Paper Wad Interceptor Project Proposal

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I. Introduction

A baseball is flying towards a window, a catapult is hurling stones at a castle, and a paper wad is being thrown at a teacher, all these creative scenarios share one common theme: a flying projectile. The projectile, which is about to cause some sort of damage, needs to be knocked off course. Any of these scenarios would be a way to describe the main purpose of the assignment the team has been given. Our specific scenario involves plastic golf balls, also referred to as paper wads, which are heading towards the deflector. We would achieve the deflection by using our maximum of six sensor stands to track the plastic golf ball's speed. Once the proper location and movement of the golf ball is tracked, we will be able to fire our projectile to accurately hit the plastic golf ball. This being said, the customer, Devcom, has an objective of their own which is to generate interest in the Department of Defense. Their specific outcome of the project would be to interest STEM students, which would possibly be in middle or high school, in the Department of Defense.

The problem this project addresses has an equivalent implementation that will be explored and discussed in order to understand the full scope of the problem. The expected specifications that define the problem will also be outlined. The different possible implementations and equipment the team believes is feasible for this project will be discussed as well. The team will also establish a general approach to unforeseen obstacles and issues that will undoubtedly occur during this project. Lastly, the resources and skills of this team will be addressed before concluding the proposal.

II. Outlining the Problem

There are many different solutions to the problem that have been provided which fall within the required specifications. There are a couple of prevalent ideas that have come up during team meetings. One idea that is greatly being considered involves the use of sensors to track the speed between two points. This would allow us to consider the speed of the paper wad based on the tension of the line and the specific line that it is on. This idea requires a large amount of testing for every wire at many different tensions. The team would be able to track the speed using the sensors that we are provided and then we would assume, based on aforementioned tests, that the wad would end up at a specific location. The team would then be able to input this data to our Raspberry pi which would be the brains of our operation. Another idea would involve the use of a fan to hold the paper wad in place which would allow us to know its position. This idea could also possibly be used as a safety net if the paper wad is possibly missed.

A. Background

The equivalent of this project in the professional field is missile defense systems. It is important to observe the implementation of these systems to gain an understanding of the necessary processes and subsystems for the project. Most anti-missile systems use a satellite to track the initial launch of the incoming missile. This is used to detect the threat during the early stages of the missiles launch and trajectory [1]. For the project's purposes, this would be used to detect that a threat is coming and could relay the position. There is then a radar that is also used to track the trajectory of the incoming missile. This would correspond to the sensors found further down the arena for the golf balls. Once the missile is in range, the interceptor fires and attempts the interception [1]. In order to intercept the simulated paper wad, a projectile will be fired and have to make physical contact with the paper wad to be considered an interception. In missile defense systems, the interceptor releases a kill vehicle that is typically able to locate the target in some way [1]. While there are several different types of radars, satellites, interceptors, and launchers implemented, the project is a much more scaled down version that is outside the caliber of the equipment used for this. These systems and strategies should be considered and scaled down appropriately for the purpose of this project.

Implementing a project that scales down anti-missile defense systems is certainly a daunting task. Several different types of knowledge and skill sets will be necessary to achieve the intended goal for this project. This project has been proposed to spark students' interest in defense systems by scaling down a defense process to be implemented into an everyday scenario. Working on this project as a university student can generate interest in future engineers and provide limited experience to the field of defense. In addition, implementing this paper wad interceptor can generate interest in the younger generation for defense and STEM in general.

The major purpose of the project is to intercept incoming paper wads. There are many different solutions to this problem.

The part of the project that would track the golf ball may involve cameras, motion detectors, and possibly lasers or other tools to assist and enhance the tracking. The tracking portion of the project would relay its information to the main brains of the operation which would most likely be a Raspberry Pi. This would allow easy communication between the different aspects of the design. The final consideration is the projectile which will be chosen. Above all else the projectile needs to fall within the design specifications outlined in the rule-book to ensure that the design starts out with as many points as possible.

B. Specifications

The Devcom Paper Wad Interceptor's restrictions and requirements are implemented to remove risk from spectators and judges. The restrictions are needed to stop any danger with an acknowledged risk of the use of safety glasses. The project is centered around striking a balance between creative ideals and safety, ensuring a secure and safe competition environment.

