ECE 445 / ME 470

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

Robotic T-shirt Launching System Mark III

Team #39

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1 Introduction

1.1 Problem

The old Mark II T-shirt launcher is just too bulky and heavy to lug around easily. It's a pain for transport and using it is a hassle. Plus, if you're carrying it by hand, it could be risky because it's not stable enough. We really got to make it smaller and lighter so it's more portable and safer to handle. Moreover, considering the intended deployment in large stadiums, there's a pressing need to distribute T-shirts to a larger audience. Consequently, we must enhance the T-shirt launcher's capacity for spare ammunition and streamline the reloading and firing processes. Regrettably, the MARK II model currently entails a prolonged reloading cycle, which significantly impedes efficient T-shirt distribution. This issue demands immediate attention and resolution. When we're designing the system, it's crucial to anticipate any uncertainties that could throw a wrench in the works. We need to conduct a comprehensive risk assessment to pinpoint potential pitfalls and gauge their severity. For instance, issues like air pressure leaks in the chamber or the risk of explosions leading to safety incidents must be carefully considered. Moreover, we need to be mindful of the possibility that the T-shirt launcher's high velocity might pose a danger to spectators. To mitigate these risks, we can incorporate additional safety features, implement backup systems, and conduct rigorous testing protocols to ensure smooth operations and prevent 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. In 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

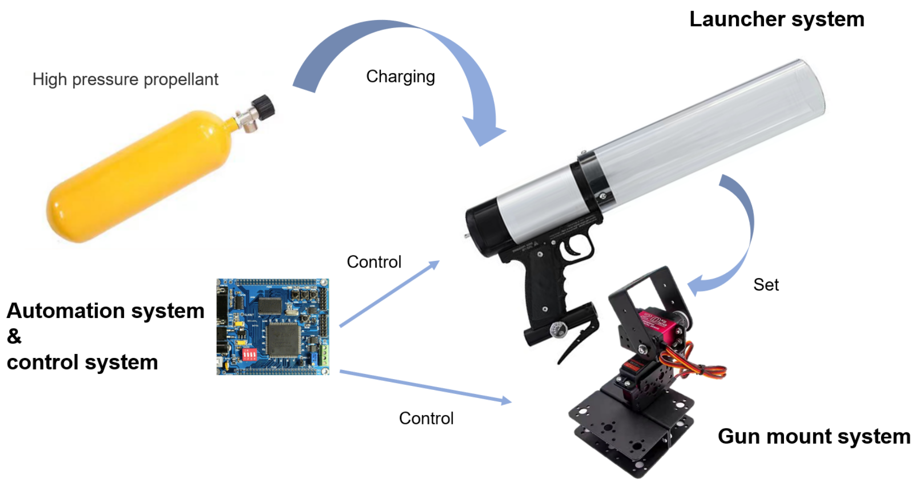


Figure 2: Automatic Mode

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.

