Zhejiang University/University of Illinois Urbana-Champaign Institute

Senior Design Individual Report

MECHANICAL DESIGN OF ROBOTIC T-SHIRT LAUNCHER

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Abstract

The T-Shirt Launcher Mark II is an innovative device designed to efficiently fire packed T-shirts into crowds. Building upon the success of the Mark I, this upgraded version introduces significant enhancements that allow for continuous launching, improved launching efficiency, change in launching direction, and auto aiming capabilities.

With its two degrees of freedom, the Mark II provides precise control over the launch direction. It offers two distinct modes of operation: manual and auto. In the manual mode, users can control the launcher using a joystick, granting them direct command over the firing process. On the other hand, the auto mode utilizes a program that interacts with a phone camera, enabling automatic aiming functionality. This advanced feature ensures accurate targeting and enhances the overall user experience.

Key words: Launcher, Gas control, Automation

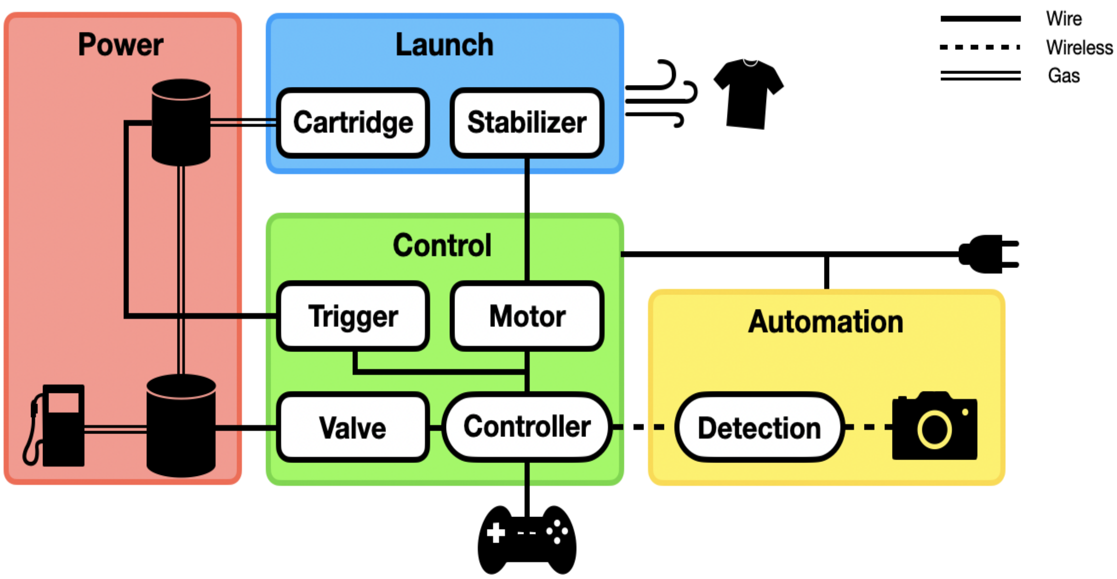
Contents

1. Introduction

Our T-shirt launcher system is an advanced and interconnected network of subsystems meticulously engineered to deliver a powerful and dependable weapon system. At the heart of this system lies the main gas cylinder, storing high-pressure gas that provides the required energy and force to propel the T-shirt. To ensure operational safety, the gas pressure is continuously monitored by a gas-pressure sensor.

The release of gas is precisely controlled by an electromagnetic valve, which responds to signals from the control system. This vital component allows us to regulate the timing and quantity of gas released, enabling accurate targeting of the T-shirt. Constant performance is maintained using a gas buffer space, which stabilizes pressure levels. Equipped with a constant pressure valve, this buffer space ensures that the pressure remains within safe limits.

Efficient loading of T-shirts is facilitated by an ammunition belt and an auto-loading mechanism. This automated feature eliminates the need for manual reloading, enabling the system to seamlessly launch multiple T-shirts. To enhance stability during firing, a bottom stabilizer is incorporated, ensuring the launcher remains steady, thereby improving accuracy and reliability. The system exemplifies an advanced solution for crowd control scenarios, boasting a robust design and seamless functionality.

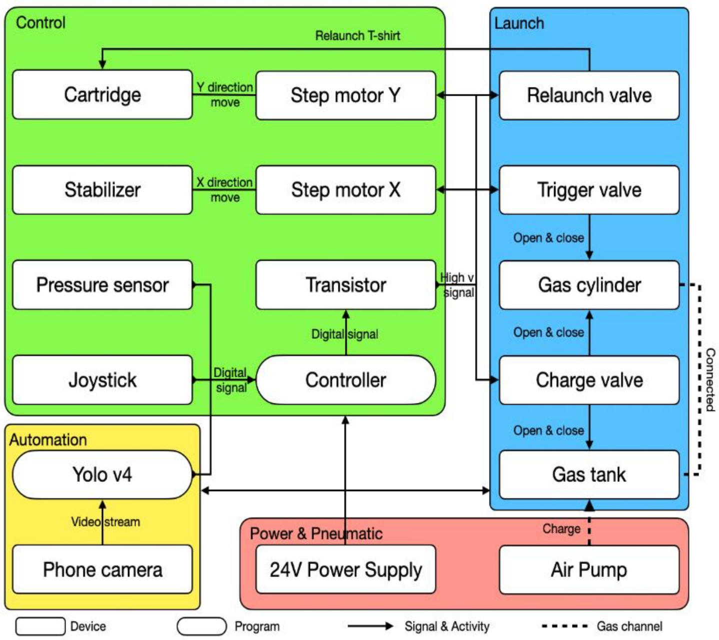


2 Design

Our T-shirt launcher employs a block diagram that illustrates the interconnected components working harmoniously to create a powerful and dependable weapon system.

2.1 Block diagram

The Ammunition Belt and Auto Loading system collaborate seamlessly to ensure a continuous supply of ammunition to the launcher. The Electromagnetic Valve plays a crucial role in regulating airflow and maintaining precise control over the launching pressure.



