Laser Target Hit Sensor

DESIGN DOCUMENT

Team Number: sdmay23-49
Client: Tyler Brockel
Advisers: Jaeyoun Kim
Team Members/Roles
Lincoln Khongmaly - Advisor Meetings
Neftali Medina - Client Meetings
Adam Runde - Design
Sidney Stowe IV - Timeline Management
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Executive Summary

Development Standards & Practices Used

List all standard circuit, hardware, software practices used in this project. List all the Engineering standards that apply to this project that were considered.

IEEE Guide for Safety Specification of Laser Transmission in High-Power Industrial Laser Systems

Summary of Requirements

List all requirements as bullet points in brief.

- Create a Product that can detect light and trigger the client's product.
- Products must cost less than $100.

Applicable Courses from Iowa State University Curriculum

List all Iowa State University courses whose contents were applicable to your project.

- EE 230: Electronic Circuits and Systems
- EE 330: Integrated Electronics
- EE 333: Electronics Systems/PCB Design
- Com S 207: Fundamentals of Computer Programming
- PHYS 232: Introduction to Classical Physics 2

New Skills/Knowledge acquired that was not taught in courses

List all new skills/knowledge that your team acquired which was not part of your Iowa State curriculum in order to complete this project.

- Light Diffraction/Diffusion

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1 Team

1.1 Team Members

Lincoln Khongmaly
Neftali Medina
Adam Runde
Sidney Stowe IV
Akashkumar Patel
Elijah Bryant

1.2 Required Skill Sets for Your Project

Software Development/Testing - This project required the need to create Arduino code for a prototype. In the final interaction, we needed to transfer this logic to Python.

Electrical Circuitry - In order to properly detect a "hit" light sensor must be used in line with resistors and a PCB board. These are soldered together to create a permanent circuit.

1.3 Skill Sets covered by the Team

Software Development/Testing - Lincoln, Akashkumar.

Electrical Circuitry - Neftali, Adam, Sidney, Elijah

1.4 Project Management Style Adopted by the team

We used an AGILE methodology to keep track of a backlog of tasks and who was to complete those tasks. We also set up bi-weekly meetings with our advisor to make sure we were kept on track.

1.5 Initial Project Management Roles

Lincoln Khongmaly - Advisor Meetings
Neftali Medina - Client Meetings
Adam Runde - Design
Sidney Stowe IV - Timeline Management
Akashkumar Patel - Meeting Management
Elijah Bryant - Testing

2 Introduction

2.1 Problem Statement

What problem is your project trying to solve? Use non-technical jargon as much as possible. You may find the Problem Statement Worksheet helpful.

Trigger Interactive would like to have a laser fire detection system to be able to attach to their existing product. This would be used during any firearms training in place of live rounds because it would lower the cost and allow the customer to practice anywhere they wanted. We will design an attachment that will take in the laser fire and translate it as a hit in the system to solve this problem. The users will also be able to view statistics from their firing sessions, such as the amount of targets hit and reaction time.

Who: Trigger Interactive(Client) and intended users (such as the personas discussed in question 1.2).

What: The objective of this project is to modify a live fire target system to detect laser fire and relay a hit or miss signal back to the app on the user's phone.

When: This product will likely be used during firearms training or casual target practice.

Why: This implementation is a safer and cheaper alternative to live fire rounds. It also provides the user with a product that can be used in more environments.

Diagram of components to be modified.

2.2 Intended Users and Uses

Who will use the product you create? Who benefits from or will be affected by the results of your project? Who cares that it exists? List as many users or user groups as are relevant to your project. For each user or user group, describe (1) key characteristics (e.g., a persona), (2) need(s) related to the project (e.g., a POV/needs statement), and (3) how they might use or benefit from the product you create. Please include any user research documentation, empathy maps, or other artifacts as appendices.

Overall Benefits:

❖ Inexpensive: Laser substitute eliminates the cost of ammo.
❖ Safe: Provides a harmless alternative to firearms training with live ammo.
❖ Adaptable: The safe nature of lasers allows users to utilize the product virtually anywhere. ❖ Precise: Users are allowed to keep data records of their accuracy and reaction time in the mobile app.

Intended Users:

Military:

Key characteristics

- Patriotic
- Love guns
- Desire to serve
- Protective

Project needs

- Need a safe and cheap way to practice using various firearms
- Bootcamp firearms training
- Staying up to date on gun qualifications

Uses/benefits

- Cheaper alternative gives them more range time
    - More range time leads to better trained military
- Safer
- Will help veterans with PTSD

Police:

Key characteristics

- Community focused
- Sense of ethics
- Driven to serve

Project needs

- Good alternative to shooting in a live fire range that will fit their needs of changing scenarios they may face on the job
- Increased training will lead to better-equipped officers

Uses/benefits

- Saves space
- Cheaper because live rounds are not used so they can conduct firearms training more often

Home Defense:

Key characteristics

- Homeowner
- Family focus

- Beginner to expert user with firearms

Project needs

- These users would need to be able to practice with firearms in a cheap way
- A laser alternative would allow them to practice in their own home without damaging

anything Uses/benefits

- Able to practice whenever and wherever
- Low costs

Airsoft Enthusiasts:

Key characteristics

- Is likely an airsoft hobbyist
- Want to simulate real combat
- Enjoys the competition

Project needs

- Need to be able to practice at home without mess or use of pellets

Uses/benefits -

- Cheap dynamic combat scenario practice
- Ability to enjoy the product at home rather than going to a course

2.3 Requirements & Constraints

List all requirements for your project. Separate your requirements by type, which may include functional requirements (specification), resource requirements, physical requirements, aesthetic requirements, user experiential requirements, economic/market requirements, environmental requirements, UI requirements, and any others relevant to your project. When a requirement is also a quantitative constraint, either separate it into a list of constraints, or annotate at the end of the requirement as "**(constraint)**." Ensure your requirements are realistic, specific, reflective or in support of user needs, and comprehensive.

Functional requirements:

The attachment should be able to detect a hit within the 1 - 2 mm radius of the laser pointer when it is pointed toward the target. (constraint)

The attachment should fully integrate with the existing product with little to no user interaction.

Resource requirements:

The prototype should cost no more than $100 in supply and production cost. (constraint)

Physical requirements:

The attachment should weigh no more than 10 pounds to ensure ease of use and transportation. (constraint)

The attachment should allow the user to easily access any part of the product they desire.

Aesthetic requirements:

The attachment should have a sleek and professional look to indicate quality towards the customer.

User experiential requirements:

The user can attach and remove the attachment to any target without considerable effort.

The user will have a similar experience shooting the laser-modified target as with the live fire method, as no complications for the user will be added.

Environmental requirements:

The attachment should be viable for both outdoor and indoor use.

The attachment should be weather resistant (i.e. rain, wind, lighting).

