# Golf Ball Deflection System Conceptual Design

Adam Morrow | Allen Watson | Colby Drake | Jonah Burke | Tyler Kasuboski | James Jones
*Electrical and Computer Engineering Department*
*Tennessee Technological University* Cookeville,
TN
awmorrow42@tntech.edu, arwatson42@tntech.edu, cjdrake42@tntech.edu, jlburke42@tntech.edu,
tkasubosk42@tntech.edu, jtjones49@tntech.edu

## I. Introduction

The Golf Ball interceptor project is expected to be a competition between two teams of engineers, and the goal of this competition is to intercept incoming projectiles in a manner that is safe to be done in a classroom. The safety requirements and competition process are provided by DEVCOM [1]. The design to complete this task is expected to be function effectively as well as being cost effective. In order to completing this task, our team has divided the project into six modules that work together seamlessly. Within these modules the minimum requirements are explained for each to properly complete our given task. All these requirements will be determined by our shall statements below. Finally, all requirements must be able to be completed by following all the relevant standards that are listed below.

### *A. Formulated Problem*

In order to successfully complete this project and compete well the interceptor must be fast, efficient, accurate, and safe for all observers. The following constraints are all included in our design to confirm our interceptor meets expectations.

1) Create an interceptor capable of functioning on its own without outside interaction.
   - This constraint that is a direct requirement from the provided rule book [1]. The rule book states, "Interceptor must work on its own. Any outside interference or assistance will cause for immediate disqualification." Therefore, the team must design the interceptor to be autonomous for the entire duration of the competition.
2) Create an interceptor capable of wirelessly communicating with the sensor array.
   - This is a constraint that is required by the costumer and is explicitly stated in the provided Rule book [1]. This constraint also explains how the interceptor's main body will communicate with the systems sensor arrays.
3) Create an interceptor capable of fitting inside a 1x1x1 foot box before powering on.
   - This constraint was required by the customer and is stated in the competition rule book [1]. This constraint governs the footprint of the interceptor ensuring that the size of components is a factor.
4) Create an interceptor that poses no danger to spectators.
   - This constraint is required by the customer and is stated in the rulebook [1]. The constraint ensures that each part of the interceptor cannot harm spectators.
5) Include a clearly marked power switch on the interceptor.
   - This constraint is required by the customer and is stated in the rulebook [1]. This constraint will ensure that the interceptor will not operate unless the device has deliberately been powered on.
6) Include a clearly marked emergency stop option on the interceptor.
   - This constraint is required by the customer and is listed in the provided competition rulebook [1]. This constraint also falls under the NFPA 79-10 standard which governs the color and shaped of an emergency stop button. This constraint ensures that should an issue arise with the interceptor there is a way to quickly stop all motion of the machine.

7) Design a sensor array that can detect approaching objects and relay their locations to the interceptor.
    - This is a constraint that was created to take full advantage of available resources provided in this competition. Due to the lack of space allocated for the interceptor, it is paramount to use all available resources to determine incoming projectiles trajectory.
8) Design a sensor array that operates on battery power.
    - This constraint is required by the costumer, as well as a explicitly stated in the provided rule book [1]. This constraint directly impacts all sensor array designs.
9) Design an interceptor that complies with the safety check list provided in the competition rules [1].
    - This constraint was formulated by the team to ensure that before completion of the interceptor the team reviews the safety list. This helps to ensure that the interceptor poses no threat to the safety of spectators and the environment.
10) Design an interceptor that has lights.
    - This constraint was created due to additional points being rewarded for interceptors making use of lighting [1]. This constraint will help ensure that the team will obtain those additional points. Additionally, this constraint adds an extra layer of safety to the device by helping to make the interceptor visible to spectators.
11) Design an interceptor with decorations contributing to camouflaging of the device.
    - This constraint was made due to the additional points awarded for interceptors with decorations that aid in camouflaging the device listed in the rule book [1]. This constraint helps to ensure the team is mindful of even the smaller details of the project.
12) Design an interceptor which plays an alert noise before firing.
    - This constraint was made due to the additional points awarded for interceptors with decorations that aid in camouflaging the device listed in the rule book [1]. This constraint ensures the team gets those points. Additionally, this constraint will play a sound that clearly indicates that a projectile will be launched from the interceptor which adds to the safety of the device by audibly notifying spectators that the interceptor is about to fire.
13) Design a network that has the capability to have up to six inputs to a master device.
    - This constraint was formulated due to the amount of sensor posts given in the competition rule book [1]. It is expected to have a maximum of one wireless signal transfer device per sensor post.
14) Design a system with a maximum sensor input delay of 100ms.
    - This constraint is a rough estimate of how much time will be available for Sensor wireless transmission. Using the calculations shown in Figure 7 in the Appendix, the team can assume the worst case scenario for a projectile to reach the interceptor is about 2.2 Seconds. The team believes that that if less than 10 percent of the allocated time is used on signal transmission the interceptor will have an adequate amount of time to deflect projectiles.
15) The Interceptor project shall have solders that conform to the IPC -J-STD. [2]
    - This constraint, due to the IPC-J-STD soldering standard, will allow the team to hold all solders made throughout the project to a professional level.
16) The Interceptor project shall have a safe wiring scheme for all components of the project.
    - Using the NEC 310.15(B)(16) standard, [3] the team will be able to gain the insight needed to design a safe, and reliable wiring scheme for the components throughout the

