WATER BLASTER

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Abstract

The electric water blaster is an automated, high-pressure device designed to improve traditional water guns by eliminating the manual pumping and ensuring consistent water bursts. It integrates advanced electronics for precise control, real-time feedback, and enhanced safety features such as leak detection and pressure regulation. The system is built with robust mechanical structure for durability and smart automation for user friendly experience. It complies with industry safety standards to ensure reliability and safety. Extensive testing had been done on the product to verify its performance, making it a high-powered, user-friendly alternative to conventional water blasters.

Contents

1. Introduction

Traditional water blasters are often characterized by inconsistent pressure, limited range, and reliance on manual operation, which can result in user fatigue and unreliable performance. Furthermore, these devices lack intelligent feedback mechanisms, preventing users from effectively monitoring operational status and adjusting as needed. This project seeks to address these limitations by developing a fully electric, high-pressure water blaster capable of delivering controlled bursts, real-time monitoring, and enhanced durability through advanced engineering solutions.

During the initial design phase, three high-level requirements were established to ensure optimal functionality.

- The blaster should consistently shoot water bursts covering a distance of over 20 ft.
- The blaster must be lightweight with a total weight not to exceed 10 lbs.
- The display must accurately reflect the state of the state machine and update in under one second to ensure accurate data is displayed.

The blaster is operated via an STM32G070KBT6 microcontroller, which manages pressure regulation, leak detection, and user input processing. MOSFET-powered actuation enables responsive firing, while an SPI-driven OLED display presents real-time system information. Power is efficiently supplied by a high-capacity battery system, ensuring extended usage without performance degradation.

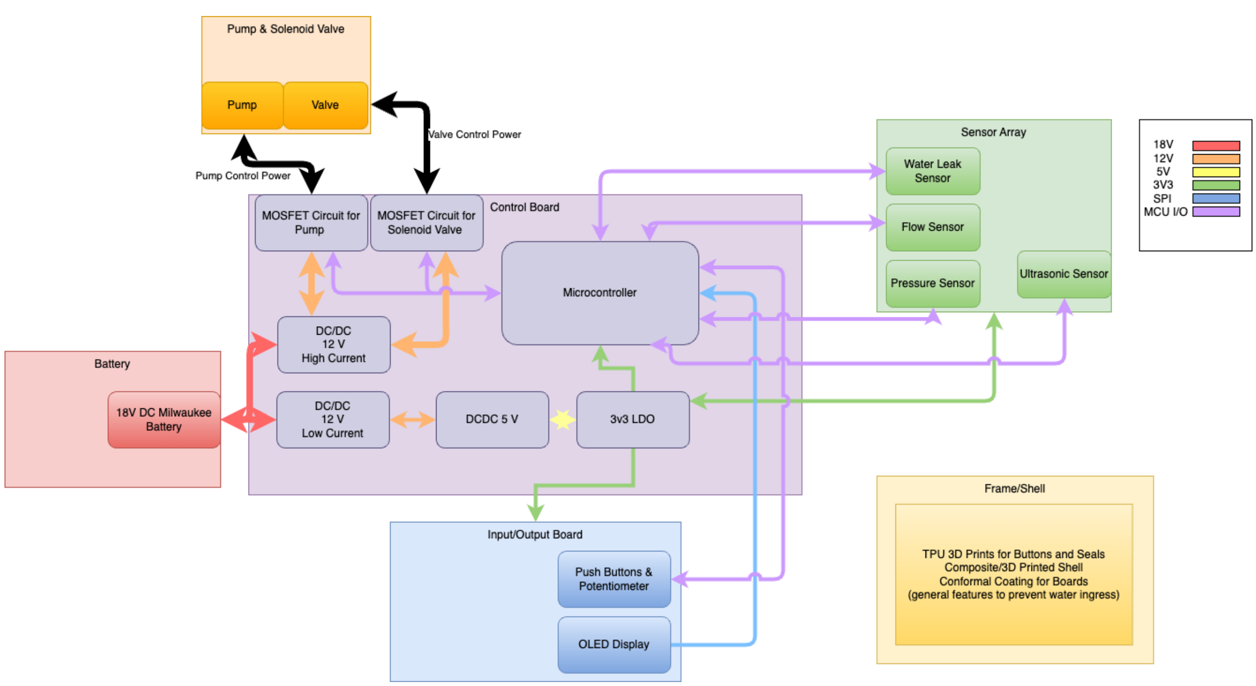

Figure 1: Block Diagram

The system consists of multiple interconnected subsystems that contribute to its functionality. The control board processes sensor data and user inputs while managing actuation. The input and output interface incorporates a step encoder for precise firing adjustments and a push-button trigger for activation. The battery system supplies stable power, maintaining efficient voltage regulation. The structural frame and shell offer water resistance and durability. The sensor array monitors water levels and leak detection to ensure safe operation, while the pump and solenoid valve deliver controlled bursts of water, ensuring a consistent range of fire.