Providing the primary power source for the system, the Gas Cylinder block stores high-pressure gas. The Stabilizer component guarantees stability during the launch process, enhancing accuracy and effectiveness.

The core of the control system is the Arduino-based Controller Program, which orchestrates the functionality of various system components such as the Electromagnetic Valve, Step Motor, and Automation System. User interaction is facilitated by the Joystick, enabling manual control over the launching direction and switch.

Automated target detection and tracking are handled by the Camera, facilitating efficient engagement with moving targets. Lastly, the Motor controls the launching direction and switch, ensuring precise and effective targeting.

2.2 Power & Pneumatic System

The Power & Pneumatic system consists of essential components, including an air pump, air cylinder, quick exhaust valve, and connecting elements. These components collaborate to provide the necessary power and pressure for launching the T-shirt.

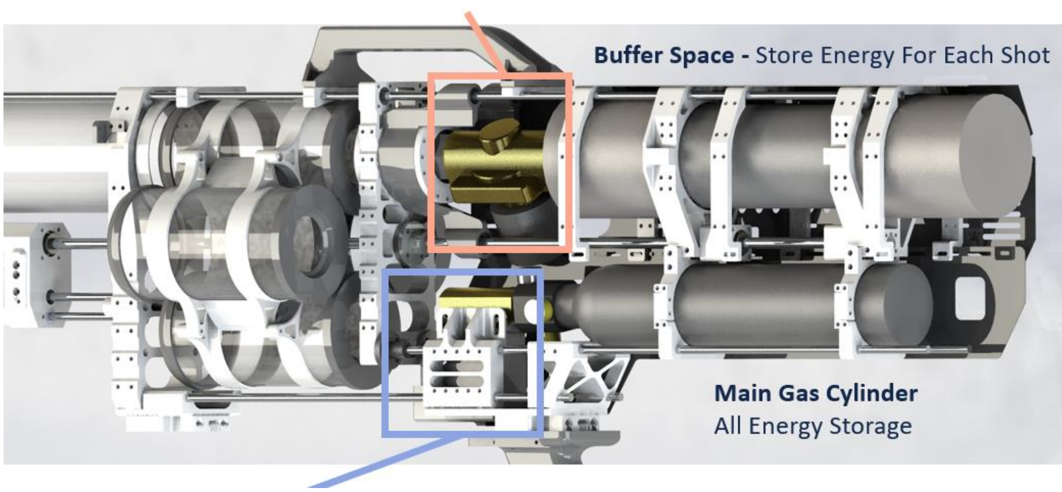
The air pump plays a vital role in recharging the air cylinder, which serves as a reservoir for storing the compressed air required for launching. Meanwhile, the quick exhaust valve enables a rapid release of the compressed air, propelling the T-shirt at high speed. Seamless integration of the components is ensured through the connecting elements, resulting in a robust and comprehensive power system.

2.2.1 The mobile power system

The mobile power system includes a buffer space to support the energy for each shot and a main gas cylinder to contain all energy for manual mode. The buffer space has 1.07-liter space and can suffer 1.0 MPa pressure maximum. The main gas cylinder has 0.5-liter space and can suffer 30MPa pressure safely. Assume ideal gas, the main gas cylinder can support 15 shots if the launching pressure is set to 0.7 MPa.

A Resupply valve is directly connected to main gas cylinder. It can suffer 6 MPa maximum and is used to recharge the buffer space by controlling the opening of the main gas cylinder. A launching valve with 25mm effective diameter of flow is directed connected to the buffer space and controls the energy release from the buffer space to the nozzle. All valves are driven by 24 volts power.

To ensure safety, a safety valve is connected to the buffer space, next to the physical pressure meter. The valve will open automatically at 1.0 MPa and close at 0.9 MPa to release gas. Also, a trigger is connected in parallel with the launching valve. If the seal system is not locked in position, the trigger will not be activated, and the launching valve will not be able to open.

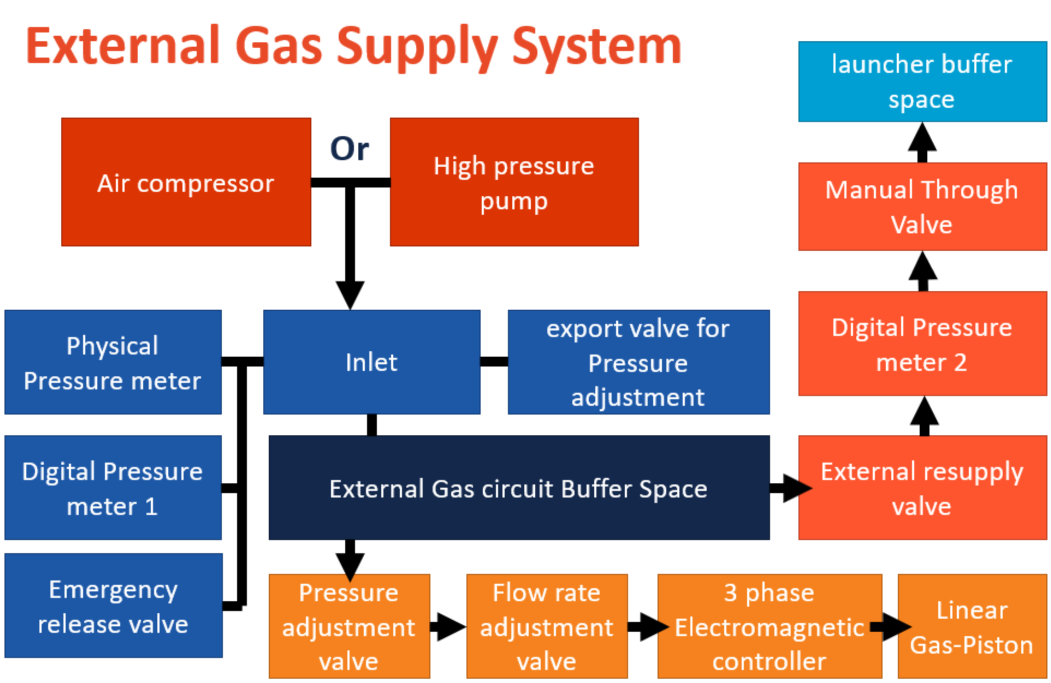


2.2.2 The External Gas Supply System.

The external gas system is designed to supply large amounts of continuous power for full-auto mode. It can receive power supply from both air compressor and high-pressure pump. An external gas circuit buffer space is designed to bring space for adjusting the pressure. The pressure inside of the external gas circuit buffer space is adjusted by an export valve and monitored by a physical pressure meter and a digital pressure meter. An emergency release valve is also assembled to support emergency release. This manually activated safety valve cannot be closed until the pressure inside of the system reaches zero. An automatically activated safety valve is also attached. The working pressure for this valve is 1.35 MPa.

