P.U.T.T.I
Portable Unitary Throwable Target Interceptor

Department of Electrical Engineering and Computer Science

Group 18 Authors:

Alex Evison	Callum Fuller	Nathan Kimmel	Jake Tattersall
Electrical Engineering	*Electrical Engineering*	*Electrical Engineering*	*Computer Engineering*

Review Committee:

Dr. Sonali Das	ECE	Lecturer
Dr. Swaminathan Rajaraman	MSE	Associate Professor
Dr. Xun Gong (Pending)	ECE	Professor

Advisors:

Dr. Saleem Sahawneh	ECE	Lecturer

Chapter 2 – Project Description

2.1 Project Background and Motivation

From early fortifications to the development of missile defense systems, humans and the societies they reside within have always designed and built protection technologies to protect themselves from outside threats. In today's day and age, war makes use of small drones, UAVs, and other improvised aerial projectiles. These hazards pose threats to not only soldiers on the frontlines but also to civilian infrastructure, where defenses such as missiles are too costly or rifles which are too impractical to hit and stop their target. Active defense technology has seen major processes in recent decades from large-scale missile interceptors to vehicle mounted active protection systems, yet these solutions remain inaccessible outside of military use due to their high costs, large footprints, and complexity. This makes a gap for smaller, more adaptable systems that can quickly respond to threats.

This is where the P.U.T.T.I. comes in, the Portable Unitary Throwable Target Interceptor. The P.U.T.T.I is a compact, deployable defense device unit equipped with sensors to detect any threats such as UAVs or grenades. Once a target is identified, the unit deploys countermeasures to neutralize or disable the object before impact. The P.U.T.T.I balances effectiveness with practicality, showing that a defense solution can be lightweight and cost efficient while also being reliable.

In addition to its practicality, this project allows our team a unique challenge. It requires us to use what we have learnt up until this point to create something to help solve an existing problem with our own take on the subject.

2.2 Current Commercial Technologies and Existing Projects

This project takes inspiration from the *Tom Clancy's Rainbow Six Siege* video game character Jäger, who can deploy an "Active Defense System" (ADS) which automatically detect and intercept incoming projectiles such as grenades or flashbangs. While fictional, this concept provided the initial motivation for our design, though our implementation will serve as a non-destructive proof-of-concept[1].

[1] "Tom Clancy's Rainbow Six Siege X: Ubisoft (US)," Ubisoft, https://www.ubisoft.com/en-us/game/rainbow-six/siege.

Figure 1 – Active Defense System (ADS) from Tom Clancy's Rainbow Six Siege

Real world parallels to this gadget already exist in the real world in the form of Active Protection Systems (APS), like the Russian Arena. These systems detect and neutralize large incoming projectiles like rockets and anti-tank missiles, typically using Doppler radar. A drawback to this type of detection system is susceptibility to clutter from terrain reflections, but these military systems are still a good demonstration for the feasibility of quick time automated threat detection and response. However, these systems are expensive, destructive, and too large to be suitable for small-scale applications.

Figure 2 – Iron Fist Active Protection System

A related field is anti-drone and counter-UAV technology, where systems deploy RF sensors, radar, and/or cameras to detect arial vehicles. These systems are also capable of taking down said vehicles with high precision from long distances, often through high powered lasers or net deployment. This technology highlights the effectiveness of combining multiple sensors for automated targeting and demonstrates practical ways to intercept flying objects.

By contrast, our project aims to create a compact variant of these types of systems, focusing on safe, low-cost devices capable of removing the threat of thrown weapons. Instead of intercepting targets with destructive force, our system will emphasize detection speed, accuracy, and response time using commercially available components. This approach attempts to tie together the inspiration of Jäger's ADS with principles seen in real life technologies.

2.3 Objective and Goals

It is important to establish goals and objectives that we plan to achieve through the entire process of designing and developing the P.U.T.T.I. For both the goals and objectives there will be aspects that are essential to the success of the project that will be required for it to function effectively. Additionally, there will be stretch which may be difficult to achieve within the scope of the project but will add extra functionality and complexity to the design.