The requirements for the project are clearly stated by Devcom [2]. The play area that was defined will be sixty-four inches by seventy-eight inches. This area will be split into one-by-one-foot squares. Three of those squares will be used for placing our Paper Wad Interceptor. The arena layout can be seen in figure 1 and 2 for aerial and side view respectively. The team's final design shall fit in a one-by-one-foot square box. The location of the device will be chosen out of the three designated squares by the team. The devices shall not initially be taller or wider than one foot, though it may expand after pressing the on button. The interceptor shall be safe and shall not cause any harm to humans or judges that may be in the area. The design shall implement an emergency shutoff switch to de-energize the device if it poses any danger and shall implement a power switch to initiate operation. It shall also involve a pause switch that will be implemented between states and if the golf ball does not make it all the way down the wire. The interceptor shall only rotate from zero to one-hundred and eighty degrees. The interceptor shall in no way alter or damage the arena. The projectile launched from the interceptor shall be allowed to hit the fishing line but shall not break the fishing line. It may extend parts or components past the one-by-one-foot square after it is powered. The interceptor shall not use explosives, pyrotechnics, toxic or corrosive materials, and anything that causes flames. The projectile itself shall not be made of glass or metal. The projectile shall shoot a maximum of six feet and shall not penetrate an eight by eleven piece of paper from two feet away.

As a team we are allowed access to have a total of six sensor stands. The sensors shall be wireless and stand on the outlined design. The sensors shall also have standalone power. The stand itself is two feet tall and the base is one foot wide. There are two holes drilled into the stand from each side they are one inch from the sides and two inches apart. The holes are also one foot ten inches from the base of the stand. The

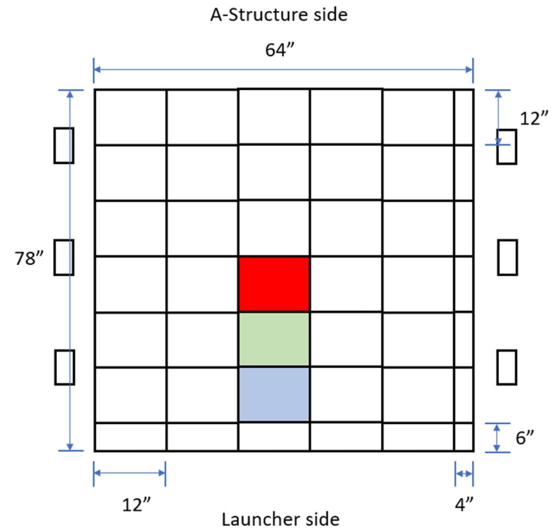

Fig. 1. Aerial View of Arena

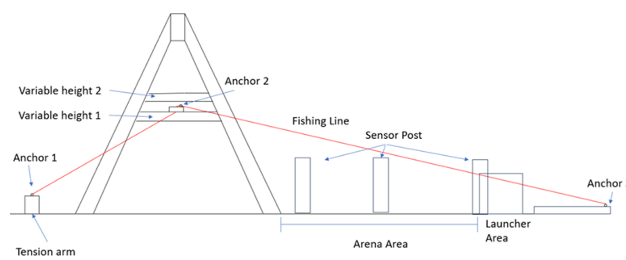

Fig. 2. Side View of Arena

sensor stands shall not be altered with any extra drilled holes. The sensor shall be able to balance on the stand if it cannot be secured with the provided holes. If it cannot, the interceptor will have to function without this sensor. During operation no one on the team is allowed to touch the Paper Wad Interceptor, or the design will be disqualified.

C. Standards

There are several standards and regulations that will need to be considered when implementing this project. One important standard to consider is the government regulations for wireless communication. The team has not decided whether Bluetooth or Wifi will be used for communication between the sensors and the interceptor. Thus, the standards for each type of device will be considered. The FCC 15.247 standard outlines the specific ranges each device can operate in. While Wifi can be used in the 2.4 and 5 GHz operation frequencies, Bluetooth is only allowed to operate in the 2.4 GHz band. These bands are actually a much smaller range than one might originally think. The 2.4 GHz band is from 2.4 to 2.4835 GHz, and the 5 GHz band is from 5.725 GHz to 5.85 GHz. These are the wireless communication frequencies for legal operation in the United States [3]. While other standards like FCC-

21 propose expanding the range into the large 6 GHz range, these proposals do not seem to be fully established yet [5]. Therefore, the team will work with the 2.4 and 5 GHz bands. For each range, there is also a variety of other requirements for power output, bandwidth, and channel hopping to consider when the sensors and interceptor are communicating.

Regulations for launching projectiles is also important when considering standards that could apply to this project. The ASTM F590-22 standard outlines specifications for velocity, size, and shape of different types of projectiles being launched. This standard needs to be adhered to because it is a government regulation [6]. Furthermore, this standard is helpful in meeting the safety standards presented by the customer. The USCODE Title 15 outlines safety standards for distinguishing an imitation firearm from a real one. It is stated that any imitation firearm needs to have an orange tip at the muzzle [8]. This safety standard would be important to consider in the design since this interceptor is meant to be implemented publicly in a classroom around children.

Another safety standard to consider is emergency shutdown procedures. OSHA 1910.147 outlines procedures for properly shutting down and de-energizing electrical devices. The most applicable part of this standard is the use of an energy isolating device, or EID, to properly de-energize a system rather than using components like switches or gates [10]. However, it has also been questioned whether or not these components can be as effective for emergency shutdowns [11]. Since the shutdown will not be used for maintenance and repair of the device by any person afterwards, these components might be considered and used for the device shutdown while still complying with the guidelines.

