ECE 445 / ME 470

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

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# Robotic T-shirt Launching System Mark III

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# 1 Introduction

## 1.1 Problem

The Mark II T-shirt launcher poses significant challenges due to its bulky and heavy design, making it difficult to transport and operate effectively. Its instability when carried by hand will also increases the risk of accidents. Consequently, it is imperative to implement measures aimed at minimizing its dimensions and weight to enhance portability and ensure safer handling.

Additionally, considering its predominant deployment in expansive stadiums, there exists a critical imperative to broaden the distribution of T-shirts to a larger audience. Therefore, enhancing the launcher's capacity for spare ammunition and refining both reloading and firing procedures are paramount to facilitate seamless operation in such settings.

Regrettably, the current version of the MARK II model faces a prolonged reloading process, significantly hindering the swift distribution of T-shirts. This issue requires immediate attention. During the system's design phase, it is crucial to anticipate and address any potential uncertainties that could disrupt its functionality. A thorough risk assessment is necessary to identify possible problems and evaluate their potential impact. For instance, issues such as air pressure leaks in the chamber or the risk of explosions leading to safety concerns must be carefully considered.

Furthermore, we must remain cognizant of the potential hazards posed by the high velocity of the T-shirt launcher, which could endanger spectators. To mitigate these risks effectively, we can integrate supplementary safety features, establish backup systems, and enforce stringent testing protocols. These measures are essential to guarantee seamless operations and prevent any untoward accidents.

## 1.2 Solution

While preserving the achievements of ROBOTIC's T-SHIRT launcher, the MARK II, our team will address its key shortcomings. For example, the MARK II was too large and heavy for its function; we will reduce the overall weight of the launcher, where the air chamber can be reduced in size, by switching to a larger volume bottle to inflate the chamber and reduce the weight in the user's hand. Secondly, the design of the launcher can be simplified to reduce weight. To address the slow firing rate of the MARK II, we will abandon the revolver loading method and adopt a machine-gun style of loading, with top-down loading to enable continuous firing of the launcher, and use a quick exhaust valve to provide sufficient air pressure to increase the efficiency of firing the rounds. At the same time the use of fast filling valve, and high pressure cylinders for the transmitter gas chamber filling energy, to realize the rapid filling of gasIn addition, in terms of system automation, we will strive to achieve the unfinished business of MARK II by using a new control system that ensures smooth operation and allows for the controlled release of gas to ensure the safety of the experiment. An automated system to control the gimbal, including a computer vision module that automatically recognizes spectator behavior for fully automated firing. All in all, we are delivering a new version of MARK III that is more reliable and efficient.

## 1.3 Visual Aid


Figure 1: Manual Mode

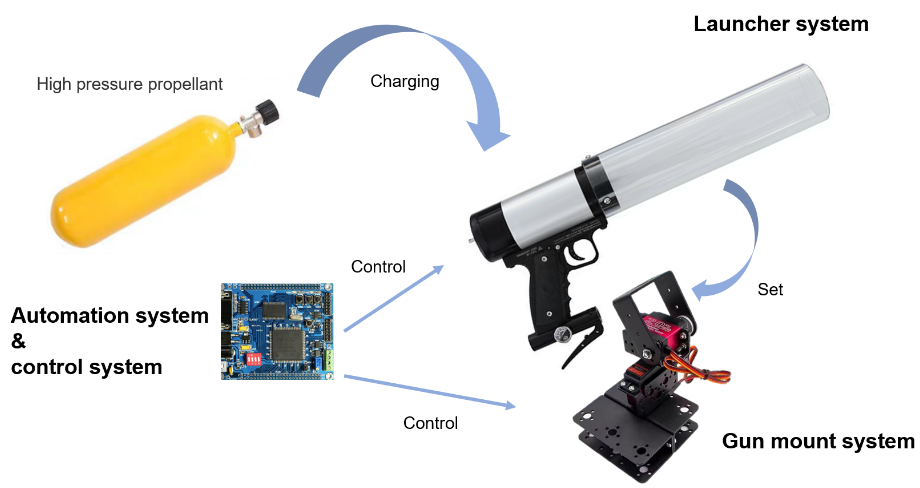



Figure 2: Automatic Mode

### 1.4 High-level requirements list

1. Pressurized Chamber Pressure Range: The pressurized chamber should be capable of maintaining a safe operating pressure ranging from 1 atmosphere to 20 atmospheres. The system should allow for precise adjustment of pressure levels within this range to accommodate different launching scenarios.