2.4 Engineering Standards

What Engineering standards are likely to apply to your project? Some standards might be built into your requirements (Use 802.11 ac wifi standard) and many others might fall out of design. For each standard listed, also provide a brief justification.

IEEE Guide for Safety Specification of Laser Transmission in High-Power Industrial Laser Systems

The description of this standard depicted what industries should consider and take action upon with regard to optical machines and laser systems. In short, the goal is to reduce casualties from laser radiation or otherwise. Though our team is not within an industry and the scope of our implementation is relatively small-scale, this standard may still apply. We are working with Trigger Interactive who themselves are a company and are planning to implement our design on their sensors. We should resultantly consider the potential for harm that laser radiation or burns could have on their customers.

2.5 How The Project Evolved

The project changed little by little over the course of this class. We first started with an idea for a better, more improved version of our prototype and for the most part stuck to it. We downsized, added more parts, and replaced others with better alternatives. In the end, we designed an entire stand alone target that integrated all of our original functionality. Instead of connecting to the device digitally, we implemented a vibrating motor that set off a flag module for ease of use. We changed out the Arduino for a Raspberry Pi Pico in order to supply power to the components of the board. Because of this change, we also had to change the arduino code to a python code.

3 Project Plan

3.1 Project Management/Tracking Procedures

Which of agile, waterfall or waterfall+agile project management style are you adopting? Justify it with respect to the project goals.

- We will use a combination of waterfall and agile. We want to maintain the manufacturing process that has worked for a very long time while still incorporating a dynamic system that is flexible to change when needed. Due to the fact that our project is a product, waterfall would benefit us however by allowing agile practices, we can stay up to date with any possible changes and react accordingly.

What will your group use to track progress throughout the course of this and the next semester. This could include Git, Github, Trello, Slack or any other tools helpful in project management.

- We will use Trello to keep track of tasks and assignments.
    - Git will be used if any big coding modifications are needed for the module, but I do not think that there will be a lot.

3.2 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and subtasks and to understand interdependence among tasks. This step might be useful even if you adopt agile methodology. If you are agile, you can also provide a linear progression of completed requirements aligned with your sprints for the entire project.

Task 1: Develop the Prototype

1. Research and decide on the final prototype design.
2. Research components and evaluate their effectiveness, compatibility, performance, and cost.
    - Acrylic Plate
    - Light Sensor
    - Processing Component
3. Submit a detailed component list with alternatives and required specifications to the client for purchase.
4. Build the prototype.

Task 2: Testing the Prototype

1. Test the prototype target with different types of lasers
2. Test the effective range of the prototype target.
3. Test the response time of the prototype target to laser fire.
4. Test the prototype target's resistance to interference from different light sources.

Task 3: Finalizing the Design and Integration with the existing System

1. Based on the testing, make improvements to the prototype design and design and fix any bugs.
2. Integrate with the existing live fire system.
3. Test the integrated prototype with the system and ensure that it works the same as it does with live fire.

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

What are some key milestones in your proposed project? It may be helpful to develop these milestones for each task and subtask from 2.2. How do you measure progress on a given task? These metrics, preferably quantifiable, should be developed for each task. The milestones should be stated in terms of these metrics: Machine learning algorithm XYZ will classify with 80% accuracy; the pattern recognition logic on FPGA will recognize a pattern every 1 ms (at 1K patterns/sec throughput). ML accuracy target might go up to 90% from 80%.

In an agile development process, these milestones can be refined with successive iterations/sprints (perhaps a subset of your requirements applicable to those sprints).

Milestones

- Finalize prototype design that is functional and below $100 production cost
- the light sensor will correctly communicate a hit when a hit condition occurred with 95% accuracy.

- the light sensor will correctly communicate a miss when a miss condition occurred. with 95% accuracy.
- The light sensor will detect a hit condition on all visible light lasers.

3.4 Project Timeline/Schedule

• A realistic, well-planned schedule is an essential component of every well-planned project

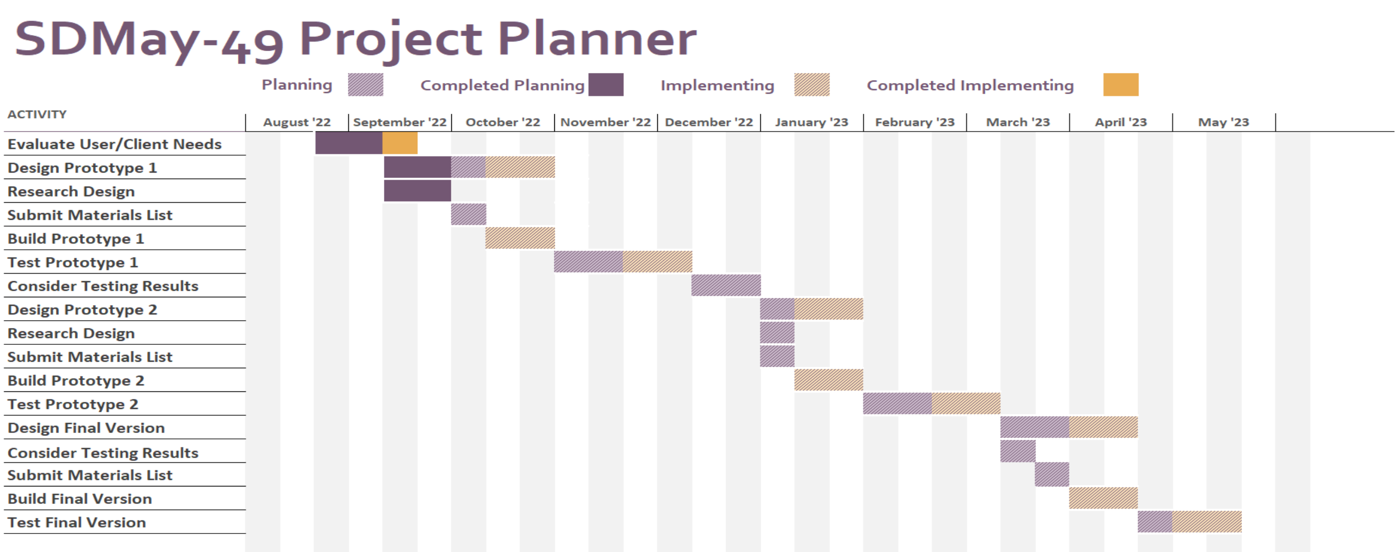
• Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity

• A detailed schedule is needed as a part of the plan:

– Start with a Gantt chart showing the tasks (that you developed in 2.2) and associated subtasks versus the proposed project calendar (including both 491 and 492 semesters). The Gantt chart shall be referenced and summarized in the text.

– Annotate the Gantt chart with when each project deliverable will be delivered

• Project schedule/Gantt chart can be adapted to Agile or Waterfall development models. For agile, a sprint schedule with specific technical milestones/requirements/targets will work.