The IEC 60335-1 standard contains specific standards for either single phase or multi-phase devices and the respective voltage levels for each. It is important to consider these specifications since the interceptor will be a device powered by a wall plug [13]. The IEC 602368-1 standard is also important for power in both wall powered devices and battery power devices. This standard focuses on having safeguards for components against hazardous energy during the device's operation [14]. Operations adhering to this standard ensure safer operations which is important for the long-term goal of implementing this device in a classroom as well.

D. Externalities

As mentioned in the introduction, there are many different ways to categorize the main objective of this project. The main objective can be seen as something as simple as protecting a teacher from a paper wad, but it can also be scaled up and then referred to as protecting ammunition and troops from incoming threats. Even though our project is done on a small scale, there is a possibility that some of the thought processes or designs that we create may actually be a helpful thought in the defense industry. Though in all actuality the odds of this happening are very low, there is always a possibility that it could happen. If the team was to come up with some groundbreaking innovation in our design who could guarantee that it stayed in the right place? Even if the odds of this happening are extremely low, it is an interesting thought. If this was the case it is very doubtful that any one of us would know it therefore it would be seemingly easy to understand the design. Because this project is not taking place in a top-secret laboratory, one would assume that the risk associated with this is extremely low if not zero. Regardless, it would be interesting to see how a scenario like this might play out.

Even though our design is made to be used in a classroom setting there are still ways that external forces have an impact on the design of our project. As the customer Devcom mentions this project's main goal for them is to steer the interest of STEM students towards the Department of Defense. This is the reason for the limitations previously outlined regarding the projectile and use of fire and other dangerous operations. This brings up a possible discussion regarding the impressionable children, or teenagers, that may see an iteration of this design, created by this group or another, in the classroom. A younger student may be interested in working for the Department of Defense, which is the goal of this endeavor, and may attempt to undertake the project themselves. This may cause some unforeseen consequences and possibly damage to self or property. That is why this project should not be seen as a toy by any means. Though the projectile must fall within the safety regulations outlined in the rule book, it should be reiterated by the team that may be presenting the interceptor that this is a product that is once again not intended to be used as a toy. The Paper Wad Interceptor has one job which will be to intercept a paper wad, or plastic golf ball in this scenario. This constraint will be diligently monitored by the team and though we may try, we cannot guarantee the proper usage and administration of the warning aforementioned around students.

E. Survey of Solutions

As mentioned earlier, this project is essentially a scaled down version of anti-missile defense systems. While several systems and devices like this already exist on a large scale, the constraints the team faces make the implementations slightly different. However, it is important for the general approach and structure of these devices to be considered when possible. Due to this, it is necessary for the team to consider the current technologies on the market that can be used to build this scaled down system. This system also has a variety of subsystems with multiple implementations to consider when looking at approaches and solutions. The most relevant solutions the electrical engineering team needs to consider is how to track the trajectory of the golf ball and how to communicate this information to properly coordinate the projectile's launch.

Motion sensing cameras seem like a sensible approach for detecting the trajectory of the golf ball using the provided sensor posts. However, it is important to remember that many motion sensing cameras activate when motion is detected [15]. While it has been shown through experimentation that motion sensing cameras are capable of tracking movement, this is in conjunction with an inertial sensor [16]. These inertial sensors tend to be much more expensive than the preferred budget for this project especially since there are cheaper options that achieve the same goal for the slower moving targets in this system. This leaves more simplified options for the motion sensing cameras. One of these options is tracking the time it takes for the ball to travel from one sensor to the next. Doing this will allow the velocity of the ball to be estimated which can be used with the angle of the fishing line to predict the trajectory.

There are also other camera-based options like depth sensing. These cameras could be used to map out the field [18]. Changes would be tracked similarly to the motion sensing cameras approach to calculating and predicting the trajectory. It is also worth noting that other sensors like a microwave motion detector can be used and implemented this way as well. This could offer more flexibility and cheaper options. The general solution of tracking the speed and position of the golf ball by using multiple sensors seems to be achievable through the combination of different types of sensors. In addition to this, tools can be used to make the detection easier. For example, a filter could be applied to the camera to only detect one color range, and a light could be used to make the golf ball that color since it has been shown camera tracking is easier if it is done by color [21] [22].

The technology behind these motion detecting cameras should also be examined to find a variety of solutions. For the purposes of tracking a golf ball, sensors that output frequencies like microwave or ultrasonic sensors are ideal. These sensors function by emitting a frequency of varying range depending on the type of sensor and then detecting motion through changes in the signal that is bounced back to the sensor from the area being scanned. The sensor has to send out frequencies and then received the signals before motion in order to detect changes in the area [23]. This provides a map of the arena that the sensor can detect the difference in once a new object is introduced. This allows for the position of the golf ball to be well known since the arena is mapped out and how the frequency bounces back determine location. Multiple sensors can help track the speed and relay the necessary information the launcher needs to aim at the target.