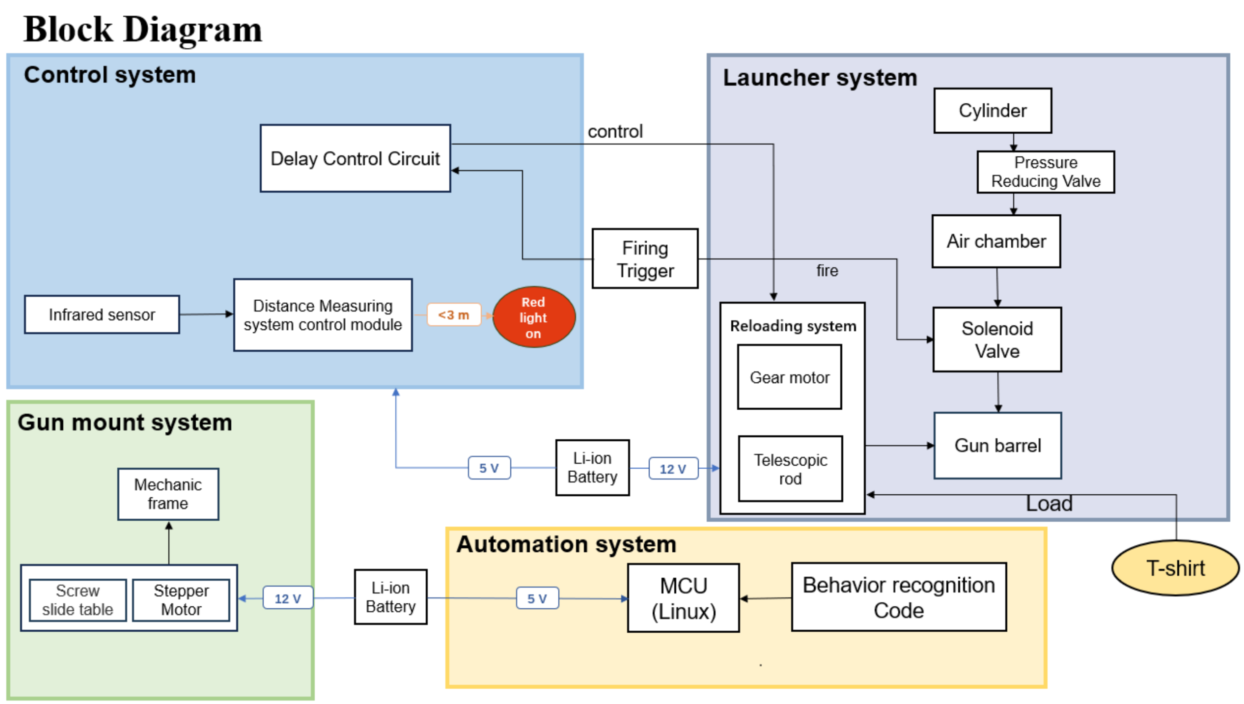
2. Maximum Projectile Range: The T-shirt launcher must be capable of propelling T-shirts to a maximum distance of 80 meters.This range ensures effective distribution of T-shirts within large sports arenas or stadiums.

3. Gun Mount System Adjustability: The gun mount system should provide one degrees of freedom for precise targeting.

Horizontal Rotation Angle: The system should be able to rotate horizontally through a full 360 degrees.