project. The 310.15(B)(16) shows the ampacity limits for different kinds of insulated conductors.

17) The Interceptor project shall not emit a harmful amount of Radio Frequency (RF) or Electromagnetic Interference (EMI)
    - This constraint from the FCC standard parts 15 and 18, [4] will allow the group to ensure a level of safety when the project is in operation.
18) Design a wireless transmission network that complies with all applicable Standards. [5] [6]
    - There are multiple IEEE standards that applicable to wireless networks. Two of these standards are IEEE 802.11 for Wi-Fi as well as IEEE 802.15 for WPAN, like Bluetooth. As engineers it is our ethical duty to follow all industry standards in order to follow the IEEE code of ethics.
19) The Design shall implement the best remote battery power solution to limit the interceptor's environmental impact.
    - This constraint is chosen to address the broader impacts that batteries have on environmental contamination. The design choice of the battery is determined by the power draw of the system as well as the expected runtime of the system.

## II. Ethical, Professional, and Standard Considerations

### *A. Ethical Considerations*

As electrical and computer engineers, the team has a commitment to the IEEE code of ethics [7]. In the team's design it was a high priority to consider the safety of the people involved in the competition and the environment around them. Therefore, the design of the interceptor is intended not to harm any bystanders which is listed as constraint 4 above. This includes ensuring that the projectiles used in the launcher do not harm the game board or anything outside the game board. The sounds played on the interceptor will act as an alert to bystanders rather than just a decorative function to ensure the safety of everyone involved as mentioned in constraint 12. In addition, the team is responsible for following the rules of the competition rule book. This includes if any ideas obtained directly from the other team that were used in the design of the interceptor, the team would cite those ideas accordingly so that the opposing team would receive credit. Also, the interceptor will go through a safety checklist as mentioned in constraint 9.

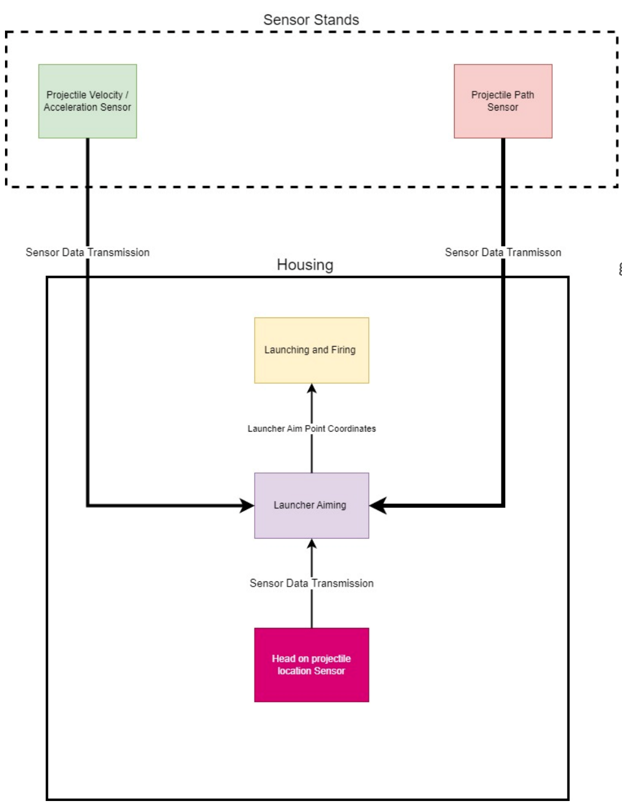
### *B. Standard Considerations*

Any standard applicable to the design and function of the interceptor will be followed and used as a constraint in order to achieve a safe and reliable solution. Rules given in the DEVCOM rulebook will also be used to meet customer needs. For example, in the DEVCOM rulebook [1] it is stated that the interceptor should fit in a single foot of cubic space (1ft in length width and height) so during the design process, we will take this into consideration to ensure that the specific need is met. In another example, the customer states a requirement where a specific standard would apply, such as the emergency power stop mentioned above in constraint six. This constraint may exist due to the customer requirement, but the NFPA 79 – 10 standard [8] will be followed to ensure that the emergency stop button placement and function operates in a safe and reliable way. For the wireless data transmissions that will occur form the sensor posts to the main body, the Wi-Fi standard [5], the Bluetooth standard [6], and the FCC standard on RF emission [4] mentioned above in constraints seventeen and eighteen will be followed when applicable. Other standards such as the standard from NEC on insulated wire ampacities [3] will also be followed. This standard is mentioned in constraint sixteen.