For the sake of integrating the sensor's information with the interceptor, a wireless connection will be made via transceivers. However, a device will be necessary to interpret the information from the sensors and determine the action needed to intercept the projectile. Two types of devices would be able to perform this task. One is an Arduino which can be connected to a transceiver. The other is a raspberry pi which could connect via a WiFi network which, in this case, would be established with the sensor as the means for wireless communication. These two devices could both be programmed to make calculations based on the information from the sensor. The exact action will come from testing, experimentation, and calculations from the team to model the expected action of the golf ball. There are several options for the actual programming process to determine the trajectory of the approaching golf ball.

Several trajectory predicting algorithms exist and have been implemented with tracking projects. There is also an open-source computer vision software that can be used for sensor tracking and trajectory prediction. This project will require a lot of data and modeling acquired from experimentation in order to predict the golf ball's trajectory. However, it could be useful to look at these algorithms to understand how to implement the data model. It could also be useful to understand how these algorithms are used in other tracking software for accurate trajectory prediction and apply it to the interceptor design. These algorithms also utilize several important equations like the Kalman filter [28]. This filter is considered highly accurate and is commonly used for tracking and predicting trajectory.

While the launching mechanism and choice of projectile is largely a mechanical problem, it is still important to discuss the different possibilities for this mechanism. The team is considering several options at the moment. One is to use a set of gears for rotating vertically and horizontally in order to aim at the incoming golf ball. The actual mechanism for firing itself has several different options. One is using a spring that is calibrated to keep the projectile's launch short and just impactful enough to create a collision with the target but not hard enough to be dangerous. Another option is compressed air or carbon dioxide for the launching. These both will require careful calculations to stay within the specifications. The final option that has been presented is a using motor for the launching process. It has also been proposed to attempt changing the velocity of the fired projectile based on the position and velocity of the golf ball. The main deciding factor for this system will be the projectile that the team ultimately decides to choose. A final decision will be made after further discussion, research, and testing on the proposed projectiles.

There are several options for each different subsystem in the project. Each implementation has advantages, disadvantages, and unknown factors. However, each implementation is plausible for the team to use in order to achieve this project's goal. This leaves several options open for the team to consider during final stages of design.

F. Challenges

Challenges have already begun presenting themselves in the early portion of this project. These challenges include lack of experience (mainly in signal analysis and sensor knowledge), limited time, maintenance of a smaller budget to improve our scoring multiplier, and limited communication and separation from the mechanical team. These are, of course, the early-stage challenges we are facing, and we fully expect more problems to arise throughout this entire process.

G. Summary

Our project, paper wad or golf ball interceptor challenge, poses four main design and implementation goals: design of a tracking system, a wireless system that connects the tracking to the firing mechanism, a firing mechanism, and finally the powering of the entire system. This, of course, must be accomplished while also adhering to each relevant standard and the rules and regulations laid out for use by our customer.

III. The Solution Process

The problem has been defined with constraints, necessary systems, and possible equipment for a solution. Now, the problem has to be solved. The team intends to outline the process for finding and developing the best possible solution. This includes an outline of more specific implementations of how to solve the problem and how to integrate all the subsystems into one system.

A. Unknowns and Obstacles

When working on a multi-phase project there are many things that could go wrong, so addressing as many of those problems before they happen will help us prepare and minimize obstacles we may face. Mentioning the anticipated problems will minimize wasted time and money. This will also keep the team properly informed which will reduce down-time and confusion.

1) Working with another team: This is probably the most apparent unknown that raises the most concerns when examining the project. Issues of communication between the two teams need to be addressed with a plan that is agreed upon by both teams to be effective. In general, clear and concise communication will be the best way to keep everyone involved in the project informed, prevent design incompatibilities, minimize pressure and hostility, and overall make the design and building process go smoothly. The goal for addressing this issue is to establish an open line of communication between the two teams and to have reoccurring meeting that allows each team to update the other on progress, ideas, and new expectations and possible problems. This will most likely take a few meetings between the teams for each party to properly understand the other, divide the work and systems based on skills and knowledge of each individual team, and determine how in-depth of an explanation is relevant for the other party to integrate the systems together.

2) System Malfunction and Fire: Per rule book guidelines given by our stake holder we are required to design a clearly marked emergency cut off switch that will make the contraption immediately cease function when pressed. However, this is not the only standard we intend to follow to ensure the safety of our team and others since there are several federal standards that are also important to consider. If, unfortunately, a fire or malfunction occurs, the team is ready to implement the required fire safety training to properly handle the emergency situation. Possible malfunctions in specific components and subsystems should be found in the extensive experimentation the team plans to perform before implementing the system as a whole and testing the system in its entirety. Entire system failures should be found during the experimentation involving the game board and with many possible game situations. Of course, simulations will also need run with the code to ensure it is safe to implement with the interceptor.