Figure 1 visually represents the interconnection of these core subsystems, demonstrating their role in the overall system design and functionality.

Over the semester, the design evolved based on testing and optimization.

- Sensor selection optimization: Initially, the block diagram included flow sensor, ultrasonic sensor and pressure sensor for measuring the water fill level. After testing, we found that the pressure sensor alone provided the required functionality while keeping costs and complexity in check.
- Step encoder over potentiometer: Our initial design featured a potentiometer for adjusting firing power, but we ultimately switched to a step encoder, allowing for precise and incremental control.

Further optimizations included refining pressure regulation to consistently maintain a minimum firing distance of 20 ft and testing various nozzle designs to determine the optimal stream performance. Additionally, leak detection capabilities were improved to ensure the system shuts down within 0.25 seconds upon detecting internal water exposure.

Through rigorous testing and iterative refinements, the final design successfully meets the reliability, efficiency, and safety standards required for deployment. This system presents a modern, user-friendly, and high-performance alternative to conventional water blasters, integrating advanced engineering principles to enhance functionality and usability.

2 Design

2.1 Design Procedure

When we began our design we found many different potential solutions, some we were able to rule out quickly due to lack of part availability, such as an expandable water bladder to attach to our pump, as when we went to work on this, we found it would need a custom rubber part to be manufactured and they had an order minimum of 100 units. As a result, that method was ruled out. However, we were left with many feasible configurations just between the pump, valve, tank, and nozzle, which we needed to test ourselves as we found no effective way to model these components due to a lack of availability of technical specifications and performance.

As for electrical design, we completed our first iteration of the board quickly because we wanted to be able to control various mechanical components, specifically the pump and valve subsystems. We knew that these would be crucial for our final design so evaluating what would be feasible early on was essential. With our initial PCB design, we were able to successfully control the pump and valve using an N-Channel MOSFET. This allowed us to test various pumps, such as self-priming pumps, diaphragm pumps, low voltage pumps, and so on. We also tested various water holding methods, such as reservoirs, expandable bladders, accumulator tanks, and no large water method other than the pipes. Using our early iteration of the PCB we managed to narrow down what would work best, in terms of tanks. The accumulator tank consistently outperformed the other methods and allowed for easy filling with minimal parts. We also found that the water reservoir worked quite well, but was more expensive, and had a special air bleeding valve that was required to remove air from the system, which was quite costly. This also puts a restriction on the orientation of the gun for firing which we believed would negatively impact the end users experience. Given that we had established the accumulator tank as the superior method we then began evaluating the pumps. We determined that threaded pumps worked best for our use, although the assembly became a bit more tedious as opposed to hose clamp pumps, the threaded fittings virtually eliminated all the internal leaks which was a huge benefit for preventing water ingress. With the main components of the water blaster finalized we were able to evaluate different nozzles. We started with a pressure washer nozzle, thinking that would be the ideal nozzle, but it ended up missing the water after 5-10 ft, which did not meet our high-level criteria. We found that a 1/8 in diameter nozzle ended up working best as the water clumped together increasing the firing distance significantly.

In terms of the sensors, we had to decide between a few different things, we found commercially available water sensors, but we were unhappy with the formfactor, ultimately, we decided to design our own to know the exact dimensions, ensure connector compatibility, and ultimately ensure it would fit inside our enclosure where we would like it to go. For the I/O board we also needed to have a knob to adjust the settings menu, we initially planned to use a potentiometer hooked up to our ADC, but then realized that this would have limits in our settings menu, and jump to whatever value the potentiometer was at when the page was opened, so we instead switched to a step encoder. This allowed the encoder to spin all the way around every time, and instead we tracked the relative change in the encoder position to adjust the settings value. Finally, we had to decide on a water level monitoring system. We knew we wanted to monitor pressure for safety, and with a working mechanical enclosure we were able to see that after 25 psi the water distance started to decrease significantly. As a result, instead of tracking the quantity of water, we tracked the pressure of the water. This makes more sense as the pressure determines what is a suitable shot rather than the amount of water inside of the water blaster. The other options we evaluated for this were flow sensors and ultrasonic sensors, both would be costly and unable to evaluate the exact number of usable shots remaining as the water out does not directly correlate to what is a usable shot inside of the tank which is why pressure monitoring ended up coming out on top.

2.2 Electrical and Mechanical Design Details

The design integrates multiple subsystems for pressure regulation, sensor monitoring, power management, and actuation. The control board processes sensor data and user inputs, executing the state machine to regulate system behavior. Figure 2 (MCU Schematic Diagram) provides a schematic overview of core electrical connections.