### C. Broader Impacts Considerations

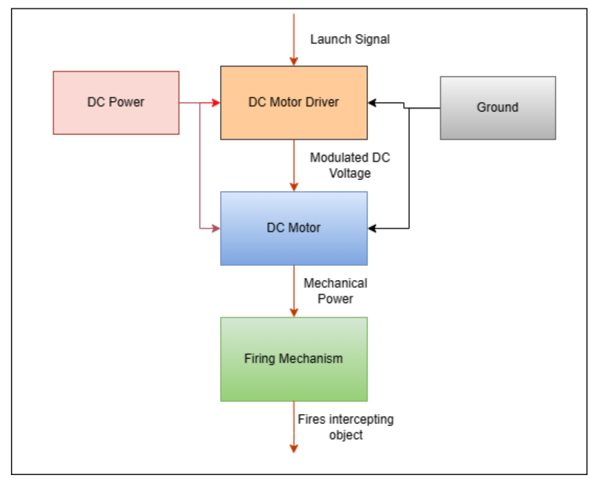
The team heavily considered the broader impacts of the interceptor project. The effect of the interceptor on future competitions is likely to be significant. The team's design will show some of what is and isn't possible for future competitors. While the scope of this project is largely restricted to the competition it is feasible that a scaled-up version could have impacts to the world outside of the competition and academia. Such a project could have impacts to the average person's faith in missile interception showing that it is possible. It could inspire students to go into related fields. While these impacts are largely good the team has considered negative impacts. A chief concern is the environmental impact a scaled-up interceptor and sensor array would have. Batteries used in the sensor posts have the potential to cause a large impact to the environment. In order to help mitigate the impact of the interceptor and pave the way for sized up versions the team drafted constraint 19. This constraint helps to ensure the team is focused on the impact on the environment the interceptor may have.

## *IV. Block Diagram Modules*




### A. Launching and Firing

The Interceptor will be able to accurately fire an object toward the incoming projectile before the projectile reaches the Interceptor without interaction during the competition(C1). The projectile will remain compliant with the projectile guidelines given in the DEVCOM rulebook. [1] This subsystem contains three smaller subsystems which are the DC Motor Driver, DC Motor, and the Firing Mechanism subsystems. This subsystem will be physically located in the main housing within the single cubic foot of space allowed for the Interceptor body. A block diagram showing the Launching and Firing subsystem is shown in Fig. 2 below.




g and Firing Block Diagram

1) DC Driver: The DC driver contained in the Launching and Firing Block Diagram will be able to send the proper voltage and current to the DC motor to allow this motor to work to its specifications when given the signal to fire from the aiming subsystem.

Inputs: Firing Signal, DC Voltage

Outputs: Modulated DC Voltage

Applicable Constraints : C1, C3, C9, C15, C16

Analytical Verification: The specific DC driver used will be selected as a result of the DC voltage that the DC motor will be running off of as well as the voltage and current requirements needed to allow the DC motor to supply mechanical power as needed for the firing mechanism.

2) DC Motor: The DC Motor contained in the Launching and Firing Block Diagram will activate and supply mechanical power to the firing mechanism when activated by the DC driver.

Inputs: Modulated DC Voltage

Outputs: Mechanical Power

Applicable Constraints: C1, C3, C9, C15, C16

Analytical Verification: The specific DC motor used will be selected as a result of the DC voltage available, mechanical power required for the firing mechanism, and the type of motor action needed to engage the firing mechanism.

3) Firing Mechanism: The firing mechanism will be built mainly by the mechanical engineers to safely fire the object towards the incoming projectile when prompted by the DC motor. To minimize risk to bystanders, the object shall be no more than 6 feet away from the Interceptor when the object comes to rest, as stated by the DEVCOM competition rule book. [1]

Inputs: DC Motor Mechanical Power

Outputs: Fires an object

Applicable Contraints : C1, C3, C4, C9, C15, C16

Analytical Verification: The firing mechanism will be built to comply with the safety and competition-rule constraints listed in the DEVCOM rulebook.

## A. Housing

The main housing for the interceptor is crucial to the operation of the device. It serves as the platform from which the rest of the interceptor will be built from. This subsystem will contain three smaller subsystems.

