Smart Shot: Electronic Target with Smartphone Application

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Abstract

The objective of this project is to develop an electronic system for recreational shooters that functions as a target with real-time feedback. The system provides a user-friendly alternative to paper targets and expensive competition scoring systems. One of the largest challenges presented by this project is balancing cost, durability, and sensitivity. The scope of this project includes the design and implementation of a target assembly, an electronic system, and a smartphone application.

The system is comprised of three main modules: the target, the control module, and the smartphone app. The electronic target communicates wirelessly with the smartphone via Bluetooth. Once the shot information has been sent, the app receives the data and stores it for retrieval and analysis. The app also retrieves and logs environmental data through the www.worldweatheronline.com free API.
1.0 Introduction

1.1 Market Overview

The market sector targeted by this project is recreational target shooters and hunters. According to the National Shooting Sports Foundation, there are over 20 million recreational target shooters in the US [7]. These shooters spend $9.9 billion annually on guns and accessories [7]. There is a lot of money in the gun market and target systems for recreational users are largely underexplored. These people are willing to invest in guns and accessories and this product is designed with them in mind.

The most popular target used by recreational shooters today is a simple paper target (Figure 1). Typically mounted on a wooden or cardboard stand, the paper rips and in some models, changes color where the bullet pierces. This target has the advantage of being cheap, but the technology is primitive. The shooter is required to use an optical device such as binoculars to view when the target is downrange; even with optical aid, it can be difficult to clearly see the shot placement from a far distance. In addition, the shooter must go walk out periodically to view the shots up close or to apply a replacement target.

![Figure 1: Example of a commercially available paper target. Pros: convenient and cheap. Cons: Non-reusable and no technology integration.](image)

Electronic target and scoring systems do exist for competitive sport shooting. SIUS is one of the leading manufacturers of electronic target systems. They have a wide variety of products. The SIUS systems range from those that are bulky, permanent installations (Figure 2), to some smaller caliber targets as well. The majority of their products, however, are expensive and designed with sport shooting in mind. These systems are designed to be used in conjunction with a portable monitor with a computer for shot display.
Figure 2: Example of a SIUS competitive scoring system. [4] Pros: Accurate electronic system. Cons: For competitive shooters, non-portable, expensive.

There are currently few software options on the market for target shooting. For PC based systems, there is software that is designed for shooting competition scoring and database logging. These programs are also designed primarily for competitive shooting applications. The few apps on the markets that do exist use a variety of methods to determine shot location. The most common methods include photographic scanning of a paper target or direct user input via touch screen. None of these include integrating electronic systems with a smartphone app directly. Furthermore, these systems typically do not have any type of automatic environmental data collections system.
### Table 1: Target Solution Comparison

<table>
<thead>
<tr>
<th>Solution</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper Target</td>
<td>- Cheap: $5 for a 12 pack</td>
<td>- Disposable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Have to store larger quantity for any type of log</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- No technology integration</td>
</tr>
<tr>
<td>SIUS Competitive Scoring Systems</td>
<td>- Highly accurate</td>
<td>- Expensive</td>
</tr>
<tr>
<td></td>
<td>- High quality</td>
<td>- Designed for competition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Not readily available for consumers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Permanent installation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Difficult and impractical for average person to use</td>
</tr>
<tr>
<td>Current Smartphone Applications</td>
<td>- Cheap: ~$5</td>
<td>- Not integrated with target</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manual user input required via image scanning or touch screen</td>
</tr>
<tr>
<td>System to be Designed</td>
<td>- Cheaper than SIUS systems: ~$300 for complete system</td>
<td>- More expensive than paper targets</td>
</tr>
<tr>
<td></td>
<td>- Robust</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Long-term or temporary installations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Portable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Easy to use</td>
<td></td>
</tr>
</tbody>
</table>

### 1.2 Project Description

The goal of this project is to create an alternative system to current targets. The current technologies used are either primitive or too expensive for the average recreational shooter. The systems that exist currently are not designed for use with smartphones either. This project aims to create a system that utilizes electronic sensors on the target, and a smartphone application on the user end.