# 2 Design

## 2.1 Block Diagram




## 2.2 Subsystem Overview

### 2.2.1 Launcher system

The launcher system consists of two cylinders, an inlet valve, an exhaust valve, a firing trigger, an inlet valve and a barometer. One of the cylinders is used as a gas chamber to store compressed air so that there is sufficient air pressure to fire the bullet when the gas is released. The other cylinder is used to fill the gas chamber with gas in time for rapid firing. The inlet and exhaust valves are used for rapid inflation and exhaust respectively. The trigger is the on/off switch for the gas valve. The barometer is used to detect the gas pressure inside the gas chamber and to adjust the range of the bullet according to the gas pressure. All components are connected together to form a firing system capable of rapid firing. The launch system is directly connected to the gun mount system for 360 degree launching. The control system and automation system allows for an electronically controlled trigger and remote manipulation.

### 2.2.2 Gun mount system

The gun mount system plays a pivotal role in adjusting the firing angle, ensuring firing accuracy and stability during the operation of the t - launcher. It can be thought of as a targeting head with one degrees of freedom, incorporating advanced components such as stepper motors, precision reduction gear sets and durable aluminum frame construction. Together, these components provide the system with the degrees of freedom that can be easily controlled and adjusted for precise horizontal rotation angles. To enhance functionality and reliability, the frame system is constructed with lightweight yet strong materials. The aluminum frame construction provides an excellent strength-to-weight ratio, ensuring structural integrity while minimizing the overall weight of the system. In addition, the use of a reduction gear set ensures that the system has sufficient torque to maintain smooth control and movement of the frame while effectively preventing sudden jerks or wobbles, thereby improving aiming accuracy.

### 2.2.3 Control System

The function of the control system is to control components such as the solenoid valve of the launcher system to achieve the functions of the launcher through the trigger. The control system also acts as an interface between the launcher system and the automation system, enabling the launcher to connect to the automation system. In addition, the control system should be equipped with a sensor to measure the distance of the launcher's front end from the nearest object and light a red LED to alert the operator when the distance is too close, which can allow the operator to avoid some dangerous operations.

The control system uses a PCB board to achieve these functions. A delay circuit should be included to correctly implement the launcher's combination of features. An infrared sensor measures the distance of the object in front of the launcher and transmits it to the circuit of the PCB board to light the LED on it. A trigger emits a specific electrical signal that causes the launcher to fire. We need some chips to perform specific functions to achieve these circuit designs.

### 2.2.4 Automation System

For the case of use on the gun mount, we want the launcher to be able to fire automatically. Therefore, the system should have a suitable function to automatically adjust the direction and force of the launch according to the situation. In addition, for safety reasons, the system will include a computer vision module to conduct spectator behaviour recognition to avoid potential accidents, such as stampedes. The Automation System is responsible for implementing the function of behaviour recognition, which can recognize the abnormal behavior of the audience and avoid firing the T-shirt into these areas to avoid the occurrence of dangerous incidents.

The Automation System needs to control the movement of the gun mount system and the launch function of the launcher. These functions are realized through the MCU output electrical signals and control the voltage of the corresponding parts of the gun mount and launcher.

In addition, the Automation System also needs algorithms to implement the automatic launch function. The Automation System algorithm code will be installed on an MCU with a Linux system installed. On the subsystem, a camera takes image information from the audience and transmits it to the MCU. Algorithms in the MCU will process the image information from the camera to identify crowd behavior in the audience, such as stillness, cheering, commotion, etc. The recognition of these images will be used to decide where the Automation System controls the launcher launch.

## 2.3 Subsystem Requirements

### 2.3.1 Launcher system

Gas chamber capable of withstanding high air pressure and capable of storing a certain amount of gas for continuous launching of at least 2 T-shirts.

The two valves need to be able to inflate and deflate quickly to realize the rapid launching of bullets and shorter launching intervals.

The capacity of the gas cylinder for inflation should be larger than that of the gas chamber, which is used to inflate the gas chamber quickly, so that the launcher system has enough gas for launching.

The air tightness of the launcher system needs to be ensured to prevent air leakage and the connections of the various components need to be able to withstand high air pressure.

### 2.3.2 Gun mount system

Ability to quickly and accurately help the launcher reach the set position by rotating it horizontally in less than 10 seconds.

Aluminum frame can stably withstand at least 80N pressure.

Stepper motors can receive electrical signals transmitted from the control system in real time and realize accurate 0-360 degree rotation angle adjustment.