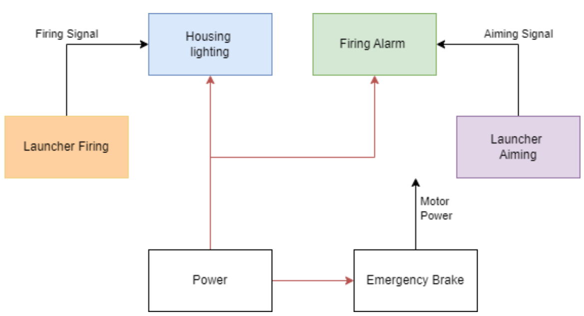



Figure 3. Housing Block Diagram

1) Emergency Break

Inputs: Emergency Brake button, power

Outputs: Motors

Applicable Constraints: C3, C4, C6

Analytical Verification: The interceptor must have a clearly labeled emergency break which will stop all mechanical function. This is to verify constraint six is met. When activated the emergency break will open all circuits connected to motors and other select components. This will prevent power flow therefore preventing motion of the interceptor.

2) Firing alarm speaker

Inputs: Aiming signal, power

Outputs: Audible sound

Applicable Constraints: C3, C11, C12

Analytical Verification: Before firing a projectile, the interceptor must play an audible sound. This to verify constraint twelve is met. A human being takes on average 140-160 ms to react to a sound. [9] To ensure spectators are aware that the interceptor is about to fire the interceptor will begin playing a sound at least 200 ms before firing.

3) Housing Lighting

Inputs: Firing signal, power

Outputs: always on lights, firing lights

Applicable Constraints: C3, C10, C11

Analytical Verification: The interceptor must have lights on it to both indicate that it is powered on and indicate that it has fired. The lights will also serve as part of the interceptor decorations. This is to verify that constraint ten and constraint eleven are met. The typical human eye can see lights with a wavelength of 380 to 700 nanometers. Therefore, any lighting on the interceptor intended to be seen by the human eye will fall within this range.

## B. Aiming

The purpose of the aiming subsystem is to keep the apparatus pointed in a safe direction and be able to follow the projectile to result in a reliable interception. The aiming system needs to be fast, in order to lock onto the projectile with the most up-to-date position data.

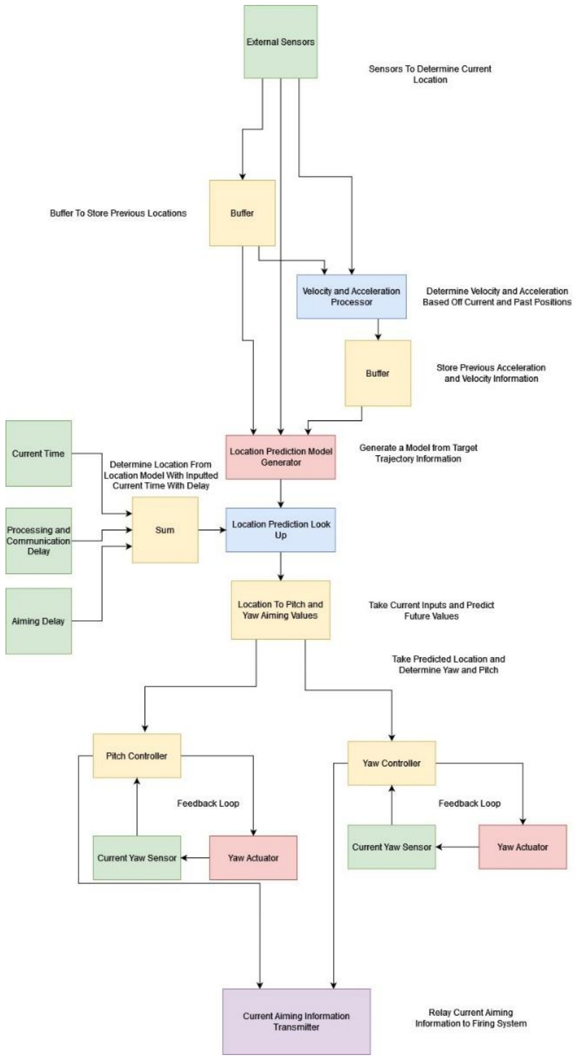



Figure 4. Aiming Block Diagram

The aiming subsystem has the job of taking current and past values of the target's location (position, acceleration, and velocity) and generating a location prediction model. A location prediction model would be a three variable output equation with and input of time. For any value of time the location model should return the expected x, y, and z values of the ball's location.

To determine where the ball will be when the interceptor fires the current time and the sum of all delays will be inputted.