This Gantt chart represents our Waterfall/Agile development model where we progress in a linear fashion to meet the requirements while still being able to adapt to changes in our development circumstances. This chart depicts three periods of designing/creating prototypes and testing them. The project could require more periods of development depending on testing results in which the time-frame for each would need to be shortened.

3.5 Risks And Risk Management/Mitigation

Consider for each task what risks exist (certain performance targets may not be met; certain tools may not work as expected) and assign an educated guess of probability for that risk. For any risk factor with a probability exceeding 0.5, develop a risk mitigation plan. Can you eliminate that task and add another task or set of tasks that might cost more? Can you buy something off-the-shelf from the market to achieve that functionality? Can you try an alternative tool, technology, algorithm, or board?

Agile projects can associate risks and risk mitigation with each sprint.

Laser not working as intended - 20% probability: The laser might not be strong enough to register a hit or the laser might be faulty. We would have to buy a new laser of a different brand that we think might work.

User tampers with code - 10% probability: The code can be accessed if a user happens to charge the target battery with their laptop. To mitigate this, we will make sure that the files will be either hidden or set to no-editing. There is also a button that can be pressed that will wipe the code, this button will not be accessible to users due to the soldering orientation.

Faulty light sensor/acrylic sheet - 30% probability: This would lead to highly inaccurate data and would need the accurate data to be collected again. Make sure each item used is in proper condition before using it for testing.

3.6 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be the projected effort in the total number of person-hours required to perform the task.

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1 Person-hour = estimate of 1 hour of work by 1 person

= (people to complete task $\times$ hours worked per person)

Task	Description	Estimat

		e of Person-hours
Research	This is preliminary work to determine how an acrylic panel will be implemented and function with Trigger Interactive's module. Alternative research may be done throughout the design process to explore methods of testing, installation, etc.	5-10
Laser detection testing	Once a feasible acrylic panel is acquired and assembled, testing will be done to determine accuracy of laser detection for various distances. From this, we can obtain an accurate drop-off plot and search for methods of improvement as needed. Testing will also need to be conducted for numerous environments that may affect detection accuracy.	15-20
Mechanical stabilization	The design would need to be built onto the premade module given by Trigger Interactive. We need to take this into consideration when constructing the plate, ensuring that the design is not bulky, flimsy, or inoperable.	10-15
Editing of prototype 1	After the above steps are completed, the first prototype can be made. We will then need to test this prototype in real scenarios, essentially acting as the customers of our own product. Then, we will note flaws, inaccuracies, or oversights in our design and begin editing them to construct prototype 2. The person-hours needed for this step depend highly on the success of our first prototype. More changes may need to be made (and thus more time will be needed) if the initial design contains many errors.	15-20
Editing of prototype 2	Similar to the previous step, we will edit the second prototype and make changes as needed. We will also begin demonstrating the operations of our design to the client to receive further feedback on how we can improve the design. Subsequently, the module will be edited to become our final product.	15-20

3.7 Other Resource Requirements

Identify the other resources aside from financial (such as parts and materials) required to complete the project.

- Acrylic Sheet
- Light Sensor
- PCB board
- 3D printed housing unit
- Lasers for testing detection accuracy
- Vibrating Motor

4 Design

4.1 Design Context

4.1.1 Broader Context

Describe the broader context in which your design problem is situated. What communities are you designing for? What communities are affected by your design? What societal needs does your project address?

Our project is designed to fit the needs of the population that wishes to grow their skills with a firearm. These people will have the ability to practice whenever and wherever they desire. Those that wish to own a gun and get better with it can now do it in their homes with little to no fear or harming their property or someone. The only communities affected by this are those that contain gun owners.

List relevant considerations related to your project in each of the following areas:

Area	Description	Examples
Public health, safety, and welfare	This would benefit the general population that wants to learn how to use a firearm better. However this may influence an increase in the purchasing of guns and could be seen as a bad thing.	Increasing the amount of land that a gun could be used for would help those who want to practice at home but would hurt those that don't want guns in their own community.

Global, cultural, and social	This product should help the communities and their overall opinion/practices. Some may think of this product as unsafe and supporting bad ethics but most would disagree.	People learning to use a gun safely wherever they want to would allow everyone to have access to gun safety. However this would possibly promote gun activity within areas where guns are not usually around.
Environmental	The ideal material used would be plastic thus adding to the earth's pollution in the future. Whether these products last long or not, they will not decompose.	We would be increasing the production of non-renewable resources as well as increasing the energy cost for these resources.
Economic	This would allow the user to decide what they want to buy. Our project is a supplementary product that is not needed but a very good product to have. We will also try to make it very affordable.	Product needs to be relatively affordable considering that it is an addition to a product and not the product itself. We also need to consider the consumers and how they live to be able to consider our product.

4.1.2 Related Product/Literature

Include relevant background/literature review for the project

– If similar products exist in the market, describe what has already been done

– If you are following previous work, cite that and discuss the **advantages/shortcomings**

– Note that while you are not expected to “compete” with other existing products / research groups, you should be able to differentiate your project from what is available. Thus, provide a list of pros and cons of your target solution compared to all other related products/systems.

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

LaserLyte: A similar product that uses laser cartridges using real gun triggers. This product also has a target that uses lead and sound effects when on and when it is hit. Commonly used for dry firing around the house.

Pros:

- Uses actual trigger
- laser cartridge fits real firearm

- clock that counts time between start beep and first impact on the laser bullseye
- led that lets you know when targets on
- many attachments for gun and laser

Cons:

- very costly
- have to replace cartridges (specific to company)
- low range

Compared to Laserlyte, our product would be usable at longer distances(gun range) and be considerably cheaper as that is the focus of this product. A similarity between these products is that both will have lasers that can be attached to a real firearm. It is also possible to include sound/led features on our product just like LaserLyte.

https://laserlyte.com/

4.1.3 Technical Complexity

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

1. The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles –AND–
2. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

The product has many different parts that communicate with each other that use both hardware and software. The construction of the board itself required the strategic placement to ensure that there were little to no spots on the board that could not detect the laser. We then had to create a program that allowed all the photodiodes to take in the readings and process them to signal a hit. We then had to find a way to get the product to interact with the client's existing product without having any changes made to it. All of this with the total cost, usability, and professional look of the product in mind.

4.2 Design Exploration

4.2.1 Design Decisions

List key design decisions (at least three) that you have made or will need to make in relation to your proposed solution. These can include, but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc. Describe why these decisions are important to project success.

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1. Method of laser detection

We ended up choosing photodiodes to detect the laser and a frosted acrylic plate to diffuse the laser.

The method of laser detection being used for this is a combination of a frosted acrylic plate covering a pcb board of photodiodes. The frosted acrylic plate will help diffuse the light while the photodiodes below will produce a current when they detect a photon. When it detects a laser beam hit, it will cause a spike in sensor value output.