The proposed project would be a system that could automatically measure and record the location of a shot, along with the environmental data at the time of the shot, and output the information to the user via smartphone (Figure 3). The user interface will update in real-time and show the location of each shot on a digitally rendered on-screen target. After measuring the shot information, the data will be stored on the phone for later retrieval and analysis. The user will be able to retrieve previous shooting session data and overlay the shots on a single screen to compare the variation in shot placement over time. This will allow the user to compare shot performance in relation to varying parameters such as ammunition type, sight settings, or environmental conditions.
The project will require two main divisions of labor: system design and implementation, and android app development. This will require two students, an Electrical Engineer (EE) for system design and implementation, and a Computer Engineer (CPE) for app development. Once the two sections are complete, the two engineers will work in conjunction to achieve total system integration. A further breakdown of the project is shown in Table 2.

Table 2: Division of Labor

<table>
<thead>
<tr>
<th>Major Contributions</th>
<th>Tyler Pickett (EE)</th>
<th>Taylor Hutchinson (CPE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Assembly design and fabrication</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Wireless communication system</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Control Module design and fabrication</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Software and sensor algorithms in control module</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bluetooth communication module</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Application Development</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>System Integration</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
2.0 Requirements and Specifications

2.1 Customer Needs Narrative

In order to create a product that is successful in the marketplace, the customer needs need to be taken into consideration when developing requirements and specifications. The primary customer for this project is middle and upper class recreational shooters and hunters. This market sector was chosen because they are potential customers who have money to spend, and have already demonstrated their willingness to spend money on guns and shooting related accessories. The ideal customer would also have an interest in technology and care about precision, reliability, and convenience as these are the type of considerations that would attract a potential consumer to the final product.

The first market requirement is cost. The initial cost requirement is an approximate selling price of $300. This price would allow the system to be competitive in marketplace while still making a profit. For this project, smaller caliber ammunition such as .22LR rounds will be focused on due their popularity and low cost. The following requirements will be based off of .22LR ammunition.

With the customer paying a large price tag, the system must be durable. This system should be robust enough to withstand the impact of smaller caliber ammunition of the lifetime of the product. While being durable enough to withstand the impact of bullets, the system must be accurate enough to determine the shot placement within 0.1”, approximately half the diameter of a 0.22LR round [1]. One of the features this system will have is wireless communication with the smartphone. One of the features of the app is the system should store data from previous shooting sessions for later retrieval. Due to the compact nature of the data, an average smartphone should be able to store several thousand sessions with little effect on available storage space.

Table 3: Market Requirements Summary

<table>
<thead>
<tr>
<th>#</th>
<th>Market Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Designed for small caliber rounds</td>
</tr>
<tr>
<td>2</td>
<td>Durable enough to withstand shot impact over product lifetime</td>
</tr>
<tr>
<td>3</td>
<td>Precise and accurate to detect correct shot location within half the diameter of a 0.22LR round</td>
</tr>
<tr>
<td>4</td>
<td>Selling price: $300 to be competitive in the market</td>
</tr>
<tr>
<td>5</td>
<td>Storage of previously recorded data for easy retrieval</td>
</tr>
<tr>
<td>6</td>
<td>Adult should be able to carry without assistance</td>
</tr>
<tr>
<td>7</td>
<td>Easy to use for someone with little to no technical experience</td>
</tr>
</tbody>
</table>
2.2 Engineering Specifications

Taking the market specifications into consideration, the engineering specifications act as guideline for this project. Table 4 shows a summary of the Engineering Specifications for this project.

Because the method of shot detection has not yet been determined, a variety of options will be researched. The current methods on the market include laser or infrared detection and acoustic sensors. Bases on the market requirements of accuracy and affordability, acoustic sensors appear to provide the best method of detection for this project. Further research and experimentation will be performed to determine the type and exact specifications of the sensors.