The external gas circuit buffer space will provide gas to the launching buffer space through the external resupply valve and the output pressure will be monitored by the external digital pressure meter. A manually controlled through valve is connected in serial with the launching buffer space. It can cut off the power supply in full-auto mode and function as the emergency release valve in manual mode.

Also, the external gas circuit buffer space will support the linear piston to drive the loading mechanism in full-auto mode. This piston is controlled by a 3-phase electromagnetic valve and the speed of the piston is controlled by 3 individual flowrate adjustment valves.



2.3 Mobile Launch System

The Mobile Launch System, as depicted in the block diagram, consists of an air cylinder and a pressure release valve, both of which are essential components for the T-shirt launcher.

The air cylinder serves as a storage unit for the compressed air necessary to launch the T-shirt. It plays a vital role in providing the power required for the launch process. To ensure safe reloading, the pressure release valve allows for the venting of the air cylinder. This feature enables the system to be reloaded without the risk of excessive pressure buildup.

Together, these pneumatic components form a critical part of the Launch System, enabling the T-shirt launcher to harness the necessary power for effective launching.

2.3.1 The Steel Rod – Plastic combination frame design

It is difficult to do the structure design of the device. Since the size of the rolled T-shirt has at least 75 mm diameter, this value is like the size of a lightweight tank canon. This decides that the overall dimension of the device should be relatively large. However, the device should be held by hand, so the weight should be under 10 kilograms. The main gas cylinder is made of thick aluminum and will take 3 kilograms weight, and the buffer space will take another 3 kilograms. Considering the weight of the barrel and the weight of the shells and T-shirts in the magazine, not much weight is left for the structure.

The structure also needs to be able to absorb impact due to the reaction force generated while launching, it needs to be robust enough. Considering that the easiest way for me to do prototype fabrication is to use 3D printing and basic machining tools, so I decide to use steel rods as the skeleton and use 3D printed parts with PLA and ABS materials as other structural components like connectors.

Such a design is light enough but cannot avoid deformation. However, it is acceptable since elastic deformation can help absorb compact and protect the structure.

2.3.2 Spring and Rail System

To make the device easy to manipulate and easy to be activated by electronic actuators, it is good to use pure mechanical design to achieve more functions automatically. Therefore, I designed a set of revolver structures which served by a group of complex spring systems. This system uses a cylinder shape rail and a pair of spring-pins to achieve the rotation of revolver driven by linear piston. The system can automatically stay at neutral position. If the piston is pulled backward, the revolver will be driven to rotate, and the piston will be pushed back to neutral through the force of a long spring. When pushing the piston forward, the revolver and the button inlet nozzle will be individually driven forward and finally lock the shell into seal system through a special set of two-step spring system. Specially, a set of small spring systems is designed to make up the dimension difference between each shell. The piston will also be automatically pushed back to neutral position through the group two-step spring system after unlocking from sealed statue.

2.3.3 Shell Connector

A specially designed shell connector supports both drum and belt mode. The connectors include two ears which supports screw as rotate shaft. Four connectors connected as a loop will form a drum. An unlimited number of connectors will form an ammunition belt.

2.3.4 Bearing System for Center Shaft

Since structure deformation cannot be avoided, many groups of special bearing system for center shaft are inserted, ensure function during and after structure deformation. The bearing system is a combination of linear bearing and roll-bearings. Therefore, it can both support the linear movement and the rotation of the center shaft in a small size and light weight.

2.3.5 Rubber seal system

A group of well-designed rubber seal system with perfect geometry prevent leak from joints between shell with the barrel and the nozzle. The design of seal system has considered the fluid pressure principle, achieve self-lock when there is pressure inside of the shell and help extend the effective length of the barrel.

2.3.6 Human-Centered Design for Interaction Parts

The geometry of handle and piston fits good with our hands and can provide good friction for manipulation. The position of triggers and pressure meters are easy to access for better use efficiency.

2.4 Control System

The Control System plays a crucial role in efficiently managing the components of the system. It encompasses a gimbal controller, actuator controllers, electromagnetic valves, and a microcontroller like Arduino.The gimbal controller enables precise aiming of the launcher, while the actuator controllers handle the loading mechanism, ensuring smooth and accurate operation. The electromagnetic valves serve to regulate airflow, controlling the release of compressed air for launching.

As the central control unit, the microcontroller orchestrates the synchronization of all components, ensuring their seamless operation and coordination. The system's secure design incorporates essential features to enhance its functionality. These include a one-way valve that facilitates the flow of compressed air in a single direction, preventing any undesired airflow into the air pump. Airtightness within the system is maintained to prevent air leakage and ensure consistent pressure levels. Pressure sensors are implemented to monitor the air pressure, ensuring it remains within safe operating limits.

Together, these elements create a robust and reliable control system for the T-shirt launcher, guaranteeing efficient management and safe operation.

2.5 Automation System

The Automation System encompasses key components, including a camera, aim assist, rangefinder, and detection software, all working together to enhance the targeting capabilities of the T-shirt launcher. The camera plays a pivotal role by providing visual feedback, enabling accurate targeting and lock-on capabilities. This visual input assists in aligning the launcher effectively, ensuring precise aim. The aim assist system aids the user in aligning the launcher by providing additional guidance and assistance, further enhancing targeting accuracy.

The rangefinder measures the distance between the user and the target, providing crucial information for precise targeting, allowing the user to adjust their aim accordingly.

