electric tow-behind weed eater for bicycles. Our design aims to significantly reduce the time and effort required for trail maintenance by combining the mobility of a bicycle with the power of two electric Milwaukee Tools weed eater motors.

Our literature review revealed several insights that highlighted the need for this project. The most significant discovery was the lack of suitable solutions for bicycle-towed, lightweight, and wireless electric trimming. Although pull-behind weed-eating equipment like the DR Pro XLT Tow-Behind ATV Trimmer Mower [1] exists, its heavy-duty profile is designed for ATV towing, making it unsuitable for narrow trails and low-speed bicycle use. Our review identified this gap and further supported our project's necessity through three key findings. First, while ATV-towed solutions offer power and durability, they are all too large and heavy for bicycles. However, products like the Burley Coho XC trailer [2] demonstrate that a lightweight, single-wheel platform can offer the necessary balance, suspension, and modularity for off-road towing behind bicycles. Its adaptable frame and hitch system provide a stable foundation for mounting electric trimming equipment without compromising the rider's control or safety.

Second, we discovered that integrating wireless control is achievable and reliable using ESP32 microcontrollers and Espressif's ESP-NOW protocol [3]. ESP-NOW enables fast, low-power, one-way communication between microcontrollers without the overhead of standard Bluetooth or Wi-Fi protocols, making it ideal for real-time motor control during operation. This allows the rider to wirelessly turn the weed eater motors on and off and select different speed settings via a handlebar-mounted controller.

Lastly, the motor and power systems required for effective vegetation trimming were carefully considered. While it was a constraint to only use Milwaukee's brushless M18 motors in our design, their sufficient torque and efficiency made them suitable for our application [4]. To control these motors, we discovered that their speed can be adjusted via built-in actuator switches [5]. This finding motivated us to research options to remotely activate the switch, leading us to incorporate stepper motors in our wireless control system design [6]. Powering the M18 motors reliably requires high-capacity batteries—our design leverages two Milwaukee M18

HD batteries wired in parallel (for each motor) to maintain voltage while extending runtime [7], [8].

These findings validate our system's necessity and highlight how existing technologies—lightweight trailers, wireless microcontrollers, efficient motors, and battery systems—can be integrated into a bicycle-towed weed-eating solution. By combining these elements, our design provides a scalable, electric-powered alternative to manual trimming that increases efficiency, reduces physical strain, and improves trail maintenance accessibility.

2.2 Design and Methodology (ALL)

2.2.1 Design Overview (TD)

The final design focuses on four key values: efficiency, durability, ease of use, and environmental friendliness. It features high-performance Milwaukee electric motors powered by a combination of Milwaukee M18 5.0Ah and 8.0Ah lithium-ion batteries, providing a minimum of one hour of runtime under typical load conditions. The system weighs under 70 pounds, ensuring ease of towing and handling, and is built on a Burley Coho XC trailer, chosen for its rugged construction and proven off-road towing performance.

For vegetation control, we originally planned to use Weed Shark Pro trimmer heads, known for combining a durable stainless-steel blade with strategically positioned trimmer lines. However, due to supply chain issues, we transitioned to using the Rino-Trim trimmer head instead. Unlike the Weed Shark Pro, the Rino-Trim does not feature a steel blade, which reduces the risk of debris impact or injury and ultimately enhances the safety of the system, especially when operating near other trail users or in unpredictable terrain. Despite the change, the Rino-Trim unit remains a reliable and effective alternative for both dense and light vegetation, still compatible with ECHO Black Diamond trimmer line, which delivers excellent cutting performance and durability.

The overall design is composed of four main subsystems: the wireless control system, wing and motor subsystem, battery subsystem, and subsystem integration. These elements were developed to work cohesively and meet the demands of reliable and safe operation in varied outdoor environments.

The wireless control system allows the operator to control the weed eater remotely via an M5StickC Plus microcontroller, which interfaces with the main control unit over a wireless connection. This setup enables remote activation and deactivation of the cutting system with variable speeds, which in turn, also acts as a wireless kill switch. This is a crucial feature that allows the rider to immediately shut off the system in the event of a fault or emergency. This safety mechanism eliminates the need for a mechanical switch, improving usability and response time while maintaining rider control from the bicycle's handlebars.

The wing and motor subsystem contains the core mechanical cutting elements of the design. Initially, our design proposal called for two motors, one mounted on each of the two wings extending from either side of the trailer. However, due to unforeseen supply delays, only one motor was received in time for assembly. Despite this, both wings were fully fabricated, and the non-functional side was designed to support future installation with a “plug-and-play” style motor mount and wiring interface. This forward-thinking approach maintains system flexibility and ensures the upgrade to dual motor operation can be implemented with minimal redesign. Additionally, our original concept had the wings mounted perpendicular to the trailer frame to maximize cutting width. During assembly, it became clear that this orientation made the system too wide for typical trail conditions. As a result, the mounting angles were adjusted, bringing the wings closer to the trailer frame and shortening the effective cutting width. This change improves trail compatibility while maintaining cutting performance on one side.

The battery subsystem supplies power to the motor system. We originally designed the system to use four batteries, two per motor, with each pair wired in parallel to increase current supply and runtime. Following the reduction to a single motor, we retained the four-battery setup but modified the wiring to run all four batteries in parallel to support the single motor. This configuration maximizes available power, extends operation time, and enables future scalability once a second motor is integrated.

The subsystem integration stage brought together all major components onto the trailer platform. This included securely mounting the motor and battery assemblies, routing wiring harnesses through protective sleeving, and positioning the control modules for easy access and stable connectivity. Special care was taken to ensure balanced weight distribution and minimal drag on the bicycle, maintaining safe handling and rider control. The modular design of each subsystem ensures that future improvements, such as motor addition, can be incorporated without major overhauls. Figure 2.1 shows all the subsystems incorporated together, illustrating how each component interfaces with the others to form a unified and functional trail maintenance device.

Compared to gas-powered or traditional handheld weed eaters, this system provides a quiet, zero-emissions alternative with enhanced coverage and operator comfort. Adjustable features and modular design make it adaptable for various terrain conditions, while reducing fatigue and increasing safety for trail workers. In summary, our tow-behind weed eater is a versatile, user-friendly, and eco-conscious innovation aimed at transforming the way trails are maintained.

2.2.2 Wireless Control Subsystem (CB)

The wireless control subsystem enables the user to wirelessly turn on/off the weed eater motors and cycle through three distinct motor speed settings, providing seamless interaction between the user and the trailer. To achieve this, the design consists of two ESP32 microcontrollers communicating via a one-way ESP-NOW wireless protocol connection. The sender ESP32, mounted on the bicycle handlebar, acts as the control interface and sends input commands to the

receiver ESP32 attached to the trailer. This receiver ESP32 interprets these commands and controls two stepper motors, each pushing the Milwaukee M18 motor assembly's actuator switches (Figure 7.1); the pressure applied to these switches determines the motor's speed. To better understand this subsystem's design and functionality, we have broken it down into two units: the Handlebar Control Unit and the Trailer Control Unit.

The Handlebar Control Unit (HCU) uses the M5StickC Plus [34]—an ESP-32 development board—to handle user inputs and display the system's power state and speed settings. The M5StickC Plus functions as the sender ESP32 for the ESP-NOW protocol and dramatically reduces the need for complex hardware integration with its numerous integrated features. Its onboard buttons enable simple user interaction, its LCD provides a visual interface for the power and speed settings, and its rechargeable 3.7V LiPo battery is maintained by built-in power circuitry. Moreover, the M5StickC Plus comes in a compact, pre-assembled enclosure, eliminating the need for custom PCB fabrication. These characteristics simplified the overall subsystem design and allowed for easy mounting on a bicycle's handlebars.

The Trailer Control Unit (TCU) includes the following components: a receiver ESP32 development board, two DRV8825 stepper motor drivers, two NEMA 17 stepper motors, and a Talentcell dual-output rechargeable battery pack (12V/5V). The receiver ESP32 continuously listens for ESP-NOW packets transmitted by the HCU, with each packet containing commands for the power state and speed settings. After receiving these commands, the ESP32 processes them and generates step signals for the DRV8825 motor drivers. These drivers enable precise current control, allowing the stepper motors to perform fine movements, activating the M18's motor assembly switches. The stepper motors feature oval-shaped cams that rotate to engage the actuator switch. To reduce the stepper motor's power output, there is a lever placed between the cams and the actuator switches. This mechanism's goal is to recreate the functionality of someone manually controlling the M18 weed eater. The TCU is powered by the Talentcell rechargeable battery pack, which provides dual outputs: 12V for the stepper motors and 5V for the ESP32. This compact battery will ensure efficient operation without the reliance on external power sources. All components will be housed in an outdoor box, which will feature cutouts for the battery pack's charging port and motor wiring, ensuring ease of access and secure integration. Figure 7.2 presents a simplified block diagram of the planned TCU design and Figure 7.3 provides a detailed wiring schematic of the completed TCU design.

Once parts arrived, I began implementing the subsystem's design by first writing and uploading a simple sketch (code) that established an ESP-NOW connection between two ESP32s. For testing, I created a basic circuit and sketch so that pressing two buttons on the sender ESP32 would wirelessly turn on/off an LED connected to the receiver ESP32. However, I noticed that when I cut power to the sender, the LED on the receiver stayed on. This happened because the sender had only sent a single ESP-NOW message, and there was no mechanism in place to signal that it had disconnected. To solve this, I needed to implement a keep-alive system where the

sender transmitted an ESP-NOW message every five seconds. If the receiver did not receive one of these messages within seven seconds of the last one, it automatically turned off the LED.

Next, I implemented the stepper motors and their drivers by first wiring them according to a schematic shown in Figure 7.3. I then updated my sender and receiver code to include stepper motor control, allowing their positions to be adjusted by the sender's two buttons: one to toggle power to the drivers and one to cycle through three stepper motor positions. To power the system, I connected the battery's 12V output to the stepper motor drivers and the 5V output to the receiver ESP32. After verifying all connections, I improved the system's wire management. Figure 7.4 shows the TCU at this stage of the subsystem design's implementation.

Once the M5StickC Plus arrived, I updated the sender ESP32 sketch to match the M5StickC's pinouts and then uploaded the new sketch to the device. I used Figma to design a user interface to display power and speed settings (Figure 7.5) and then coded the design to the M5StickC's LED display (Figure 7.6). I also added encryption to the ESP-NOW connection.

With the wireless control functioning as intended, I transitioned to designing the mechanical interface between the stepper motors and the M18 motor actuator switches. Using TinkerCAD, I explored various configurations, eventually developing a design that uses an oval-shaped cam (Figure 7.7)—rotated by the stepper motor—to push a lever (Figure 7.8) that activates the M18's actuator switches. To ensure the switches remained stationary during activation, I designed a shelf (Figure 7.9) to secure them, which could be bolted to the TCU's enclosure. This lever mechanism required multiple iterations to optimize the cam geometry, ensuring full actuation of the motor switches and reliable engagement. I also modeled a cradle for the battery and breadboard, designed to adhere to the TCU's enclosure and featuring a mount to hold the battery's DC jack for charging (Figure 7.10).

Once the stepper motor and actuator switch placement were verified, I used a drill to secure the actuator switch shelf and stepper motor brackets to the enclosure's base. Following repeated testing, I confirmed that the system successfully activated the weed eater motor wirelessly with adjustable speed settings. Figure 7.11 provides a visual overview of the TCU's design and part layout after mechanical functionality. It's important to note that this figure does not showcase the TCU's finalized design, but rather a snapshot of its late development stage.

To address heat concerns with the stepper motor drivers, I installed an exhaust fan and dust cover in the enclosure's lid. I also designed and added a hinged panel to the lid, which allowed access to the TCU battery's charging port, life indicator, and power button. To aid in future troubleshooting, I installed a plexiglass window above the lever mechanism. Finally, I drilled a small hole at the enclosure's lid's edge to route the two M18 motor switches' wiring externally. Figure 7.12 displays the finalized TCU design, and Figure 7.13 shows the finalized HCU design. All code for the wireless control subsystem can be found at https://github.com/kaliberxzy/saluki-ripper.

2.2.3 Wing and Motor Subsystem (BJ)

The wing and motor subsystem uses two BLDC 18-volt motor assemblies from Milwaukee's M18 String Trimmer (Figure 7.14) to supply the sufficient power required for trimming weeds on a bicycle. The M18's gearboxes, which are the angled ends of the string trimmer that fit the weed eater head, are attached to the ends of two metal wings. These gearboxes are then linked to the M18's motors via a tube-encased shaft. Reusing Milwaukee's M18 parts significantly reduces design complexity; however, it constrains future part replacement to the 2825-20 M18 model.

To adhere to nature's obstacles, the design features a mechanism so that if a wing encounters, for example, a tree, the wing can rotate and retract back towards the bicycle trailer's frame and clear the tree. Once cleared, the wing, with the use of a spring, can automatically rotate back to its original placement. Furthermore, to account for varying elevation, the wings can pivot upward from the base of the trailer much like a bird's wings. Finally, each wing is supported by a caster wheel. Figure 7.15 and Figure 7.16 illustrate an early cardboard mock-up of this wing design, and Figure 7.17, Figure 7.18, and Figure 7.19 show various preliminary CAD drawings of the wing mechanism and its motor integration.

During the wing and motor subsystem implementation phase, I first finalized the CAD drawings of its wing assembly, motor mounts, and hinges using Creo. To fabricate these components, we cut sheet metal using the plasma table with Creo-exported DXF files. These DXF files are shown in Figure 7.20 - Figure 7.24 (these DXF file screenshots are the finalized versions). After the plasma table finished cutting, we used a grinder to remove burrs and smooth the edges of the sheet metal. Figure 2.25 shows how these wing pieces are assembled once cut and how the gearbox and motor are attached.

To connect the gearbox with the electric motor, we reused the M18's original shaft. We used a chop saw to cut the correct length off each end of the shaft. Once the correct length was cut, we TIG welded them together and cut the aluminum tube that housed the original shaft. We then attached the shaft and tube to the gearbox to ensure proper fitting and length.

Next, we welded the motor mounts to the wing piece; however, an issue with weld warping led to an incorrect alignment with the weed eater shaft and motor completed assembly. To address this concern, I designed the wing assembly pieces with a slot and tab method to ensure proper placement before welding. We also 3D-printed a spacer to support the gearbox to the wing. Once the wings were assembled and welded, we bolted in the weed eater gearbox, shaft, and motor. Additionally, to protect the motor's electronics from debris, we designed and 3D-printed a housing (Figure 7.26).

I then created a bearing sleeve in Creo to allow the wing to swivel back while attached to the hinge mounted to the trailer's aluminum plate (Figure 7.27), which was plasma-cut and placed on the trailer's base to provide sufficient support. I then fitted a bearing, sourced from Summit

Colliers, into the bearing sleeve (now welded to the hinge piece), allowing the wing to rotate 180 degrees. The wing was secured to the bearing by using a ¾ inch bolt, washer, and nut. To allow for smooth rotation, I designed and 3D-printed a spacer that fits between the top of the wing and the bottom of the bearing. For the hinge, we cut a hinge pin from ½ inch round stock, then cut a notch for a C-clip. We then drilled a small hole for a cotter pin so that the hinge pin does not escape.

Once the wings were attached to the trailer, we cut and welded a metal extension (Figure 7.28) on each wing's back to accommodate a caster wheel, ensuring structural support and ground clearance. This configuration was flawed because it lacked sufficient support for the wings. Furthermore, although we initially planned to position the wings perpendicular to the frame, we found that this placement caused the weed eater heads to extend too far outward. Rotating the wings forward resolved both issues by bringing the weed eater heads closer to the desired shoulder-width spacing and repositioning the caster wheel support to the outside. Finally, to ensure the wings return to their original position after rotation, we installed a spring mechanism secured with eyebolts between the wing and the trailer.

Once this configuration proved functional, we bent and welded metal bars along the perimeter of the wings at the same level as the weed eater heads. This protected both the weed eater string and the user. Finally, to enable easy transportation, we installed eyebolts and carabiners to secure the wings in a folded position against the top of the trailer frame. Figure 7.29 displays the fully welded wings and hinges, completed with a clean coat of paint for a finished, professional appearance.

2.2.4 Battery Subsystem (JW)

To power the tow-behind weed eater reliably and extend its operational runtime, a battery subsystem was developed and implemented through a multi-stage design and testing process. The approach began by creating a simple schematic of the parallel battery system in KiCAD to illustrate how two Milwaukee M18 batteries would be connected in parallel (Figure 7.30). This was followed by circuit modeling in MATLAB (Figure 7.31), where simulations confirmed that the configuration would maintain a steady 18V supply while effectively doubling the available current (Figure 7.32 and Figure 7.33). This configuration was chosen to improve power delivery and extend the motor's runtime without overloading the system.

The M18's motor housing was disassembled to analyze internal wiring and determine how to accommodate the new battery configuration. After careful examination, a parallel battery design was proposed and validated through real-life tests using jumper wires to ensure that both batteries would supply current evenly and the motor would operate without fault.

Accurate measurements of the motor and trailer mount area were taken to design custom battery brackets. These brackets were 3D-modeled and printed to securely hold the batteries in place on the trailer, maintaining both safety and accessibility. The team then proceeded to modify the

motor’s wiring by cutting and extending the original wires to suit the new configuration, taking care to maintain proper polarity and gauge compatibility.

To ensure durable and low-resistance electrical connections, soldering was performed at key junctions. A wire harness was fabricated to link the batteries in parallel, simplifying installation and minimizing clutter. Terminals on the original battery mount were drilled and prepared for the new wiring, with careful insulation to prevent any risk of short circuits. An overview of the completed battery wiring can be seen in Figure 7.34.

Once all wiring and structural supports were cmplete, the batteries and motor were mounted onto the trailer. Full system testing was conducted to verify functionality under load, and the trailer operated successfully with the upgraded power system. The process concluded with wire management refinements, securing all connections and organizing cables to prevent movement or wear during use.

2.2.5 Subsystem Integration (TD)

Subsystem integration plays a crucial role in ensuring that each individual component of the electric tow-behind weed eater functions seamlessly as part of a unified system. The wireless control system communicates with the motor subsystem via a central microcontroller, allowing the user to initiate and stop the cutting mechanism remotely while riding. This motor system receives power from the battery subsystem, which is wired in parallel to ensure consistent voltage and extended operation time. The power supplied from the four Milwaukee M18 batteries is routed through protective wiring to the motor, enabling reliable and uninterrupted cutting performance. The structural design of the trailer accommodates all components in a balanced configuration, minimizing drag on the bicycle and maintaining smooth maneuverability on trails.

Mechanical and electrical components were mounted to ensure clean integration, both for safety and accessibility. Wiring harnesses were routed on the trailer frame and secured to prevent interference with moving parts. The wing and motor subsystem connects directly to both the power and control systems, and the angular wing adjustment ensures the trailer remains within the trail width constraints while still allowing effective weed cutting. This cohesive design allows for a modular and scalable platform, whether for adding a second motor, expanding battery capacity, or upgrading control features.