2. Attachment size and portability

Trigger Interactive's receiver module is currently built to be easily portable and attachable to various targets. When we built our attachment to the module, it was important to not hinder this portability much if at all. We simply attached the module to our target with tape and velcro to safely secure it.

3. Attachment appearance

Making the housing unit visually appealing was important to us and our client as it will be a product being sold by their company, Trigger Interactive. We consulted the client on the best way to solve this problem and he provided us with a 3-D printed housing unit to store our device. The housing unit needs to be able to stand up right and not take up too much space. The 3-D printed material also seems to be perfect for what we are trying to accomplish with it being light weight as well.

3. Vibrational Motor

To transmit voltage data from our Thonny software and the client's app, we contemplated using direct bluetooth communication. However, we found that the client did not have much insight into changing the app's code, as it was outsourced during initial development. Thus, we decided to utilize a vibrating motor to mechanically interact with the app. That is, the client's bullet receiver was implemented in our design as a vibration receiver. When the laser was detected by the code, the motor would vibrate and trigger the client's receiver to lower the flag.

4.2.2 Ideation

For at least one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). Describe at least five options that you considered.

The method of laser detection was the most significant key decision we made. While making this decision we looked into numerous possible options and weighed their pros and cons before deciding on one. The first option we looked into was camera based laser detection in which we would use a camera attached to the target to detect when a laser came into contact with the target. The second option we looked at were light dependent resistors which would need to be assembled into a grid as their detection radius is extremely small. The third option we looked at was an acrylic sheet combined with a photodetector where the acrylic sheet would disperse the laser while the photodetector sensed the light produced by the sheet. The fourth option we looked at was using IR sensors however this option had a very limited range. The fifth option we looked at was a retro-reflective system in which both the receiver and emitter elements are attached to the gun. Ultimately we went with the second option and used multiple photodiodes assembled on a pcb board.

4.2.3 Decision-Making and Trade-Off

Demonstrate the process you used to identify the pros and cons or trade-offs between each of your ideated options. You may wish to include a weighted decision matrix or other relevant tool. Describe the option you chose and why you chose it.

Criteria	Weight	camera		resistors		acrylic		IR sensors		retro-reflective	
		Score	Total	Score	Total	Score	Total	Score	Total	Score	Total
cheap	0.3	2	0.6	2	0.6	5	1.5	3	0.9	1	0.3
easy production	0.25	0	0	2	0.5	5	1.25	4	1	3	0.75
range	0.15	3	0.45	4	0.6	4	0.6	5	0.75	5	0.75
Accuracy	0.3	4	1.2	2	0.6	4	1.2	5	1.5	4	1.2
Total	1		2.25		2.3		4.55		4.15		3

To analyze the trade-offs between our options, we weighed how well each option fit the needs of our client and the end users. We did not use a decision matrix in our discussions but it quantifies the main talking points nicely and provides easy to understand insight into our decision making process.

4.3 Proposed Design

4.3.1 Overview

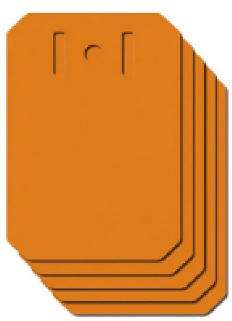
Provide a high-level description of your current design. This description should be understandable to non-engineers (i.e., the general public). Describe key components or subsystems and how they contribute to the overall design. You may wish to include a basic block diagram, infographic, or other visual to help communicate the overall design.

Our design uses a frosted acrylic panel to capture and diffuse the light to the photodiode sensors strategically placed underneath the panel. Once the laser is detected by the photodiode sensors, the motor goes off alerting the Smart Target attachment that the target was hit.

4.3.2 Detailed Design and Visual(s)

Light Sensor: Used to see whether a user is pointing and shooting towards the target to detect hit. Once it detects the laser, then a signal is sent to the switch module to indicate a hit.

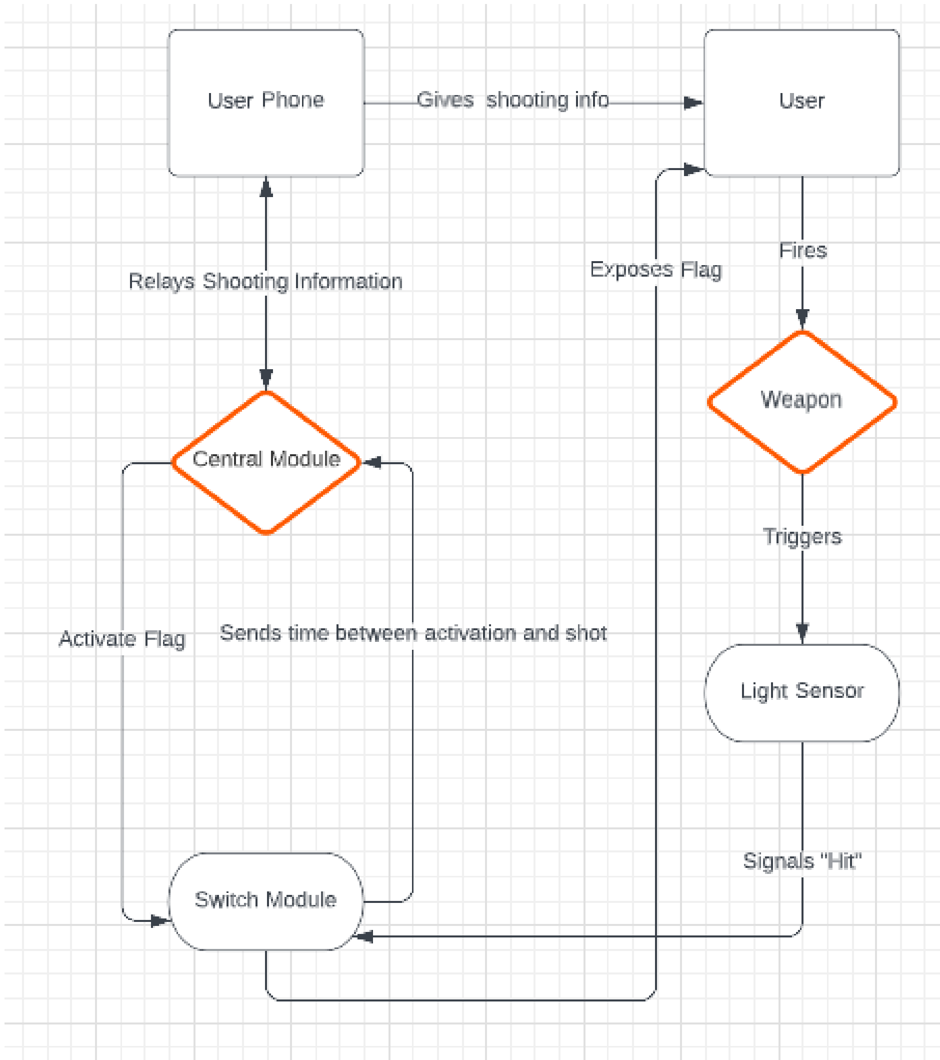
Flag: Used to indicate whether a target is active or inactive. Will sit behind the target until the module exposes the card to the user to be hit.