2.3.1 Goals

Basic Goals:

- Create a compact defense system capable of detecting and targeting stationary targets
- Allow for quick deployment and moving
- Be able to target within a 150-degree field of view around the center of the device

Advanced Goals:

- Target and track moving projectiles consistently without significant delay
- Shoot projectile at target, resulting in the target's trajectory being significantly altered

Stretch Goals:

- Decrease the power consumption of the device to allow it to last longer, especially in combat zones where the device may have to be deployed for significant number of times without access to new batteries.
- Increase the durability of the frame making it more resistant to a vast number of harsh conditions, including sandstorms, rain, snow, etc.
- Allow for the product to attach to different faces including walls and ceilings without a loss of function to allow for more stealth

2.3.2 Objectives

Basic Objectives:

- Use cameras and sensors in combination with one another to detect targets around the device and send this information to a laser to be able to pinpoint stationary targets.
- All the hardware will be placed inside the shell of the device which will be 3D printed.
- Use a Raspberry Pi to control the motors, camera, and laser as well as communicating with the camera and sensors to create a radar.
- Use a camera to gain a full 150-degree field of view around the center of the device.

Advanced Objectives:

- Using the Raspberry Pi and FPGA board map out the entire surrounding area and calculate the trajectory of moving projectiles with a latency of less than 50 ms to ensure that the target can be hit.

Stretch Objectives:

- Use aluminum to create the frame of the device allowing for a more durable but slightly costlier design for the device whilst still being less than five pounds in weight.
- Add suction cups to the base of the device whilst still allowing for the device to be deployed in less than one minute.
- Create an easily detachable section of the device where batteries can easily be changed or the device can be charged to increase the battery life past one hour.
- Using a small projectile powered by pressurized gas hit the moving projectile with a success rate greater than or equal to 80% of the time

2.3.3 Hardware

P.U.T.T.I. will need to be portable and unitary to maximize ease of use. It is a poor assumption to assume there will be time to prepare and set aside the time to deploy the system. To ensure easiest portability, there are a couple of options, but further research is necessary. The device could be adhesive to surfaces with an easy manner to adhere and detach from surfaces. Options like suction cups could make the system easily adhere and detach from indoor floors but may have difficulty in outdoor areas. Another option is to use weights or a heavy body to reduce movement from external forces or air bursts. The downside would be that carrying the system would be more difficult. Although less portable, one final option is to use screws to be able to drill the system into any malleable surface. This would have significant setup time and would be improper for certain floors, but it would help guarantee stability.

To ensure that P.U.T.T.I. remains unitary, there should be no detachable objects or objects separated from the main body. The cameras and air mechanisms should all remain on the main body. While detachable cameras would be ideal to create three-dimensional view of targets or to isolate the target detection zone, this will severely increase preparation time. Cameras should remain on the main body. Details on camera options are further explored in the software section.

To improve on the target detection, microwave sensor modules may be ideal for detecting moving objects. The sensors could check for moving objects as a primary targeting method, then move to the camera and image processing for secondary targeting to confirm object shape and size and to avoid humans.

While it would be ideal to both intercept and neutralize targets, for safety purposes, the neutralization aspect shall be discarded. Interception can remain for proof of concept, and the interception method should be replaceable with a future neutralization method. Using a laser pointer to show that the target was acquired is one option. While less optimal, it would suffice for proof-of-concept and may reduce the mass and size of the targeting system to aid in response time with improved physical movement.

A motor system would be required to rotate the laser module up and down as well as left and right. To do this, a pan-and-tilt method would be most appropriate. Some motor options include stepper, servos, and brushless[2]. Stepper motors have specific angles that it can align to and are fast to move between angles. Servos require a position feedback sensor and manual tuning for the inertial load but may prove to be a valid option. Brushless motors have lower duty cycles but can last longer than other motors. More research is required.