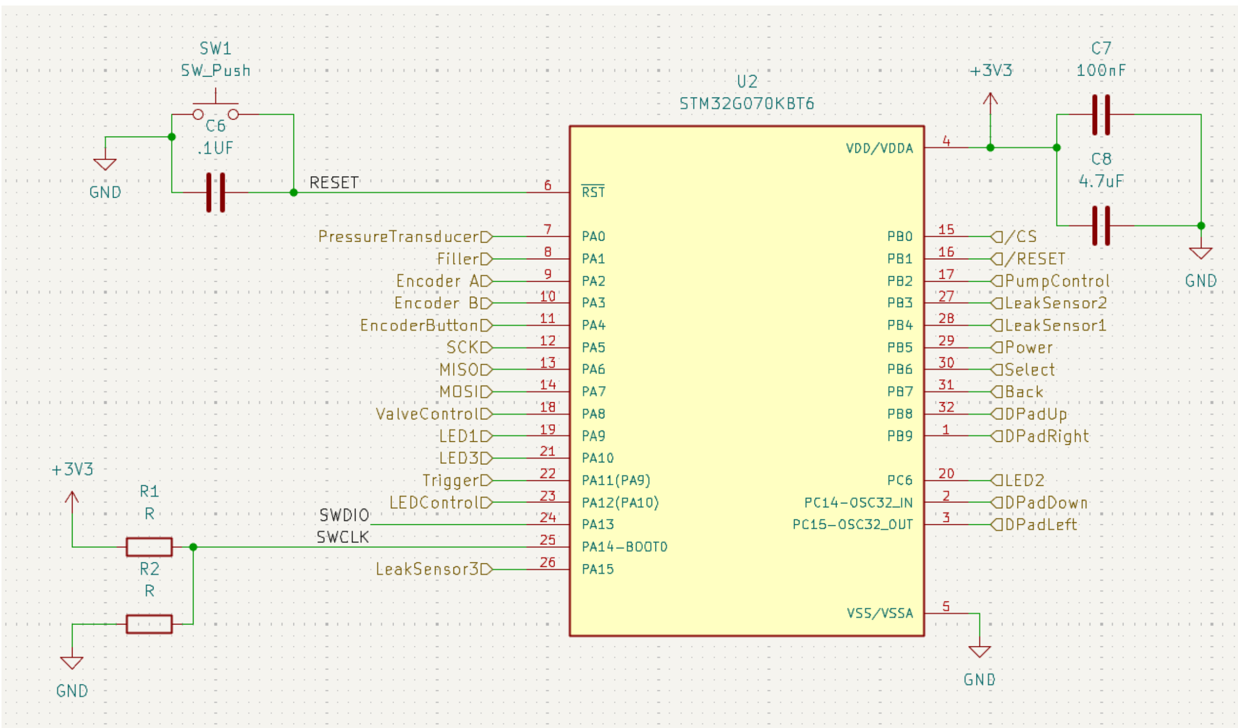

Figure 2: MCU Schematic Diagram

Component Specifications

Microcontroller: STM32G070KBT6 – manages logic.

Power System: 18V rechargeable battery, stepped down via DC-DC converter (regulated to 12V).

Display: SPI-driven OLED screen providing system feedback.

Actuation Components: MOSFET-controlled pump and solenoid valve for burst precision.

Sensors: Pressure sensor for water level detection; leak sensors ensuring safety.

2.2.1 Control Board

The control board is the brain of the system, processing data from sensors and user inputs and controlling the operation of other subsystems. It coordinates the flow of information from the sensor array, user I/O, and the pump and solenoid valve. The control board uses a microcontroller (STM32G070KBT6) to execute the state machine that determines system behavior based on sensor data and user commands. The control board manages key operations like adjusting water pressure, activating the solenoid valve for bursts, and updating the SPI display to show real-time status.

2.2.2 Inputs & Outputs

The I/O subsystem allows the user to interact with the water blaster. It consists of a display for showing system status (e.g., water fill level, pressure, firing mode) and user controls such as buttons and a step encoder. The user inputs allow for adjustments in firing mode and burst lengths, ensuring that the system can be customized based on the user's preferences. The push button is used to trigger the water blaster's firing action. The system continuously sends user input data to the control board, which processes it and adjusts the system accordingly.