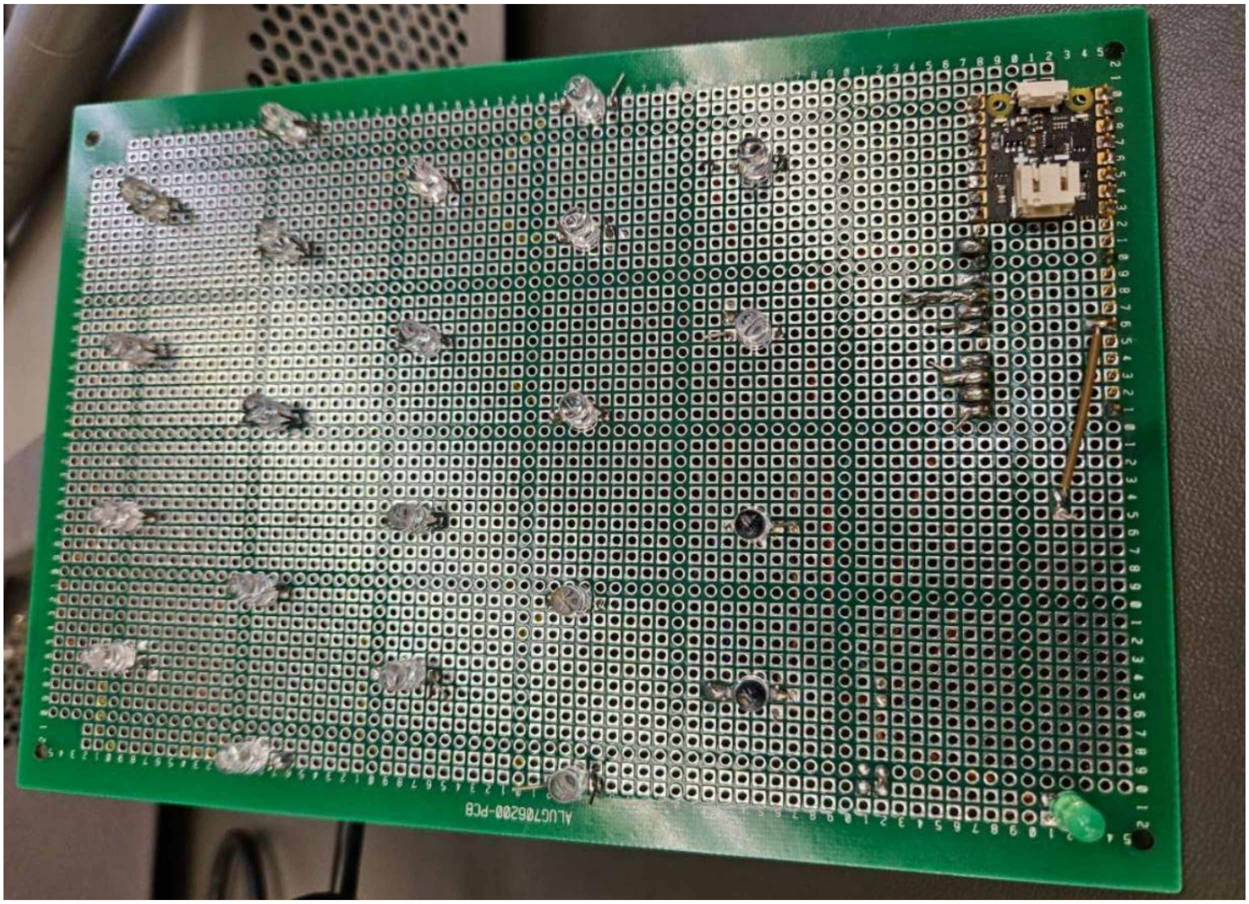
Central Module: Will act as a hub for all the switch modules to record and relay information between them. Will also connect to the users phone to show information about target hit times and more.

Switch Module: Will be used to either hide or expose flags. This also starts a time when exposed and records until it is hit. Then it sends the data back to the central module for the user to see.

Velcro Sticker: Used to attach the switch modules to any target of choice.



PCB Board with Photodiode Sensors: Used to detect laser beam light.



Raspberry Pi Pico: used to control and receive input from sensors.

4.3.3 Functionality

For our product, a user will simply have to mount their target wherever they wish to practice firing and turn the targets on. They will then need to attach the flag module to the back of the target with the velcro tape provided. After initial setup is complete, the user will start the application for the target module and wait for the flag to show. Once the flag shows, the user will aim towards their target and fire the laser that will be picked up by the sensor and cause the flag to hide. Then the time difference between the flag showing and hiding is recorded for the user to check later on.

4.3.4 Areas of Concern and Development

How well does/will the current design satisfy requirements and meet user needs?

Based on your current design, what are your primary concerns for delivering a product/system that addresses requirements and meets user and client needs?

What are your immediate plans for developing the solution to address those concerns? What questions do you have for clients, TAs, and faculty advisers?

The primary requirement for this project is to be able to consistently detect laser beams and send the detection to a receiver. This should then be sent to the attached module which will inform the user that the target has been hit. The following remarks address two foreseeable concerns that may change our design choices.

Concern 1: Cost of production

The cost of production will be somewhat higher as we used around 22 photodiodes. We also used multiple jumper wires and resistors for each unit. Each unit also contains a Raspberry Pi Pico and pico shim which could get costly. This can be made cheaper if we used less photodiode sensors but that would make the detections of the laser inaccurate. The housing model is also 3_d printed so the material used to produce this can get costly.

Concern 2: Being used in complete darkness

If s user were to use this in complete darkness, the changes in lighting could cause a spike even if a laser did not hit the target. The code is modified to be able to handle the changes in lighting and it gradually sets the average so shadows and changes in lighting don't affect the rolling average too much.

Questions for advisor and client:

Are there any durability concerns?

What is the maximum distance users will shoot the targets from?

4.4 Technology Considerations

Describe the distinct technologies you are using in your design. Highlight the strengths, weaknesses, and trade-offs made in technology available. Discuss possible solutions and design alternatives.

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1. The first technology in our design is the light sensor. This sensor will be able to detect visible light lasers with great accuracy however detecting infrared lasers would require a different sensor to overcome this one solution would be to place an IR and Visible light sensor next to each other in the acrylic plating.
2. The second technology utilized in this design would be the design of the acrylic plates by creating a repeating pyramidal structure on the back plate that will refract light anywhere on the plate to the outside edge where it can be reflected to a singular point with the sensor. This design has a strength in the aspect of light that hits anywhere on the plate will be directed to a singular point. One weakness in this design is each time the laser is reflected there may be a small amount of photons that leak out of the plate and create a smaller signal for the sensor to pick up in the end.