Table 4: Engineering Specifications Summary

<table>
<thead>
<tr>
<th>Market Requirement</th>
<th>Engineering Specification</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Design for .22LR ammunition</td>
<td>Smaller caliber ammunition, such as .22LR rounds will be focused on due their popularity and cost</td>
</tr>
<tr>
<td>1, 2</td>
<td>System must be able with withstand repeated impacts from .22LR ammunition and retain functionality</td>
<td>System must be robust in order to withstand lifetime of use</td>
</tr>
<tr>
<td>3</td>
<td>Shot detection within 0.25” of true location</td>
<td>Approximately the diameter of .22LR bullet [1]</td>
</tr>
<tr>
<td>5</td>
<td>Data storage up to 1000 sessions</td>
<td>This will provide ample space for data retrieval</td>
</tr>
<tr>
<td>2</td>
<td>Target and Control Module should have weather proofing equivalent to NEMA Enclosure Type 3 Standards</td>
<td>Designed for indoor/outdoor use with a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow) [5]</td>
</tr>
<tr>
<td>4</td>
<td>&lt;$200 to manufacture per unit</td>
<td>In order for the system to be competitive in the market, it must be affordable for recreational shooters while still making a profit</td>
</tr>
<tr>
<td>7</td>
<td>Android 4.0+ based application</td>
<td>Ease of use and development, covers 93.2% of android users [6]</td>
</tr>
<tr>
<td>6</td>
<td>2 hour battery life</td>
<td>Allows System to be portable and wireless, yet functional for the duration of a shooting session</td>
</tr>
<tr>
<td>6</td>
<td>≤35lbs total weight</td>
<td>Light enough for a single adult to carry</td>
</tr>
<tr>
<td>1, 4, 6</td>
<td>Dimensions of the Target Assembly should be 1x1ft</td>
<td>Dimensions chosen based on caliber, portability, material cost and current target size</td>
</tr>
<tr>
<td></td>
<td>&lt;2 seconds for shot to display on screen</td>
<td>Allows time for transmission and calculations</td>
</tr>
</tbody>
</table>
2.4 Deliverables and Schedule

Table 5 shows a breakdown of deliverables and milestones that occur throughout the 2014-2015 academic year.

Table 5: Deliverables

<table>
<thead>
<tr>
<th>Delivery Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/1/14</td>
<td>Senior Project Definition Document</td>
</tr>
<tr>
<td>2/4/15</td>
<td>EE 461 Midterm Demo</td>
</tr>
<tr>
<td>3/19/15</td>
<td>EE 461 Final Demo</td>
</tr>
<tr>
<td>5/1/15</td>
<td>EE 462 Midterm Demo</td>
</tr>
<tr>
<td>5/1/15</td>
<td>Final Report Rough Draft</td>
</tr>
<tr>
<td>5/29/15</td>
<td>Senior Project Expo</td>
</tr>
<tr>
<td>6/12/15</td>
<td>Final Report</td>
</tr>
</tbody>
</table>

2.5 Cost Estimation

In the previously stated requirements, a manufacturing cost of less than $200 was specified. This rough estimate will allow the final product to be sold at $300 while still making a profit. The initial cost of the device is high due to the fact design costs must be paid before any units are sold.

The estimated number of development hours required for this project is 500. The work for the project by the design engineers will be done free of charge, keeping the overall costs low. The main costs will be materials. A budget breakdown is show in Table 6. This cost breakdown also assumes the user already owns an android smartphone for use with the system.

Table 6: Summary of Cost Estimate

<table>
<thead>
<tr>
<th>Cost Description</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials for target frame and control unit housing</td>
<td>$50</td>
</tr>
<tr>
<td>Sensor cost</td>
<td>$50</td>
</tr>
<tr>
<td>Control unit and communication electronics</td>
<td>$100</td>
</tr>
<tr>
<td>Total Cost Estimate</td>
<td>$200</td>
</tr>
</tbody>
</table>

This system is being designed to be completely reusable. Once the system is purchased, no replaceable parts should be required for operation. The only long term cost would be battery replacement if disposable batteries are chosen. This helps keep the ongoing cost low.
3.0 Functional Decomposition

3.1 System Description

Level 0 block diagram for the initial project design is shown in Figure 4. The description of all inputs and outputs is shown in Table 7.