2.2.3 Battery

The battery subsystem powers the entire water blaster, supplying the necessary energy to all components, including the pump, solenoid valves, and control board. A Milwaukee® M18™ lithium-ion tool battery was selected due to its high current delivery capability and long runtime. Power is stepped down using a DC-DC converter to provide appropriate voltage rails to both the logic and high-power subsystems

To ensure the battery could support extended use, a theoretical runtime analysis was conducted. The pump draws approximately 5 A during operation. Given the 12 Ah capacity of the battery, the expected continuous operation time is:

$$\text{Runtime} = \frac{12\,Ah}{5\,A} = 2.4 \text{ hours}$$

Each fill cycle takes about 20 seconds, refer Section 3.1 for details, resulting in approximately:

$$\frac{2.4 \times 3600}{20} = 432 \text{ tank refills}$$

With each tank refill supporting an estimated 75 shots, the system is theoretically capable of delivering up to:

$$432 \times 75 = 32,400 \text{ shots per full charge}$$

Accounting for system inefficiencies and conservative margins, the final estimate is approximately 27,000 bursts per charge, comfortably exceeding the 30-minute runtime and operational reliability requirements.

2.2.4 Frame & Shell

The frame and shell of the water blaster provide structural support and protection for the internal components. It prevents water ingress and ensures that all components are securely housed. The frame is made from 3D-printed or composite materials, which offer a lightweight yet durable solution. TPU-sealed buttons and NPT fittings are incorporated to prevent leaks. A conformal coating protects the electronics from potential moisture exposure. Ultimately the mechanical components that provided the most powerful water bursts required a significant amount of research and development. We tested many different configurations ranging from a direct pump to nozzle layout, a pump to expandable bladder to nozzle layout and a pump to accumulator tank to nozzle layout. Ultimately the accumulator tank proved to be the superior method. The accumulator tank is charged with a pressure of roughly 5psi of air, which the pump overcomes with its suction of water, increasing the pressure past this, as this happens the air becomes more and more compressed because its volume decreases, essentially increasing the pressure and putting a force behind the water, helping maintain higher pressure for longer. As seen in the figure below, the inlet goes to the pump, which then pumps water into the accumulator tank where it is stored in a pressurized state, there is then a pressure transducer inline on the barrel which records the pressure and reports it out to the main board. Right before the nozzle there is a solenoid valve. This valve is capable of opening and closing very quickly, releasing powerful bursts of water. For whatever duration is configured in the firmware. After component selection was completed, we began optimizing the enclosure. We placed mounting holes for all of our boards, such as leak sensors, trigger boards, the IO Board, and Main Board. This ensures that everything is mounted properly and stays exactly where we want it. We also opted for an asymmetrical parting line in the design, allowing all for a functional water blaster with only half of an enclosure, meaning all components can be installed into the left side of the shell, and the right side is removable to see what is going on inside.

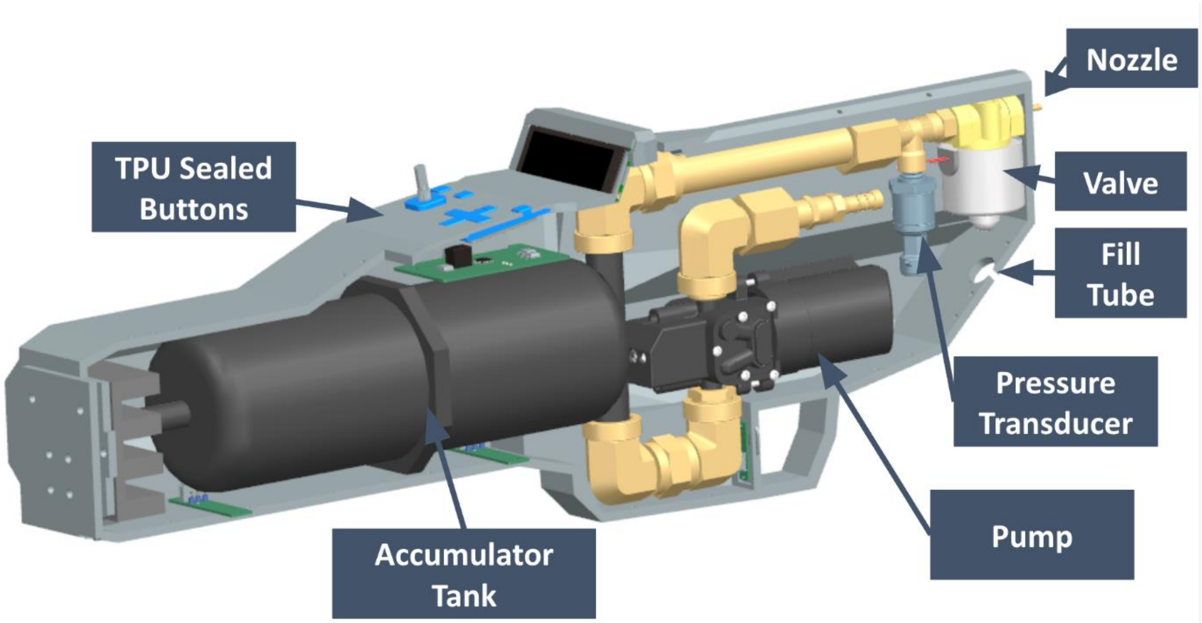

Figure 3: Labeled Mechanical Design

The Final mechanical enclosure came out to look exactly how we expected. We were able to clean everything inside and take advantage of TPU button covers to prevent water ingress. The final assembled water blaster can be seen below.