3) Supply chain issues: Finding multiple companies that sell similar products at similar prices is the only reasonable solution to this problem. The team plans to have multiple options early on as the solution starts to become more detailed. If this issue still persists after having a few options for implementations and a variety of products to use, the team will make choices based on quality and company reputation to find the best solution that can arrive in time for the prototype to be created.

4) Personal and Family issues: Personal and family issues should be addressed to the group as soon as possible; details are not required. Estimated time of arrival back should also be addressed so distribution of workload can be delegated to the rest of the team so that the team does not fall behind during their absence.

5) Safety hazards while calibrating: While trying to meet safety standards outlined in the rule book, we must consider the risk and hazards that come with testing a firing mechanism. While testing, eye protection is always required. One constraint imposed by the rule book is that the projectile must not break through a piece of paper from two feet away. To maintain a safe environment during testing the sheet of paper will be clipped instead of held to reduce the possibility of injury.

B. Measurements of Success

The overall measurement of success for our system can be recorded as: this system will accurately deflect and intercept each moving target, even with the variable heights and speeds. Simply put, our system needs to stop moving the target every time. This can be tested and observed on the day of the competition when reviewing the score sheet, as the score sheet depicts the misses and hits for each round. For the team's own experimentation, at least one full simulation of the competition should be conducted to determine success before presenting the final design to the customer. Now, this overall success is broken down into several smaller components, each with its own standard for success. These components include: several sensors implemented to track height, speed, and tension; firing mechanism; possible wind barrier; software that could include some machine learning; and projectile used.

Sensors: The system will accurately detect which height the golf ball is travelling from, and it will detect the speed at which that golf ball is moving. Height tests could be developed by setting up the desired sensor in the location predetermined to track height, and have it connected to some sort of light or buzzer system that will clearly show the sensor or sensors have detected the correct height. As for speed, an experiment can be created between the multiple sensors, lights/buzzers and a clock that will all work in unison and clearly show the system's ability to capture speed.

Firing Mechanism: The system will fire on time when given the customer defined command when given the correct command. Both successful measurements can be easily tested through the proper experiments. To test the system's ability to fire on time, we will design an experiment centered around giving the mechanism delayed firing or signals that become delayed through its path, and then record if the mechanism fired at the correct time. Testing the force is also simple, as we will fire the projectile at the golf balls to determine if enough force is applied to get the desired result, while also testing against the rule book's standards.

Wind Barrier (potential system): The system will stop the golf ball's forward movement toward the finish and allow the firing system to have a simple and direct trajectory. It would also be successful if the wind barrier slowed the golf ball down in some way if we decided not to implement it as a full-on stopping device, but just as something to slow the speed. To test this system's capabilities, we will simply have the golf ball go at various speeds on its fishing line trajectory and record the results if the wind barrier had any effect on the golf ball's speed.

Software: The system needs to take the speed inputs and height input, then calculate the proper friction and fishing line tension, to calculate an accurate time to fire the projectile so the projectile contacts the incoming golf ball. This can be tested through experiments designed to measure the delay between initial input and firing of the projectile. This also includes some machine learning, as the software needs a large portion of data that includes different speeds and heights so it can understand what kind of tension and friction to expect. This will require our team to run a large portion of experiments centered around measuring different speeds relative to the line tightness, so our system knows what to expect.

Projectile: The projectile will be large enough to give the firing mechanism some leeway on calculating the exact firing time but needs to be small and light enough to be easily fired from the mechanism. This can be easily tested by loading different potential projectiles into our simulated firing mechanism, and, using data gathered from our tests, determining the most optimal projectile size. The size limitation of the entire mechanism will also be considered. Because the team is not allowed to touch the mechanism during fifteen rounds, the projectiles need to be housed within the one foot area. If the projectiles are too large, they will take up too much room.

C. Anticipations and Reasoning

It is important to use the current solutions the team knows about to develop a line of reasoning that will be used when designing the interceptor. This will be done by examining implementations more in-depth and weighing the advantages and disadvantages of the possibilities. This is to outline the process of what the team expects to face and how these design choices will be handled. There are detailed examples to accurately showcase the thought process that will be incorporated for this project.

The launching mechanism consists of a turret that must be able to aim at the target. Therefore, servo or stepper motors are being considered for implementation. These options both have their pros and cons. Stepper motors are cheaper and faster but have low torque at high speeds and cause a lot of mechanical vibrations especially at lower speeds. Servo motors on the other hand, have consistent torque regardless of speed, has a closed loop operating system, which can help with making sure the turret is aimed correctly, and is more accurate with movements. However, servos cost and weigh more than steppers [29]. Due to the mechanical vibrations of the stepper motor and the closed loop operating system of the servo motor, the servo motor is what this part of the team will be recommending to the Mechanical team. An Arduino can be used to control each of the servo motors and read the feedback to make sure that the turret is aimed properly at the target. The programming language used for programming the Arduino is C++.