The detection software integrates advanced functionalities such as automatic firing, angle adjustment, and target recognition lock. These features significantly enhance the user's ability to engage targets, improving accuracy and efficiency.

3. Design Verification

3.1 Design Verification of Mechanical Launching system

3.1.1 Verification Process of Gas Circuit

3.1.1.1 First version with 12 mm effective diameter for flow.

This version did not use the current launching valve. The effective diameter for flow rate of this version was 12mm. The positive side of such a design is that the shape of the gas circuit for this version is more flexible.

The performance of this version is not satisfying. It can reach 20 meters shot distance with over 1.5 MPa launching pressure and 45 degrees tilt up angle. It is not acceptable since the maximum pressure of the buffer space should not exceed 1.0 MPa.

3.1.1.2 Experiment about the factor that influences the releasing power of gas circuit.

To improve this system to make it more powerful, I tested the influence of various factors that might affect the releasing power.

The first is the bending of the gas circuit. I use many 90-degrees connector to form a short tunnel with lots of bending. The influence is not obvious.

The second factor is the effective diameter of the flow rate. I changed different size of the narrow zone for the releasing tunnel and found this has huge influence on the releasing power. Therefore, I largely increased the launching valve size to 25 mm diameter. According to calculation, the cross-section area of the releasing tunnel increases over four times, and after testing, the releasing power does increase four times.

3.1.1.3 The tests of gas circuit connection leaking rate and the experiments to find the best connection solution.

Firstly, I used rigid brass connector, but this solution is hard to prevent small leaking and is not flexible. Then I tried brass tower head connector, but the rubber pipe can be used for brass tower cannot support 1.0 MPa pressure. Finally, I tried quick assembly connectors with PU pipe and reached success.

3.1.2 Verification Process of Mechanical System

3.1.2.1 The test about the performance difference between tightening sleeve and shaft collar with set screw.

The synchronization between the main shaft with the revolver is key to the success of the loading system. The synchronize mechanism needs to support smooth linear sliding between the revolver with the main shaft while locking them together for rotating in same phase.

The fixture of the structure on the main shaft initially uses shaft collar and set screw. However, this design will lose gradually and wabbling a lot. Then I tried tightening-sleeve and reached success. This mechanism can provide a strong friction for synchronization and will fail when reaching a certain value of torque. This is good for our device, since if any stuck happens, this feature will protect the structure instead of breaking any parts.

3.1.2.2 The verification of revolver rotation rail and spring reaction system.

The key to the success of the revolver rotation leading rail is to find the best clearance between the spring-pin with the wall of the rail. A good clearance can not only make the sliding smooth but also prevent obvious wabbling of the revolver. I used multiple settings for the rail gap at different positions, to make the gap size at sliding zone different with the zone for final fixture.

For the spring reaction system, different springs with different sizes and elastic coefficient are used at each position. More different springs were bought and assembled into the system in order to test the best combination of the spring system that could provide the best reaction force for smooth manipulation.

3.1.2.3 The limiting system to prevent stuck of the ammunition belt or the drum.

The design of limiting system for shell loading is accurate and compact. Considering the difference of the dimensions between each shell, the limiting system preserved good free space to prevent any unexpected stuck. This limiting system helps synchronize the linear movement between the revolver with the shells and ensure the transition between used shell with the next shell is smooth enough.

3.1.2.4 Bearing system

The bearing system for the main shaft is critical to this device. The deformation of the whole structure is unavoidable, so we need a bearing system at all the points where we are limiting the main shaft to reduce the friction and ensure smooth manipulation all the time.

The bearing system mainly includes a component which is the combination of a linear bearing and two roll bearings. Two roll bearings are directly fixed at the outside of the linear bearing to form a compact structure which can not only support the linear movement of the main shaft, but also able to allow its smooth rotation.

3.2 Design Verification of the 2-Axis Stabilizer Base

3.2.1 Components

The base supports the entire launcher and provides two degrees of motion for the firing direction of the cannon, left and right rotation and pitch and lift. It consists of a bottom frame, horizontal rotation mechanism, pitch angle adjustment mechanism and cannon connection structure.

3.2.1.1 Bottom Frame

For the bottom support frame, we directly use 20X20 aluminum profiles and corresponding connectors to build. At the same time, we installed wheels at the four corners of the frame to make it easier to move the entire base.

3.2.1.2 Horizontal Rotation Mechanism

To achieve horizontal rotation, we first use a 45*58*7 load bearing as a moving mechanism. Screws and 3D prints are used to clamp the inner ring and outer ring of the bearing respectively to create a horizontal rotating range of motion.

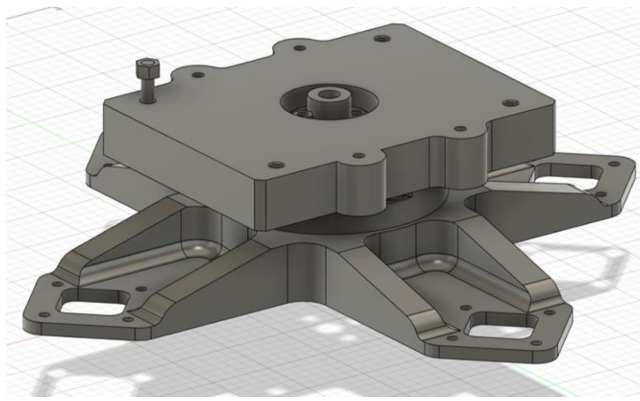


Figure 3.2.1.2.1. Overview of Horizontal Rotation Mechanism

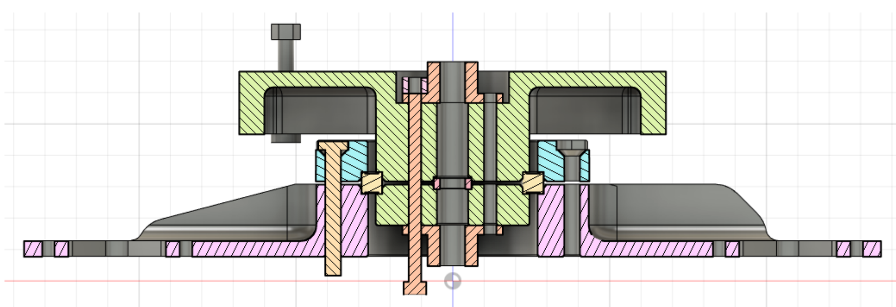


Figure 3.2.1.2.2. Cross-sectional View of Horizontal Rotation Mechanism

In the picture above (Some screws are hidden, the same goes for subsequent figures), the light-yellow part is the bearing, and the green part clamping the inner ring can rotate horizontally with respect to the fixed base clamping the outer ring.