Figure 4: Fully Assembled Water Blaster

2.2.5 Sensor Array

The sensor array provides essential feedback to the system regarding the water blaster's operation. It monitors leak detection and pressure, providing real-time data to the control board. This data ensures that the system operates safely and efficiently. The leak detection sensor is custom made to meet our needs. As shown in figure 3, the traces of SENS and GND are interlaced; if a water drop lands on the surface of the board, if will drive the SENS low, triggering the shutdown signal on the control board to prevent further damage. The pressure sensor ensures that the internal water pressure remains within the safe and effective thresholds. It is also used to calculate the water level left in the tank as the pressure. A leak detection or a pressure above the threshold, 110 psi, will trigger an immediate shutdown.

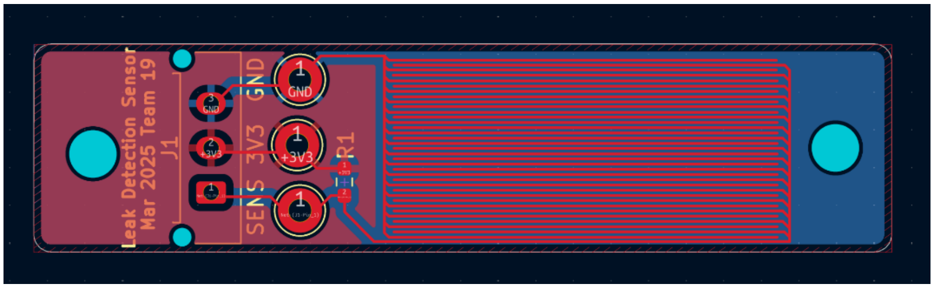

Figure 5: Water Detection Sensor Layout

2.2.6 Pump, Solenoid Valve & Tank

This subsystem is responsible for pressurizing and delivering water through the system. The 12V diaphragm pump pressurizes the water to the required level, while the fast-actuating solenoid valve releases water in short bursts. The tank stores pressurized water, and its operation is monitored to ensure safe performance. The subsystem works closely with the control board to deliver precise water bursts when triggered by the user.

2.3 Firmware Design Details

The firmware is the central software layer controlling the electric water blaster, developed in C using the STM32 HAL libraries for the STM32G070KBT6 microcontroller. It integrates hardware control, user input processing, display management, and safety monitoring through a structured state machine approach.

2.3.1 System Overview and State Management

At its core, the firmware leverages a hierarchical state machine to manage overall operation. The system transitions between different modes—such as Home, Settings, Refill, and Drain—based on real-time sensor data and user actions. For example, routines that capture rotary encoder inputs (via a function like read_encoder_delta()) and continuously monitor sensor signals (using methods such as monitor_status()) ensure that the state machine can quickly respond to changes and enforce safety protocols. This organization guarantees that safety checks remain active at all times, even during intensive tasks like water refilling.

2.3.2 User Interface and Display Management

The firmware's user interface is built around an SPI-connected OLED display paired with physical buttons and a rotary encoder. An internal variable keeps track of the current page (e.g., Home or various Settings screens), while dedicated routines format and update display content. For instance, a function like pad_center() is used to neatly format text, and an update routine (such as update_display_chunks()) ensures that only changed portions of the screen are refreshed—minimizing communication overhead and maintaining smooth, real-time updates.

2.3.3 Sensor Monitoring and Safety Management

To ensure safe operation, the firmware continuously monitors critical sensor data. It calls a function like read_pressure_psi() at regular intervals to convert analog signals into pressure readings. These readings are then evaluated to detect unsafe conditions such as over-pressure or leaks. When necessary, the system promptly triggers an emergency protocol (via, for example, a shutdown routine like enter_emergency_shutdown()), which safely disables the pump and solenoid valve while displaying an alert message.

2.3.4 Operational Modes: Firing, Refill, and Drain

The firmware supports multiple operational modes to match diverse user requirements:

Firing Modes: The device offers single shot, burst fire, and continuous stream options. The firmware regulates the opening and closing intervals of the solenoid valve to generate precise water bursts, providing immediate feedback to the user.