A microcontroller will be necessary to control all these components. One option is a microcontroller from the Arduino brand. While these controllers would be low power, it is unlikely that image processing will be able to be used to full capacity with these boards due to RAM sizes. An ESP-32 does have more processing power and resources so image processing is a possibility, but further research will need to be done to ensure that proper response times can be achieved. A Raspberry Pi seems optimal for image processing tasks. With access to Python, sufficient CPU speeds, and sufficient RAM sizes, using a Pi should ensure the ability to perform fast targeting.

With extra time and resources, there are some better alternatives to achieve goals. While the previous neutralization options would be sufficient to provide the proof of concept, the ideal situation would be to simulate the neutralization of targets. Launching a projectile like a small foam ball or a net towards targets could fulfill this. To intercept thrown objects, one option would be implementing an air system to shoot a short burst of air at targets. Initial research shows that an air compressor, air tank, and linear actuator with solenoid will be sufficient to achieve this objective[3]. A PSI of approximately 20-40 PSI will suffice to affect targets within a 10-20 ft radius but may have poor results. A 12V linear actuator with a solenoid should also suffice for releasing air. Further research is required. The air system may be replaced with another projectile method, or the projectile may be added on top of the air system so that the existing air system will launch it.

2.3.4 Software

P.U.T.T.I.'s main goal is to target thrown objects and intercept them. To be able to do this, P.U.T.T.I. will need to use image detection to identify these thrown objects. Live capture of the surroundings will need to be captured via camera, and to fulfill the unitary description of P.U.T.T.I., the camera(s) should be located on the system rather than be detachable or located away from the system.

Two main options prevail with image capture. The first option is to use a fisheye camera[4]. This will give P.U.T.T.I. a wide field of vision while making calculations easier since images from multiple cameras will not need to be stitched together; however, there will be some distortion from the shape of the lens, so calculations to trajectory may be more difficult. The fisheye camera will need to be placed in a manner that the barrel and camera do not obstruct each other. The ability to target objects that are rolled or very low may be nonexistent. The second option is to use multi-camera adapter to connect four different

---

[2] TWPe-jpc, "Servo vs. Stepper vs. Brushless DC Motors," Elinco International, Inc. Japanese Products Corp., https://www.e-jpc.com/servo-stepper-brushless-dc-motors.

[3] ChatGPT, https://chatgpt.com/

[4] "Arducam 5mp OV5647 ultra wide angle fisheye camera for Raspberry Pi," Arducam, https://www.arducam.com/arducam-ultra-wide-angle-fisheye-5mp-ov5647-camera-for-raspberry-pi.html

cameras, each pointing in a cardinal direction[5]. The resulting images would need to be stitched together or track objects between them.

The primary option for image detection is to use the open-source software library OpenCV. OpenCV specialized in computer vision and machine learning, has numerous algorithms to detect objects and track movements, and has a large community with open forums for easy question and answer. It is also under an Apache 2 license, so OpenCV is a solid choice for an image detection library[6].

While the methods mentioned above will provide a solution to the goals and objectives, there are some drawbacks. The camera options may prevent low to the ground objects from being targeted. One solution to this would be to use additional cameras pointed downward to detect those objects. Object range will not be able to be determined, so only the apparent size will be useable. A solution to this would be to attach a sensor, such as an ultrasonic sensor, to the targeting barrel. When a target is determined, the barrel can align to the target and activate the ultrasonic sensor to determine range before intercepting, but this will increase response time. Bright lights or dark rooms may make object detection difficult. This may warrant looking into infrared cameras or night vision cameras.