Figure 7.35 shows the fully assembled final design from a side view, highlighting how the trailer is towed and how the subsystems are arranged in relation to the bicycle. Figure 7.36 provides a top-down view of the complete system, clearly illustrating the adjusted wing angle, battery placement, control housing, and wiring layout. Together, these images demonstrate the integration of each subsystem into a finished, operational product, ready for real-world trail maintenance.

2.3 Standards (BJ)

Our design integrated OEM parts and materials, relying on the standards followed by the manufacturer. While this simplified development and reduced costs, it also limited the standards we followed. As a result, we have separated the design's standards into standards followed by manufacturers and standards that we will adhere to.

Notable standards our OEM parts adhere to:

1. **CISPR 14-1:2020** [9] specifies the requirements for radio-frequency disturbance emissions from appliances in the 9 kHz to 400 GHz frequency range.
2. **IEEE C37.18-1979** [10] defines the temperature limitations and classification of insulating materials, dielectric withstand voltage requirements, and test requirements.
3. **IEEE 113-1985** [11] outlines tests for DC motors and generators designed for ripple-free operation and tests for DC motors designed for use with rectifier power supplies. It also covers the electrical measurements and power sources required for all test procedures.

The standards we adhered to:

1. **IEEE P2962** [12] recommends practices for installation design, storage, installation, ventilation, instrumentation, charging, maintenance, capacity testing, and replacement of Li-ion (Lithium-ion) batteries. It also provides guidance on complying with safety standards and outlines best practices for worker safety during installation, maintenance, and testing.
2. **IEEE 802.11** [13] is a set of standards defining wireless local area network (WLAN) protocols, commonly referred to as Wi-Fi. ESP-NOW operates over the physical and MAC (Media Access Control) layers defined by 802.11. ESP-NOW specifically follows the IEEE 802.11-2012 amendment.

2.4 Requirements and Constraints (JW)

We needed to meet several key requirements and constraints to ensure the functionality and practicality of our design. A primary requirement that was met was the implementation of wireless control, enabling communication between the rider and the trailer. Another essential requirement met was the auto-fixing of weed eater heads, ensuring proper alignment and preventing the heads from getting caught on trees, rocks, etc. Finally, the design needed to be lightweight, ensuring ease of towing and balance while behind the bicycle. A major constraint in our design involved only utilizing Milwaukee Tool’s electric weed-eating equipment. Additionally, due to the trailer in our possession during the design process, we were constrained by its characteristics, including adjustable suspension and single-wheel profile.

2.5 Courses (JW)

The development of this project incorporated knowledge from several key courses. ECE 296 provided the foundation for writing code that enabled communication between the HCU and the trailer. ECE 385 contributed to the understanding of motor properties, ensuring the proper selection and configuration of weed eater motors. We applied knowledge from ECE 484 to power the motors with a new battery configuration. Finally, ECE 356 deepened our understanding of variable motor speeds, which was essential for designing a user-friendly and efficient control system.

2.6 Tools (ALL)

2.6.1 Universal (ALL)

- **Standard toolbox and drill** to fasten hardware and create holes
- **Calipers** to perform measurements of various objects
- **TinkerCAD** to design 3D models
- **Creality Ender Pro V3 3D Printer** to print 3D models
- **Wire strippers** to strip wires

2.6.2 Wireless Control Subsystem (CB)

- **Arduino IDE** to write, compile, and upload C code to microcontrollers
- **Figma** to design concept for M5StickC Plus user interface
- **Tweezers** for breadboard wire placement
- **Multimeter** to measure and adjust stepper motor driver potentiometer
- **USB-C cable** for serial communication with microcontrollers
- **Dremel** to cut holes in outdoor box lid

2.6.3 Wing and Motor Subsystem (BJ, TD)

- **Welder** to fuse metal parts together
- **Mill/Lathe** to create bearing housing
- **Drill Press** to drill holes through metal to assembly wing and hinges
- **Break press** to bend metal for guards
- **Plasma table** to cut sheet metal
- **Chop saw** to cut metal shaft
- **Band saw** to cut aluminum tube
- **Grinder and sander** to smooth metal
- **Creo** for wing CAD drawings
- **SolidWorks** for trailer floor CAD drawing

2.6.4 Battery Subsystem (JW, TD)

- **Soldering iron** to attach wires
- **Multimeter** to measure current and continuity
- **KiCAD** for parallel circuit schematic and simulation

- **Heat gun** for heat-shrink tubing over solder joints

3. Ethical Considerations (TD)

During the development of the bicycle-towed weed eater, ethical considerations are integral to every phase of the engineering process, from initial concept to final testing. One of the primary ethical concerns is ensuring user safety. Because the device involves a high-speed cutting mechanism that operates in close proximity to the rider, there is a significant need for reliable safety systems. To address this, our team has implemented a kill switch directly into the wireless control system, using an M5 Stick microcontroller. The M5 Stick, mounted on the bicycle handlebars, includes a physical button that can instantly shut down the weed eater system in case of an emergency. If the rider feels unsafe or loses control of the bike, pressing this button immediately cuts power to the motor, stopping all weed trimming activity.

Beyond safety, we are also mindful of the project's environmental and social responsibilities. Since the device is electrically powered, we are choosing energy-efficient motors and environmentally conscious battery options to reduce our carbon footprint. We are also selecting recyclable materials through 3D printing where possible for several components and minimizing waste through careful prototyping practices.

From a societal perspective, the purpose of this project is to support trail maintenance workers, volunteers, and trail staff by providing a tool that reduces physical labor and increases efficiency. By making trail upkeep more accessible, the project serves a broader public good. In line with the principles of engineering ethics, we are committed to transparency, safety, sustainability, and the development of a practical solution that has a positive impact on both users and the environment.

4. Skills (CB)

Over the past two semesters, our team developed a wide range of technical and professional skills that strengthened our project implementation and team collaboration. We learned to work in an agile framework, which improved both sponsor and internal communications while refining our problem-solving abilities. We gained valuable experience in microcontroller programming and wireless communication protocols using the Arduino IDE. We also became more adept at breadboarding and constructing electronic circuitry. Our hands-on experience extended to utilizing 3D printing for rapid prototyping, learning how to use CAD software (including TinkerCAD and SolidWorks), and fabricating parts through the operation of machinery. In addition, we gained experience in part selection, practiced iterative design, learned cable splicing, implemented parallel and switch circuitry, and sharpened our skills in welding. Finally, our efforts in document preparation reinforced our understanding of the comprehensive technical processes involved in modern engineering.

5. Conclusion (TD)

Our tow-behind electric weed eater is a practical and eco-friendly tool that makes trail maintenance easier, faster, and more efficient. Designed to attach to a bicycle, it trims vegetation as you ride, saving time and effort compared to traditional handheld weed eaters. The system is lightweight, portable, and built to handle tough terrain while being easy to use and maintain. The wireless control system allows users to adjust motor speed and turn the weed eater on and off with the press of a button, all from the handlebars. The powerful Milwaukee motors and reliable batteries provide plenty of cutting power and runtime, while the sturdy trailer design ensures stability and durability. Additional safety features, like a mechanism to protect the motor if it hits an obstacle, keep everything running smoothly.

To bring this concept to life, we began by modifying a Burley Coho XC trailer as the foundation for our system. We designed and fabricated two custom wings to hold the motor assemblies, adjusting their angles for optimal trail width and stability. We integrated Milwaukee M18 batteries into a parallel configuration to supply consistent power and constructed a wireless control system using an M5StickC Plus microcontroller. Despite supply chain challenges, we adapted our design by substituting the trimmer head and implementing modular mounts to allow future upgrades. Throughout the build, we conducted iterative testing to validate performance, safety, and user control.

Compared to gas-powered or handheld options, this system is quieter, cleaner, and less physically demanding. It’s designed to adapt to different conditions, making it a versatile tool for trail crews and outdoor enthusiasts alike. Overall, this weed eater is a simple, effective solution for keeping trails clear, all while being kind to the environment and easy to use.

Appendix A: References (All)

[1] DR PRO XLT Tow-behind ATV Trimmer Mower | Dr Power Equipment, https://www.drpower.com/Power-Equipment/Trimmer-Mowers/Tow-Behind-Trimmer-Mowers/DR-Tow-Behind-Trimmer-Mower/p/TT13097DMN (accessed Sep. 26, 2024).

[2] Burley, “Coho® XC,” Burley, https://burley.com/products/coho-xc (accessed Oct. 2, 2024).

[3] “ESP-NOW Wireless Communication,” Expressif, https://www.espressif.com/en/solutions/low-power-solutions/esp-now (accessed Nov. 5, 2024).

[4] *M18 FUELTM STRING TRIMMER ATTACHMENT W/ QUIK-LOKTM ACCESSOIRE DE TAILLE-BORDURES M18 FUELTM AVEC QUIK-LOKTM ACCESORIO DE LA BORDEADORA DE HILO M18 FUELTMCON QUIK-LOKTM OPERATOR’S MANUAL MANUEL de L’UTILISATEUR MANUAL del OPERADOR.,* Milwaukee Electric Tools.

[5] K. Koehler, "Pro tool Reviews," 16 March 2017. [Online]. Available: https://www.protoolreviews.com/milwaukee-m18-fuel-string-trimmer-review/. [Accessed 10 October 2024].

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[9] “CISPR 14-1:2020,” International Electro Technical Commission, https://webstore.iec.ch/en/publication/60734/ (accessed Dec. 3, 2024).

[10] “IEEE IEEE C37.18-1979,” IEEE Standards Association, https://standards.ieee.org/ieee/113/277/ (accessed Dec. 3, 2024).

[11] “IEEE 113-1985,” IEEE Standards Association, https://standards.ieee.org/ieee/113/277/ (accessed Dec. 3, 2024).

[12] “IEEE SA P2962,” IEEE Standards Association, https://standards.ieee.org/ieee/2962/10402/ (accessed Dec. 3, 2024).

[13] “IEEE 802.11-2012,” IEEE Standards Association, https://standards.ieee.org/ieee/802.11/4523/ (accessed Dec. 3, 2024).

Appendix B: Subsystem Integration Block Diagram (CB)

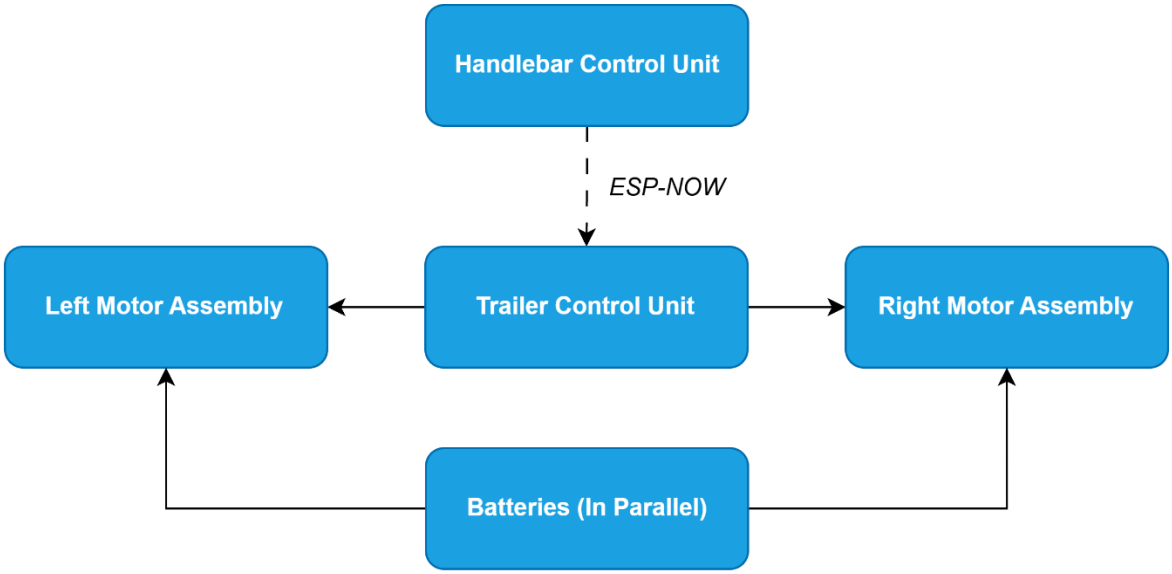
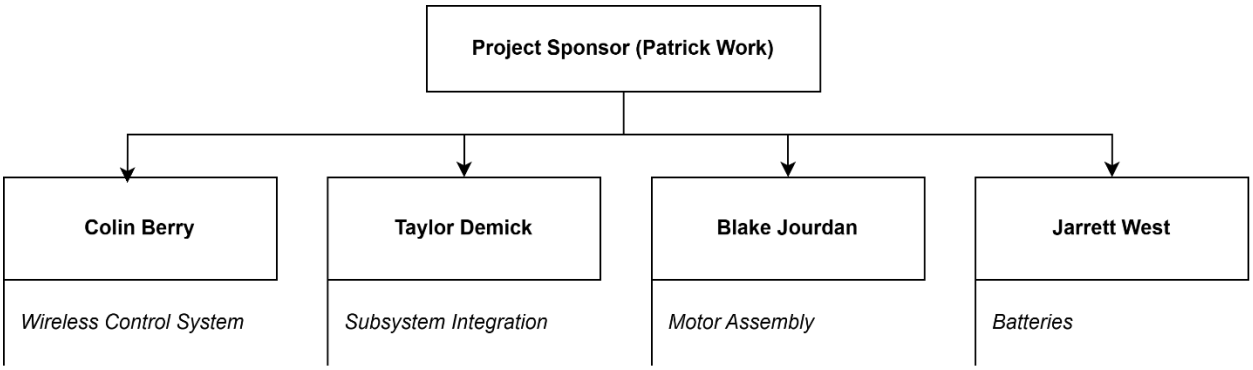


***Figure 2.1**: Subsystem Integration Block Diagram*

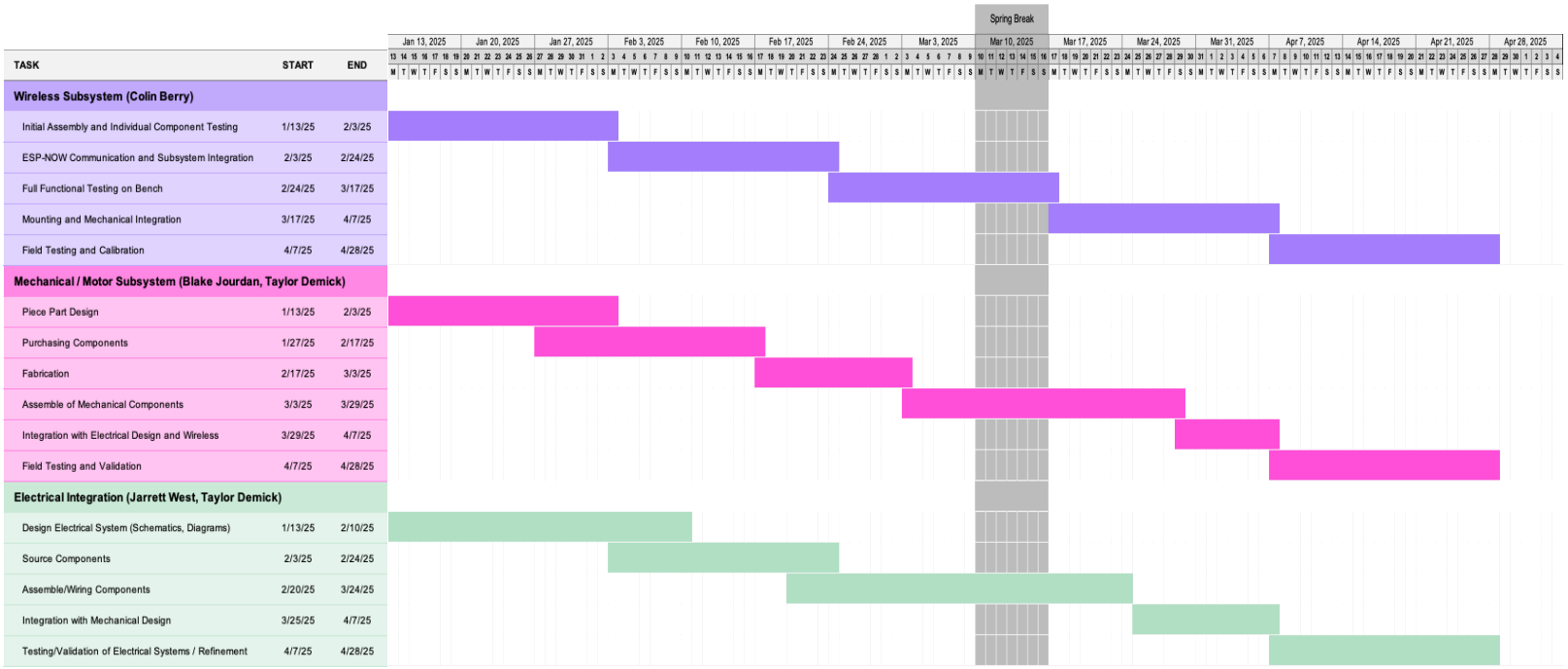
Appendix C: House of Quality (All)

1 to 5 Customer Priority	% Importance		Target or direction		↑	⇓	=	⇓	↑	↑	↑	↑	=	↑					
			Technical requirements		1 Battery Capacity	2 Weight	3 Head Circumference	4 Head Height from Ground	5 Operating Time	6 Number of Storage Batteries	7 Maximum Head Angle	8 Blade/head/wire Material	9 Material used in IP Rated	10 Electric Motor	Customer Assessment / Competitive Evaluation (1-5 scale with 5=best, 1=worst at meeting customer requirements)	SECTEAM # WW-202420	Competitor 1: DR Pro XLT Tow-Behind Trimmer (Gas powered)	Barrier Mower RI 60	RasterMaster
			Customer Requirements																
5	11.9	1	Wireless Control		1									9		5	1	1	1
5	11.9	2	Transferrable Wireless Device		3	3			1				9			5	1	1	1
5	11.9	3	Single Wheel Bicycle Mounted Trailer			9	3	6		9	6		6			5	1	1	1
3	7.14	4	Breaks Away if Caught			1	9	9			6	3	6			4	4	4	4
5	11.9	5	Milwaukee Battery Powered		9				9					9		5	1	1	1
4	9.52	6	Adjustable Suspension (for trailer)			1		9		6	6		3			4	3	1	1
4	9.52	7	Adjustable Head Width			9	6	3		1	3		3	3		3	3	4	4
4	9.52	8	Adjustable Head Height			9	6	9		3	6		3	3		4	1	3	3
4	9.52	9	Adjustable Head Angle			9	6	6		3	9		3	3		4	1	1	1
3	7.14	10	Battery Storage		1	9			1	9	1		6	9		5	1	1	1
42																			
			Importance Rating ∑(priority×relationship)		162	481	271	393	126	295	350	21	378	364					
			Technical Assessment																

Appendix D: Organizational Chart (CB)