Water Refill Process: On a user command, the refill sequence initiates the pump and valve to gradually pressurize the water tank. A “final boost” phase refines the process based on ongoing sensor measurements, allowing user cancellation if safety thresholds are approached.

Tank Drain Mode: During the drain operation, the firmware opens the valve for a set duration while displaying a countdown, all the while monitoring sensor data to ensure safe progression or facilitate early termination if conditions change.

2.3.5 Hardware Initialization and Error Handling

Before the main operational loop begins, the firmware performs thorough hardware initialization. Dedicated routines (such as MX_ADC1_Init() and MX_GPIO_Init()) establish configurations for the ADC, GPIOs, and other peripherals, ensuring that actuators like the pump and solenoid valve are in safe default states at startup. Error_Handler() function ensures that any critical malfunction halts the system in a controlled manner, preventing unsafe scenarios and easing the troubleshooting process.

3. Design Verification

To validate the performance and reliability of the electric water blaster, a comprehensive set of subsystem level tests was carried out. While some tests originally planned during the early design stages were ultimately not applicable or provided little value to the final system, they provided valuable insights and served as a foundation for evaluating the design. The finalized tests were essential in verifying compliance with the high-level system requirements. The full

Requirement and Verification Table in included in the Appendix for reference. This section will discuss critical tests and some quantitative results.

The results for each requirement are presented in this section, along with the specific test methods used. Where applicable, quantitative data such as timing measurements, voltage readings, and distance measurements are provided.

3.1 Fill Timing

As discussed in Section 2.2.3, minimizing the water fill time is essential to ensuring high burst throughput and efficient operation. One of the initial system requirements specified a maximum fill time to 30 seconds per cycle. During the verification phase, the system we tested across multiple trials by filling the tank from 0% to 100% capacity, defined as reaching 80 psi, and timing the duration using a digital stopwatch. The average fill time was measured to be 18.6 seconds, significantly below the design threshold. This result confirms that the pump and fluid delivery system are capable of rapidly recharging the tank, contributing to sustained high performance operation. The detailed results are shown below in Table 1.

Table 1: Fill Time Across Trials

Trial	Fill Time (seconds)
1	19.0
2	18.6
3	18.5
4	18.3
5	18.7
6	18.5

The first trial took 19.0 seconds, slightly higher than others. This was due to the tank being completely empty at the start, which required the pump to overcome initial priming and pressure build-up time. Subsequent trials began from a partially primed state, resulting in more consistent and slightly faster fill times. This behavior reflects realistic usage conditions, where the system is rarely fully depressurized between bursts. Overall, the consistent sub-19 seconds fill times across later trials confirm that the design comfortably meets the 30-second fill time requirement with ample margin.

3.2 Shot Distance

One of our primary high-level requirements-and perhaps the most critical metric for evaluating the success of the design- was achieving sufficient shot distance. The initial specifications called for a maximum firing distance exceeding 20ft, with consistent performance above 15 ft. Through iterative testing and optimization, including the pressurized pump and evaluating multiple nozzle and valve configurations, the final design significantly outperformed these goals.

Using the final mechanical configuration, we conducted range testing across three different days to capture performance under varying wind conditions. We fired using a single fire mode with one second shot duration. Measurements were taken using a tape measure from the nozzle tip to the farthest visible point of water impact. The results, shown in Table 2, confirm that the blaster consistently exceeded the 20 ft requirement, even under light headwind conditions, with peak distances surpassing 34 ft when aided by tailwinds.

Table 2: Shot Distances Under Varying Wind Conditions

Trial	Wind Condition	Distance (ft)
1	No wind	25.5
2	No wind	23.8
3	No wind	26.2
4	Light wind (head)	20.3
5	Light wind (tail)	29.3
6	With wind (tail)	33.2
7	With wind(tail)	34.1

These results demonstrate not only compliance with the original specification but a specification far stronger than what was anticipated initially, validating the system's configuration and firing mechanisms in outdoor conditions.

3.3 Other Verifications

In addition to the primary metrics of fill time and shot distance, several other subsystem requirements were verified through observable confirmation. Many tests covering responsiveness, reliability, and mechanical frame did not require quantitative results; rather, they evaluated on a pass or fail basis.

3.3.1 Control Board and Display

The control board was required to respond to user inputs and sensor data within 100 ms, as well as drive the OLED display over SPI. During the development and demonstration phase, all inputs including the trigger, encoder, leak detection were processed and updated on the display immediately with no noticeable delay from the naked eyes. The final product consists of an OLED display without visible glitches or flickering. No data loss was observed using the SPI communication between the STM32 microcontroller and the OLED display throughout the entire process.