2.4 Required Specifications

Table 2.4.1 *Overall System Specifications*

Overall System Specifications		
Parameter	Description	Target Values
Detection Latency	Time from projectile entering field of view to detection.	≤ 50 ms
Targeting Response Time	End-to-end delay from detection to targeting.	≤ 500 ms
Range	Maximum distance at which projectiles can be detected and tracked.	1 m -> 5 m
Field of View	Angular coverage.	≥ 120° H × 60° V
Targeting Success Rate	Probability of successfully detecting and targeting projectiles.	80% -> 100%
Operational Lifespan	Minimum continuous operation time.	≥ 1 Hour
Weight	Total system weight.	2 – 5 kg
Device Dimensions	Overall size of device.	≤ 0.5 m × 0.5 m × 0.5 m

---

[5] "Mini Multi-Camera Adapter Board for Arduino-Arducam," Arducam, https://www.arducam.com/mini-multi-camera-adapter-board-for-arduino-arducam-b0074.html
[6] OpenCV Team, "About - OpenCV," *OpenCV*, Jul. 18, 2025. https://opencv.org/about/

Table 2.4.2 *Component Specifications*

Component Specifications		
Components	Parameters	Target Values
Laser Module	Wavelength Output Power	630 nm – 680 nm ≤ 5 mW
Motors	Angular speed Resolution	≥ 150°/s ≤ 1°
Camera	Frame Rate	≥ 60 fps
Microwave Sensor	Detection Range	≥ 5 m
Microcontroller	Communication	UART/I2C Interface