Appendix E: Timeline (All)



TASK	START	END
Wireless Subsystem (Colin Berry)		
Initial Assembly and Individual Component Testing	1/13/25	2/3/25
ESP-NOW Communication and Subsystem Integration	2/3/25	2/24/25
Full Functional Testing on Bench	2/24/25	3/17/25
Mounting and Mechanical Integration	3/17/25	4/7/25
Field Testing and Calibration	4/7/25	4/28/25
Mechanical / Motor Subsystem (Blake Jourdan, Taylor Demick)		
Piece Part Design	1/13/25	2/3/25
Purchasing Components	1/27/25	2/17/25
Fabrication	2/17/25	3/3/25
Assemble of Mechanical Components	3/3/25	3/29/25
Integration with Electrical Design and Wireless	3/29/25	4/7/25
Field Testing and Validation	4/7/25	4/28/25
Electrical Integration (Jarrett West, Taylor Demick)		
Design Electrical System (Schematics, Diagrams)	1/13/25	2/10/25
Source Components	2/3/25	2/24/25
Assemble/Wiring Components	2/20/25	3/24/25
Integration with Mechanical Design	3/25/25	4/7/25
Testing/Validation of Electrical Systems / Refinement	4/7/25	4/28/25

Appendix F: Budget and Expenses (CB)

Proposed Budget:

Mechanical Fabrication:	
Burley Coho XC Trailer (DONATED FROM BURLEY)	
Various Hardware	$100
2x Sheet Metal (4'x4' .125')	$219.84
Angle Aluminum (3/4"x3/4" 2')	$7.20
5052-H32 Aluminum Sheet (4'x4' .125')	$220.48
Bearing (1/8 Thick Bearings)	$14.99
Burley Nutted Axle (3/8 x 26)	$25.99
4x 3" Caster Wheels	$26.16
2x Weed Shark Pro 16-inch Heads	$79.98
ECHO .105" Black Diamond Trimmer Line	$25.97
	$720.61
Wireless Subsystem:	
M5StickC PLUS	$22.90
Bike Computer Mount	$8.79
Bike Computer Mount Male Bracket	$4.91
ESP-WROOM-32	$9.00
Talentcell Rechargeable Battery Pack	$33.79
DRV8825 Stepper Motor Drivers	$14.49
2x NEMA 17 Stepper Motor	$27.99
Stepper Motor Mounting Brackets	$9.00
2x Female DC Jack Adapter	$4.90
Breadboard	$8.99
DC Jack Splitter Cable (3M-to-1F)	$7.99
Junction/Outdoor Box	$19.49
Adhesive Tape	$9.98
Electrical Tape	$2.78
Breadboard Jumper Wires	$9.99
Zip Ties	$3.99
	$198.98
Electrical Integration:	
2x Milwaukee M18 String Trimmers	
4x Lithium-Ion Milwaukee M18 HD Batteries	$398.00
Various Connectors/Wires	$996.00
Wire Loom Tubing (30FT, 1/2in)	$50.00
3D Printing Filament (1.75mm)	$12.99
	$24.99
	$1,481.98
Overall Total (30% Shipping + Tax)	**$3,122.04**

Actualized Expenses:

Wing and Motor Subsystem	
Burley Coho XC Trailer (DONATED FROM BURLEY)	
Scrap Metal (PROVIDED BY SCHOOL)	
M18 String Trimmer	$200.00
5-inch Caster Wheels	$17.54
String Head	$30.00
String	$30.00
Wire Loom	$13.14
Various Hardware	$26.67
Springs	$11.50
Eyebolts	$12.32
Carabiner	$2.26
Paint	$13.54
	$356.97
Wireless Control Subsystem:	
ESP32 Development Board	$11.50
Breadboard	$6.99
Stepper Motor Bracket	$9.99
NEMA 17 Stepper Motor (2x)	$27.98
DRV8825 Stepper Motor Drivers	$14.49
Talentcell Rechargeable Battery Pack	$32.99
PLA 3D Printing Filament	$24.99
Jumper Cables	$9.99
DC Jack Splitter Cable (3M-to-1F)	$7.99
Junction Box	$19.49
M5StickC Plus	$31.00
M5StickC Battery Bank	$16.55
Buckle Latch	$7.67
Rubber Grommets	$4.54
Furniture Sliders	$6.16
Command Hooks	$10.95
Various Hardware	$23.00
	$266.27
Battery Subsystem:	
M18 Batteries	$300.00
Disconnects	$10.01
Copper Wire	$19.21
	$329.22
Total:	**$952.46**

Appendix G: Design Work (All)