In order to drive the rotating part, we used a motor and gear set. Considering that our launcher is very heavy, we finally decided to use a worm gear set with a gear ratio of 60:1 to amplify the torque of the motor. At the same time, use set screws to fix the worm gear and the flange assembled on the green part in the above picture on an optical shaft to achieve the driving effect.

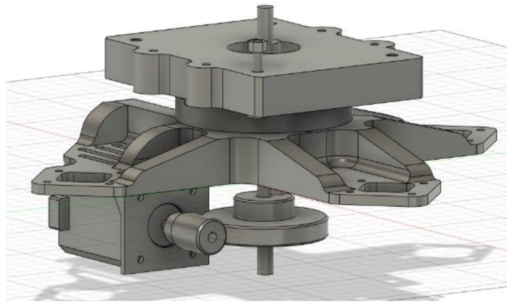


Figure 3.2.1.2.3. Overview of Horizontal Rotation Mechanism with Worm Gear Set

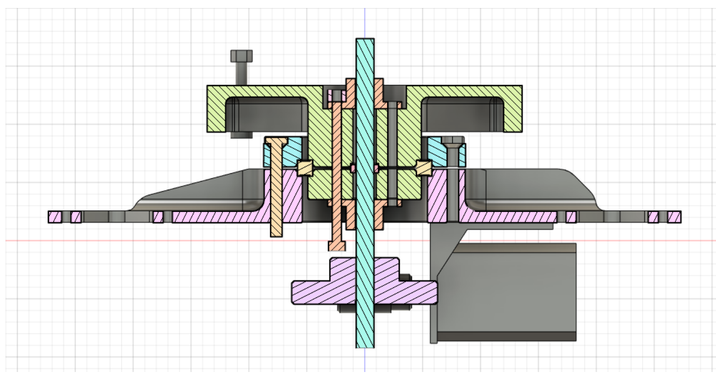


Figure 3.2.1.2.4. Cross-sectional View of Horizontal Rotation Mechanism with Worm Gear Set

However, problems followed one after another: because we used a Bluetooth controller for remote control, the signals received by our motor had a specific frequency, which caused slight vibrations in the rotating mechanism and had a great impact on the fixing effect of the set screws. We later changed the optical shaft to a D-shaft and still could not solve the problem. In the end, we designed a strong part to directly connect the rotating part and the worm gear concentrically (Red part below).

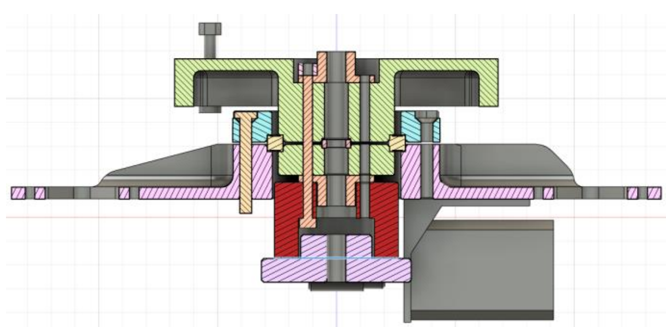


Figure 3.2.1.2.5. Cross-sectional View of Horizontal Rotation Mechanism with Connection Part

We underestimated the weight of the entire launch system (about 15kg), and the 3D printed parts of the entire base still underwent considerable deformation even with at least fill rate of 80% and thickness of 15cm, resulting in the worm and worm gear not being tightly combined and often slipping. The current improvement measure is to change the drive part to belt transmission.

3.2.1.3 Pitch Angle Adjustment Mechanism

For the pitch angle adjustment system, the initial design was like the principle of the horizontal rotation mechanism: two pillars installed on the rotating platform each clamped the outer ring of a 20*32*7 bearing, and the structure clamping both the inner rings was fixed to a shaft through a flange. The end of the shaft was fixed to the worm gear and driven by the worm connected to the motor. See Figure 7, the red parts are the bearing, and the purple part is the worm gear.

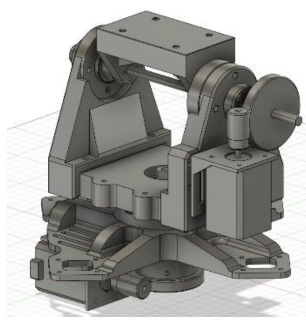


Figure 3.2.1.3.1. Overview of Early Design of Pitch Angle Adjustment Mechanism

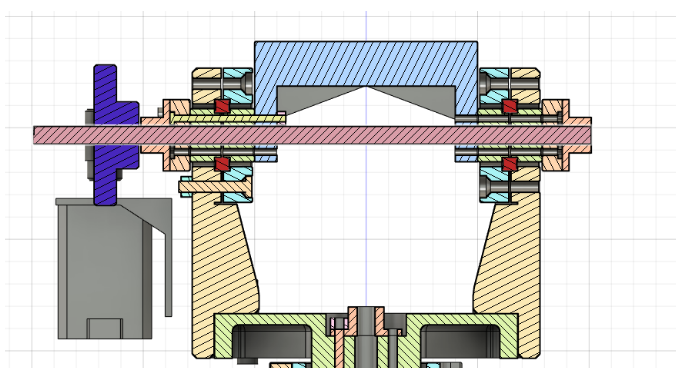


Figure 3.2.1.3.2. Cross-sectional View of Early Design of Pitch Angle Adjustment Mechanism

However, as the product gradually completed, this design exposed irreparable problems. Compared to the vertical pressure borne by the horizontal rotation part, this mechanism's shaft also bears considerable torque. On this basis, due to the worm and worm gear not being precisely matched caused by the deformation, the problem was infinitely magnified to an unacceptable level, and the design change is necessary.