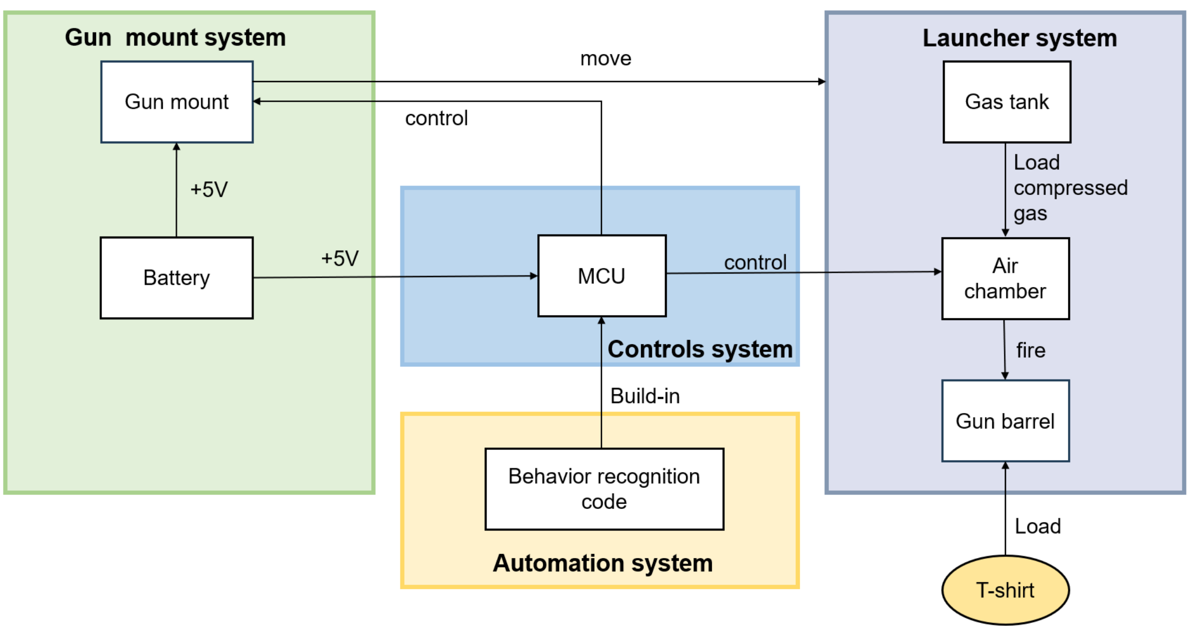
3. Gun Mount System Adjustability: The gun mount system should provide two degrees of freedom for precise targeting.

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

Pitch Angle: The system should be capable of adjusting the pitch angle from 0 to 60 degrees, allowing for versatile targeting capabilities.

2 Design

2.1 Block Diagram



2.2 Subsystem Overview

2.2.1 Launcher system

The launch system consists of two gas cylinders, an intake valve, an exhaust valve, a launch trigger, an intake trigger and a barometer. One of the cylinders is used as a gas cylinder as a gas chamber to store compressed air so that it has enough air pressure to fire the bullet when releasing the gas. The other air cylinder is used to fill the air chamber with gas in time for a quick burst of shots. The inlet and exhaust valves are used to fill the gas quickly and discharge the gas respectively. The trigger serves as the on/off switch for the gas valve. The barometer is used to detect the gas pressure in the gas chamber and adjust the range of the bullet according to the gas pressure. All the components are connected together to form a launcher system capable of rapid-fire bursts.

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 two 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 two degrees of freedom that can be easily controlled and adjusted for precise pitch and 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 control system is responsible for managing the various components of the system, including the electromagnetic valves that control the airflow, the actuator controllers for the loading mechanism, and the gun mount controller for targeting.

All in all, The control system sends instructions through the MCU to all the other parts so that they can complete their functions.

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.

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 10 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

In order to enable the gun mount system to fulfill the function of fast and precise positioning of the launcher in three-dimensional space. We need the aluminum frame, the stepper motor system and the reduction gear system to work perfectly together. Therefore, we need a precision-machined reduction gear set, an advanced stepper motor system that can accurately adjust the angle of rotation according to the electrical control signal, and a well-designed and assembled aluminum frame.

2.3.3 Control System

At the heart of the control system is an MCU that requires a voltage of +5V, with a worst-case voltage range of +4.5V to +5.5V and a maximum operating current of 3A.

2.3.4 Automation System

In order to implement behaviour recognition functions, 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 0.1TFLOPS of computing power.

Since the code carrying behaviour recognition runs on the MCU of the control system, the automation system has the same requirements as the control system in electrical terms. The MCU require a +5V power supply. In the worst case, the voltage should be between +4.5V and +5.5V.

2.4 Tolerance Analysis

The weight of the transmitter poses a risk to the successful completion of the project. Our project required a two-degree-of-freedom gimbal-controlled launcher that could fire bullets at multiple angles and ranges. Excessive weight of the launcher would make it impossible for the gimbal to function properly. In order to ensure that the gimbal works properly, we need to perform a tolerance analysis to determine the maximum weight. Another risk to the success of the project is air pressure. The amount of air pressure. Too much air pressure will create a safety hazard, while too little air pressure, such as low air pressure due to poor air tightness, will result in the inability to fire bullets. For this reason, we will perform a tolerance analysis, a finite element analysis, to simulate the effects of different air pressures on the launcher.

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).