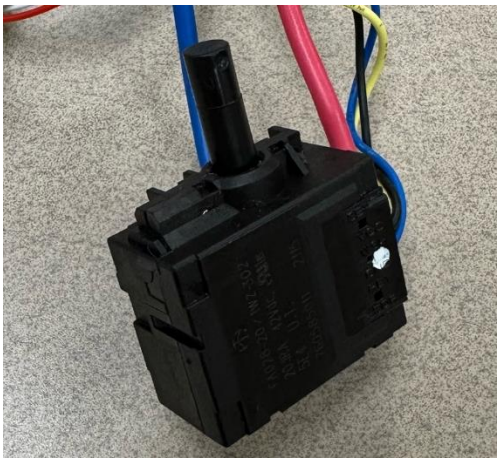


Figure 7.1: *Milwaukee Motor Actuator Switch*

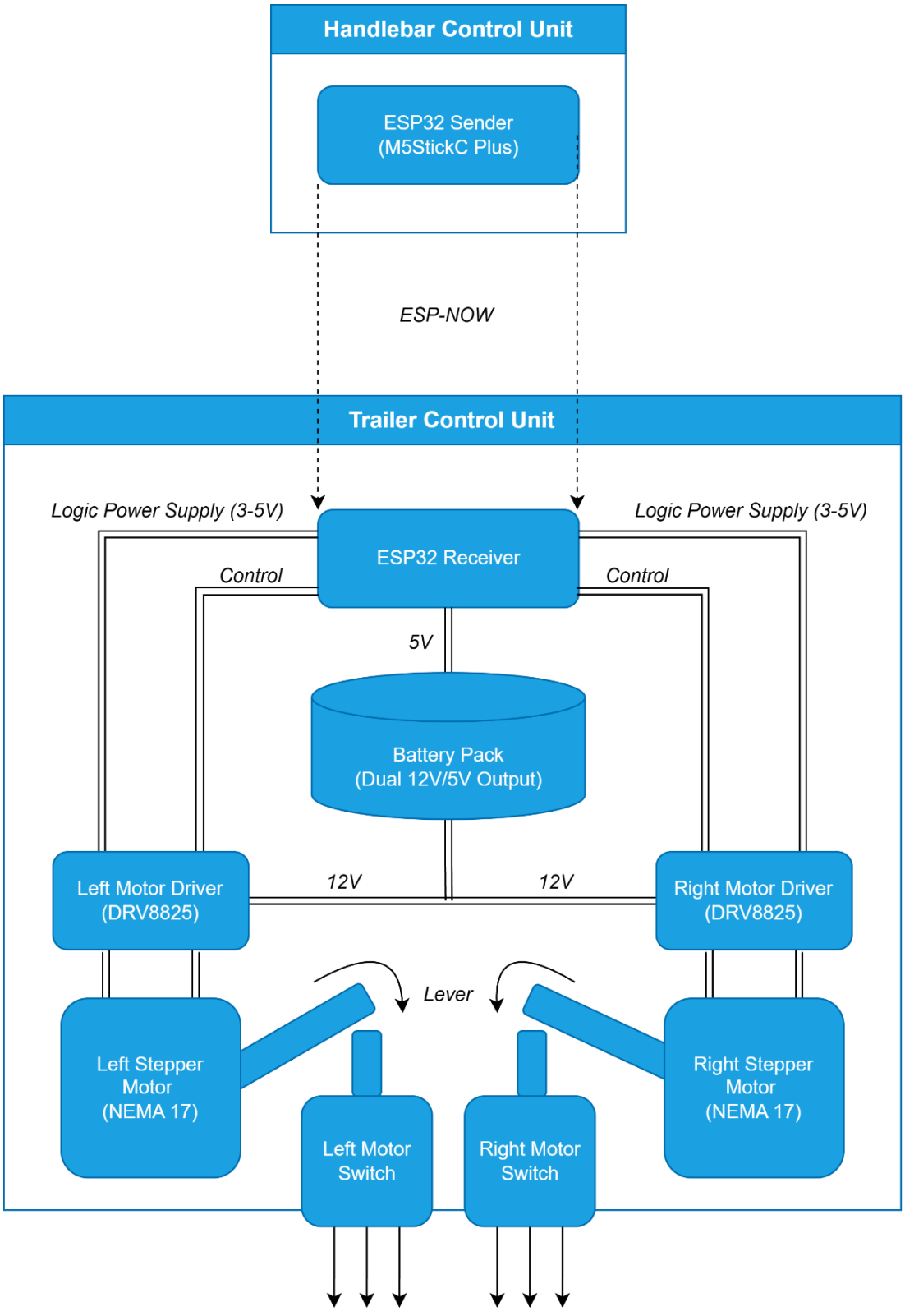


Figure 7.2: *Wireless Control Subsystem Block Diagram*

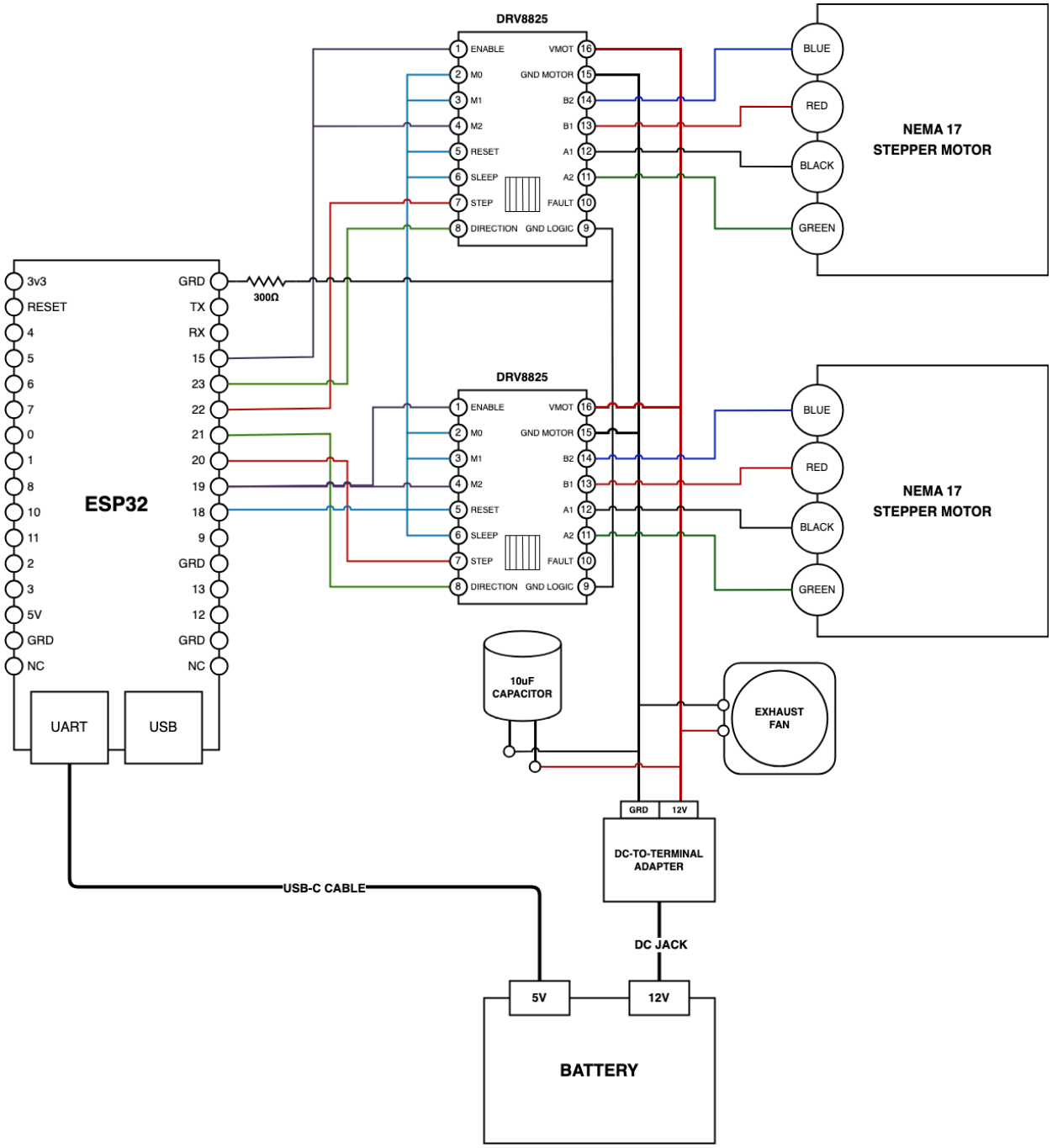


Figure 7.3: *TCU Wiring Schematic*

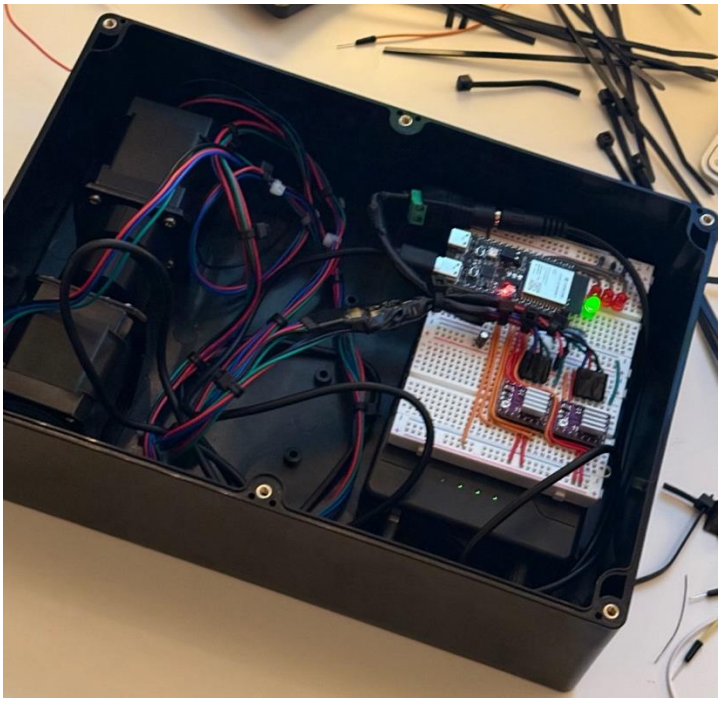


Figure 7.4: *TCU Early Development Stage*

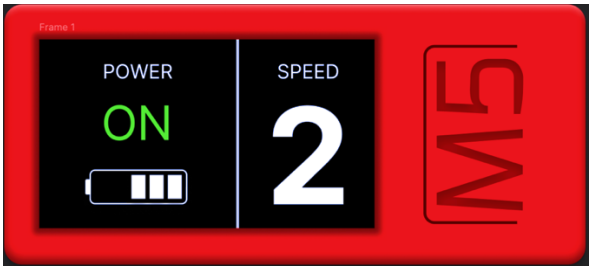


Figure 7.5: *HCU User Interface Design Concept*

Figure 7.6: *HCU User Interface Implementation*

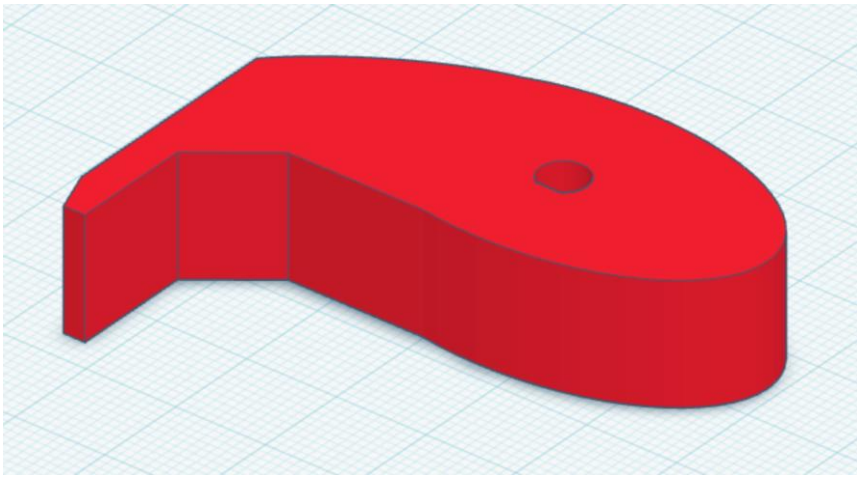


Figure 7.7: *Finalized Cam Design for Stepper Motors*

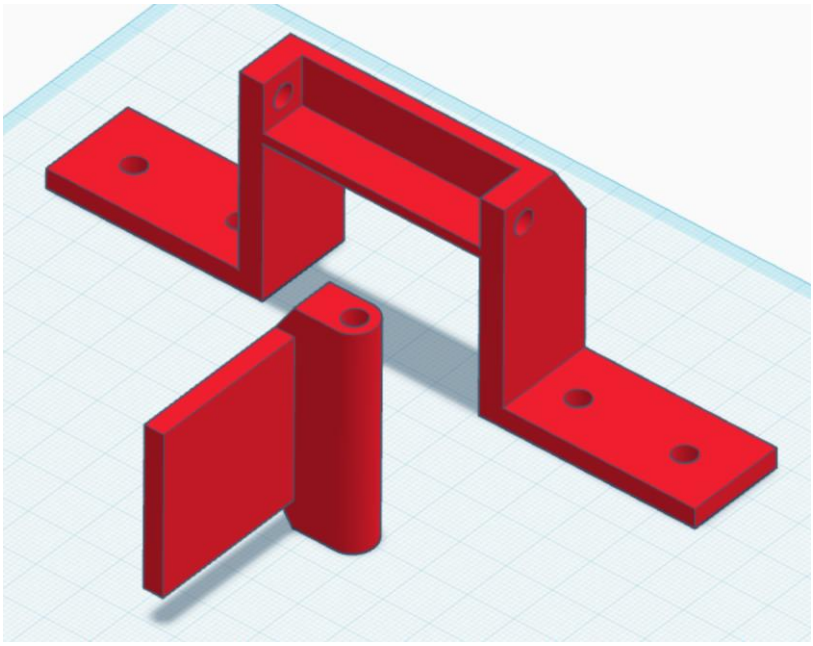


Figure 7.8: *Lever Design for M18 Motor Switch Activation*

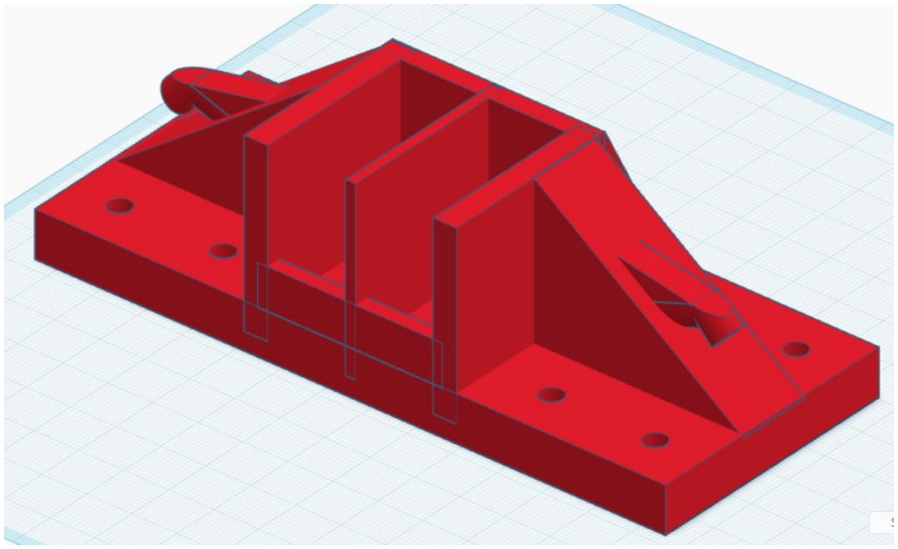


Figure 7.9: *Actuator Shelf Design for M18 Motor Switches*

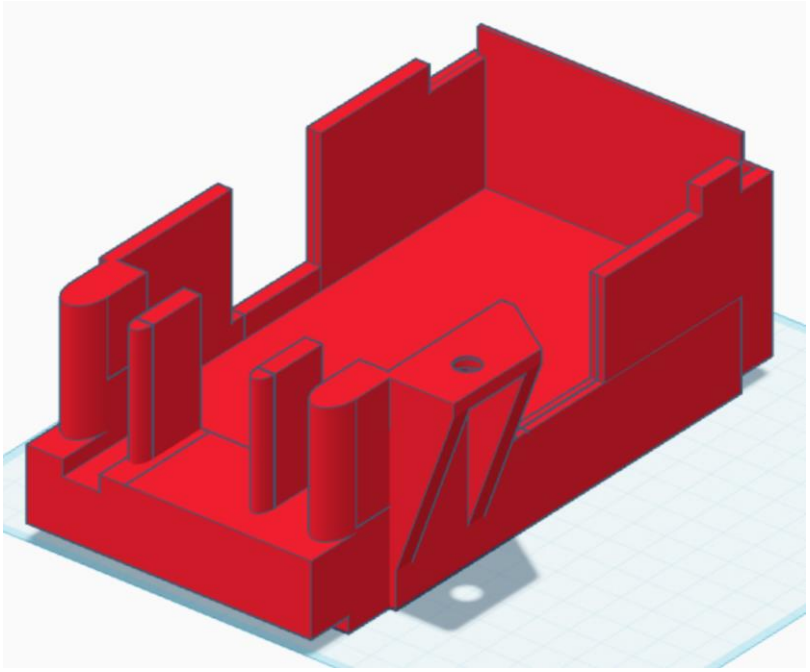


Figure 7.10: *Battery Shelf Design*

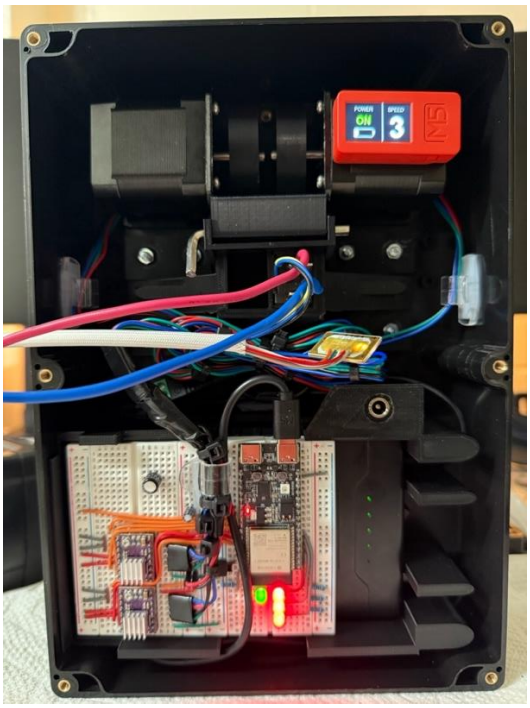


Figure 7.11: *TCU Late Development Stage*

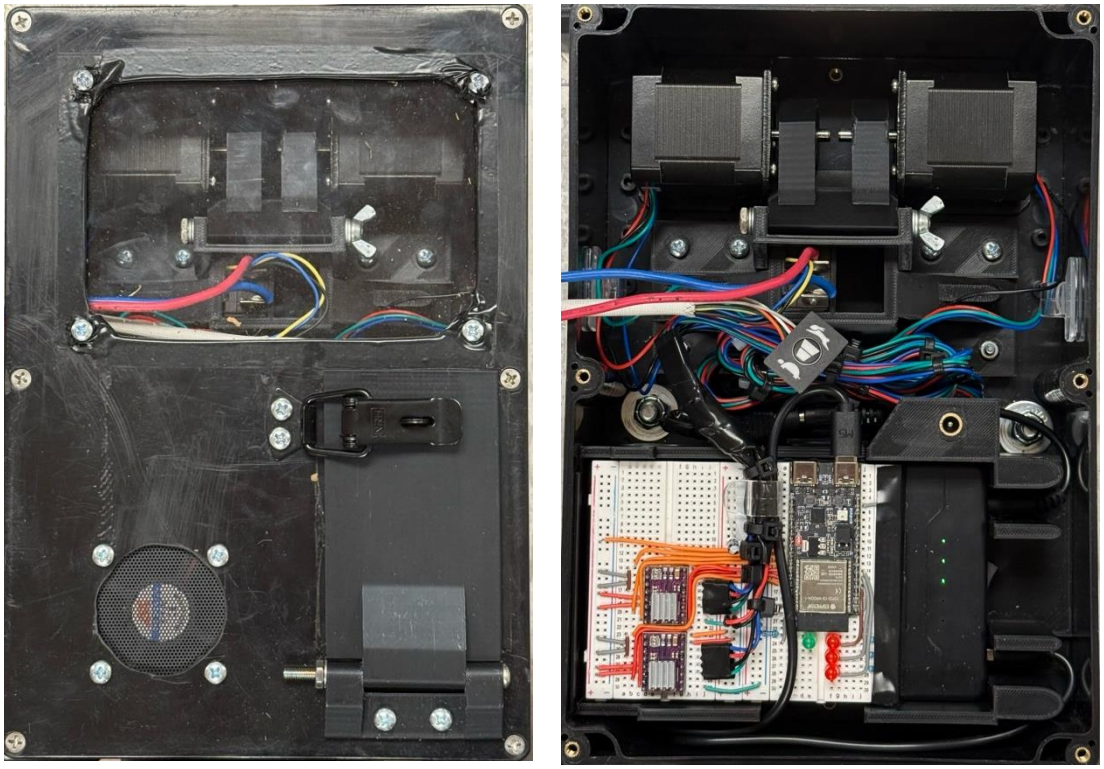


Figure 7.12: *TCU Final Design*

Figure 7.13: *HCU Final Design*

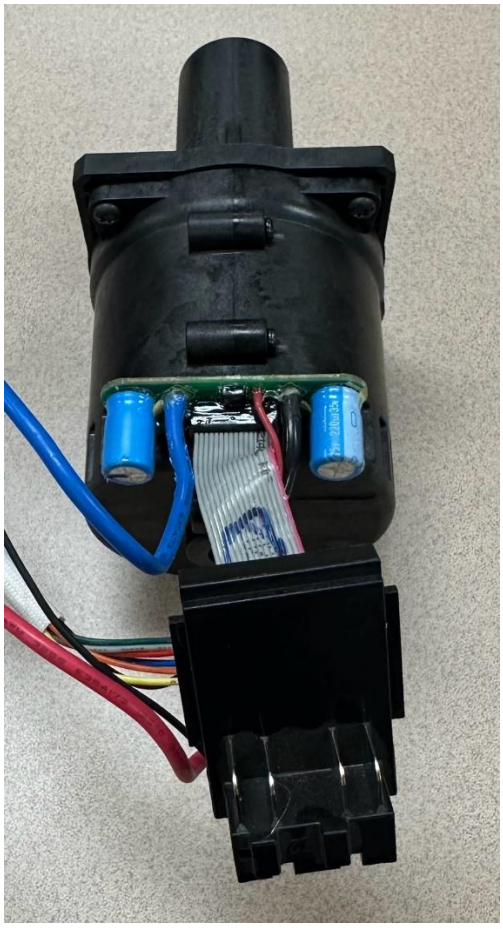


Figure 7.14: *Milwaukee Electric Motor and Battery Terminal*

Figure 7.15: *Cardboard Mechanical Design on Burley Trailer*

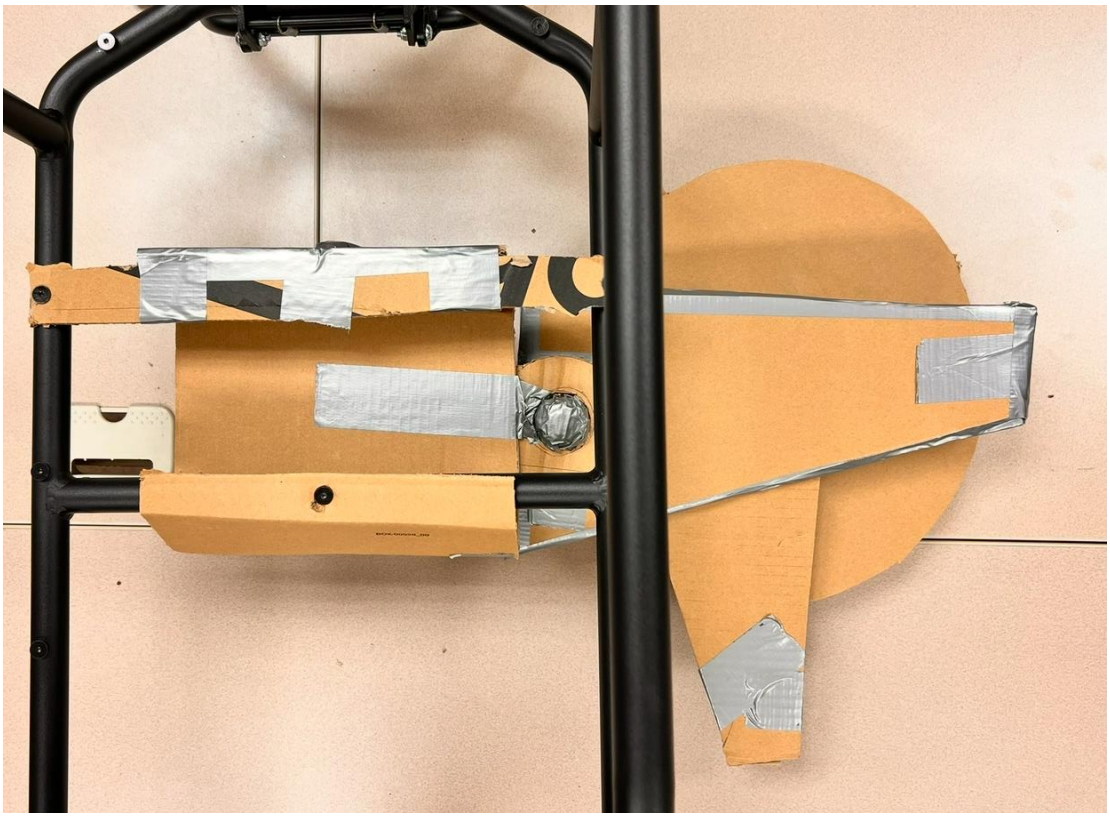


Figure 7.16: *Cardboard Mechanical Design on Burley Trailer (Above)*

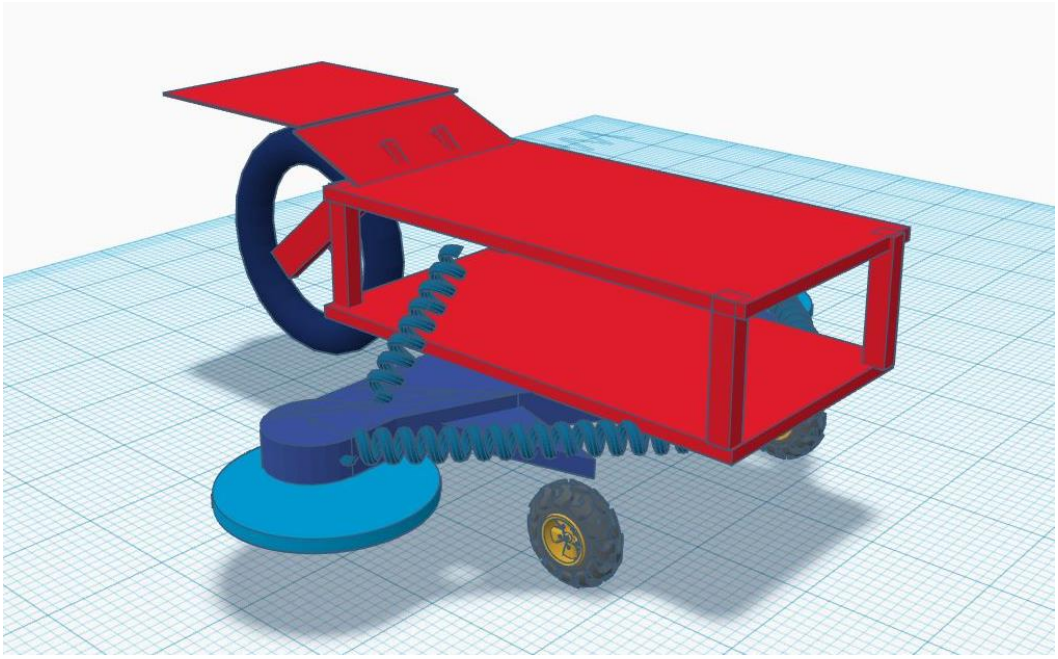


Figure 7.17: *Early CAD Drawing of Mechanical Design using TinkerCAD*

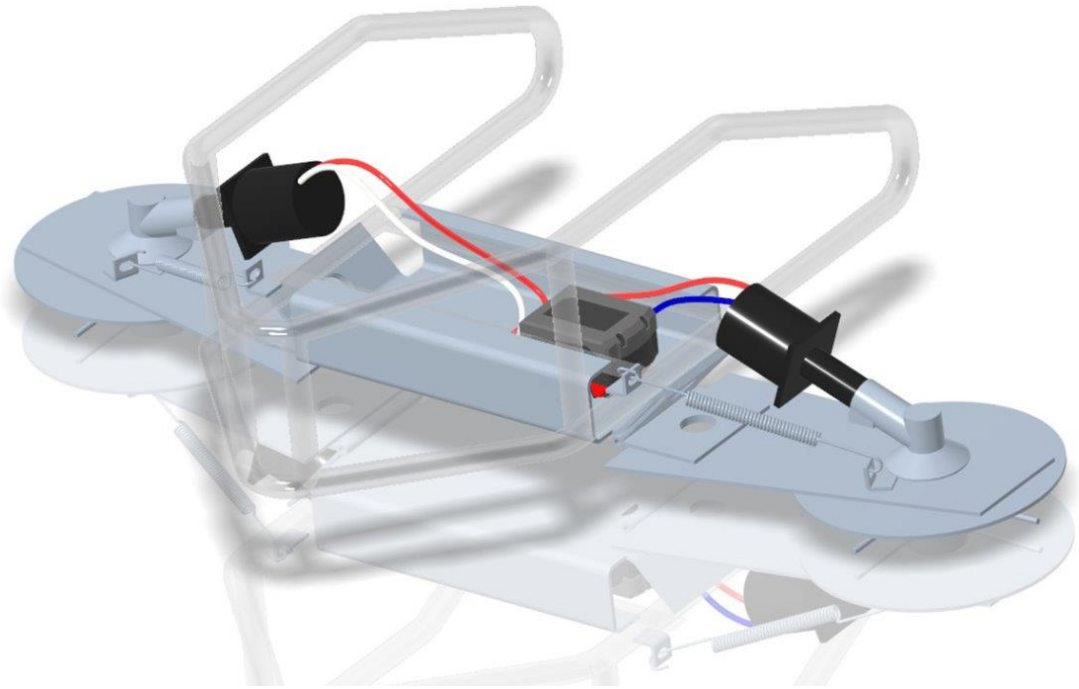


Figure 7.18: *Preliminary Mechanical Design CAD Drawing (Isometric)*

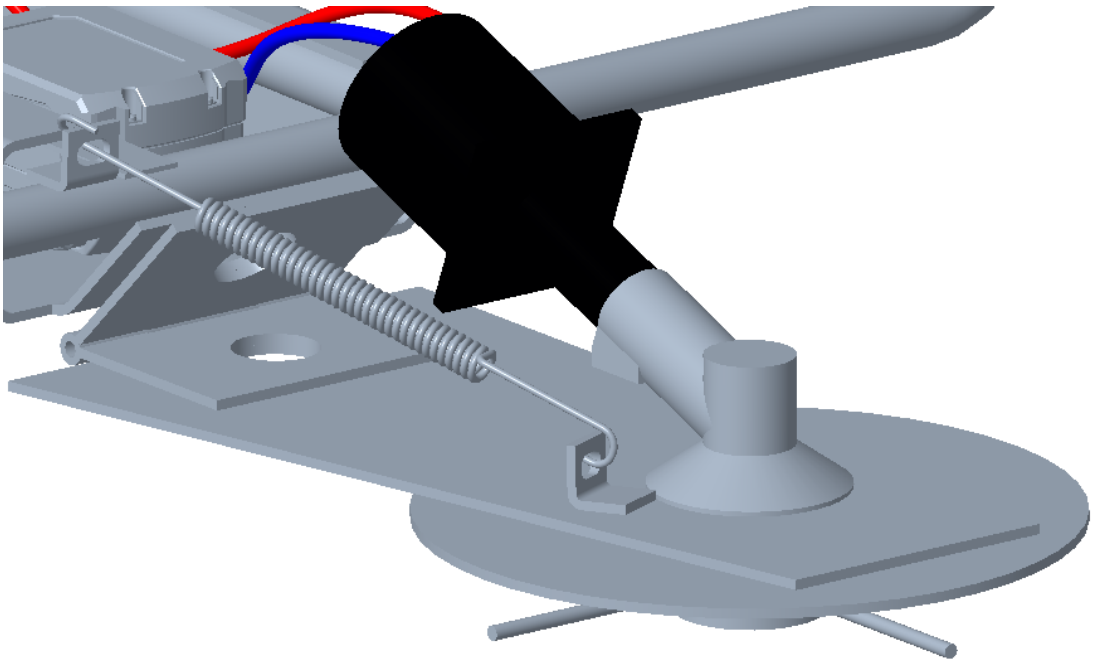


Figure 7.19: *Preliminary Mechanical Design CAD Drawing (Isometric, Zoomed)*

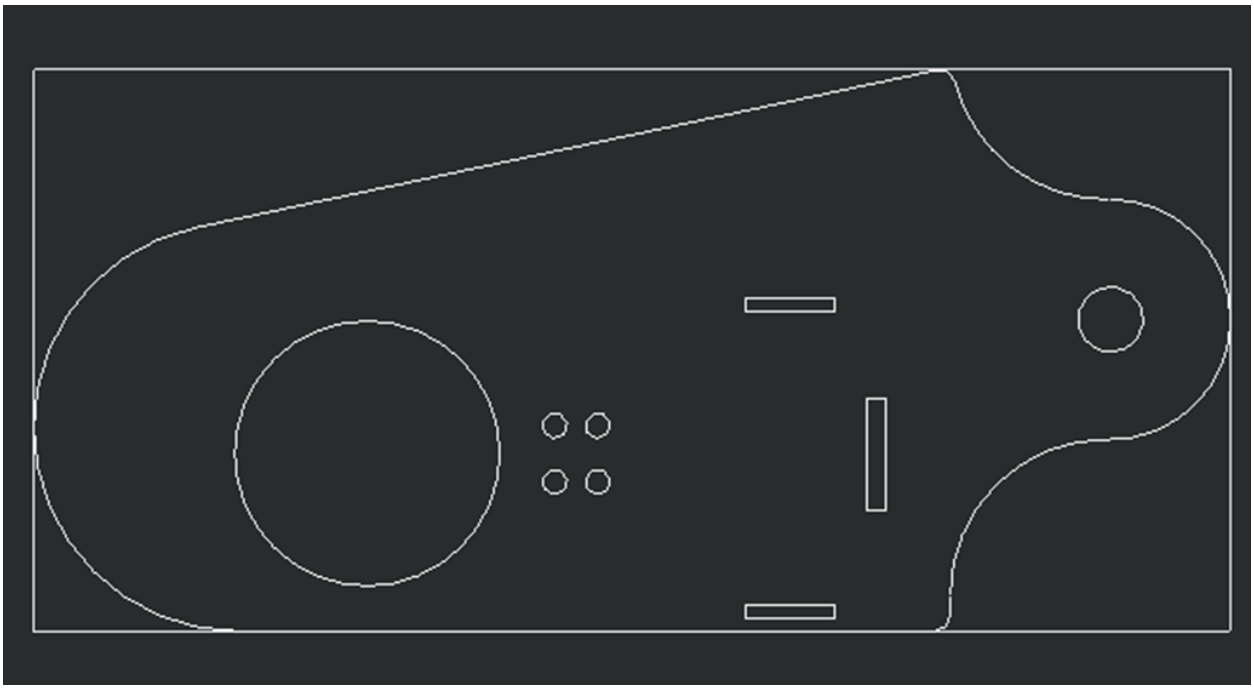


Figure 7.20: *Finalized DXF File of Wing*

Figure 7.21: *Finalized DXF of Hinge*

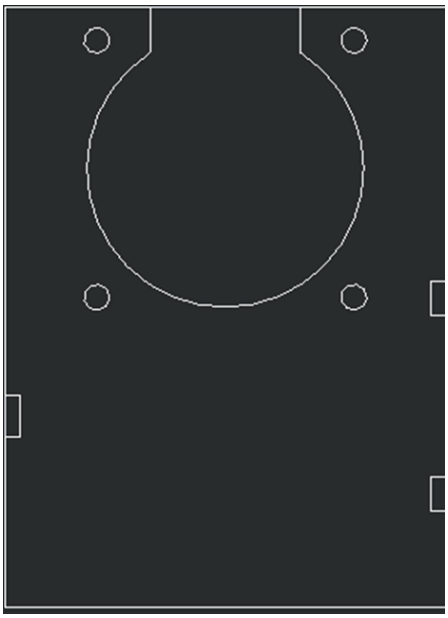


Figure 7.22: *Finalized DXF of Motor Mount Plate*

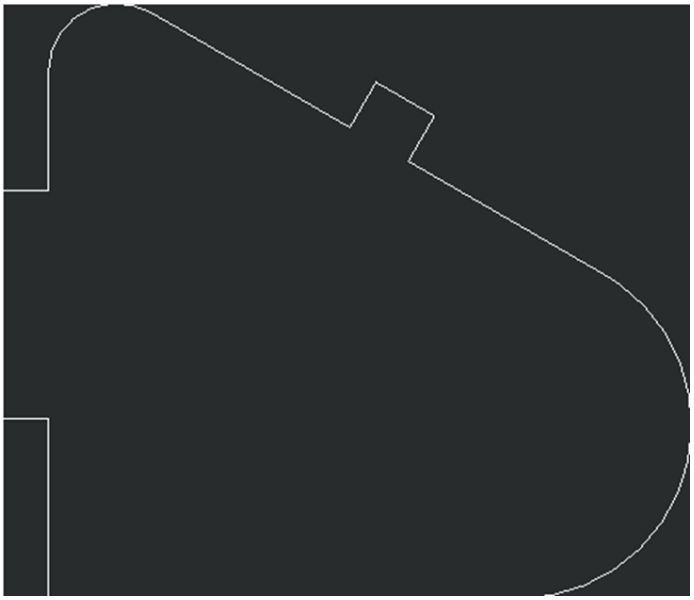


Figure 7.23: *Finalized DXF of Gusset 1*

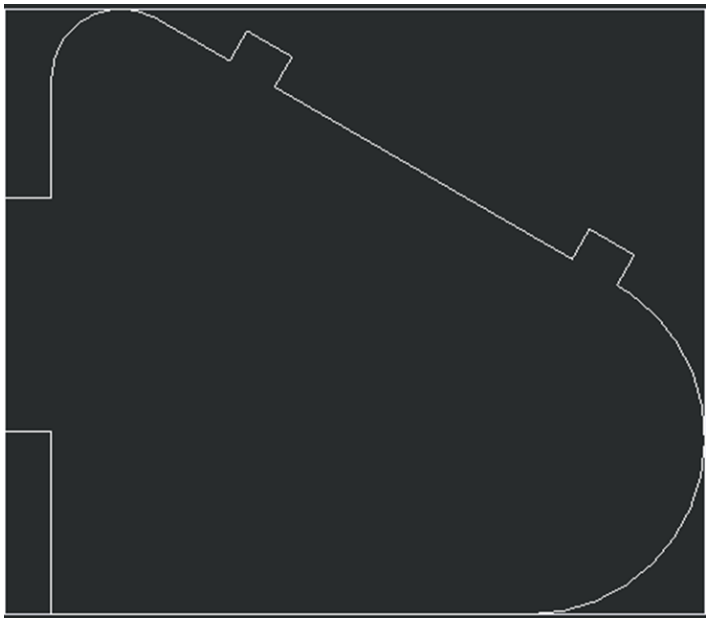


Figure 7.24: *Finalized DXF of Gusset 2*

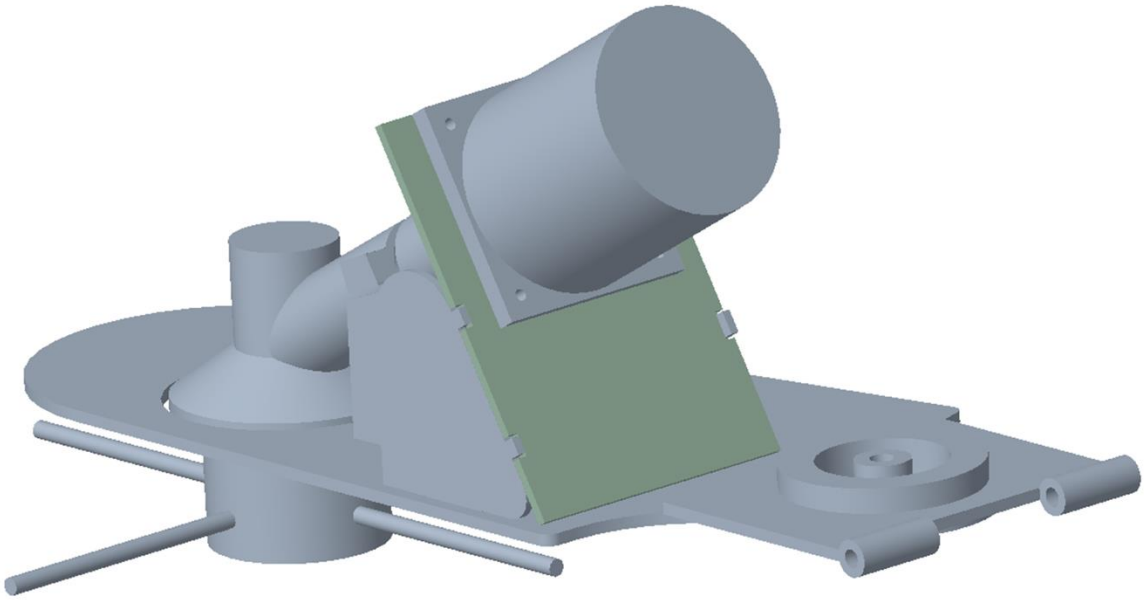


Figure 7.25: *Finalized Wing Assembly CAD Drawing (Isometric, Zoomed)*

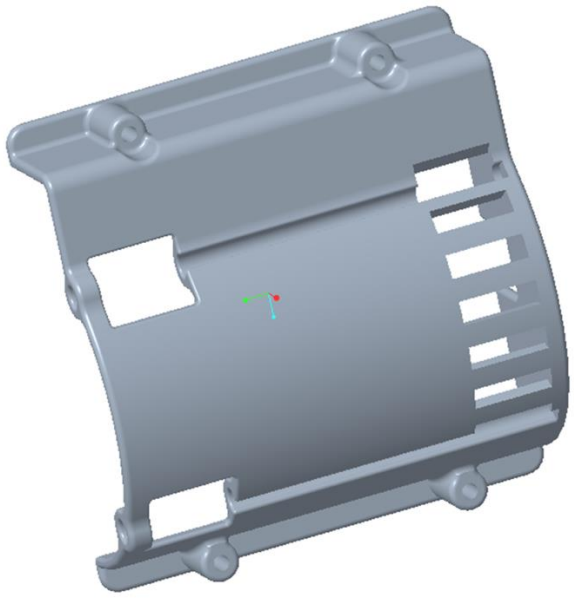


Figure 7.26: *Motor Housing CAD Drawing (Isometric, Zoomed)*

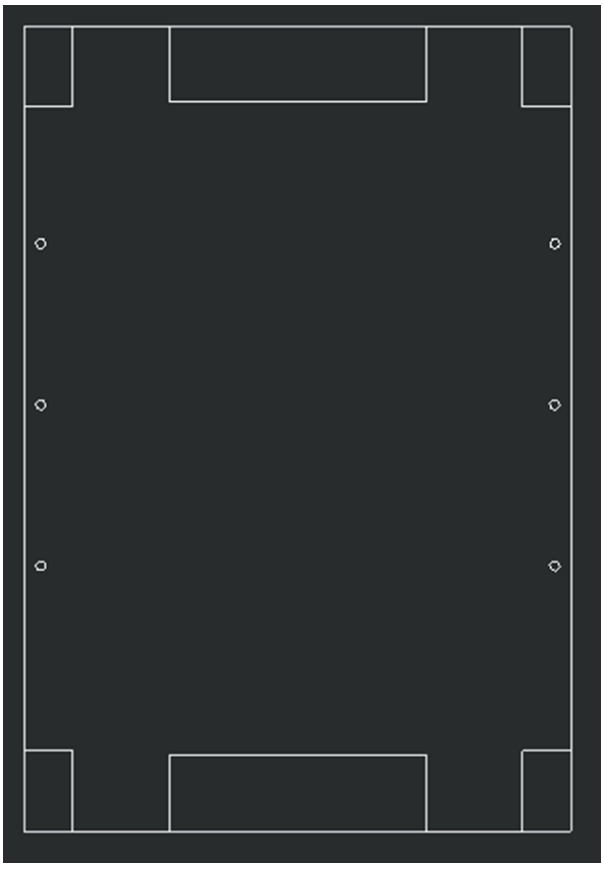


Figure 7.27: *Finalized DXF of Aluminum Plate*

Figure 7.28: *Finalized DXF of Caster Wheel Plate*

Figure 7.29: *Welded Wing Assembly and Hinges*

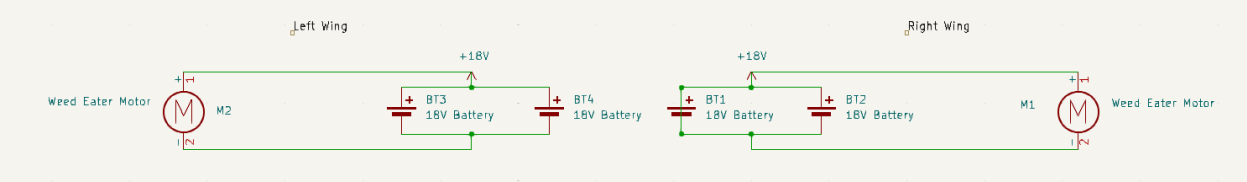


Figure 7.30: *Battery-Motor Electrical Schematic*

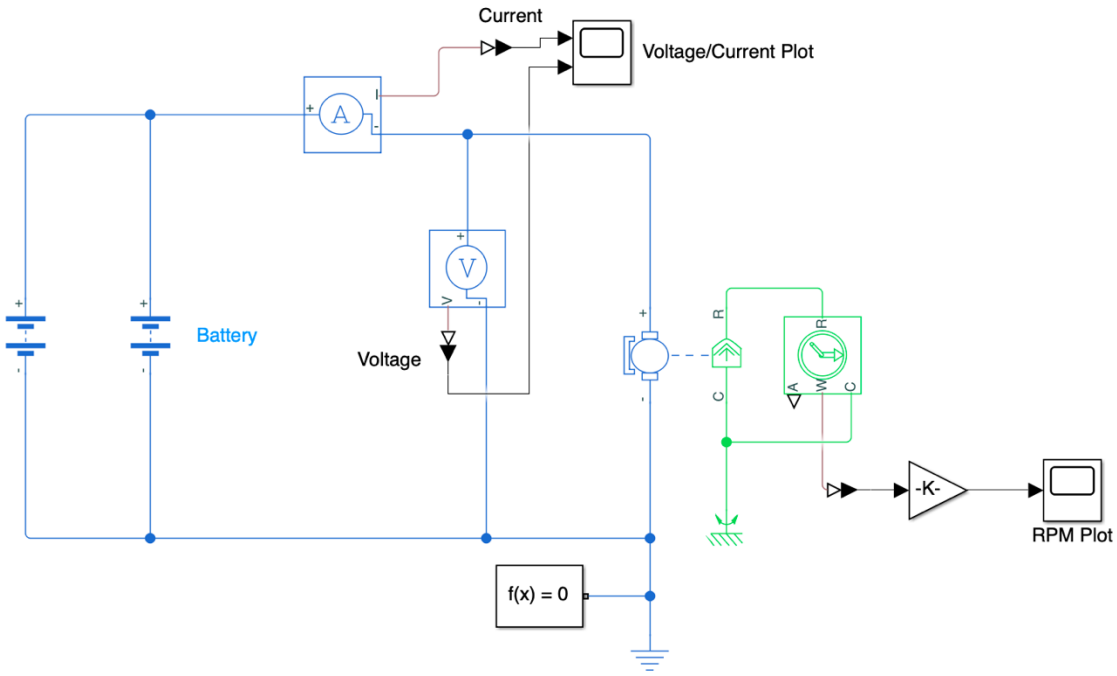


Figure 7.31: *MATLAB Simulink Schematic*

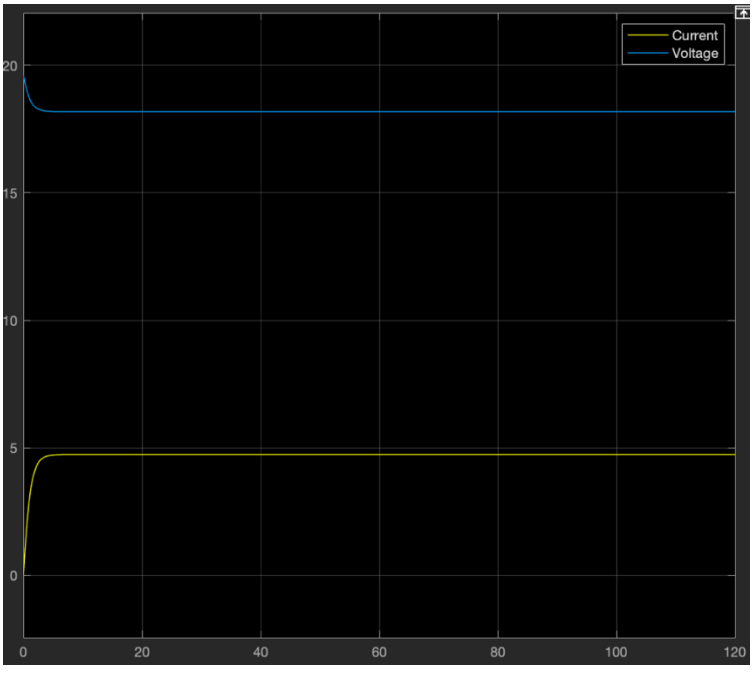


Figure 7.32: *MATLAB Simulation, Voltage and Current Profiles*

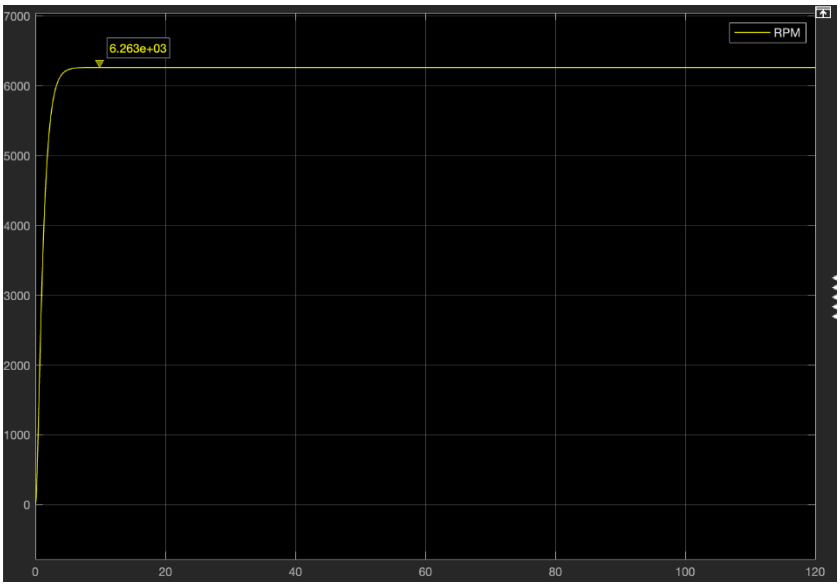


Figure 7.33: *MATLAB Simulation, RPM Profile*

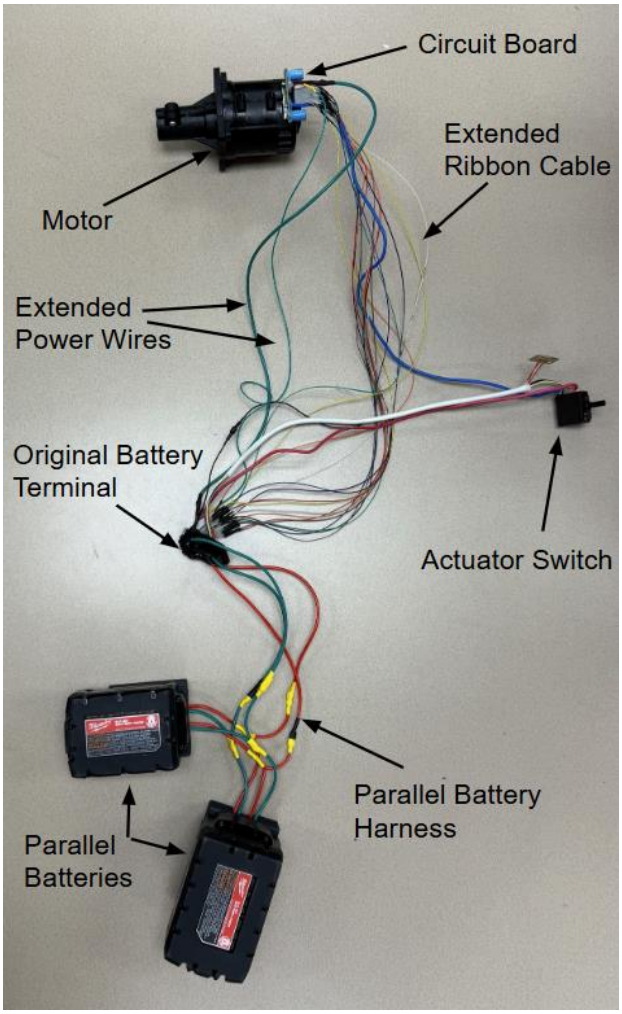


Figure 7.34: *Battery Subsystem Wiring Overview*

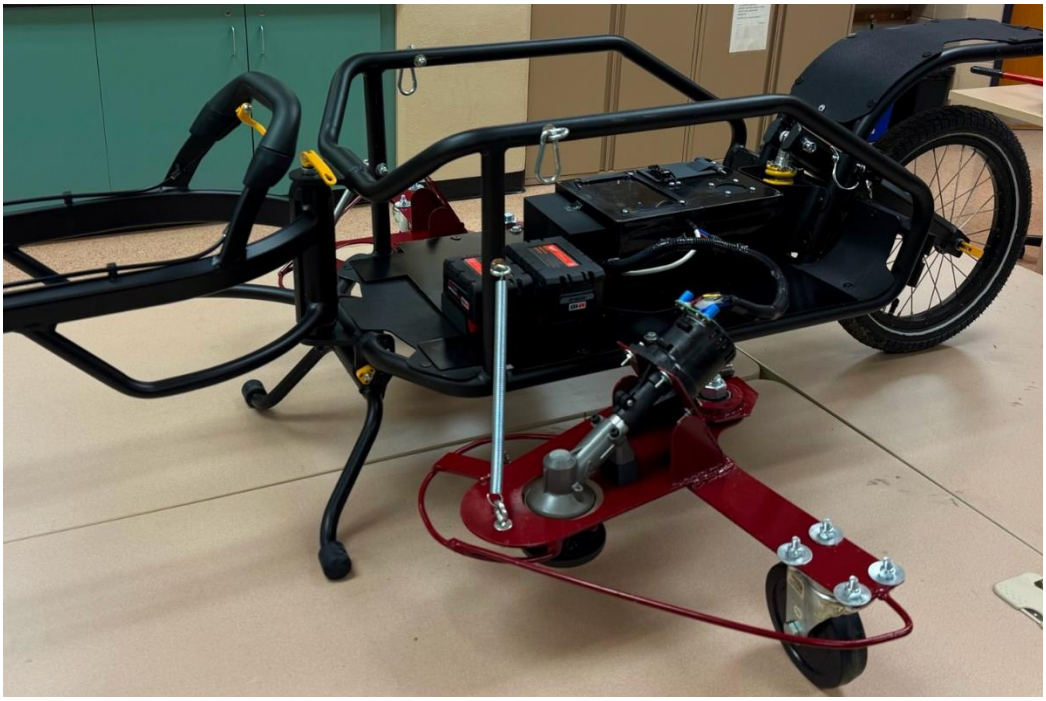


Figure 7.35: *Finalized Subsystem Integration, Side View*

Figure 7.36: *Finalized Subsystem Integration, Top View*