3.3.3 Inputs and Outputs

The trigger button was actuated hundreds of times during the development and demonstration phases of the product. The button was reliably able to trigger the solenoid valve every time; however, due to the fault of the mechanical enclosure (not adding enough spacer washer between the trigger board and the frame), the trigger button was jammed during the live demonstration. Following the structural modification, the trigger operated consistently without further issues. The step encoder provides smooth and deterministic feedback on adjusting different firing options as well as scrolling through the menu settings on the OLED display.

3.3.4 Mechanical Durability

The assembled frame was dropped from the lab bench in ECE 2070 during the development phase. There were no observable cracks or damage to the frame and the design remained functional, confirming the integrity of the mechanical frame.

4. Cost & Schedule

4.1 Costs

The cost of our project, including all materials spent on research and development comes to around $500. We ended up purchasing many different configurations of mechanical parts to be tested to ensure we were using the optimal configuration to meet our goals. Ultimately the unit cost per water blaster is much less as many of the purchased parts were not needed in the final design. The final BOM can be seen below in Table 3 below.

Table 3: Cost

Item	Quantity	Unit Price	Total
Pump	1	$15	$15
Solenoid Valve	1	$15	$12
Accumulator Tank	1	$25	$20
Used Battery & DCDC	1	$30	$20
Right Angle Fittings	5	$2	$10
Flexible Tubing	6 Inches	$1.50/ft	$.75
Pipe & Joints	1	$10	$10
OLED	1	$20	$20
PCB Set	1	$7.50	$7.50
Filament 1kg	1	$7.50	$7.50
Electrical Components	N/A	$15	$15
		Grand Total:	$137.75

$$\text{Labor Cost} = \$\,45 \times 25\,\frac{\text{hours}}{\text{week}} \times 6\text{ weeks} \times 3\text{ person} = \$\,16,200$$

$$\text{Total Cost} = \$\ 16,200 + \ \$\ 137.75 = \$\ 16,337.75$$

4.2 Schedule

Table 4: Schedule

Task	Assignee	Week
PCB Sent out	Clark	Week 8
Basic Firmware Setup	John, Jaejin	Week 9
CAD Review	Clark	Week 9
PCB Assembly Power	Jaejin	Week 10
PCB Assembly Control	Clark, John	Week 10
PCB Assembly MCU	Jaejin	Week 10
PCB Testing Power	Clark	Week 11
PCB Testing Control	John	Week 11
PCB Testing MCU	Jaejin, Clark	Week 11
CAD Enclosure	Clark	Week 12
Firmware OLED	John	Week 12
Firmware Buttons	Jaejin, John	Week 12
Print Enclosure	Clark	Week 12
Firmware Testing on Bench	Jaejin	Week 12
GUI Testing on Bench	Clark	Week 13
Final Integration	Clark, Jaejin, John	Week 13
Validation Efforts	Clark, Jaejin, John	Week 14
Fix and Debug	Clark, Jaejin, John	Week 14
Finalize Documentation	Clark, Jaejin, John	Week 15

5. Conclusion

Our project has demonstrated that a fully electric, high-pressure water blaster can effectively address the shortcomings of traditional water blasters, including inconsistent pressure, limited range, and manual operation—by integrating advanced electronic controls, real-time monitoring, and safety mechanisms. The final design meets the specifications, delivering controlled bursts over 20 feet, maintaining a portable structure, and providing rapid display updates for user feedback.

5.1 Accomplishments

The project successfully implemented a modular design with a central STM32G070KBT6–based control board that coordinates sensor inputs and manages key operations such as pressure regulation and burst actuation via MOSFET circuits. Key subsystems have been developed, including an I/O module featuring a step encoder for precise control, a durable and efficient battery system that extends runtime beyond multiple hours, and a sensor suite capable of initiating a system shutdown within 0.25 seconds upon detecting unsafe conditions. Extensive simulations and testing validate that the design fulfills its functional requirements and adheres to rigorous performance standards.

5.2 Uncertainties

Notwithstanding these successes, some uncertainties remain. For instance, the long-term durability of the 3D-printed frame and waterproof coatings under continuous use has yet to be fully validated through extended field testing. These areas will be the focus of subsequent testing phases to quantify potential deviations and ensure the system's reliability over its intended lifecycle.

5.3 Ethical considerations

In accordance with the IEEE Code of Ethics, the project has incorporated risk mitigation strategies to ensure user safety and product reliability. The design includes safety interlocks and rapid shutdown protocols to protect against hazardous conditions such as over-pressurization and internal water exposure. Ethical responsibilities have been addressed by conducting the project with a focus on environmental sustainability and responsible engineering practice. Furthermore, the potential societal impact ranging from increased user safety in recreational products to economic benefits derived from innovative manufacturing practices—have been carefully considered and will guide future improvements.