The core component of the new design is a ball screw. By driving the screw to rotate through the motor, the screw nut will move back and forth. Connect the screw nut to the aluminum profile above through hinges and rods, the position of the screw nut can determine the pitch angle of the cannon. According to the calculation, the motor can produce far more support force than required through the system I designed, and the actual performance of the mechanism has also proved this.

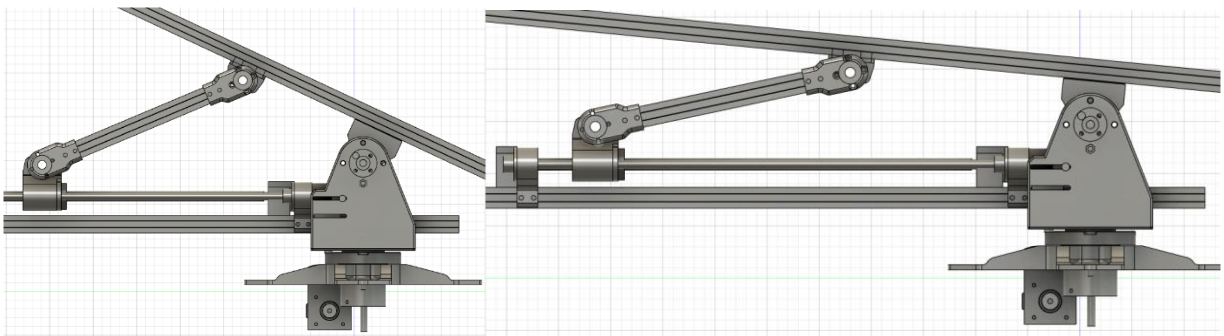


Figure 3.2.1.3.6. Change of Angle Based on The Position of The Nut

3.2.1.4 Cannon Connection Structure

Since the reloading of the launch mechanism depends on the back-and-forth movement of the piston, to achieve fully automatic launch, an extraction cylinder is also installed on the base. By connecting the slider and slide rail through a floating joint and installing two buffers, the reciprocating movement is achieved while ensuring the reliability and stability of the mechanism.

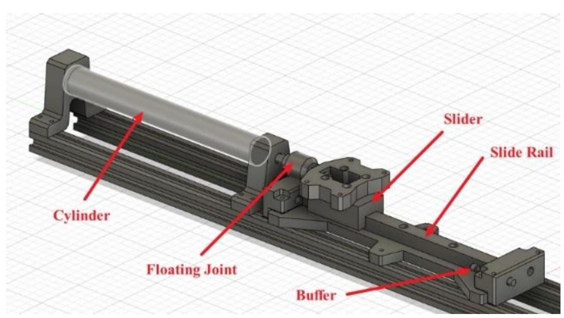


Figure 3.2.1.4.1. Overview of Piston Driven Mechanism

As for the connection mode to the launch system, two connectors with specific screw holes are assembled to fit the quick connection part on the launch system. Please refer to Yixiang Guo's report for the specific content of quick-connect part.

3.3 Design Verification of automation system

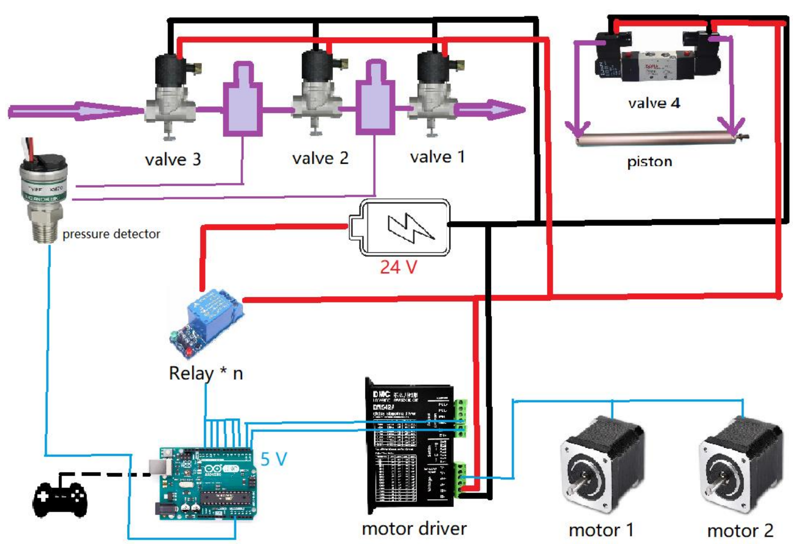
In this part, I provide more details about the control system for demonstrating individual work. I will show more design information and working process for the control system, including diagram, message flow and design consideration.

3.3.1 Components

The control system facilitates joystick-based aiming and firing functionality, as well as auto mode aiming by receiving signals from a camera. It comprises four electric valves, two stepping motors, and two Arduino boards, which serve the purpose of transmitting and receiving digital signals in the form of instructions.

3.3.2 Circuit

The central element of the circuit design consists of an Arduino Uno board integrated with a Bluetooth module. This configuration enables the reception of signals from a PS2 joystick, processing them, and generating 5-volt digital signals to control various electronic devices. Since the devices we acquired operate on a 24-volt basis, the integration of 5-volt to 24-volt transfer relays between the high-voltage and low-voltage segments allows for straightforward utilization of the 5-volt digital signals to govern the 24-volt circuit.