Appendix H: Engineering Standard Excerpts (BJ)

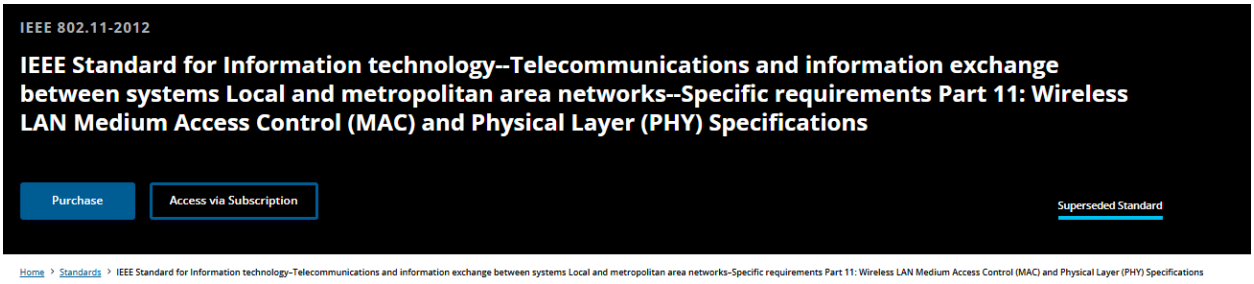


Figure 8.1: *IEEE 802.11 Excerpt*

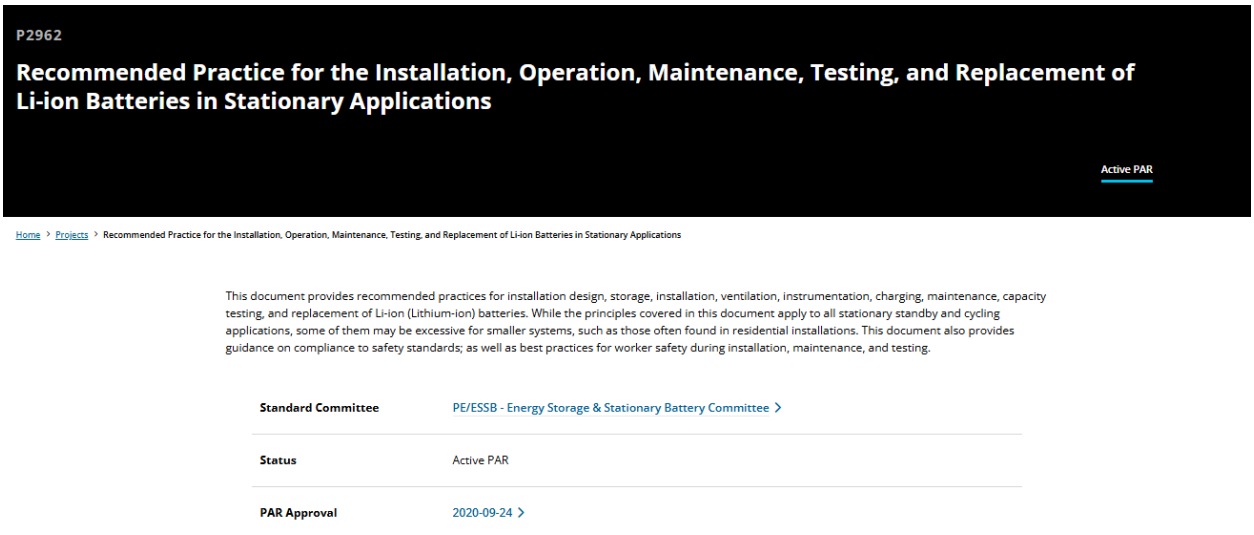


Figure 8.2: *IEEE SA P2962 Excerpt*

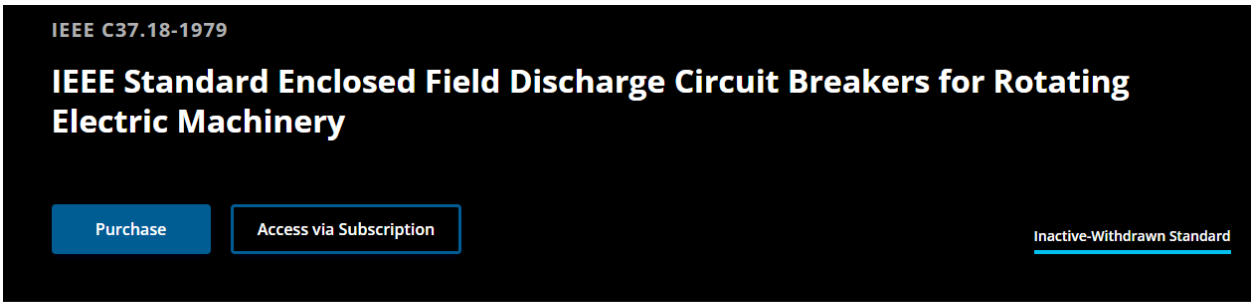


Figure 8.3: *IEEE SA C37.18-1979 Excerpt*

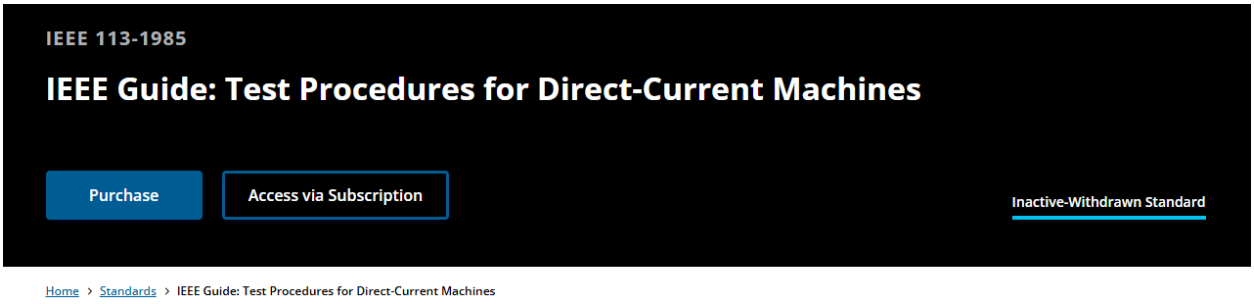


Figure 8.4: *IEEE 113-1985 Excerpt*

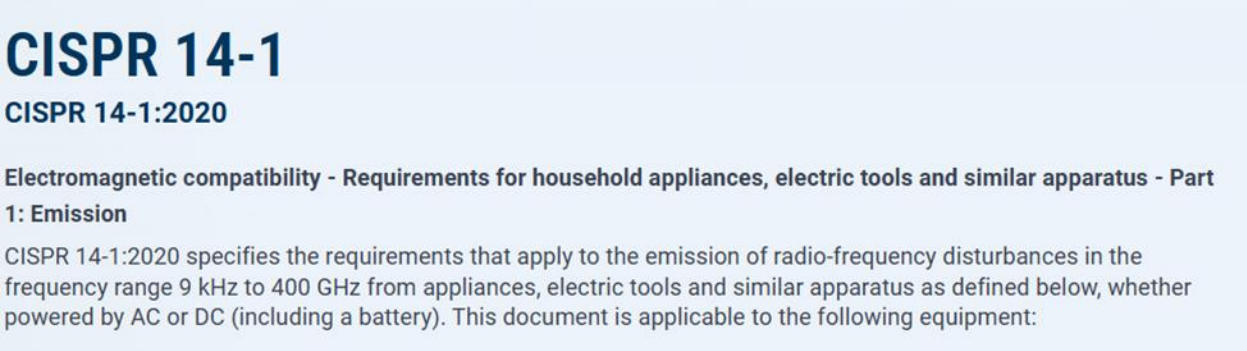


Figure 8.5: *CISPR 14-1:2020 Excerpt*

Appendix I: Applied Codes and Regulations (All)

Figure 9.1: *M5StickC Plus Codes and Regulations*

RoHS 2011/65/EU amended by 2015/863 Compliant

According to the manufacturer, this product is RoHS Compliant with RoHS Directive 2011/65/EU and as amended by Directive 2015/863, and without material exemptions.

Please see the Environmental Documents section of this product for any Manufacturer information on RoHS.

The RoHS Compliance of any product so designated is based upon evidence from the producer (manufacturer) that the part number complies with the RoHS Directive. Mouser Electronics has taken all reasonable steps to confirm producers' statements and other evidence regarding the absence of the restricted substances to support the manufacturers' claim of compliance.

To the best of our knowledge, the below referenced product is RoHS compliant per the producer's documentation.

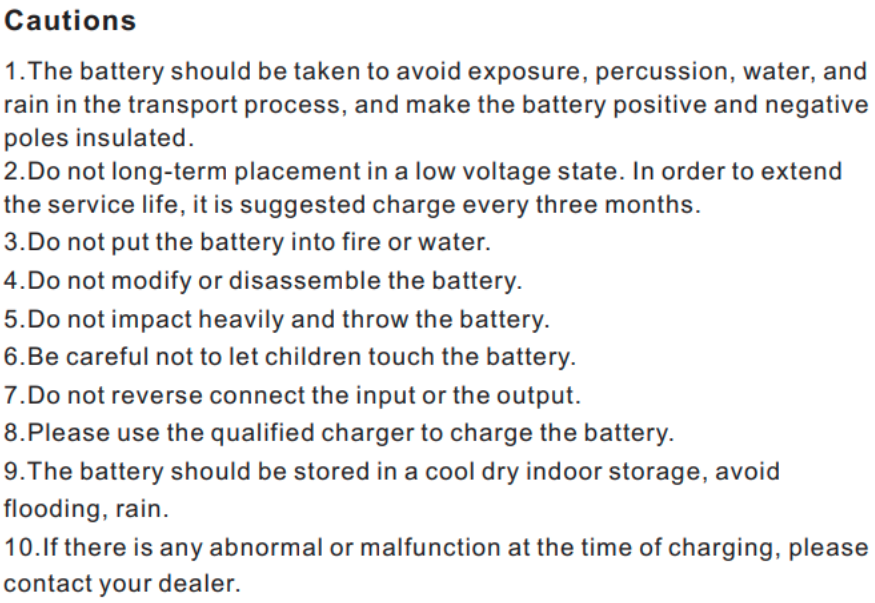
Date:	12/3/2024
Mouser Part #:	356-ESP32C6DKC1N8
Mfr.'s Part #:	ESP32-C6-DevKitC-1-N8
Mfr.:	Espressif Systems
Description:	Multiprotocol Development Tools ESP32-C6 general-purpose development board, based on ESP32-C6-WROOM-1. It has all the ESP32-C6 pins exposed and is easy to connect and use. Most of the I/O pins are broken out to the pin headers on both sides for easy interfacing. Developers can eith

Figure 9.2: *TCU ESP32 Codes and Regulations*

Figure 9.3: *TallentCell Battery Pack Codes and Regulations*

Figure 9.4: *Stepper Motor Codes and Regulations*

Appendix J: Safety Plan (All)



Cautions

1.The battery should be taken to avoid exposure, percussion, water, and rain in the transport process, and make the battery positive and negative poles insulated.
2.Do not long-term placement in a low voltage state. In order to extend the service life, it is suggested charge every three months.
3.Do not put the battery into fire or water.
4.Do not modify or disassemble the battery.
5.Do not impact heavily and throw the battery.
6.Be careful not to let children touch the battery.
7.Do not reverse connect the input or the output.
8.Please use the qualified charger to charge the battery.
9.The battery should be stored in a cool dry indoor storage, avoid flooding, rain.
10.If there is any abnormal or malfunction at the time of charging, please contact your dealer.

Figure 10.1: *TallentCell Battery Pack Safety*

IMPORTANT SAFETY INSTRUCTIONS

⚠WARNING Read all safety warnings, instructions, illustrations and specifications provided with this power tool. Failure to follow all instructions listed below may result in electric shock, fire and/or serious injury. **Save all warnings and instructions for future reference.**

READ ALL INSTRUCTIONS BEFORE USE