Each sensor will most likely consist of one or two cameras that will provide data on where the target is along the fishing line as well as the height of the target. In order to track the position along the fishing line there is a popular open-source API that is able to use the cameras as an input and track a moving object's position called OpenCV [30]. There is another option available called Tensorflow, however it goes much further into deep learning algorithms which is not as ideal for this project given the time constraints and the specific nature of the problem [31]. There are two different strategies for tracking the height of the target. One way would be to use one camera and measure the diameter of the target. As the target gets closer to the camera, it will cover more pixels which can be measured to get a reading on how high up the target is. The other way is to use two cameras and calculate the distance from the camera using triangulation. The images pulled from the camera will immediately be sent to a transmitter which will send the data to a receiver located on the launcher itself. If cameras are not used, some other type of sensor will have to be used such as an ultrasonic sensor, microwave sensor, or laser sensor. Using these types of sensors, tracking the target would have to be done by checking the position of the target in two places and calculate the speed and then predict where it will be when the launching mechanism fires. Each sensor must also be battery powered. Therefore, a small battery, battery management system, and charging system are needed to ensure safe operation.

The processing unit will most likely be a Raspberry PI. The PI will allow us to process the images from the sensors using OpenCV and calculate where the target is as well as predict where the target will be when the projectile is launched. The PI will be directly connected to the Arduino controlling the turret but not directly connected to the sensors. Instead, it will be connected to a receiver pulling data that is being transmitted from the sensors.

The power management system will route quality power to both the processing unit and the launching mechanism. Since the launcher will be plugged into the wall, the system will have to convert from AC to DC and ensure that the signal is consistent and does not fluctuate so that it will not harm any other component involved.

Some of the skills needed to complete this project include both programming and hardware skills. On the programming side, C++ is needed to program the Arduino to aim the turret to certain points along each fishing line as well as tell the launcher when to shoot. C++ or python can be used to process the images into data points that can be sent to the Arduino. Also, some computer networks knowledge will be helpful in ensuring that data being transmitted is being received properly and accurately. As for the hardware side, circuit design will be used when designing the PCBs for the power management system and battery management system. Also, individual circuit components will need to be soldered on to the PCBs.

D. Responsibilities, Ethics, and Broader Implications

As mentioned, one ethical concern we may have for our system is that it is meant to simulate a defense system for incoming projectiles within a classroom setting. It would be unethical to not consider the impressionable children, or teenagers, that may see this design at school. This may cause some unforeseen consequences and possibly damage to self or property. That being said, it may be an ethical decision to add a warning label to a design that may end up in a classroom. Though the team's design may not specifically be used in this setting, based on the rulebook some future designs may make it to schools. Implementing a warning label at this stage in the lifespan of this outreach project may lead to it being implemented when it possibly makes it to that stage.

Another concern when implementing this device is the use of Wi-fi to communicate between the sensors and the interceptors. The Wi-fi bands the team is considering are both for unlicensed public use. This brings up the concern of privacy for the network the system will be using. As engineers, the team needs to consider how to keep other devices from connecting to the signal. This means we need to take measures to ensure the connection and network is secure. The team plans to look for different implementations ensuring privacy like using password protection on the network to ensure only pre-determined devices are able to access the system.

It is important that we consider the possible environmental impact of our project. This includes the materials and parts used in the Paper Wad Interceptor, their recyclability, and overall sustainability. As engineers it is best to use environmentally friendly options whenever feasible. This will ensure that The Paper Wad Interceptor's global impact is small while ensuring the team's end goal is met.

The team also needs to create and up-keep documentation on the interceptor which plays a crucial role in responsible engineering. Providing detailed instructions, guidelines, and safety protocols in our documentation and additional created materials is vital for the proper understanding and utilization of the Paper Wad Interceptor. Documenting progress updates, implementation, and obstacles will keep all parties involved informed. Clear documentation will contribute to the responsible and informed adoption of our technology, aligning with our commitment to safety, ethics, and engineering responsibilities. Communicating with the necessary parties and sharing documentation is essential to achieve all of the team's goals and deliver the best product possible.

IV. Resources

It is important to understand the constraints imposed by the stakeholders for this project and design an approach to finding a solution that stays within these specifications. However, it is also important to outline the constraints that come from the time, money, and skills necessary to complete this project. All three of these aspects need to be addressed with a plan to implement the project successfully.