![Figure 4: Level 0 Block Diagram of Electronic Target System](image)

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
</tr>
<tr>
<td>Shot Impact</td>
<td>The mechanical energy of the impact of the shot will be used to determined shot location.</td>
</tr>
<tr>
<td>Environmental Data</td>
<td>Data collected via website and will be recorded for data logging.</td>
</tr>
<tr>
<td>Power</td>
<td>Power will be supplied to the control module.</td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td></td>
</tr>
<tr>
<td>Shot Location and Environmental Data</td>
<td>Data will be output into memory and to the user via app interface.</td>
</tr>
<tr>
<td><strong>Functionality</strong></td>
<td>The completed system will be able to take the input shots and environmental data, perform calculations to determine shot location within the control module and output the data to the user via app interface.</td>
</tr>
</tbody>
</table>

Figure 5 shows the level 1 block diagram of the system. The acoustic data is collected with four PMOD-MIC modules; the data is then transferred to the FPGA on the Zynq-7000 via SPI. The FPGA receives the acoustic data and packages it into an array which is passed along to the Coretex-A9 processor via the AXI bus. The Coretex-A9 runs the algorithm to determine the point of impact. An (x,y) coordinate is then passed along to the Arduino which relays the coordinate to the Android via Bluetooth. The Android App collects environmental data from a website and then communicates the shot location and environmental data to the user through a custom GUI.
3.2 Testing and Verification

To verify the data collection is working properly, an oscilloscope probe connected to the pins of a PmodMIC displays the serial data on screen. This data should match up with the values being recorded by the Zybo.

To test the sensor system, the sensors are hardwired to a Zybo Zynq-7000 and the output from the sensors will be relayed directly to a computer via USB. A hammer strikes various locations on the plate and the sensor output is recorded and analyzed.

The next phase includes design and testing of the wireless communication system. A test program generates simulated coordinates on the Zybo, relays the data to the Bluetooth module which then transmits to the phone. The output coordinate on the phone should match the coordinate generated on the Zybo.
4.0 Target Assembly

4.1 Preliminary Design

The finished Target Assembly is shown in Figure 6. One of the design characteristics of the assembly is the composition. In this drawing, the majority of the parts are carbon steel (CS). This is to provide durability while maintaining a low cost. One of the downsides of this design is the fact CS is vulnerable to rust after prolonged exposure to moisture and adverse weather. Another distinctive part in the design is the stainless steel button head cap screw in the center of the target. This provides the user with a shiny object at the center of the target to aim at. This is made of stainless steel to contrast the CS and maintain the shine despite exposure to moisture.

The legs are designed to fold out from the back of the assembly to provide a stable base for the target. The flat bottom of the legs will allow the user to press down the foot, effectively forcing the spikes into the ground. This will provide a sturdy base for the target while allowing the user to install and remove the target easily by hand.

Figure 6: Target Assembly deployed. The spikes have been pressed into the ground to create a sturdy base.
5.0 Sensors

The sensors used in the project are PMOD-MICs from Digilent. They are microphones combined with 1 MSPS (Mega samples per second) ADCs. With all four sensors being read simultaneously at 1MSPS, the system should be able to achieve 0.25” resolution.

The acoustic sensor array is shown in Figure 7. \( T_n \) represents the time it takes for the sound wave from the bullet impact to reach acoustic sensor \( n \). By analyzing multiple sensor response times, one can calculate the impact location. The first sensor to detect the sound wave will be used as the reference sensor, and the subsequent sensors will be used to calculate the position relative the reference sensor.