WORK AREA SAFETY

- **Keep work area clean and well lit.** Cluttered or dark areas invite accidents.
- **Do not operate power tools in explosive atmospheres, such as in the presence of flammable liquids, gases or dust.** Power tools create sparks which may ignite the dust or fumes.
- **Keep children and bystanders away while operating a power tool.** Distractions can cause you to lose control.
- **Do not allow to be used as a toy. Close attention is necessary when used by or near children. Store idle power tools out of the reach of children and do not allow persons unfamiliar with the power tool or these instructions to operate the power tool.** Power tools are dangerous in the hands of untrained users.
- **Do not use the tool near anything that is burning or smoking** such as cigarettes, matches, or hot ashes.
- **To reduce the risk of health hazards from vapors or dust, do not use tool near tool toxic, carcinogenic or other hazardous materials** such as asbestos, arsenic, barium, beryllium, lead, pesticides or other health endangering materials.

ELECTRICAL SAFETY

- **Do not expose power tools to rain or wet conditions. Do not immerse in water or spray with a hose. Do not clean with a pressure washer.** Water entering a power tool will increase the risk of electric shock. Store tool indoors.

PERSONAL SAFETY

- **Stay alert, watch what you are doing and use common sense when operating a power tool. Do not use a power tool while you are tired or under the influence of drugs, alcohol or medication.** A moment of inattention while operating power tools may result in serious personal injury.
- **Always wear eye protection. Use of this tool can result in foreign objects being thrown into eyes,** which can result in eye damage.
- **Wear a face or dust mask** when working in dust situations. Dust particles can harm your lungs.
- **Use personal protective equipment.** Protective equipment such as hearing protection, protective clothing, and non-skid safety shoes used for appropriate conditions will reduce personal injuries.
- **Dress properly. Do not wear loose clothing or jewelry. Keep your hair and clothing away from moving parts.** Loose clothes, jewelry or long hair can be caught in moving parts.
- **Do not overreach. Keep proper footing and balance at all times.** This enables better control of the power tool in unexpected situations.
- **Use the power tool, accessories, etc. in accordance with these instructions, taking into account the working conditions and the work to be performed.** Use of the power tool for operations different from those intended could result in a hazardous situation.
- **Prevent unintentional starting. Ensure the switch is in the off-position before connecting to power source and/or battery pack, picking up or carrying the tool.** Carrying power tools with your finger on the switch or energising power tools that have the switch on invites accidents.
- **Do not let familiarity gained from frequent use of tools allow you to become complacent and ignore tool safety principles.** A careless action can cause severe injury within a fraction of a second.