4.5 Design Analysis

Discuss what you have done so far, i.e., what have you built, implemented, or tested? Did your proposed design from 4.3 work? Why or why not? Based on what has worked or not worked (e.g., what you have or haven't been able to build, what functioned as expected or not), what plans do you have for future design and implementation work? For example, are there implications for the overall feasibility of your design or have you just experienced build issues?

Our proposed design from the beginning did not work as we had hoped it would. The original design consisting of a frosted plate to direct light to a photodiode sensor would not read laser hits if the laser wasn't in the range of the sensor. To address this problem we implemented multiple sensors and calculated the range and overlap to find out where we need to place them on the pcb board. We were pleased with the results and we continued with the original design with some modifications. The target can now sense the laser and adjust to the changing light levels in a room. The next step was making it work with our clients system, this was an issue because at first we wanted to use bluetooth to interact with their device however this was not possible because the client would have to recall every model to implement bluetooth. We then decided to use a motor to imitate the vibration caused by a bullet hitting a target. This allowed us to simply attach the device to the back of our target and take input from the motor vibration to send the flag back down after a hit has been registered. The motor did not work as intended at first because it was not strong enough so we had to keep testing to make it work as the deadline was approaching. The solution ended up being that we attached the motor directly to the device and this worked just as we had hoped. We ended up having our target system work as we intended, minor modifications we would make are aesthetic changes.

5 Testing

When writing your testing planning consider a few guidelines:

- Is our testing plan unique to our project? (It should be)
- Are you testing related to all requirements? For requirements you're not testing (e.g., cost related requirements) can you justify their exclusion?
- Is your testing plan comprehensive?
- When should you be testing? (In most cases, it's early and often, not at the end of the project)

5.1 Unit Testing

1) Raspberry Pi Pico

This component of our module functioned as the brain of our module and needed to be tested for feasibility in many respects. This testing was done using Thonny, the Pico's software, and in the language of MicroPython. We also utilized multimeters to examine voltage and current readings at the ports of the Pico and basic circuit components such as resistors, breadboards, and jumper wires. Most of this testing was with respect to other components in the circuit, so it will be mentioned in interface and integration testing.

2) Elements of Thonny Code

Some aspects of the code, especially the threshold given to the photodiodes needed to be analyzed using the Pico itself, along with the basic circuit components listed above. A major portion of the testing involved transliterating our original Arduino code to MicroPython, a language that the Pico would be able to interpret. We wanted to ensure that the code would function with no errors, while still completing the same functions as before. This testing involved running the code on a trial circuit with the Pico, photodiodes, and resistor on it. We continued to tweak the code until it would accurately read a laser using the diode. More on such software testing will be discussed further in integration testing.

3) Vibrating Motors

We also assessed the power capabilities of a small motor, which vibrated to indicate a laser hit. Testing of this component also made use of the multimeter and basic circuit components, as well as the Pico and a voltage generator. This portion of testing was extensive because of power issues that will be discussed later on.

4) Metal Connections

After soldering our first module, we observed that some of the photodiodes would not function at times, and even groups of diodes would cease to work. Determining the cause of this issue involved testing the metal connections between each of the diodes, which were all connected in parallel.

Since some of the diodes were working, we concluded that the route to the series resistor and eventually the Pico was satisfactory. Thus, there was likely a connection issue further in the parallel connections. Using the multimeter, we tested the continuity between each soldered metal joint in the circuit. Our findings matched our predictions; some of the solderings were not sufficient for electrically connecting some of the photodiodes.

If the connection issue was in the photodiode's path to ground, we would observe this particular diode not responding to laser data. If the connection loss was in the parallel connection to the diode, we perceived all other diodes after the connection experience the issue as well. To fix this issue, we resoldered the unreliable connections and ensured that there was continuity between the metal joints. However, we suggest that later prototypes be made with integrated wiring in the PCB instead of jumper wires for a number of reasons, one of which is the observed inconsistent connections.

5) Acrylic Diffuser

The last individual element we tested was the rectangular plate used to diffuse the laser light. Such diffusion was necessary to reduce the amount of photodiodes needed on the final PCB. After sanding the surface of the acrylic diffuser to increase effectiveness, we assessed the radius of light diffusion it was capable of providing. This was done using the laser pointer, which was approximately 3 to 4 feet away from the plate, and a marked piece of paper behind the diffuser.

We then shined the laser and drew out a circle representing the radius of light above a certain intensity. This intensity was chosen based on what the photodiodes were able to detect with the digital threshold we set. This testing also allowed us to approximate the number of photodiodes needed to cover the entire board and avoid areas where the photodiodes could not detect the laser.

5.2 Interface Testing

1) Motor Connection to GPIO Output Ports

Much research was conducted in this area of testing, as the power portion of our project was very important to the design. We utilized a Pico for the final prototype instead of an Arduino but found a drastic downside in this IC. That is, the Pico's current output limitations were too low, namely around 16 to 25 mA per GPIO pin. This meant that the connection to the motor would receive 3.3 volts, but not enough current, ultimately resulting in limited vibration in the motors. We attempted to use step-up voltage converters and voltage regulators to fix the issue, at the time not realizing the problem originated from the current instead.

We then were told by our advisor that an additional source of power would be needed to increase the vibration. At that point, we were far along in the design process and needed to focus on other elements of the module. Thus, we resorted to using one motor instead of four and ensured that this motor would set off the flag. Flag detection will be discussed in more detail in integration testing.

2) Acrylic Diffuser and Photodiodes

In order to accurately detect laser light on the entire target, both the photodiodes and diffuser would need to be tested. These elements of the system work in tandem in this design to receive and deliver the laser data, then interpret it as a voltage signal to the Pico. While the photodiodes would do this conversion from light to voltage, they alone could not cover the entire PCB target board. Thus, we implemented and tested several different light diffusers that would scatter the direct laser beam into a less intense area of light.

Our evaluation of this interface involved determining which diffuser was best suited for completing this task. We concluded that an acrylic rectangular diffuser would work well if it was sanded before implementation. Such sanding increased the light scattering so that fewer photodiodes were needed to make the entire board detectable.

5.3 Integration Testing

1) Threshold of Light Intensity

As mentioned earlier, our Raspberry Pi Pico used Thonny software to implement the logic for our module. It would read in light data as voltage, with the voltage value increasing with light intensity. Our primary objective after translating the code to MicroPython was to establish a threshold for the photodiodes. Simply, we needed the software to have a point at which the voltage value would be high enough to detect a hit from the laser.