![Acoustic sensor layout](image)

**Figure 7 :** Acoustic sensor layout. \( T_n \) represents the time it takes the sound wave to reach sensor \( n \).

6.0 Control Module

6.1 Embedded System Architecture

The Zybo uses a zynq-7000 chip which has an FPGA and two Cortex-A9 processors. The sensors are driven by the FPGA using a block of VHDL from Digilent called PmodMICRef (Figure 8 and Figure 9). A 160MHz clock is divided to achieve a SCLK frequency of 20MHz, which allows a maximum sampling rate of 1MHz. The RST and START control signals are driven by a Cortex-A9 processor.
Because the system is still in the proof of concept phase of development, the program only runs for one hit. If another hit’s data needs to be collected, the program needs to be rerun. In a finished product this would be modified to run continuously without the need for resetting the system.

The sensor data sampling rate is read in at 992 kHz and analyzed. A 100 sample queue for each sensor is implemented in software and refreshes until a hit is detected. A rising edge above an ADC value of 1500 or a falling edge that goes below 750 is considered a hit. When a strike to the plate occurs, another 500 data samples per sensor get added on to the end of the array. These three 600 entry arrays are then passed along to the USB port and transmitted via UART. While the data is being transmitted to the USB, a simulated X, Y coordinate is passed along to the Arduino using a parallel communication bus.
The UART terminal Realterm collects the transmitted sensor values and saves them in a text file as hexadecimal numbers. A python program called formatTXT.py then formats the data so that it is can be read in three columns by excel. Excel then plots the data in an amplitude vs index graph.

6.2 Algorithm Progress
The initial algorithm design involved comparing the time it took the sound wave to reach each of the sensors. This makes the assumption that the sound wave will be relatively uniform as each sensor it reaches. When the strike is at the center of the plate the holds true (Figure 11). The sampling rate is 992 kHz, so each index is approximately 1 µsecond.
As the strike location changes, the waveform shape at each location changes based on the phase the sound wave when it reaches the sensor (Figure 12 - Figure 14). This causes the waveform to have falling edges, rather than rising, on the initial strike. An example of a falling edge at the strike is sensor 2 in Figure 13. In addition to different directions in the edges, often there is a small peak or trough that is generated from movement of the plate when it is struck. Sensor 0 in Figure 12 has one of these small peaks. This peak makes it appear the sound wave reached sensor 0 first even though it is the farthest away. This issue manifest itself in Figure 14 where sensor 0 appears to have a rising edge at the same time as the other waveforms.

Figure 12: Hit at 1 inch left of center.

Figure 13: Hit at 3 inches left of center.
These types of abnormal peaks and troughs create a large challenge when trying to write an algorithm that compares waveforms. From visual inspection, and with enough experience, one can determine which edges correspond to each other. Getting this to work in code on the Zybo board proved to be too large of a task for the timeframe of this project. The concept of using acoustic sensors as a method to triangulate a hit has been supported by the results of this project. This system provides the platform in which an algorithm could be successfully implemented.

7.0 Smartphone Application

The smartphone application was developed on Android, targeting Android 4.0 and above devices. This provides just over 93% coverage of all Android phones currently in use [6] and allows for easier and more flexible development. The screen flow chart of the app can be seen in Figure 15.
One phone can be shared by many users. It can also store any weapons, ammunition, and locations given to it. The user can begin shooting without putting in any information at all if they choose to. They can edit this information from the shooting screen if they change their mind. A user can also continue an old session. The main use for this is if you accidentally close the app or let your phone die, you can still continue upon re-opening the app.

The app can overlay up to 10 sessions on top of each other using a different color hit indicator for each session. The user can tap a session in the listing to show or hide the shots from that session. Sessions will be saved based on the person shooting and the date of the shooting session. Multiple sessions on the same date will be given identification numbers showing the order in which they were created. Upon beginning a shooting session, the phone will use its current location and the weather service from www.WorldWeatherOnline.com to retrieve current weather conditions and display them below the target. The user can update the weather information at any time through the options menu. Example screenshots are shown in Figure 16.
Figure 16: Smartphone application screenshots
9.0 Conclusion

Although the triangulation algorithm is incomplete, this project confirms that using acoustic sensors mounted on a steel plate is a viable option for detecting shot location. One potential step towards completing the algorithm is collecting waveforms from various strikes on the plate and storing them as a database on the Zybo. The Zybo could then compare the measured signals to those of known location. This would restrict the resolution to how close the samples in the database are. This also requires a larger amount of memory and is inefficient.