POWER TOOL USE AND CARE

- **Do not force the power tool. Use the correct power tool for your application.** The correct power tool will do the job better and safer at the rate for which it was designed.
- **Use tool only as described in this manual.** Use only manufacturer's recommended attachments.
- **Do not use the power tool if the switch does not turn it on and off.** Any power tool that cannot be controlled with the switch is dangerous and must be repaired.
- **Disconnect the plug from the power source and/or remove the battery pack, if detachable, from the power tool before making any adjustments, changing accessories, or storing power tools.** Such preventive safety measures reduce the risk of starting the power tool accidentally.
- **Store idle power tools out of the reach of children and do not allow persons unfamiliar with the power tool or these instructions to operate the power tool.** Power tools are dangerous in the hands of untrained users.
- **Do not store the power tool on or near to fertilizers or chemicals.**
- **Maintain power tools and accessories. Check for misalignment or binding of moving parts, breakage of parts and any other condition that may affect the power tool's operation. If damaged, have the power tool repaired before use.** Many accidents are caused by poorly maintained power tools.
- **Use the power tool, accessories, etc. in accordance with these instructions, taking into account the working conditions and the work to be performed.** Use of the power tool for operations different from those intended could result in a hazardous situation.
- **Keep handles and grasping surfaces dry, clean and free from oil and grease.** Slippery handles and grasping surfaces do not allow for safe handling and control of the tool in unexpected situations.

BATTERY TOOL USE AND CARE

- **Remove the battery pack from the power tool before making any adjustments, changing accessories, storing, or any time the power tool is not in use.** Such preventive safety measures reduce the risk of starting the power tool accidentally.

- **Turn off power tool before removing battery pack.**
- **Do not handle battery pack, tool, or charger (including charger plug and terminals) with wet hands.**
- **Before using the battery pack or charger read the operator's manuals, and any labels on the battery pack, charger and tool.**
- **Recharge only with the charger specified by the manufacturer.** A charger that is suitable for one type of battery pack may create a risk of fire when used with another battery pack.
- **Use power tools only with specifically designated battery packs.** Use of any other battery packs may create a risk of injury and fire.
- **When battery pack is not in use, keep it away from other metal objects, like paper clips, coins, keys, nails, screws or other small metal objects, that can make a connection from one terminal to another.** Shorting the battery terminals together may cause burns or a fire.
- **Under abusive conditions, liquid may be ejected from the battery; avoid contact. If contact accidentally occurs, flush with water. If liquid contacts eyes, additionally seek medical help.** Liquid ejected from the battery may cause irritation or burns.
- **Do not use a battery pack or tool that is damaged or modified.** Damaged or modified batteries may exhibit unpredictable behavior resulting in fire, explosion or risk of injury.
- **Do not expose a battery pack or tool to fire or excessive temperature.** Exposure to fire or temperature above 130°C (265°F) may cause explosion.
- **Follow all charging instructions and do not charge the battery pack or tool outside the temperature range specified in the instructions.** Charging improperly or at temperatures outside the specified range may damage the battery and increase the risk of fire.

SERVICE

- **Have your power tool serviced by a qualified repair person using only identical replacement parts.** This will ensure that the safety of the power tool is maintained.
- **Never service damaged battery packs.** Service of battery packs should only be performed by the manufacturer or authorised service providers.

SPECIFIC SAFETY RULES FOR STRING TRIMMERS

- **Keep bystanders at least 15m (50') away during use.** Objects may be thrown or ricochet in all directions.
- **Brace for unexpected movement when contact is made with a hard object.** Loss of control could result in serious injury.
- **Do not use blades, brush cutting wheels, accessories, or attachment other than those recommended by *MILWAUKEE®*.** Serious injury or product damage may occur.
- **Do not operate the tool without the guard in place. The guard must be attached properly when trimming.** Operating the trimmer without the guard will cause serious injury.
- **Do not use tool with a damaged trimmer head.** Cracked or broken pieces can be thrown.
- **Do not operate the tool without the front handle in place. The front handle must be attached properly for use when trimming.** Using one hand could cause loss of control and result in serious injury.
- **Carry the trimmer by the front handle.** Proper handling of the trimmer will prevent injury.
- **Use both hands when operating the trimmer. Maintain a firm grip.** Using one hand could cause loss of control and result in serious injury.
- **Inspect the area before using the tool.** Remove all debris and hard objects such as rocks, glass, wire, etc. that can ricochet, be thrown, or otherwise cause injury or damage during operation.
- **Keep face, hands and feet clear of rotating line at all times.** Rotating line can cause severe lacerations.
- **Thrown objects may ricochet off of hard surfaces, such as walls, trees, and rocks and cause injury.** When possible, do trimming by hand in closed in areas.
- **When replacing the line, use only 2mm spiral or 2.4mm spiral diameter line.** Any other size can degrade performance or cause damage to the trimmer.
- **Use care when trimming around decorative plants and other obsticles.** Rotating line will cut/damage many materials.
- **Always turn off the tool between cuts or when transporting from one location to another.** Do not carry tool with finger on the trigger. Accidental starting can cause serious personal injury.
- **Do not use tool as an edger. Do not tilt tool to create a right angle to the ground. Keep trimmer head and line parallel to the ground.** Guard cannot protect against flying debris in this orientation.
- **Maintain labels and nameplates.** These carry important information. If unreadable or missing, contact a *MILWAUKEE®* service facility for a replacement.
- **WARNING** Some dust created by power sanding, sawing, grinding, drilling, and other construction activities contains chemicals known to cause cancer, birth defects or other reproductive harm. Some examples of these chemicals are:
  - lead from lead-based paint
  - crystalline silica from bricks and cement and other masonry products, and
  - arsenic and chromium from chemically-treated lumber.

  Your risk from these exposures varies, depending on how often you do this type of work. To reduce your exposure to these chemicals: work in a well ventilated area, and work with approved safety equipment, such as those dust masks that are specially designed to filter out microscopic particles.

ADDITIONAL BATTERY SAFETY RULES

WARNING To reduce the risk of fire, personal injury, and product damage due to a short circuit, never immerse your tool, battery pack or charger in fluid or allow a fluid to flow inside them. Corrosive or conductive fluids, such as seawater, certain industrial chemicals, and bleach or bleach containing products, etc., can cause a short circuit.

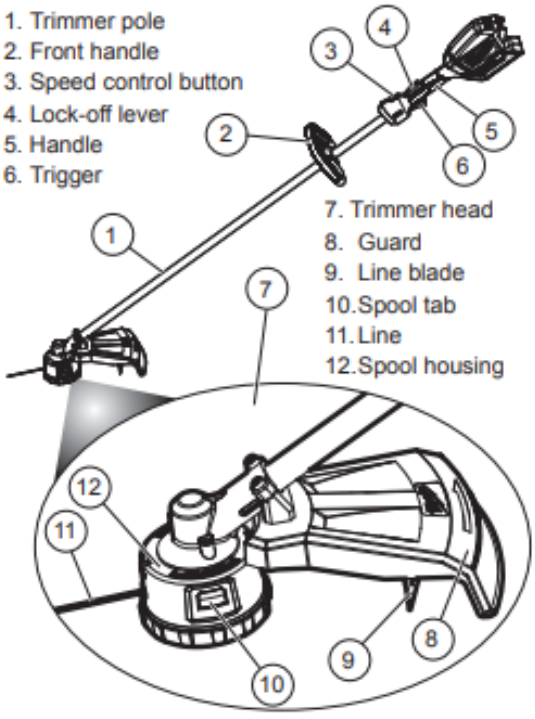
READ AND SAVE ALL INSTRUCTIONS FOR FUTURE USE

SYMBOLOGY

	Safety Alert Symbol
V	Volts
⎓	Direct Current
n_0 XXXX min^{-1}	RPM
	Read Operator's Manual
	Regulatory Compliance mark (RCM). This product meets applicable regulatory requirements.
	Always wear eye protection and hearing protection.
	Always wear gloves and personal protective equipment.
	Always wear protective clothing and footwear
	Keep bystanders 15m (50') away during use.
	Objects may be thrown or ricochet in all directions.
	Do not use in rain or wet locations.
	Do not use blades or brush cutting wheels.

FUNCTIONAL DESCRIPTION

1. Trimmer pole
2. Front handle
3. Speed control button
4. Lock-off lever
5. Handle
6. Trigger
7. Trimmer head
8. Guard
9. Line blade
10. Spool tab
11. Line
12. Spool housing



SPECIFICATIONS

Cat. No.		**M18 CLT**
Volts		18V DC
Battery Type		M18™
Charger Type		M18™
RPM		0 - 4600 / 0 - 5800
Cutting Line		7.6m x 2.0mm Spiral
		6.1m x 2.4mm Spiral
Replacement Line	2mm	49162712
	2.4mm	49162713

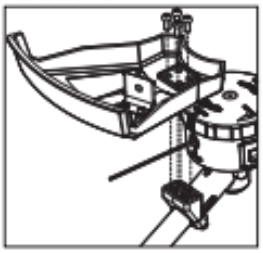
ASSEMBLY

⚠WARNING Do not operate the tool without the guard in place. The guard must be attached properly when trimming. Operating the trimmer without the guard will cause serious injury.

Installing the Guard

The guard is shipped uninstalled and must be installed before use.

1. Line up the guard bracket with the holes in the guard.
2. Insert four screws through the guard and into the bracket.
3. Tighten the screws securely using the included key.



⚠WARNING Do not operate the tool without the front handle in place. The front handle must be attached properly for use when trimming. Using one hand could cause loss of control and result in serious injury.

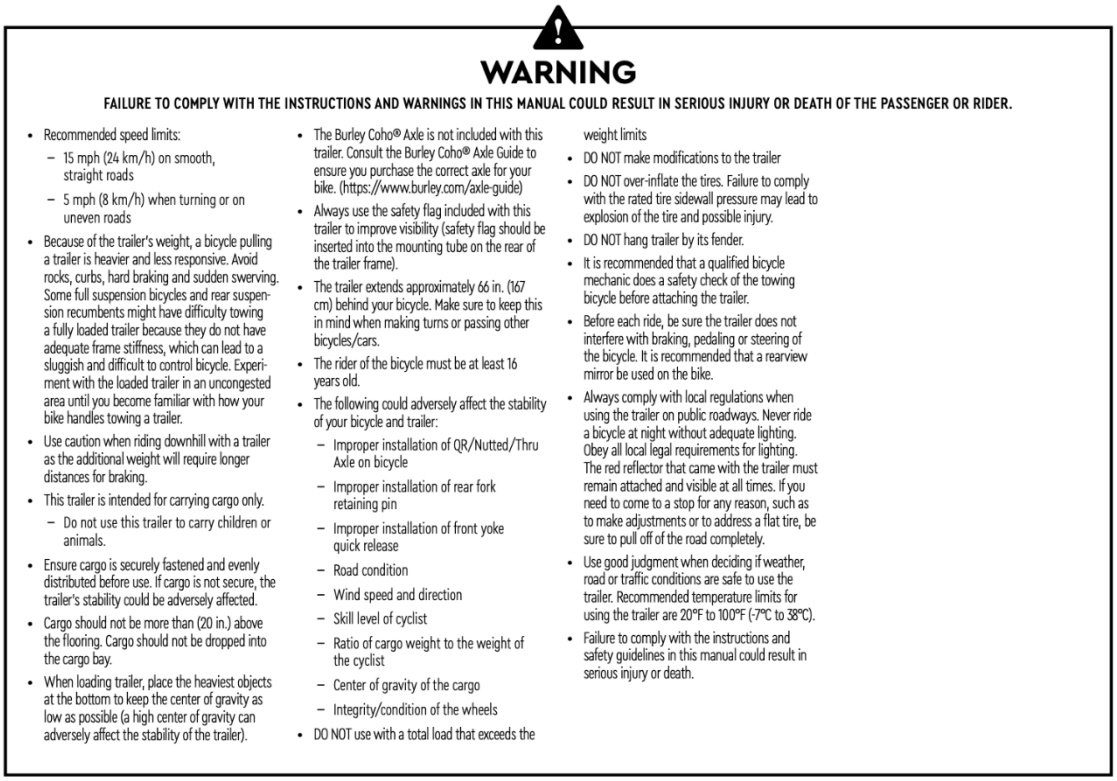
Installing the Front Handle

The front handle is shipped uninstalled and must be installed before use.

1. Place the two nuts into the front handle detents.
2. Insert one bracket into the handle.
3. Alight the front handle with the top of the warning sticker, just above the "Place Handle Here" marking.
4. Wrap the other bracket around the back of the shaft.
5. Insert the two screws through the lower bracket and into the side handle.
6. Tighten the screws securely using the included key.

4

Figure 10.2: *Milwaukee M18 String Trimmer Safety*



WARNING

FAILURE TO COMPLY WITH THE INSTRUCTIONS AND WARNINGS IN THIS MANUAL COULD RESULT IN SERIOUS INJURY OR DEATH OF THE PASSENGER OR RIDER.

- Recommended speed limits:
  - 15 mph (24 km/h) on smooth, straight roads
  - 5 mph (8 km/h) when turning or on uneven roads
- Because of the trailer's weight, a bicycle pulling a trailer is heavier and less responsive. Avoid rocks, curbs, hard braking and sudden swerving. Some full suspension bicycles and rear suspension recumbents might have difficulty towing a fully loaded trailer because they do not have adequate frame stiffness, which can lead to a sluggish and difficult to control bicycle. Experiment with the loaded trailer in an uncongested area until you become familiar with how your bike handles towing a trailer.
- Use caution when riding downhill with a trailer as the additional weight will require longer distances for braking.
- This trailer is intended for carrying cargo only.
  - Do not use this trailer to carry children or animals.
- Ensure cargo is securely fastened and evenly distributed before use. If cargo is not secure, the trailer's stability could be adversely affected.
- Cargo should not be more than (20 in.) above the flooring. Cargo should not be dropped into the cargo bay.
- When loading trailer, place the heaviest objects at the bottom to keep the center of gravity as low as possible (a high center of gravity can adversely affect the stability of the trailer).
- The Burley Coho® Axle is not included with this trailer. Consult the Burley Coho® Axle Guide to ensure you purchase the correct axle for your bike. (https://www.burley.com/axle-guide)
- Always use the safety flag included with this trailer to improve visibility (safety flag should be inserted into the mounting tube on the rear of the trailer frame).
- The trailer extends approximately 66 in. (167 cm) behind your bicycle. Make sure to keep this in mind when making turns or passing other bicycles/cars.
- The rider of the bicycle must be at least 16 years old.
- The following could adversely affect the stability of your bicycle and trailer:
  - Improper installation of QR/Nutted/Thru Axle on bicycle
  - Improper installation of rear fork retaining pin
  - Improper installation of front yoke quick release
  - Road condition
  - Wind speed and direction
  - Skill level of cyclist
  - Ratio of cargo weight to the weight of the cyclist
  - Center of gravity of the cargo
  - Integrity/condition of the wheels
- DO NOT use with a total load that exceeds the weight limits
- DO NOT make modifications to the trailer
- DO NOT over-inflate the tires. Failure to comply with the rated tire sidewall pressure may lead to explosion of the tire and possible injury.
- DO NOT hang trailer by its fender.
- It is recommended that a qualified bicycle mechanic does a safety check of the towing bicycle before attaching the trailer.
- Before each ride, be sure the trailer does not interfere with braking, pedaling or steering of the bicycle. It is recommended that a rearview mirror be used on the bike.
- Always comply with local regulations when using the trailer on public roadways. Never ride a bicycle at night without adequate lighting. Obey all local legal requirements for lighting. The red reflector that came with the trailer must remain attached and visible at all times. If you need to come to a stop for any reason, such as to make adjustments or to address a flat tire, be sure to pull off of the road completely.
- Use good judgment when deciding if weather, road or traffic conditions are safe to use the trailer. Recommended temperature limits for using the trailer are 20°F to 100°F (-7°C to 38°C).
- Failure to comply with the instructions and safety guidelines in this manual could result in serious injury or death.

Before You Ride

Contact your authorized Burley dealer for replacement of any damaged or worn parts.

Check before each use

- ○ Wheel is properly secured to the trailer
- ○ Tire is inflated to recommended pressure on the tire sidewall
- ○ Yoke is properly secured to the trailer body
- ○ Burley Coho® Receiver is properly secured to the Burley Coho® Axle
- ○ Load does not exceed 70 lbs (31.8 kg)
- ○ Bicycle is in proper working order, especially brakes and tires
- ○ Cargo is securely loaded
- ○ The spring nut is tightened against the shock

Check monthly

- ○ Inspect yoke, Burley Coho® Receivers, frame tubing, Burley Coho® Axle and hardware for damage
- ○ Check that bolts are tight
- ○ Inspect tire and wheel for wear, damage or cracks
- ○ Inspect fabric parts for rips, abrasions, and missing or damaged hardware
- ○ Contact your authorized Burley dealer for replacement of any damaged or worn parts.

Maximum Capacities

Trailer Body + Fender:
Maximum Total Weight: 70 lbs (31.8 kg)

Fender: 5 lbs (2.3 kg)

Note: if using additional Burley accessories for loading trailer, consult the appropriate manuals for loading instructions.

Always comply with local regulations for maximum trailer weight.

Maintenance

To avoid premature component wear, always clean your equipment after exposure to corrosive or abrasive environmental conditions, such as sand or salt water.

Storage

For longer product life, store trailer indoors. The trailer should not be stored at temperatures less than -10°F (-23°C) or greater than 150°F (65°C).

Fabric Care

Hand wash fabric parts with warm water and mild soap. DO NOT use bleach or solvents. Wipe dry and store out of direct sunlight in a dry, well-ventilated area.

Connect with Burley

Whether you ride your bike all year long or are a fair weather rider, Burley shares your enthusiasm for making the most of your bike. Thank you for your business. We appreciate it.