Our testing entailed finding a balanced threshold that would detect the laser every time it was shined on or within a 1-inch radius of the diodes.We also were required to set this threshold so that shadows, artificial light, or other subtle changes in the environment's lighting wouldn't be counted as a detection. This threshold was also dependent on two other factors in the circuit: the number of photodiodes used and the series resistance from the diodes to ground. We determined that, with a resistance of 33,000 Ohms and 40 photodiodes on the PCB, the data would read around 20,000 units. A laser beam would change this reading by at least 30,000 - 40,000 units. Other light sources were found to change the data by no more than 15,000 to 20,000 units. Thus, a threshold between these values was utilized.

2) Pico Software Interaction with Flag

The last element of integration testing corresponded to flag detection. Our client, Trigger Interactive, provided us with their currently in-use module for detecting bullets: a vibration reader that was connected to a flag. Once the flag was raised, the module would wait for a sensitive enough vibration and lower the flag to the start point. Our proposed design was to attach a vibrating motor to the inside of the housing that would trigger whenever the software detected a hit.

Because of the low vibration intensity, we were noticing inconsistencies in the motor setting off the flag even at the higher in-app sensitivities of the client's module. Our solution was simple: we extended the motor's wire length by adding jumper wires to the PCB and looping the motor to the back of the client's target module. This way, the motor's vibrational energy would not be dissipated through the back of the housing.

We also observed that the motor has the shape of a cylinder with a low height relative to its radius. Thus, we tried attaching the motor so that the height, or the distance between the two circular bases, was touching the vibration receiver. This vibrational impact was much higher, allowing us to turn the in-app sensitivity down and consistently set off the flag with the Thonny software.

5.4 System Testing

To meet the requirements of this project, we ensured through testing that our design was sufficient in all areas mentioned in section 2.3. After assembling the prototype module, we ensured that the PCB, housing, acrylic diffuser, and vibration receiver were not more than 10 pounds in weight. We also checked that that velcro was used for the attachment of the vibration receiver so that the user could easily use it for live-fire practice if they desire.

Regarding aesthetics, our housing hides the PCB and electrical circuitry, giving a modern and polished look to the target. Additionally, all materials used in this design do not exceed $100, as specified in the requirements. Finally, the system was ensured to function under many light conditions on a consistent basis. The acrylic plate properly diffuses the laser beam, the photodiodes accurately detect a change in light intensity and convert it to a voltage alteration, the Pico consistently reads the data and triggers the motor when the laser is detected, and the motor reliably vibrates the receiver to lower the flag.

5.5 Regression Testing

Regarding changes to the design, our project was tested to ensure that these alterations did not collapse its functionality. First, our acrylic diffuser is designed to function with various lasers of different intensities. Our Pico is also capable of having its software updated if the client desires to do so. We anticipate that he will eventually substitute the motor vibration with direct communication with his Trigger Interactive app. He will simply need to unplug the motor and update the code to communicate with his software that is currently in use for live fire. This will involve sending the voltage data from the photodiodes to his software program and triggering the flag digitally.

Also, one of the most critical features of our design is the acrylic plate. We ensured that the plate can detect lasers in several different weather conditions. The user may want to conduct target practice outside of various intensities of natural or artificial light. This is particularly related to the threshold value in our code which eliminates false positives when polling for the laser. This was extensively tested for consistency.

5.6 Acceptance Testing

The essence of acceptance testing for this design is reliability and consistency. Two areas of the project need to be validated by the client to ensure that this design is up to par with the requirements given last semester. The first validation involves ensuring that the entire target board can detect lasers consistently. Our design process was heavily tailored to establishing a digital threshold for each of the photodiodes and eliminating dead zones on the board where none of the photodiodes could read the diffused light. Our acceptance testing involved checking each inch of the board to make sure that this was the case. Additionally, we simulated sudden light changes, such as shadow movements and artificial lights turning on or off.

The second area of acceptance testing involves checking the consistency of the motor vibration. We verified that the Pico invariably gives power to the motor when the laser is detected and that this vibration is strong enough to trigger the vibration receiver. The client will likely want to check this as well. We will involve him in the acceptance testing by giving him clear instructions about how to use and test the design himself.

5.7 Security Testing (if applicable)

This area of testing was not a major part of our design process simply because the project is not exceedingly vulnerable to malicious use. The goal of this project is to make the client's target system safer by substituting live-fire targets with laser-receiving targets, which eliminates many of the dangers already present.

Additionally, we are not directly interacting with the client's software with this design, but rather mechanically triggering his receiver with vibration, as was discussed before. A devious user would only be able to alter the Pico's code and change the method of light detection, which is easily fixable with a few copy-and-paste commands.

Last, we understand that unforeseen vulnerabilities in this project may come to the client's or our attention as we finish this design. We are not stating that this project is fool-proof or fully protected from users with ill intent, only that we have not come across any vulnerabilities thus far. One example of a potential user risk that is not related to malicious intent is the laser. Users may potentially damage their eyesight from improper use of the laser, and thus warning labels for this should be put on the product for the user's safety and lawsuit prevention.

5.8 Results

The results of our final module after extensive testing were generally positive. Our target board is layered with enough photodiodes to detect laser beams on any portion of the board. The diffuser functions as intended and provides enough light-scattering for the photodiodes to read the laser within a 1-inch radius.

In addition, the soldering was verified for proper electrical connectivity. Thus, the data from all photodiodes was found to always be sent to the Pico where it could be processed. From there, the software was tested to consistently vibrate the motor. This vibration was found to reliably trigger the client's vibration receiver as well. Finally, the requirements were ensured to be met, as mentioned in sections 5.4 and 5.6.

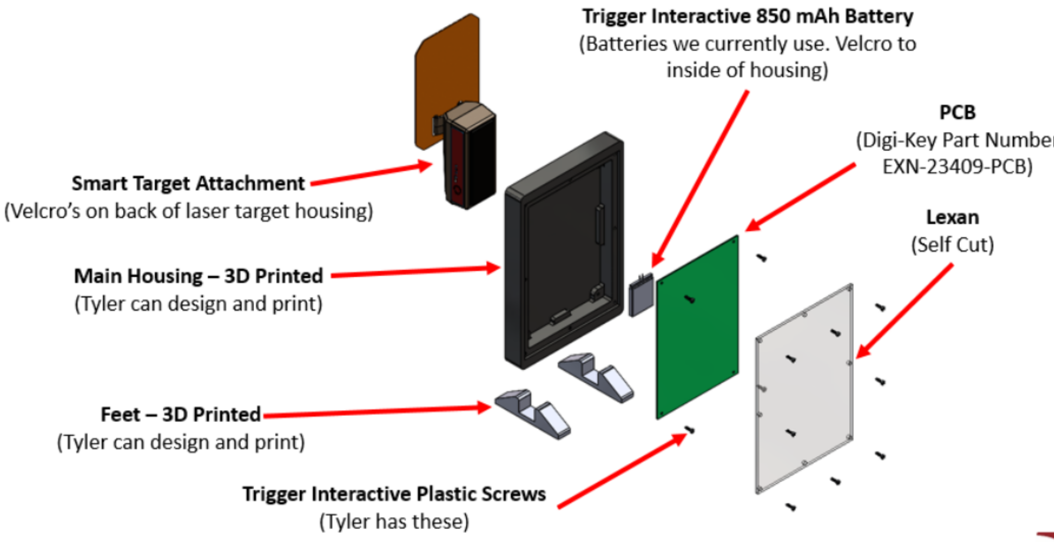
6 Implementation

At this stage in our project, we've currently built three working prototypes. Much of the design is the same as last semester with a couple of key improvements. We've replaced the Arduino with a Raspberry Pi Pico, implemented a full-size 40 photodiode array, integrated the system with the client's existing hardware, and improved the system's accuracy. We've also updated the system to be fully battery-powered and rechargeable. There are still a few improvements that could be made in the future should the client choose to continue with the project.