Further work is also required to convert this into a product that can be used by consumers. Currently, this system is suited best for a laboratory environment. Creating a system that is easier to set up and is more rugged would be a good improvement.

Overall, this prototype proved that an electronic target integrated with a smartphone is possible. With further development work and more funding, this project has the potential to become successful on the market. From an academic standpoint, this project provided a wide range of challenges in a broad spectrum of engineering topics, from signal processing and programming to mechanical design. This project was a wonderful capstone in our education and a testament to all we have learned at Cal Poly.
References


**Defense of source:** SAMMI is the association in charge of setting the national standards for ammunition.


**Defense of source:** This book provides a guideline for Electrical Engineers on design projects.

http://www.ieee.org/about/corporate/governance/p7-8.html

**Defense of source:** IEEE is the governing body of Electrical Engineers nationwide.


**Defense of source:** SIUS is one of the leading manufacturers of electronic scoring systems worldwide.


https://developer.android.com/about/dashboards/index.html

**Defense of Source:** Statistics are updated every 7 days from all apps running the Google Play Store App (Android 2.2 and above)

http://www.nssf.org/PDF/research/TargetShootingInAmericaReport.pdf

**Defense of Source:** A research paper published by the NSSF on the economic impact of target shooters. The NSSF is the trade association of the firearms industry in the US.
http://www.digilentinc.com/Products/Detail.cfm?NavPath=2,401,517&Prod=PMOD-MIC

**Defense of Source:** Digilent is the manufacturer of the PmodMIC and the corresponding VDHL driver
Appendix A: Senior Project Analysis

Project Title: Electronic Target with Smartphone Integration

Student: Tyler Pickett
Advisor: Dr. Bridget Benson
Initials: Date:

1. **Summary of Functional Requirements**
The completed system should be able to measure the impact of a 0.22LR shot and determine the location of the hit. This information, along with measured environmental data, will be processed by the control unit and sent wirelessly to an android application. The data will be stored by the app and available to retrieval upon user request, the user interface should update in real-time.

2. **Primary Constraints**
Some of the biggest challenges with this project are in the design of the target. It must be durable to withstand the impact of the projectile, while being sensitive enough to detect the shots. The other main constraint is cost. It must be affordable for recreational users.

3. **Economic**
Because this system is being developed as a senior project, it alleviates much of the labor costs that would normally be associated with the design of such a product. This means the majority of the cost will be in raw materials. The financial contribution required by such a project, would fall largely on the shoulders of the student designing the system. Below shows a preliminary cost estimate for this project.

<table>
<thead>
<tr>
<th>Cost Description</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials for target frame and control unit housing</td>
<td>$50</td>
</tr>
<tr>
<td>Senior cost</td>
<td>$50</td>
</tr>
<tr>
<td>Control unit and communication electronics</td>
<td>$100</td>
</tr>
<tr>
<td><strong>Total Cost Estimate</strong></td>
<td><strong>$200</strong></td>
</tr>
</tbody>
</table>

4. **If Manufactured on a Commercial Basis**
Given the constraints of the project, the manufacturing cost of this product should be less than $200. This will allow the product to be sold at $300. This is a $200 profit per unit. If the number of units sold per year is 1,500 the annual profit will be $150,000.

5. **Environmental**
Because this is a non-invasive system, it should have minimal environmental impact. The main concern is with manufacturing, and any byproducts that could be produced as a result.
6. **Manufacturability**
   Because of its simple mechanical design, this system should be easy to manufacture on a large scale. As the scale increases, the overall cost should go down, a benefit for both the manufactures and the consumer.

7. **Sustainability**
   This system should be able to last at least 5 years before need of repair. The overall design requires a minimal amount (if any) of replaceable parts, keeping the maintenance costs low. One area that has potential for expansion is using multiple of these systems in conjunction with one another. If a range were to purchase a set of these, the would be able to save money by only needed one RF transmitter or control unit, depending on the design upgrades that were implemented.