2.4.1 Hardware Block Diagram

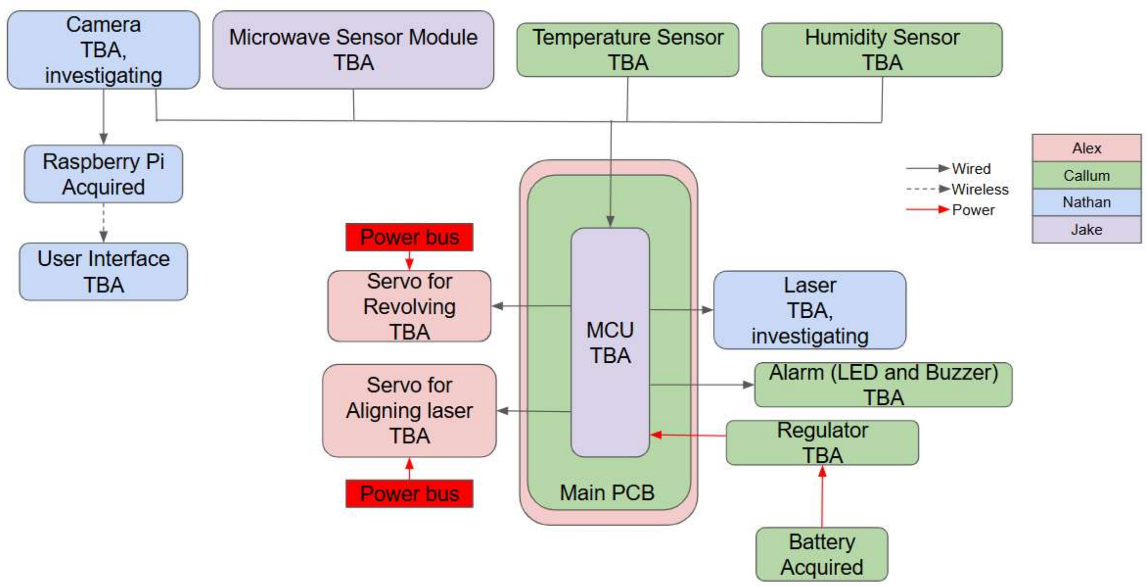


Figure 3 - Hardware Diagram

2.4.2 Software Diagram

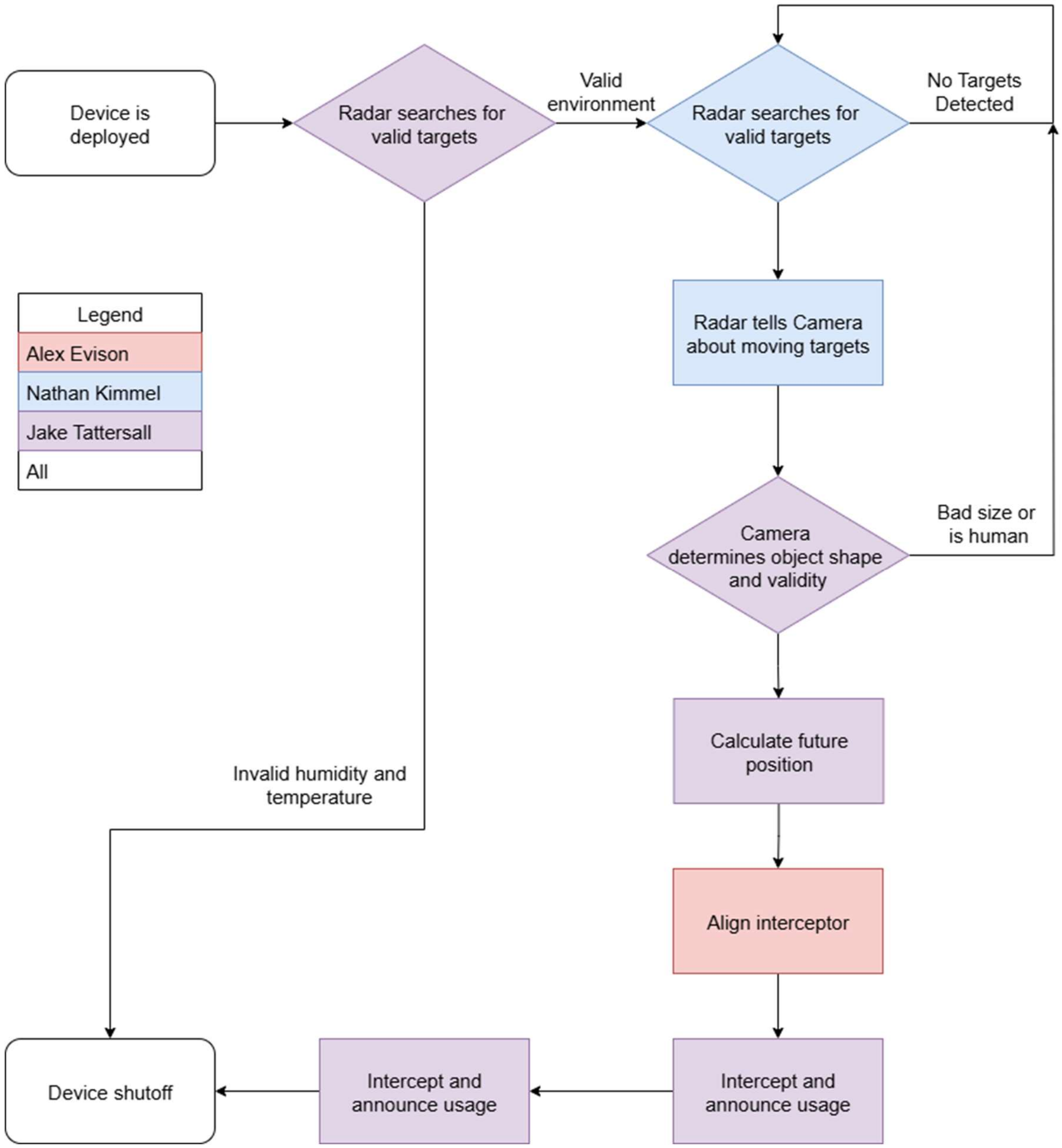


Figure 4 - Software Diagram

2.4.3 Protype illustration

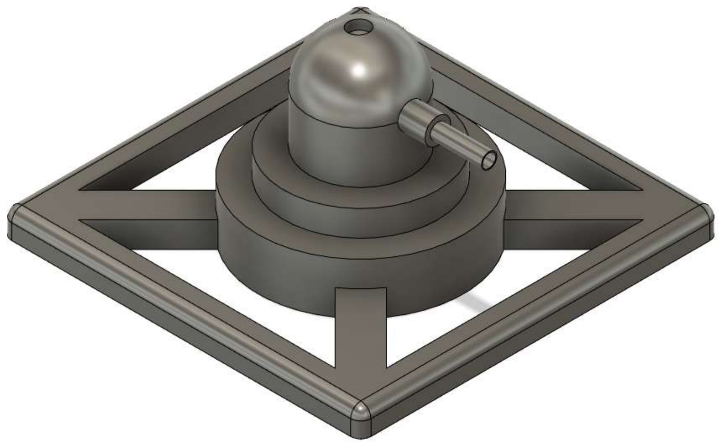


Figure 5 - Isometric view of final product includes space for camera and laser on barrel