5.4 Future work

Looking ahead, further refinements are envisaged to enhance the system's scalability and user appeal. One notable area for future work is the development of a "Water Blaster Lite", a smaller, pistol-sized version of the current design that retains the core functionalities in a more portable, lightweight form factor. This alternative would target users to desire a more compact device without compromising performance, potentially opening new market segments. Additional design alternatives, such as the refinement of the sensor array with improved sensitivity or the integration of wireless connectivity for remote monitoring, are also worthy of exploration.

References

[1] "Bernoulli's Equation." *Princeton University*, The Trustees of Princeton University, www.princeton.edu/~asmits/Bicycle_web/Bernoulli.html. Accessed 6 Mar. 2025.

[2] "Elastic Pressure Water Blaster Technology .:" Elastic Pressure Water Blaster Technology :: :: iSoaker.Com, www.isoaker.com/Tech/elastic-pressure-water-blaster-technology.php. Accessed 6 Mar. 2025.

[3] "How to Manufacture Carbon Fiber Parts." Formlabs, formlabs.com/blog/composite-materials-carbon-fiber-layup/. Accessed 6 Mar. 2025.

[4] Lam, L. (n.d.). The continuous refill, short-burst, hand- powered water toy. https://dspace.mit.edu/bitstream/handle/1721.1/59943/676918672-MIT.pdf?sequence=2

[5] Rathi, S. (2024, July 11). A critical review of leakage detection strategies including pressure and water quality sensor placement in water distribution systems – sole and integrated approaches for leakage and contamination intrusion. 2nd International Join Conference on Water Distribution System Analysis (WDSA) & Computing and Control in the Water Industry (CCWI). https://riunet.upv.es/handle/10251/205921

Appendix A Requirement and Verification Table

Table 5: Requirement and Verification

Subsystem	Requirement	Verification
Control Board	1. The control board must process inputs and update outputs within 100 ms of receiving sensor data. 2. The control board must activate the pump and solenoid valve correctly 100% of the time triggered. 3. The control board must correctly send data to the SPI display without noticeable glitches or missing updates.	1. Observe system behavior with button presses and sensor inputs to ensure there is no noticeable lag. 2. Run 50 activation cycles and verify that all commands result in the expected action. 3. Operate the system for 5 minutes, ensuring that display information updates smoothly without flickering or freezing.
Inputs & Outputs	1. The trigger button must activate the water blaster every time it is pressed, with no missed input. 2. The potentiometer must allow smooth control over firing power with noticeable differences between minimum and maximum settings.	1. Press the button 50 times and confirm that every press result in activation of some sort 2. Adjust the potentiometer and confirm that different power levels produce visibly different water blasts, the water quantity can be measured using a beaker to ensure the quantity of water fired has increased.
Battery	1. The battery must power the system for at least 30 minutes of continuous firing operation. 2. The battery system must provide a stable 12 V (1 V margin of error) output.	1. Fully charge the battery, operate the system continuously, and record runtime on a stopwatch. 2. Measure voltage before and after 10 minutes of operation to ensure no significant drop.
Frame & Shell	1. The enclosure must prevent leaks when sprayed with water from all angles for 5 minutes.	1. Spray tests the assembled device and inspect for internal moister. Ensure a maximum of 1.5 ml of water ingress.

	2. The shell must not crack or deform if dropped from 1 meter onto grass or pavement.	2. Drop test from 1 meter height and confirm no functional damage.
Sensor Array	1. The system must accurately indicate the capacity of the tank within 25%. 2. The system must alert the user within 10 seconds of detecting internal water leakage.	1. Fill and empty the tank to these levels and confirm the display updates correctly with the indicated water level after water in/water out is measured. 2. Pour 100 ml of water into the system, hold the water blaster vertically as if in firing position. The system should shut down within 10 seconds of the blaster being held vertically or never power on to begin with. Time with a stopwatch to ensure timely power down sequence.
Pump, Solenoid Valve, and Tank	1. The pump must fill the tank from empty within 30 seconds. 2. The valve must open and close within 100 ms of being triggered. 3. The blaster must shoot water at least 15 ft when fully pressurized. For at least one running configuration, a maximum shot distance of 20 ft should be achieved.	1. Time how long it takes to fill the tank and ensure it meets the requirement using a stopwatch. Ensure the tank is completely empty prior to this test. 2. Fire the blaster and use a stopwatch to tie the delay between button press and water visibly leaving the blaster. It should be within 100 ms. 3. Fire the blaster and measure the distance reached. Tune to achieve 5 powerful bursts and record the distance to ensure 15 ft is recorded. Then refill and tun the settings for the maximum power and fire one shot to ensure 20 ft is recorded.