Once a predicted location is determined the aiming system shall move the pitch and yaw of the firing apparatus to aim for the expected location. This aiming will be done with yaw and pitch actuators as controlled by yaw and pitch controllers. The actuators will be governed by pitch and yaw sensors that report to the controller.

Inputs: Target Location, pitch sensor, yaw sensor

Outputs: Pitch actuator, yaw actuator, aiming transmitter

Applicable Constraints : C1 C2 C3 C9

3) Housing Lighting

Inputs: Firing signal, power

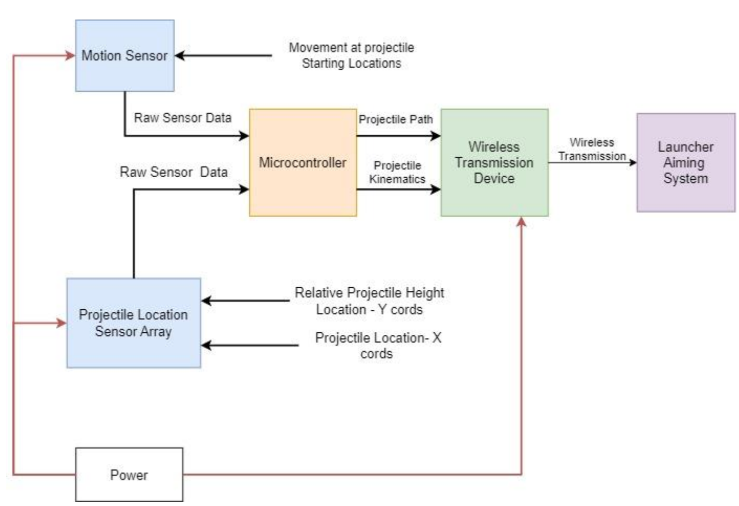
Outputs: always on lights, firing lights

Applicable Constraints: C3, C10, C11

Analytical Verification: The interceptor must have lights on it to both indicate that it is powered on and indicate that it has fired. The lights will also serve as part of the interceptor decorations. This is to verify that constraint ten and constraint eleven are met. The typical human eye can see lights with a wavelength of 380 to 700 nanometers. Therefore any lighting on the interceptor intended to be seen by the human eye will fall within this range.

C. Projectile Path Sensor

The projectile path sensor has the task of determining when a projectile is incoming and the path that the incoming projectile will take. According to the competition rule book [1] projectiles have two different starting heights and 15 possible starting positions at each height. This means that there is a



total of 30 possible starting positions. With these 30 starting locations the interceptor can estimate the trajectory.

This subsystem has five smaller subsystems within: a motion sensor, projectile location sensor, Subsystem Power, Microcontroller, and a wireless transmission device.

Figure 5. Projectile Path Sensor Block Diagram

1) Motion Sensor: The purpose of this sensor is to sense when a projectile is being prepared to be sent towards the interceptor. This will be the first signal that is sent to the interceptor, thus initializes the interception process. The team have multiple subsystems that track the start of an incoming projectile. This is done to have multiple verifications. This is to decrease risk of failure of this subsystem.

Inputs: Movement at projectile starting location, Power

Outputs: Sensor raw data

Applicable constraints: C2, C7, C8, C13, C14, C19

Analytical Verification: Sensor power requirements must be properly researched to verify that it can properly be powered to meet constraint 8. The other verification is to verify in the data sheet of the sensor has the ability to detect motion at a minimum of 64 inches from the sensor in order to meet Constraint 7. Finally, this data must be transmitted to the interceptor in under 100ms to meet the rest of this subsystem's applicable constraints.

2) Projectile Location Sensor Array: This sensor array determines the projectile starting location by sensing the relative X and Y coordinates. The starting location of the projectile helps determine the estimated projectile path to the interceptor. Similar to the motion sensor multiple sensor subsystems will measure the kinematics of incoming projectiles to limit the risk of a system failure.

Inputs: Projectile X location, Projectile Y location, Power

Outputs: Raw sensor data

Applicable Contraints: C2, C7, C8, C13, C14, C19

Analytical Verification: The sensor array must have an operating power that can be powered remotely. This is to verify constraint 8 is met. In order to properly measure the correct starting location of an incoming projectile the datasheet of the chosen sensor must have a distance accuracy of less than 4 inches. Finally, similar to the motion sensor this sensor's data must be transmitted to the interceptor in under 100ms.

Subsystem Power:

Inputs: N/A

Outputs: Motion Sensor Power, Projectile Location Sensor Power, Wireless Transmission Device Power

Applicable Constraints: C8

Analytical Verification: Proper research must be conducted to verify the chosen power supply must be able to power all subsystems in the projectile location sensor array. This will meet the requirements of constraint 8.