Figure 6 - Front view of final product includes adequate space for components

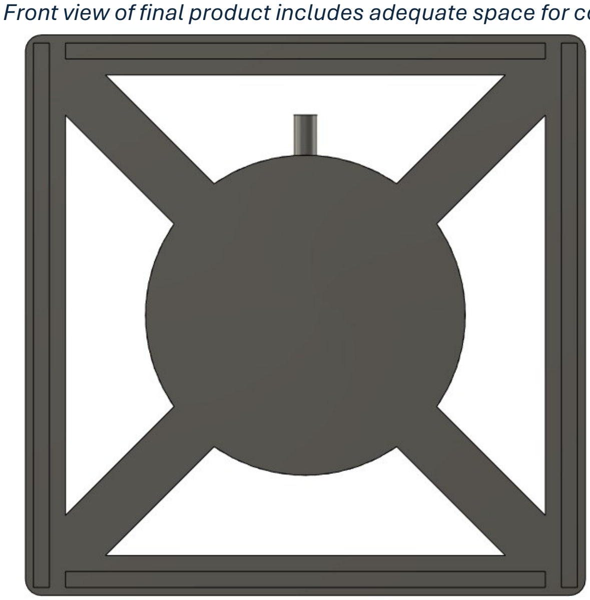
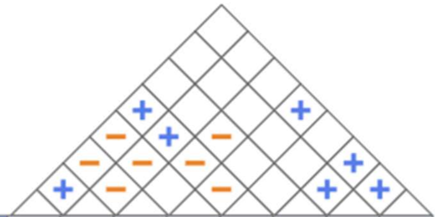


Figure 7 - Bottom view of final product includes adhesive material to allow for multi-faced deployment

2.5 House of Quality



Legend	
+	Positive Correlation
−	Negative Correlation
^	Positive Relationship
v	Negative Relationship
o	No Relationship

Marketing Needs	Parameters	Detection Latency	Targeting Time Response	Range	Field of View	Targeting Success Rate	Operational Lifespan	Weight	Device Dimensions
		-	-	+	+	+	+	-	-
Response Time	-	^^	^^	v	vv	^	o	o	o
Accurate Targeting	+	^	^	v	v	^^	o	o	o
Coverage	+	o	o	^^	^^	o	o	o	o
Portability	+	o	o	o	o	o	^	^^	^^
Safety	+	^	^^	o	o	^^	^	o	o
Battery Life	+	o	o	v	v	o	^^	v	v
Cost	-	v	v	vv	v	vv	v	v	v

2.6 Estimated Cost Table

Table 2.6.1 *Estimated Cost Table*

Item	Cost per Item	Quantity	Total Cost
Raspberry Pi 4B	$35.00	1	$35.00
Fisheye Camera	$20.00	1	$20.00
Laser Module	$7.00	1	$7.00
Radar Module	$10.00	3	$30.00
Battery Pack	$10.00	1	$10.00
3D Print Filament	$20.00	2	$40.00
PCB	$40.00	1	$40.00
Motors	$14.00	2	$28.00
Etc. Components	$30.00	1	$30.00
			$240.00

Chapter 10 – Administrative Content

10.1 Budget

The budget for our project is $1000. This value was decided on all members of the group to ensure that there is an adequate amount of funds for the initial design as well as any revisions that need to be made after testing. It is likely that the project will not reach this budget, however having a cushion will ensure that the best possible design can be created to fully achieve the desired goals and objectives of this project.