Product Identification

If you have any questions about the model name or year of your Burley, please consult our product identification web page:burley.com/support/what-year-is-my-burley

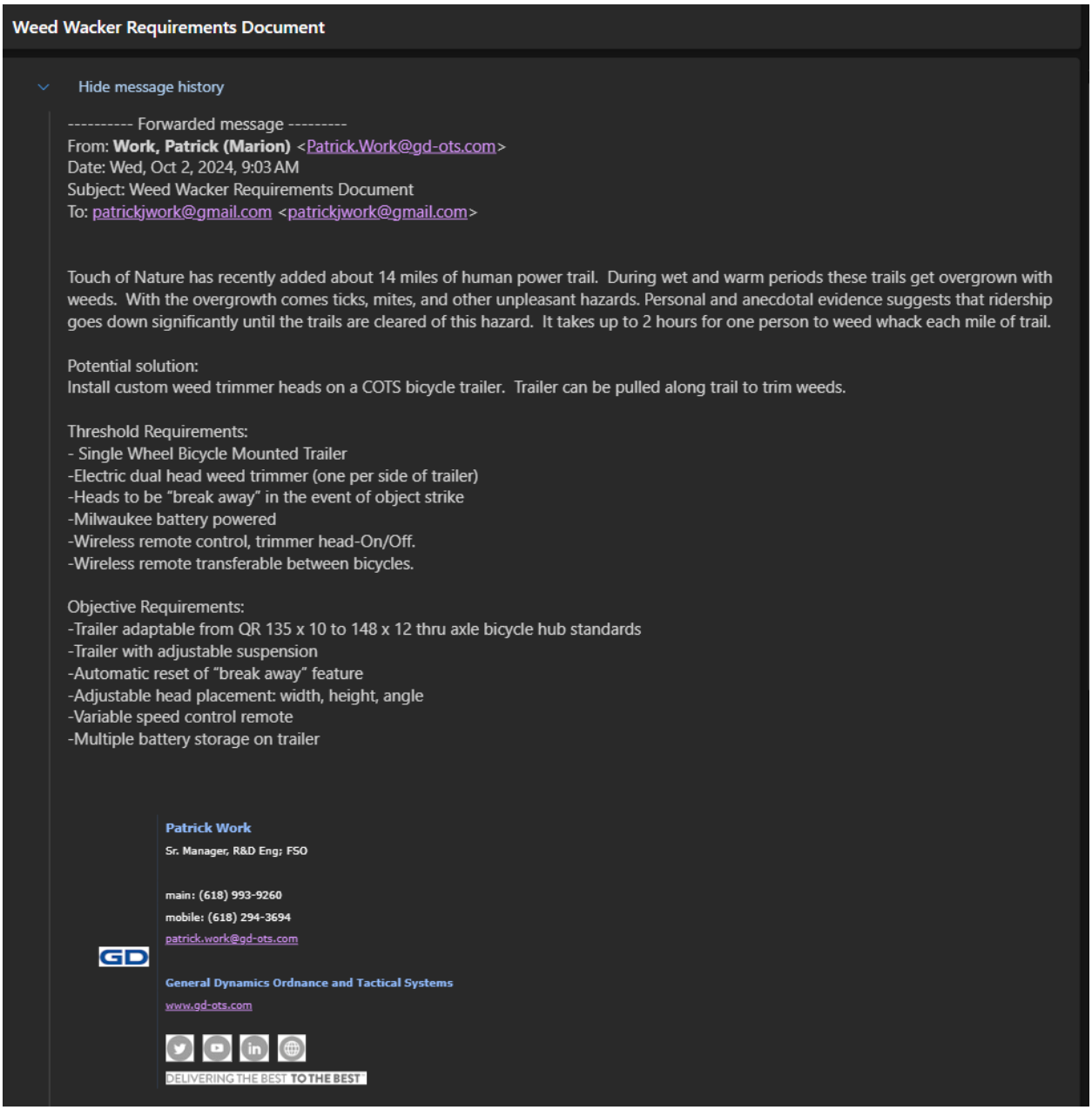
Burley Limited Warranty

This Burley trailer is warranted from the date of purchase against defects in materials and workmanship as follows: fabric parts for one year, frame and plastic parts for three years. Your original dated sales or delivery receipt showing the date of purchase is your proof of purchase. If a defect in materials or workmanship is discovered during the Limited Warranty period, we will, at our sole option, repair or replace your product at no cost to you. This warranty is only valid in the country in which the product was purchased.The Limited Warranty extends only to the original retail purchaser of this product and is not transferable to anyone who obtains ownership of the product from the original purchaser. The Limited Warranty does not cover claims resulting from misuse, failure to follow the instructions, installation, improper maintenance and use, abuse alteration, involvement in an accident, and normal wear and tear. The Limited Warranty does not cover products which are used in rental operations and Burley will not be liable for any incidental or commercial damages relating to such use. TO THE GREATEST EXTENT PERMITTED BY LAW, THIS LIMITED WARRANTY IS EXCLUSIVE AND IN LIEU OF ANY OTHER WARRANTY, WRITTEN OR ORAL, INCLUDING BUT NOT LIMITED TO ANY EXPRESS OR IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. The duration of any implied warranties, including any implied warranty of merchantability or fitness for a particular purpose that may exist during the express warranty period are expressly limited to the limited warranty period. Some states and countries do not allow limitations on how long an implied limited warranty lasts; therefore, the above limitation and exclusions may not apply to you.

THE CUSTOMER'S EXCLUSIVE REMEDY FOR BREACH OF THIS LIMITED WARRANTY OR OF ANY IMPLIED WARRANTY OR OF ANY OTHER OBLIGATION ARISING BY OPERATION OF LAW OR OTHERWISE SHALL BE LIMITED AS SPECIFIED HEREIN TO REPAIR OR REPLACEMENT, AT OUR SOLE OPTION. IN ANY EVENT, RESPONSIBILITY FOR SPECIAL, INCIDENTAL AND CONSEQUENTIAL DAMAGES IS EXPRESSLY EXCLUDED. Some states do not allow the exclusion of limitation of incidental or consequential damages, so the above limitation of exclusion may not apply to you. For Australian Customers: Our goods come with guarantees that cannot be excluded under the Australian Consumer Law. You are entitled to a replacement or refund for a major failure and for compensation for any other reasonably foreseeable loss or damage. You are also entitled to have the good repaired or replaced if the goods fail to be of acceptable quality and the failure does not amount to a major failure. This Limited Warranty gives you specific legal rights, and you may have other rights that vary from state to state or country. For warranty service or replacement part information for the USA or Canada, please contact Burley directly by calling 800-311-5294 or emailing burley@burley.com. For warranty service or replacement part information outside of the USA and Canada please contact the place of purchase for warranty service. Please be prepared to provide the product model, serial number and a description of the warranty issue. Some replacement parts may be available for purchase after this limited warranty expires. Please visit us at www.burley.com or call us at 541-687-1644 for more information.

Figure 10.2: *Burley Coho XC Safety*

Appendix K: Communications (CB)



Weed Wacker Requirements Document

Hide message history

---------- Forwarded message ---------
From: **Work, Patrick (Marion)** <Patrick.Work@gd-ots.com>
Date: Wed, Oct 2, 2024, 9:03 AM
Subject: Weed Wacker Requirements Document
To: patrickjwork@gmail.com <patrickjwork@gmail.com>

Touch of Nature has recently added about 14 miles of human power trail. During wet and warm periods these trails get overgrown with weeds. With the overgrowth comes ticks, mites, and other unpleasant hazards. Personal and anecdotal evidence suggests that ridership goes down significantly until the trails are cleared of this hazard. It takes up to 2 hours for one person to weed whack each mile of trail.

Potential solution:
Install custom weed trimmer heads on a COTS bicycle trailer. Trailer can be pulled along trail to trim weeds.

Threshold Requirements:
- Single Wheel Bicycle Mounted Trailer
-Electric dual head weed trimmer (one per side of trailer)
-Heads to be "break away" in the event of object strike
-Milwaukee battery powered
-Wireless remote control, trimmer head-On/Off.
-Wireless remote transferable between bicycles.

Objective Requirements:
-Trailer adaptable from QR 135 x 10 to 148 x 12 thru axle bicycle hub standards
-Trailer with adjustable suspension
-Automatic reset of "break away" feature
-Adjustable head placement: width, height, angle
-Variable speed control remote
-Multiple battery storage on trailer

Patrick Work
Sr. Manager, R&D Eng; FSO

main: (618) 993-9260
mobile: (618) 294-3694
patrick.work@gd-ots.com

General Dynamics Ordnance and Tactical Systems
www.gd-ots.com

DELIVERING THE BEST **TO THE BEST**

Appendix L: Resumes (All)

Colin Berry

colinthomasberry.com | ctberry21@gmail.com | Lebanon, IL | (618) 420-9789 | linkedin.com/in/colintberry

EDUCATION

Southern Illinois University **Carbondale, IL**

Bachelor of Science, Major in Computer Engineering, Minor in Computer Science *Expected May 2025*
Specialization in Cyber Systems and Security Engineering *Cumulative GPA: 4.0; summa cum laude*

- **Relevant Coursework:** C++, Software Tools & Robotics, Software Engineering, Linux/UNIX, Neural Networks in Python, Machine Learning in R, Computer and Network Architecture and Security, Ethical Hacking, Digital Forensics, Digital Circuit Design, Signals/Systems, Electronics, Cyber-Physical Systems, Calculus I, II, and III.
- **Extracurriculars:** Vice President of TechDawgs, University Honors Program, Southern Illinois Children's Choir (Assistant), College of Engineering, Computing, Technology, and Mathematics Student Council.
- **Awards:** Dean Kenneth E. Tempelmeyer Outstanding Senior Award in the College of Engineering, Dr. Glafkos Galanos Memorial Scholarship Award, High Academic Achievement Award (4x), Dean's List (4x).
- **Extracurricular Projects:** React + Tailwind personal portfolio, blockchain technology research paper and video, senior design: wirelessly controlled bicycle-towed weed eater for trail maintenance.

EXPERIENCE

Stifel Financial Corp. **St. Louis, MO**
Technology Product Development Intern *May 2023 - August 2023 / May 2024 - August 2024*

- Collaborated with a scrum team of interns and developers to build an internal web application that visualizes live metric data of the department's 15+ agile teams. Employed React, JS, Tailwind, TremorUI, and Figma to spearhead client-side development of the project, which fetched and analyzed over 200,000 Jira issues via REST APIs.
- Actively met with stakeholders to gather feedback while designing the site's user interface and functionality.
- Enhanced intracompany understanding of 8–10 technical processes by developing detailed workflow documents for Stifel's two flagship products, showcasing strong analytical skills in data collection and organization with a strong attention to detail.
- Shadowed a 14–15 member scrum DevOps team in an agile environment, gaining proficiency in software development life cycle, Jira project management, and Microsoft Azure. Participated in sprint planning, backlog refinement, and daily stand-ups.

SalukiTech Service Center **Carbondale, IL**
Information Technology Supervisor *August 2021 - May 2024*

- Led and mentored a team of 6–20 student employees, fostering technical skill development in IT troubleshooting.
- Implemented an ITSM ticketing system to manage, monitor, and document 300+ devices and IT projects.
- Leveraged Apple and Dell hardware certifications to diagnose and resolve software and hardware issues.
- Spearheaded improvements in operating procedures, enhancing workflow efficiency and reducing deployment time for 800+ faculty members.

Southern Illinois University Housing **Carbondale, IL**
Resident Assistant *August 2023 - Current*

- Maintains and supports a diverse community of 25+ residents, promoting personal growth and well-being while serving as a key liaison between students, faculty, and housing administration, ensuring clear communication and accountability.
- Demonstrates leadership and interpersonal skills by resolving housing concerns, conflicts, and emergencies.

Dairy Queen **Lebanon, IL**
Manager *January 2019 - August 2022*

- Supervised a crew of 4–10 employees while delivering exceptional customer service to more than 500 people daily.
- Managed a $1,000+ cash register on a routine basis while simultaneously reshaping crew responsibilities to preserve 8% - 19% labor costs. Trained over 15 new hires in standard operating procedures to maintain a fast-moving workflow.

SKILLS

Front-end Development: React | HTML | CSS | Tailwind | Vite | Data Visualization | UI/UX Design | Figma
Languages: C | Python | R | SQL | MatLab | Bash
Project Management: Jira | Excel | Agile/Scrum | Technical Documentation | Problem Solving | Attention to detail | Git
Business Skills: Adaptability | Business Process Mapping & Analysis | Strong Written & Oral Communication | Fast Learner

Taylor Demick

Millstadt, Illinois | (618) 581-1738 | taylorcdemick@yahoo.com | linkedin.com/in/taylorcdemick

Employment

Kiewit Corporation — Lenexa, KS
Electrical Engineer, Power Engineering Department — *June 2025 - Present*

- Support electrical drawing development for power generation and substation projects, including one-lines, schematics, and panel layouts, data sheets, and similar drawings.
- Prepare engineering calculations and drawings following Kiewit Power Engineers standards.
- Develop and manage cable and termination information utilizing plant design software.
- Research and analyze requirements from various engineering standards, contracts, and proposals.

Schnucks — Waterloo, IL
Deli Clerk — *September 2020 - January 2025*

- Maintained presence in the department, working with 100+ customer needs.
- Completed tasks to ensure cleanliness and sanitation of the department.
- Maintained a positive work environment.
- Assembled customers' orders for parties and events.

Prairie State Generating Company — Marissa, IL
Electrical Engineering Intern — *May 2024 - August 2024*

- Updated electrical schematics for various projects to ensure accuracy and alignment with design specifications.
- Transferred 40,000+ PI data points from the DCS interface to the PLC interface, enhancing data retention.
- Created detailed procedures and documentation for engineers on various projects, standardizing processes and facilitating smoother project execution.

Education

Southern Illinois University — Carbondale, IL
Bachelor of Science in Electrical Engineering, GPA: 3.8 — *August 2021 - May 2025*

- **Relevant Coursework:** Digital Computation, Software Tools/Robotics for Engineers, Mathematical Methods in Engineering, Electric Circuits, Digital Circuits, Electronics, Signals, Systems & Controls, Electromagnetic Fields, Electromechanical Energy Conversions, Electric & Hybrid Vehicles, Clean Electric Energy, Power Systems Analysis
- **Awards**: Dr. Glafkos Galanos Memorial Scholarship Award, High Academic Achievement Award (4x), Dean's List (4x)
- **Extracurriculars/Leadership:** President of SAE Saluki Baja Race Team, Vice President of the College of Engineering, Computing, Technology, and Mathematics Student Council

Skills

Technical Skills

- Knowledge in Microsoft Office and Google Workspace
- Basic knowledge with coding and programming in C++, Python, and MATLAB
- Troubleshooting skills with electrical components
- Knowledge in AutoCAD Electrical and ETAP
- Knowledge with DCS and PLC operations

Soft Skills

- Teamwork
- Leadership
- Problem-solving
- Time management
- Communication

BLAKE JOURDAN
302 W. Fourth St, Mackinaw, IL 61755 | (309) 373-7439 | JOURDAN025@YAHOO.COM

PROFESSIONAL SUMMARY

Results-driven Design Engineer with 14+ years of experience in engineering design, project management, and process improvement. Proficient in leading cross-functional teams, developing innovative solutions, and enhancing product quality.

CORE SKILLS

- **Engineering Tools: Pro/E WF4, Creo, Teamcenter, Windchill**
- **Testing & Validation: Part Validation, PPAP Approvals**
- **Project Management: Multi-Project Management, Process Improvement**
- **Technical Proficiency: Data Management, Design Implementation**
- **Communication: Cross-Functional Team Coordination, Design Reviews**

PROFESSIONAL EXPERIENCE

Belcan Engineering Inc.
Engineer
Dec 2010 – Present

- **Led a conversion project to transition components from Bucyrus to Caterpillar's HMS, involving the design of sheet metal enclosures for electrical generators. Conducted regular design reviews for heavy equipment components, assemblies, and groups, ensuring alignment with client specifications and timelines.**
- **Developed and managed 3D models in Creo for undercarriage components, including track shoes and hydraulic routing systems, and plastic parts. Created detailed business cases for new projects, including deliverables and time estimates, submitted workflows in Teamcenter for design release.**
- **Updated electrical harness models, developed hydraulic routing for mobile cranes, and created air brake routings using engineering schematics. Worked with suppliers to design HVAC systems that were manufacturable and met customer quality standards.**
- **Coordinated with suppliers to finalize designs and bring deliverables to market, conducting cross-functional meetings to resolve design issues and ensure production readiness. Developed and managed hydraulic and pneumatic routings for locomotive and motor grader products.**

- **PPAP approvals, led design documentation and created presentations to support design review processes.**

Airtex Products LP
Designer
Feb 2008 – Dec 2010

- **Redesign of GM aftermarket fuel pumps, achieving $1.5 million in cost savings by optimizing the assembly process. Modeled complex plastic components for injection molding, validated part compatibility, and collaborated with cross-functional teams for quality assurance and testing.**
- **Conducted tolerance stack-up studies, performed pressure and flow rate testing on electric fuel pumps, and managed assembly validation to ensure product reliability and functionality**

EDUCATION

Bachelor of Science in Electrical Engineering (Expected May 2025)
Southern Illinois University – Carbondale

Illinois Central College
Associates in Engineering Science, May of 2023

ITT Technical Institute August 2007
Associates in applied science, Design and drafting technology

Jarrett C. West

10373 N 1400 Blvd
Mount Carmel IL, 62863

618 263-8096
23jcwest@gmail.com

EDUCATION

- Southern Illinois University of Carbondale
  - Currently enrolled
    - Coursework:
      - Calculus III
      - Intro to Digital Computation (C++)
      - University Physics I & II
      - Electric Circuits I & II
      - Differential Equations

- Wabash Valley College
  - Associates of Science
  - Graduation Date: May 14, 2022
  - GPA: 4.0/4.0
    - Coursework:
      - Physics I and II
      - Calculus I and II
      - General Biology
      - Comp II

- Mt. Carmel High School
  - Graduation Date: May 18, 2021
  - GPA: 3.95/4.0
  - SAT Score: 1200/1600
    - Coursework:
      - Business Communications, Computer Apps, Intro to engineering, Adobe Photoshop and Illustrator, HTML skilled.
      - Spanish
      - Math Team (Geometry)

WORK EXPERIENCE

- **Naval Surface Warfare Center (NSWC Crane)**
  Crane IN (May 2023- August 2024)
  - Intern Engineer
    - Radar Systems training, testing equipment in the lab, and experience in engineering work.

- **West Berwick Golf Course (4 Year Employee)**
  Mount Carmel IL (May 2019- December 2023)
  - Cooking
    - Stymies Restaurant: preparing and serving meals, arrive early to prepare and clean.
  - Pro Shop Attendant
    - Stock shelves, close and open register, customer relations, inventory management, and office work.
  - Grounds Maintenance
    - Ground work, machine maintenance, and closing shop.

- **Communication with Businesses**
  - Took Business Communications Class for two years at Mount Carmel High School, working with other businesses and helping them get their name out into the community and doing projects for them.
  - Examples of work for these businesses include designing new logos, making informational videos about the business, and making social media posts of events.

EDUCATIONAL HONORS

- 4 Year High Honor Roll
- Presidential Scholar Award
- Teamsters Local 215 Scholarship
- American Legion Distinguished Achievement Award
- Senior Athletic Award
- Dean's List 2021-2022 WVC

EXTRA CURRICULAR ACTIVITIES

- Soccer Team
  - Played through High School
  - 2 Year Captain
  - 4 Year Scholar Athlete
- Golf Team
  - Played through High School
  - 2 Year Captain
- National Honor Society
  - Junior & Senior Year
  - Donated Time for Service Hours (20 Hours)
- Student Senate (WVC)
  - Organize events at school
  - Design and implement processes of new groups and studies