3) Microcontroller: A microcontroller will be used to input sensor raw data and compute the projectile path and kinematics. This limits the amount of data that is required to wirelessly transmit, also decreases the required computing power of the main body processor. In order to reduce the risk the team has planned on having all processing units ordered prior to summer break to verify shipping delay will not impact this project.6

Inputs: Motion Sensor Data, Projectile Location Sensor Data, Power

Outputs: Projectile path data, Projectile kinematics data.

Applicable Constraints: C2, C7, C8. C14, C19

Analytical Verification: Microcontroller must have proper IO to input the sensor's raw data. Also, the microcontroller must be able to be remotely powered. The microcontroller must have the processing speed to meet the 100ms transmission delay. Finally, the computed sensor data size must be capable of being wirelessly efficiently.

4) Wireless Transmission Device:

Inputs: Microcontroller calculated Kinematics, Microcontroller calculated path, Power

Outputs: Wireless Data

Applicable Constraints: C2, C13, C14, C18, C19

Analytical Verification: The wireless signal transmission device must have the capability to have a wireless network with 6 devices sending signals. Also, the delay of transmitting these signals must be less than 100ms. Therefore, the device selected must have the capability to use a wireless data transferring technology that meets this requirement. Also, this technology must also be available to the interceptor.

D. Head On Projectile Location Sensing

The head on projectile location sensor is locating the head- on location of the projectile as it is heading toward the launcher. This sensor needs to be able to detect and track a projectile from a maximum distance of 72 inches away and be able to view a width of 60 inches and a maximum height of around 50 inches. These dimensions were obtained from the layout of the arena in the competition rule book. With the head-on position of the ball, the launcher can then adjust itself to intercept the ball. This subsystem has been divided into 4 different subsystems: projectile detection sensing, a controller, device power, and signal data processing.

1) Projectile Detection Sensing: This sensor array must detect a moving projectile from the view of the launcher.

Inputs: Projectile Motion, Power

Outputs: Raw Sensor Data

Applicable Constraints: C1, C3, C7

Analytical Verification: This sensor array must be able to detect a projectile at a maximum of 72 inches deep, 50 inches high, and 60 inches wide. The sensor also must be able to able to sense projectiles at a speed going up to 50 feet per second based on worst-case scenario calculations. The sensor must be widely available to ensure that it will arrive in a timely manner for the construction of

2) Micro controller: This device should be able to receive the data from the sensor and convert it into a digital signal of the position of the ball that is usable for software.

Inputs: Raw Sensor Data, Power

Outputs: Digital Signal

Applicable Constraints: C1, C3, C7

Analytical Verification: The controller must be small enough to fit in the 1 cubic foot space and should leave ample space for the rest of the launching apparatus.

3) Subsystem Power:

Inputs: N/A

Outputs: Sensor power, controller power

Applicable Constraints: C1, C3, C7

Analytical Verification: Proper research must be required to ensure that the correct amount of power is supplied to the head-on sensing subsystem.

4) Signal Data Processing Algorithm: This module will get the sensor data and find the position of the projectile and transmit that information to the launcher.

Inputs: Digital Signal

Outputs: X and Y coordinates relative to the launcher

Applicable Contraints : C1, C3, C7, C14

Analytical Verification: The algorithm must be able to process the data fast enough to achieve C14 to get the launcher to intercept the projectile.

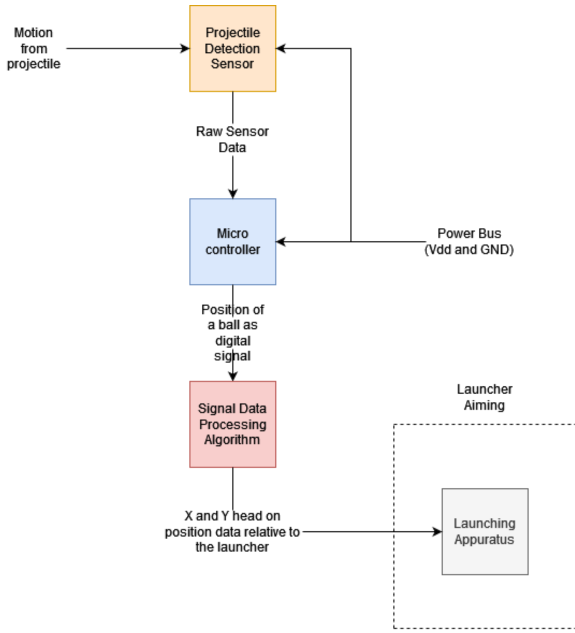



Fig 5: Block Diagram for Head On Projectile Sensing

E. Sensor Post Array

The Sensor Post array has the tasks of calculating an estimated path that the projectile has been released on, velocity of the incoming projectile, and acceleration of the projectile from the data it receives. The sensor Post will also communicate wirelessly with aiming system. This subsystem is broken up into five blocks, projectile distance sensor, velocity sensing, acceleration sensing, Sensor processing array, and Wireless Transmission Device. The block diagram for the Sensor Post Array is seen in *Figure 6*. This subsystem is broken up into five blocks, projectile distance sensor, velocity sensing, acceleration sensing, Sensor processing array, and Wireless Transmission Device.