10.3 Senior Design Milestones

It is important to have a plan for Senior Design to ensure that the group stays on track and all the future deadlines are known and achieved on time. There needs to be separate milestones for the documentation side of the project and the hardware and design side of the project since they will overlap and both sides of the project are important to map out.

Table 10.1 *Senior Design Milestones*

Task	Start Date	Anticipated End Date	Description
Brainstorming	8/24/2025	8/31/2025	Discussing project ideas that are feasible and meet all design requirements
D&C Document	9/1/2025	9/5/2025	Complete 10+ pages for Divide and Conquer document to discuss with advisor
D&C Meeting	9/9/2025 11:00 am	9/9/2025 11:30 am	Discuss Divide and Conquer document with advisor and get approval
Midterm Report	9/30/2025	10/31/2025	Complete the first 60+ pages of the document
Final Report	10/20/2025	11/25/2025	Finish the document by the end of SD1.
Mini Demo Video	10/20/2025	11/25/2025	Record demonstration of project

Table 10.2 *Project Development Milestones*

Task	Start Date	Anticipated End Date	Description
Basic Model of Project	8/31/2025	9/5/2025	Creating a model of the basic design of the planned look for the project
Selection of Materials and Components	8/31/2025	9/14/2025	Choosing and purchasing the necessary components required for the project
Designing the System	9/14/2025	10/24/2025	Coding the system, creating the system on a breadboard, and testing its functionality.
PCB Design	10/24/2025	11/7/2025	Design the PCB using Fusion.

PCB Testing	11/7/2025	11/17/2025	Solder all components and test functionality of PCB
Create Prototype	11/17/2025	11/25/2025	Combine all components together to create and demo a prototype of the project.
Testing	TBD	TBD	Test the prototype to see if any changes or revisions need to be made
Revisions	TBD	TBD	Make changes to the project or add additional functionalities.
Final Project	TBD	TBD	Create final version of the project and submit it for review.

Appendices
Appendix A – Reference

[1] "Tom Clancy's Rainbow Six Siege X: Ubisoft (US)," Ubisoft, https://www.ubisoft.com/en-us/game/rainbow-six/siege.

[2] TWPe-jpc, "Servo vs. Stepper vs. Brushless DC Motors," Elinco International, Inc. Japanese Products Corp., https://www.e-jpc.com/servo-stepper-brushless-dc-motors.

[3] ChatGPT, https://chatgpt.com/.

[4] "Arducam 5mp OV5647 ultra wide angle fisheye camera for Raspberry Pi," Arducam, https://www.arducam.com/arducam-ultra-wide-angle-fisheye-5mp-ov5647-camera-for-raspberry-pi.html.

[5] "Mini Multi-Camera Adapter Board for Arduino-Arducam," Arducam, https://www.arducam.com/mini-multi-camera-adapter-board-for-arduino-arducam-b0074.html.

[6] OpenCV Team, "About - OpenCV," *OpenCV*, Jul. 18, 2025. https://opencv.org/about/.

Appendix B – Copyright permission

Appendix E – LLM Prompts and Outcomes

[Q1] What about shooting pressurized air? how would the tracking and shooting be safely implemented?

[A1] 1. Choosing an Actuator

For a safe, classroom- or lab-friendly deployable:

Option	Pros	Cons
Compressed air via solenoid valve	Quick response, adjustable pressure, simple to control via GPIO	Need regulator for safe pressure, requires tubing and reservoir
Mini air blaster / air cannon (low pressure)	Can use canned air or small air pump, safe if low velocity	Limited range, small distance for detection
Foam projectile launcher	Safe, visible projectile, easy to aim	Slightly more complex mechanics

Recommendation: Use a **low-pressure solenoid valve with regulated air** or **foam ball launcher** for proof-of-concept.

- **Pressure**: 20–30 PSI max is plenty for 10–20 ft distances and is generally safe.
- **Components**:
    - Solenoid valve (12V or 5V)
    - Air tubing & small reservoir
    - Pressure regulator
    - Relay or MOSFET to switch the valve from Raspberry Pi