8. **Ethical**
   In the IEEE Code of Ethics it says, “To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;” [3]
   This means that safety considerations must be made when using and designing for firearms.

9. **Health and Safety**
   The safety concern of this project is higher than most. Whenever dealing with firearms, risk of injury is present if proper safety measures and firearm handling procedures are used. This is something that should be address in a user’s manual that would come with a completed system. Safe testing procedures should also be used while in the testing and verification design stage.

10. **Social and Political**
    This system will be developed for middle and upper class recreational shooters. This design costs more than most recreational shooters who are in the lower class can afford. Recreation shooting however is not a cheap hobby. However, If a range was to purchase a fleet of these systems and use them in conjunction with each other, the costumer would only need to download the app.
Appendix B: User Manual

This manual explains how to setup & use the Smart Shot system and smartphone application.

Part 1: Target & Associated Hardware
To set up the target for testing with the hammer follow the following instructions:

1. Plug in PmodMIC: Right sensor in Pmod header JD(3:0), top sensor in Pmod header JD(7:4), left sensor in Pmod header JC(3:0).
2. Connect the Arduino Uno: Digital Pins(9:2) connect to Pmod Header JE(7:0), Digital Pins(13:10) connect to Pmod Header JB(3:0).
3. Power up Zybo and download program via Xilinx SDK, connect Arduino to power.
4. Turn on app launch new session. Verify Bluetooth connection.
5. Click resume twice in SDK until idling in main()
6. Launch Realterm and connect to Zybo, check “capture Hex” and click “Start Capture”
7. Strike the plate with the hammer
8. Wait for data to finish transferring and click “Stop Capture”
9. Run formatTXT.py on capture.txt from Realterm
10. Open data in excel and select “text” as data format.

Part 2: Smartphone Application
Before opening the application, be sure that the target is set up and powered on. In your phone’s Bluetooth settings, look for the target under “Available Devices” and tap it to pair. Once it is paired successfully, it should look like the screenshot below in figure 1.
Once the target is paired successfully, open the app by tapping the icon. At this point the app will check to make sure your Bluetooth is enabled. If it is not, please turn it on by clicking “yes” on the Bluetooth permission request. From here, tap “New Session” to begin.
Once you have tapped new session, you should see the Session Info Screen, as pictured below in figure 2. You can select the appropriate information by first tapping on the drop-down menus, then tapping the correct entry. If the entry you want is not present, tap “new” to add one. Once you are done, tap “Save.” You may optionally skip this by tapping “Skip this step.”
At this point you should be on the shooting screen, as shown below in figure 3. From here you are ready to begin shooting. Any shots you take that hit the target will show up on the target. You may also access the options menu at the top right to save, exit to the main menu, start a new session, update weather information, undo shots, or clear the target. If you wish to view information about the session, tap “Session info.” If you wish to edit any of the information on screen, tap “Edit.”

When you enter this screen, the app will try to retrieve weather information based on your current location. If a failure message shows, please check to ensure that your location services are enabled. Once they are, tap “Update Weather” in the options menu to refresh.

![Figure 3: Shooting Screen](image-url)
Once you are done shooting, you can exit to the main menu via the settings menu. Any action you take which leaves the shooting screen will automatically save your session.

To review old sessions, tap the “View Old Sessions” button on the main menu. This will take you to the session management screen, as shown below in figure 4. Tap a shooter to expand or hide their files. Select files by tapping them. Once one or more files are selected, you may overlay them by tapping “Overlay Selected,” delete them by tapping “Delete Selected,” or continue a session by tapping the “Continue Session” button. Note that a single session must be selected in order to continue it.

Figure 4: Session Management Screen
If you choose to overlay sessions, you will be taken to the overlay screen, as shown below in figure 5. There you may tap each session to show or hide it from the target, or click “details” to show the information associated with that session. You may exit either by pressing the back button or exiting to the main menu via the options menu.