To minimize the risks for this subsystem some critical unknowns are if a processor is available that can take the sensor data and calculate the velocity and acceleration of the projectile within the time constraints. The accuracy of the velocity and acceleration values being calculated by the sensor post array. To prevent any delivery problems all parts are to be readily available in the largest quantity possible that will also meet the constraints for the system as well as being ordered by the end of part ordering set in the project timeline in figure 8 located in the appendix. By having the parts ordered by the end of timeline and large quantities available it will allow for replacement parts to be ordered if necessary.

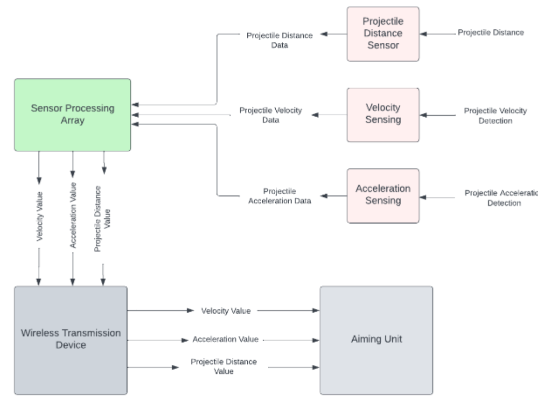



*Figure 6: Block Diagram Sensor Post Array*

1) Post Processing Array: This array must calculate the velocity, acceleration, and path that the projectile is traveling on from the data received then send the values to the wireless transmission device for wireless transmission.

   Inputs: Velocity data, Acceleration data, Estimated Path data

   Outputs: Velocity Value, Acceleration Value, Estimated Path

   Applicable Constraints: C2, C7, C8, C14, C15, C16, C17, C18, C19

   Analytical Validation: This processing array must calculate and transmit the values calculated wirelessly within the 100ms time frame. Must also operate for a minimum of one hour before needing battery replacement.

2) Projectile Distance Sensing: This sensor must detect an estimation for how far the projectile is from the sensor.

Inputs: Projectile Distance

Outputs: Projectile Distance Data

Applicable Constraints: C7, C8, C14, C15, C16, C17, C19

Analytical Validation: This must detect the Projectile distance at a maximum of 64 inches and distance measurement must be accurate within 6 inches. Must operate for a minimum on one hour.

3) Velocity Sensing: Determine the velocity that the object is traveling at.

   Inputs: Projectile Velocity

   Outputs: Projectile Velocity data

   Applicable Constraints: C7, C8, C14, C15, C16, C17, C19

   Analytical Validation: This must detect the Projectile Velocity at a maximum distance of 64 inches and transmit data within 100ms.

4) Acceleration Sensing: Will determine the acceleration of the projectile as it passes by.

   Inputs: Projectile acceleration

   Outputs: Projectile acceleration data

   Applicable Constraints: C7, C8, C14, C15, C16, C17, C19

   Analytical Validation: This must detect the Projectile Velocity at a maximum distance of 64 inches and transmit data within 100ms.

5) Wireless Transmission Device: Will communicate data wirelessly to another module.

   Inputs: Velocity, Acceleration, Estimated Path

   Outputs: Velocity, Acceleration, Estimated Path

   Applicable Constraints: C2, C8, C13, C14, C15, C16, C17, C18, C19

   Analytical Validation: This device must reliably transmit all data at a minimum distance of 78 inches and within 100ms to follow standards. Further research needs to be done to find the bandwidth needed for data transferred.

## IV. Design Timeline and Steps Required

The project timeline shown in *Figure 8* Gantt chart located in the appendix displays the project timeline for the conceptual design forward to the end of the project. After the design choices have been made for the aiming subsystem, the team will begin assigning subsystems to the individual with the proper knowledge and background for the subsequent subsystems. The deadlines may be changed due to certain circumstances but will be upheld as much as possible by the team.

## V. Conclusion

The goal of this project is to quickly and accurately intercept incoming projectiles while posing no threat to spectators. In order to complete this task we have divided our project into six subsystems that work in conjunction with each other. These subsystems are: Launching and Firing, Housing, Projectile Path Sensor, Head on Projectile Sensor, Aiming, and Sensor Post Array. With the implementation of subsystems the team can better verify what technical requirements will be needed in our design. These documents and discovered requirements will be used to construct our detailed design in the future.