A. Skill Set

This team is made up of several people with a diverse skill set. While there is overlap between the skill sets of each individual, the team has members with unique interests and backgrounds in the topics familiar to each individual. The discussion of the necessary skills and experience needed for this project has led to the creation of a list of skills team members either currently possess and can expand on or plan to learn for the project. It is important to note that the entire team also plans to learn about sensors in great detail including the possible implementations and operations since the sensor subsystem is the crux of correct operations for the project and every other system will need to incorporate the sensor or its data in some capacity. As other necessary skills are inevitably needed for the project, the team will decide who has the best background to learn and incorporate this skill into the current tasks being performed for the project.

Garret Armstrong
- Power Management
- MATLAB
- Machine Learning

Savannah Metlzer
- Control Systems
- Optoelectronics
- Power Management

Jonathan Neal
- Visual Design
- Writing
- VHDL

Finlay Patoto
- C#
- Microcontrollers
- VHDL

Katie Swinea
- PCB Design
- Algorithms
- Troubleshooting

Kevin Ulrich
- Soldering

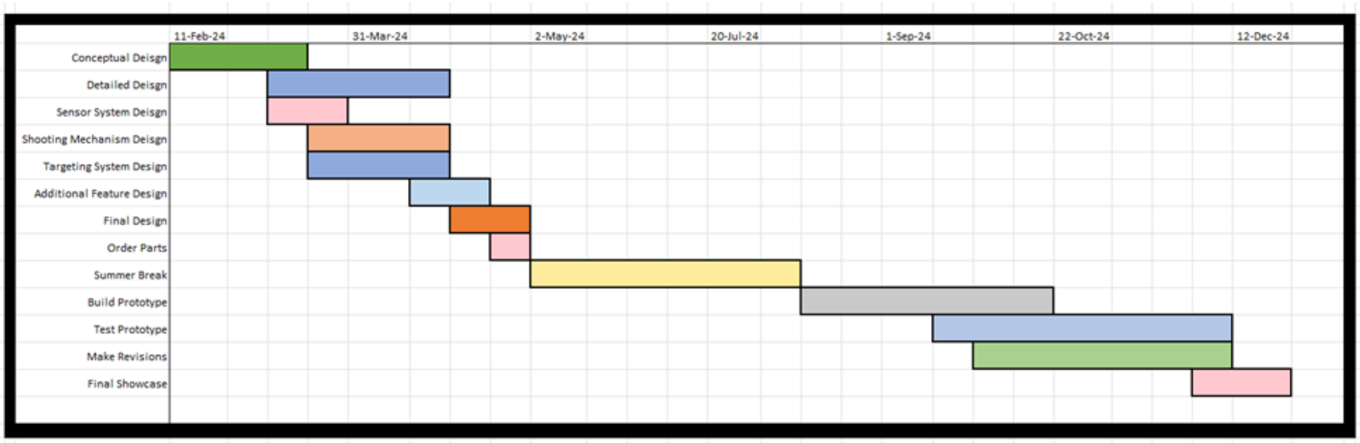

Fig. 3. Timeline

- Digital Logic Design
- C ++

B. Budget

The budget is divided by the subsystems and components that the team is considering. The different types of equipment necessary for the implementation can vary largely in price. Since the particular solution has not yet been chosen, the team is using a broad range that can accommodate different implementations.

Equipment	Min	Max
Sensors	\$100	\$200
Processing Unit	\$100	\$150
Power Management	\$30	\$60
Boards and Components	\$25	\$50
Mechanical	\$180	\$220
Unknowns	\$65	\$102
Total	\$500	\$782

TABLE I
GENERAL BUDGET

C. Timeline

The timeline shown in figure 3 is the team's plan to complete the capstone project. The current plan is to complete the interceptor in the year of 2024. The goal is to have a working project for the contest and compete against the other team next December. The timeline shows how the team anticipates to start with the design of each individual system and order parts before the summer then build, test, and optimize the prototype in the following semester before the contest. This timeline also outlines summer break as a time hiatus from any work for the project.

V. REFERENCES

[1] ”S3I Paper Wad Interceptor Challenge 2024,” DevCom, PaperWodInterceptorChallenge_Rules_V3_3.pdf

[2] “Fact sheets & briefs,” Arms Control Association, https://www.armscontrol.org/factsheets/missiledefenseataglance

[3] “What is FCC part 15.247 for Bluetooth/WLAN 802.11 b/g/n (2.4 GHz)?,” Compliance Testing, https://compliancetesting.com/what-is-fcc-part-15-247-for-bluetooth-wlan-802-11-b-g-n-2-4-ghz/

[4] Federal Communications Commission § 15.247, https://www.govinfo.gov/content/pkg/CFR-2010-title47-vol1/pdf/CFR-2010-title47-vol1-sec15-247.pdf

[5] “Commission documents,” Federal Communications Commission, https://www.fcc.gov/documents

[6] “Standard Consumer Safety Specification for Non-Powder Gun Projectiles and Propellants,” compass, https://compass.astm.org/document/?contentCode=ASTM%7CF0590-22%7Cen-US