#### 2.3.3 Control System

The control system is implemented by a PCB board equipped with a circuit. In order for the control system to work properly, we need to provide a voltage of +5 V to the circuit. The voltage range should be between + 4.5V to + 5.5V, in this voltage range, the circuit and its required chip can work normally. In addition, for unpackaged PCB boards, we need to do waterproof treatment, or avoid working in an environment with water, such as rainy days. Temperatures above 100 degrees Celsius should also be avoided.

#### 2.3.4 Automation System

In order to implement behavior recognition capabilities, we may need a powerful piece of hardware such as a Raspberry PI or Jetson Nano. This means that the MCU must have at least 0.1 TFLOPS of computing power. In order to run the corresponding algorithm code, the MCU should have more than 4GB of RAM and more than 16GB of ROM.

The behavior recognition that carries the code runs on the MCU of the control system, so we need to provide a voltage that meets the MCU. The MCU requires a + 5v power supply. In the worst case, the voltage should be between + 4.5V and + 5.5V to ensure its normal operation.

The cameras required by the automation system cannot operate in excessively humid environments to ensure the clarity of the images. Like the control system, the automation system should avoid working in an environment with water, such as rainy days.

### 2.4 Tolerance Analysis

Barometric pressure poses a risk to the successful completion of the project. Too much air pressure can cause safety hazards, while too little air pressure, such as low air pressure due to poor airtightness, can result in the inability to fire bullets. Therefore, we will perform tolerance analysis, mathematical analysis, and simulate the effect of different air pressure on the launcher.

Assuming the T-shirt is fired at a 45-degree angle.

$$W_1 = 5/2(P_1V_1 - P_2V_2)$$

$$W_2 = P_aV$$

$$L = 2(W_1 - W_2)/mg$$

W1 is the work done by the compressed gas, W2 is the work done by the atmospheric pressure, and L is the displacement of the T-shirt, when L is reasonable, it means that the system is well airtight.

# 3 Ethics and Safety

## 3.1 Ethics

We looked up the relevant laws, and under the Gun Control Act of 1968, a projectile fired with compressed gas does not constitute a firearm. Currently, the law is enforced by the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) under the United States' Department of Justice.[1]

However, Illinois excludes non-powder guns of.18 caliber or smaller and non-powder guns with muzzle velocities of less than 700 feet per second from the definition of firearms. Apparently, the muzzle speed of our launcher T-shirt is less than 700 feet per second. Therefore, under Illinois law, a T-shirt Launching System is not a firearm. However, there are areas that define all non-powder guns as firearms and therefore may consider our T-shirt Launching System to be firearms, such as New Jersey and Rhode Island. Therefore, we need to pay attention to the design of the appearance of the Launching System of a T-shirt to avoid its appearance being similar to that of a real gun.[2]

However, in conclusion, according to relevant laws, we can safely use T-shirt Launching System on UIUC campus without worrying about legal risks.

## 3.2 Safety

The dangers of using pressure vessels are well known. Therefore, in order to avoid dangers during manufacturing and use, we and all team members conducted safety training, discussed several dangerous situations we may encounter and the corresponding handling methods. According to the IEEE Code of Ethics, we will also pay attention to and remind the potential risks of the products we design, and disclose all possible dangers in a timely manner.[3] In addition, pressure vessel maintenance and pressure detection will also be part of the design.

# References


[1] F. The Bureau of Alcohol Tobacco and Explosives. “”Does ATF have a list of specific “braces” that qualify in making a pistol into a short-barreled rifle (SBR)?”” (2023), [Online]. Available: https://www.atf.gov/firearms/qa/does-atf-have-list-specific-%E2%80%9Cbraces%E2%80%9D-qualify-making-pistol-short-barreled-rifle-sbr (visited on 03/06/2024).

[2] G. L. Center. “”Non-powder Toy Guns”.” (2020), [Online]. Available: https://giffords.org/lawcenter/gun-laws/policy-areas/child-consumer-safety/non-powder-toy-guns/ (visited on 03/06/2023).

[3] IEEE. “”IEEE Code of Ethics”.” (2016), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 02/08/2020).