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# VI: Appendix

acceleration $= \frac{h}{H} \cdot g$ $\rightarrow h = 43''$ for variable height 1
$h = 50''$ for variable height 2
$\rightarrow L = 78'' \rightarrow H = \sqrt{h^2+L^2}$

acceleration for height 1 $\rightarrow \frac{43}{\sqrt{43^2+78^2}} \cdot 32.17405 = 15.533\ ft/s^2$

acceleration for height 2 $\rightarrow \frac{50}{\sqrt{50^2+78^2}} \cdot 32.17405 = 17.363\ ft/s^2$

$\theta$ for height 1 $= \tan^{-1}(43/78) = 28.867°$
$\theta$ for height 2 $= \tan^{-1}(50/78) = 32.661°$

$a_L$ for height 1 $= \cos(28.867°) \cdot 15.533 = 13.603\ ft/s^2$
$a_L$ for height 2 $= \cos(32.661°) \cdot 17.363 = 14.618\ ft/s^2$

Time to shoot for height 1 $\rightarrow$ red $\rightarrow t = \sqrt{\frac{36 \cdot 2}{13.603}} = 2.3$ sec

green $\rightarrow t = \sqrt{\frac{48 \cdot 2}{13.603}} = 2.657$

Blue $\rightarrow t = \sqrt{\frac{60 \cdot 2}{13.603}} = 2.97$ sec

time to shoot for height 2 $\rightarrow$ Red $\rightarrow t = \sqrt{\frac{36 \cdot 2}{14.618}} = 2.19$ Sec

green $\rightarrow t = \sqrt{\frac{48 \cdot 2}{14.618}} = 2.563$ sec

Blue $\rightarrow t = \sqrt{\frac{60 \cdot 2}{14.618}} = 2.865$ Sec

Figure 7. Estimated time to interception.

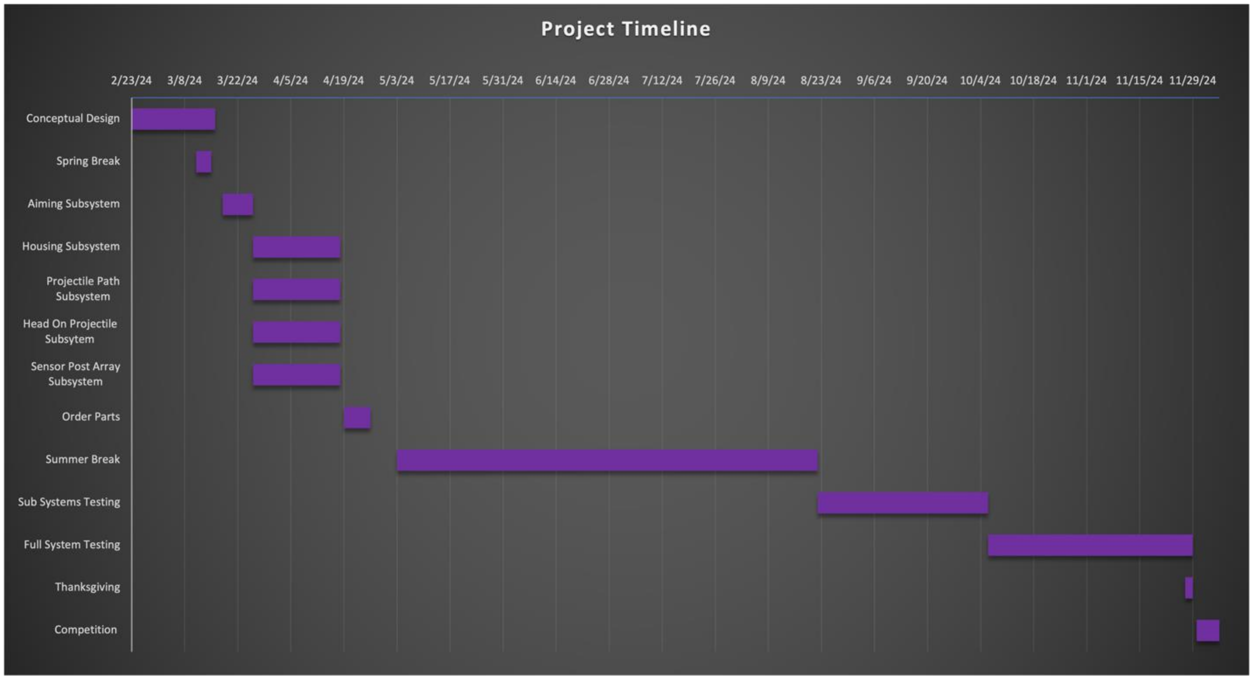


*Figure 8: Project timeline*