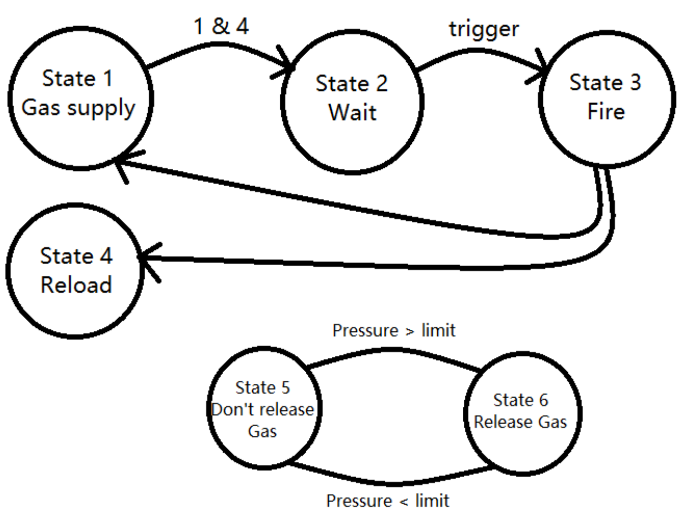
In our design, the motor and valve circuits are distinct entities. Each motor, responsible for horizontal and vertical angle movements, incorporates its respective driver that directly receives direction and pulse signals from the Arduino board. Each upward or downward pulse results in a one-degree rotation of the motor.

Regarding the valve circuit, our objective is to achieve automated gas pressure control for the launcher. Therefore, we have integrated four electric valves triggered by high-level signals. One valve enables instantaneous gas release during the firing of the t-shirt, another provides gas supply, a third valve ensures safety gas release to maintain a constant pressure in the backup cylinder. The fourth valve is a two-way variant that supplies gas to both sides of a piston, facilitating the pull and push actions required for reloading bullets. Additionally, two pressure detectors are incorporated, capable of providing analog signals to the Arduino board to indicate when to open or close the valves.

To summarize, the description encompasses the hardware component of our project.

3.3.3 Programming logic

The programming logic implemented in the Arduino follows a sequential set of steps:



1. When the pressure within the inner gas cylinder falls below a predetermined limit, the gas supply valve (valve 2) remains continuously open to increase the inner pressure. Throughout this process, the firing valve (valve 1) remains locked.

2. Once the gas pressure reaches the limit, valve 2 is closed, the firing valve is unlocked, awaiting the activation of the trigger button.

3. Upon button press, the firing valve opens, initiating the discharge. Subsequently, the gas pressure drops below the limit, returning to status 1.

4. A one-second pulse of 0 to 1 and a subsequent pulse of 1 to 0 are generated for the two-way valve whenever step 2 occurs. This action signifies the activation of the pull and push mechanisms, facilitating the reloading of a t-shirt. The fire unlocking condition is met when gas reaches the limit and the reload process is completed. Therefore, this logic ensures that no hazardous actions occur.

5. The motor's movement logic operates independently of the firing logic, allowing users to adjust the direction and angle at any desired time.

6. The gas safety valve (valve 3) functions independently of the other valves, releasing excess gas whenever the gas pressure exceeds the limit set for the outer cylinder.

State / valve	Fire (valve 1)	Gas supply (valve 2)	Safety release (valve 3)	Reload (valve 4)
1	0	1	X	X,X
2	0	0	X	1,0
3	1	0	X	1,0
4	0	X	X	1,0->0,1->1,0
5	X	X	0	X,X
6	X	X	1	X,X

(All valves are High level triggered)

Motor driven code:

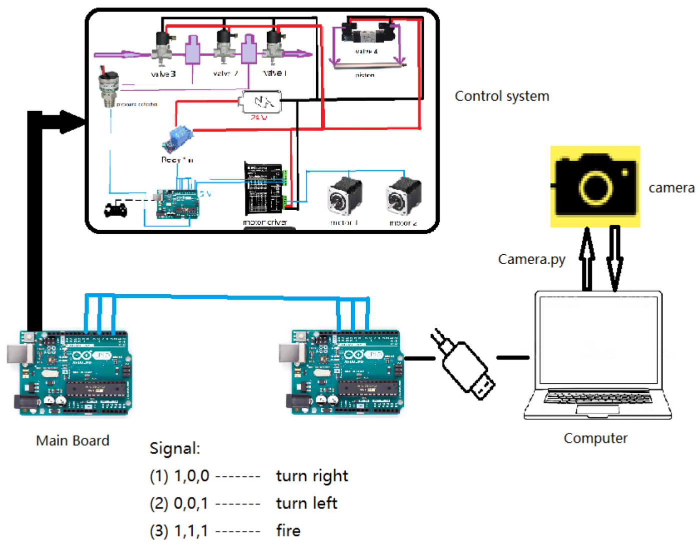
```
if (motor_1 == 0){
  digitalWrite(dirPin_1, HIGH); // set the direction (HIGH == right, LOW == left)

  for (i = 0; i < i_limit; i++){
    digitalWrite(stepPin_1, HIGH); //do high-low pulse i_limit of times in one loop
    delayMicroseconds(dy); //each high or low last for "delay" microseconds
    digitalWrite(stepPin_1, LOW);
    delayMicroseconds(dy);
  }

}
```

3.3.4 Auto mode connection

The control system includes a button on the joystick to toggle between manual control mode and auto control mode. In auto mode, the input is directed to a separate Arduino board connected to a camera. The camera sends digital signals to the main Arduino board via a transit board, indicating left or right movement when a person is detected on the screen's sides, and triggering a virtual button press when a person is in the center. The internal logic for auto mode resembles that of the hand control mode.



3.4 Design Verification of automation system

In this part, I provide more details about control and automation systems for demonstrating individual work. We will show more design information and working process for the automation system, including diagram, message flow and design consideration.

3.4.1 Components

The automation system is used for providing auto aiming functionality, it is composed of a phone camera, a detection program running in pc, and an Arduino board to accept digital signals as instructions.

3.4.2 Process

The whole auto system does the following steps.

1. Instantiate the YOLO object detector.
2. Establish a serial connection with the Arduino board.

3. Set the YOLO object's size and confidence thresholds.
4. Read frames from the webcam.
5. Perform hand detection using YOLO on the frame.
6. Display the detected hands.
7. If hands are detected, send the position value to the Arduino board for control the direction of launcher.
8. Repeat steps 4 to 7 for subsequent frames.