[7] “Standard Consumer Safety Specification for Non-Powder Guns,” compass, https://compass.astm.org/document/contentCode=ASTM%7CF0589-17%7Cen-US&proxycl=https%3A%2F%2Fsecure.astm.org&from Login=true

[8] “USCODE-2022-title15-chap76-sec5001,” govinfo.gov, https://www.govinfo.gov/content/pkg/USCODE-2022-title39/pdf/USCODE-2022-title39-partV-chap50-sec5001.pdf

[9] “Marking of Toy, Look-Alike, and Imitation Firearms,” Federal Register , https://www.federalregister.gov/documents/2023/05/11/2023-09999/marking-of-toy-look-alike-and-imitation-firearms

[10] “ETool : Lockout-tagout - hot topics - energy control program - specific procedures for energy control and control circuitry prohibition,” Occupational Safety and Health Administration, https://www.osha.gov/etools/lockout-tagout/hot-topics/energy-control-program/energy-control-circuitry-prohibition#:~:text=All%20energy%20isolating%20devices%20used,energy%20source%20and%20deenergize%20it

[11] “The control of Hazardous Energy (Lockout/Tagout),” Occupational Safety and Health Administration, https://www.osha.gov/laws-regs/federalregister/2019-05-20

[12] R. Stull, “IEC 60335-1 explained: Safety standards for household appliances,” CUI Inc, https://www.cui.com/blog/iec-60335-1-explained-safety-standards-for-household-appliances#impact-on-power-supply-design

[13] A. Johnson, “The latest on IEC 62368-1: The Time to act is now,” CUI Inc, https://www.cui.com/blog/the-latest-on-iec-62368-1

[14] “IEC 62368-1,” CUI Inc, https://www.cui.com/catalog/resource/iec-62368-1-an-introduction-to-the-new-safety-standard-for-ict-and-av-equipment

[15] S. Henry-Stocker, “How motion detection cameras work,” Network World, https://www.networkworld.com/article/930942/how-motion-detection-cameras-work.html

[16] O. Birbach, J. Kurlbaum, T. Laue, and U. Frese, “Tracking of ball trajectories with a free moving camera-inertial sensor,” SpringerLink, https://link.springer.com/chapter/10.1007/978-3-642-02921-9_5

[17] C. Yates, “High-speed vision system targets ballistics analysis,” Vision Systems Design, https://www.vision-systems.com/non-factory/article/16738233/highspeed-vision-system-targets-ballistics-analysis

[18] S. Kirci, “Depth Sensing Camera Technologies,” Medium, https://medium.com/@kircisedanur2/depth-sensing-camera-technologies-afaf9ddb5a01

[19] G. Varalijai and S. Szenasi, Projectile detection and avoidance using computer vision — IEEE ..., https://ieeexplore.ieee.org/document/9305816

[20] “Digital Camera Sensors,” Understanding Digital Camera Sensors, https://www.cambridgeincolour.com/tutorials/camera-sensors.htm

[21] L. Fermum, Colour filters, https://www.vision-doctor.com/en/colour-filters.html

[22] “Why track colors?,” Color Object Tracking, https://www.roborealm.com/tutorial/color_object_tracking_2/slide010.php#:~:text=Tracking%20objects%20based%20on%20color,cause%20the%20tracking%20to%20fail.

[23] L. Slade, “What is a microwave motion detector?,” Brinks HomeTM, https://brinkshome.com/smartcenter/what-is-a-microwave-motion-detector

[24] “Electromagnetic spectrum,” COSMOS, https://astronomy.swin.edu.au/cosmos/e/electromagnetic+spectrum

[25] K. Tross, “The beginner’s guide to motion sensors,” SafeWise, https://www.safewise.com/resources/motion-sensor-guide/#:~:text=Passive%20infrared%20(PIR)&text=This%20is%20the%20most%2Dwidely,sensor%20in%20home%20security%20systems.

[26] Ehsmaes, “Arduino wireless serial communication,” Instructables, https://www.instructables.com/Arduino-Wireless-Serial-Communication/

[27] How to connect to a raspberry pi via wireless/WIFI, https://rimstar.org/science_electronics_projects/connect_to_raspberry_pi_via_wifi_wirelessly.htm

[28] T. Lacey, Tutorial: The kalman filter, https://web.mit.edu/kirtley/kirtley/binlustuff/literature/control/Kalman%20filter.pdf

[29] V. Kohli, “Stepper vs Servo Motors: A comprehensive comparison for your next project,” Wevolver, https://www.wevolver.com/article/stepper-vs-servo-motors-a-comprehensive-comparison-for-your-next-project

[30] “About,” OpenCV, https://opencv.org/about/

[31] “Why tensorflow,” TensorFlow, https://www.tensorflow.org/about