3.4.3 Camera

In selecting a camera for this project, we considered factors such as latency and frames per second (fps). After comparing different options, we decided to use a phone camera wirelessly connected to the PC as our baseline choice. This provides low latency, high resolution, and portability, allowing for flexibility during operation. The PC connects to the phone's WiFi and accesses the video stream via IP communication, enabling real-time video capture.

3.4.4 Detection model

For real-time detection, we opted for the YOLO V4 tiny model due to its fast speed and lightweight model weights. We also conducted a comparison of different models during the training process for reference.

While the F1-scores of the four models showed minimal differences, the actual performance varied significantly. Two key factors influencing detection reliability in this project are the tolerance to vibration and scalability concerning the distance of objects from the camera. Due to time limitations, quantifying these factors proved challenging. After thorough testing, we concluded that YOLO V4 tiny was the most reliable model for our requirements.

Camera module	Connection	Resolution	Latency	Fps
OV7670	Wire	416 * 416	130%	10
ESP 32	WIFI	480 *320	210%	15
Phone camera	WIFI	1920 * 1080	100%	40

Model	Weights	Speed/fps	F1-Score
YOLO v3	241mb	15	0.76
YOLO v3 tiny	34.7mb	28	0.69
YOLO v3 tiny prn	19.4mb	26	0.72
YOLO v4 tiny	23.5mb	22	0.78

4. Costs

4.1 System Costs

The costs of this launcher are extremely complex, since just the mobile launcher already has over 400 parts, with over a hundred stand parts (not including screw and nuts) and over a hundred manually drawn fabricated parts. Therefore, we only show the costs for each system. The following cost include the cost for testing and experiments.

Table X Parts Costs

System	Group Member Who Responsible for This	Actual Cost ($)
Launcher	Yixiang Guo	424.9
Stabilizer	Hao Ding	351.5
Control	Ziyu Xiao	89.55
Total	**/**	**865.9**

4.2 Labor

Since all the parts, especially those large amounts of manually fabricated parts are all manufactured by us. Therefore, there is no labor cost for our project.

5. Conclusion

In conclusion, the design project for the T-shirt launcher has successfully achieved its objectives of creating a powerful and reliable weapon system. Through the integration of various subsystems, we have developed a sophisticated.

5.1 Accomplishments

The Power & Pneumatic system ensures the availability of electronic and gas resources for the entire system. With a main gas cylinder charged to the pressure threshold within 10 seconds and a capacity to launch 10 T-shirts per charge, the launcher demonstrates exceptional performance and endurance.

The Launch system excels in its ability to launch T-shirts in two degrees of freedom, with a capacity buffer reaching 1 liter, a valid barrel length of 50 cm, and a diameter for airflow of 25 mm. The launcher can launch T-shirts over 30 meters at 0.9 kPa with a launch speed of 25 m/s. With its reliable mechanical design and stabilizer, the launcher ensures stability during movements, providing accurate and impactful launches.

The Control system effectively manages the activities of the launcher, encompassing both software and hardware aspects. With quick-switch functionality between manual and auto modes, precise control over joystick inputs, and automation for aiming through the camera system, the control system empowers the user with seamless control over the launcher's operations.

The Detection system, equipped with a camera, aim assist, rangefinder, and robust detection software, enables efficient target tracking, automatic firing, angle adjustment, and target recognition lock. This ensures enhanced accuracy and engagement capabilities, making the launcher a formidable system.

In conclusion, the T-shirt launcher design project has successfully realized a high-performance and reliable weapon system. Through the integration of power and pneumatic systems, precise control mechanisms, advanced detection capabilities, and a robust launch system, the project delivers a versatile and efficient solution for crowd control and related applications.

5.2 Uncertainties

One significant source of uncertainty lies in the pneumatic system, specifically related to gas pressure. While the system incorporates pressure sensors and safety mechanisms to ensure the gas pressure remains within safe operating limits, variations in environmental conditions or gas supply can introduce uncertainty. It is important to regularly monitor and calibrate the pressure sensors to maintain accuracy and account for any potential fluctuations.

Another area of uncertainty is the detection system, particularly the camera and software algorithms used for target recognition and tracking. Factors such as lighting conditions, object occlusion, and variations in target appearance can introduce uncertainty in the system's ability to accurately detect and track targets. Robust testing, validation, and continuous improvement of the detection algorithms can help mitigate these uncertainties.

Moreover, the overall performance of the T-shirt launcher system, including launch accuracy and consistency, may be influenced by various factors, such as mechanical wear and tear, environmental conditions, and operator proficiency. Regular maintenance and calibration procedures should be implemented to minimize uncertainties arising from these factors and ensure the system operates optimally.

To address system uncertainties, a comprehensive risk assessment should be conducted during the design phase to identify potential sources of uncertainty and their potential impacts. Mitigation strategies, such as redundant safety mechanisms, backup systems, and robust testing procedures, can be incorporated to minimize the effects of uncertainty on the system's performance and reliability.

Additionally, ongoing monitoring, data analysis, and feedback from system operators can help identify and address any unexpected uncertainties that arise during real-world operation. This iterative process allows for continuous improvement and adaptation to changing conditions, enhancing the system's overall performance, and reducing uncertainty over time.

By recognizing and proactively addressing system uncertainties, the T-shirt launcher design can strive to deliver a reliable and consistent performance, ensuring the safety of users and bystanders while maximizing the system's effectiveness in its intended applications.

5.3 Ethical considerations

Ethical considerations play a crucial role in the design and implementation of the T-shirt launcher system. As with any weapon system, it is important to prioritize safety, accountability, and responsible use to ensure the well-being of individuals and maintain ethical standards.

Firstly, safety measures have been incorporated into the design to minimize the risk of harm to both the user and the target audience. Strict adherence to pressure thresholds, airtightness, and reliable mechanical design ensures that the launcher operates within safe limits, reducing the likelihood of accidents or injuries.

Secondly, responsible use and deployment of the launcher are paramount. It is essential to abide by legal and ethical guidelines, using the system only in appropriate situations and within the boundaries defined by relevant authorities. This ensures that the launcher is employed for its intended purpose of crowd control or similar applications, while avoiding misuse or potential harm.

References

[1] Ieee.org, “IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 7-April-2016].