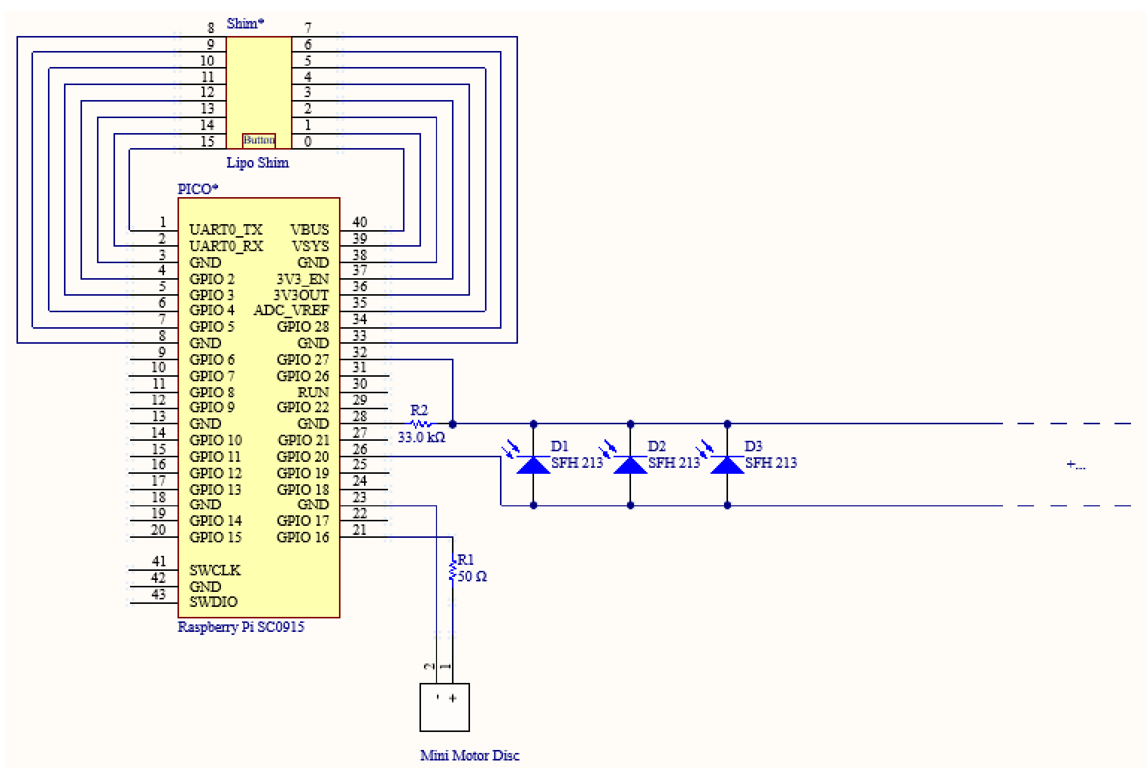
Our current prototype consists of the following components:

- Frosted acrylic sheet
- 40 SFH 213 photodiodes
- 3D Printed Housing
- Raspberry Pi Pico board
- Vibrating motor
- Lipo Shim
- 850 mAh battery
- PCB

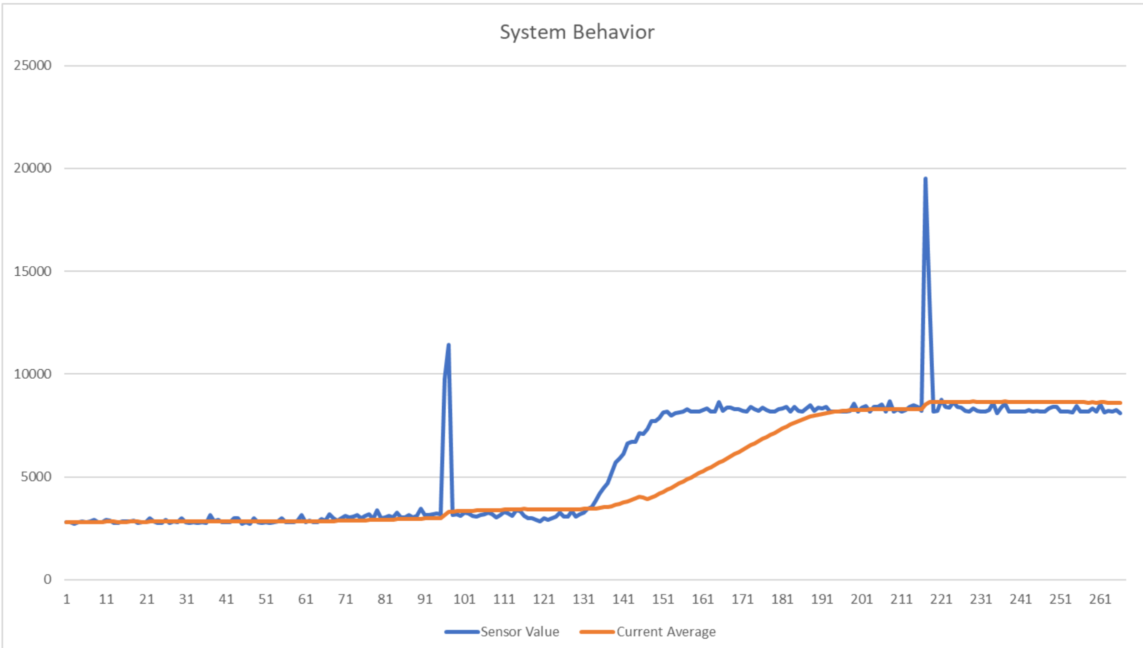
The laser is first diffused by the frosted acrylic sheet before entering the enclosure, which contains the photodiode grid connected to the Raspberry Pi Pico.The photodiode array's output is then read and averaged by the Raspberry Pi Pico, and if the current value deviates significantly from the average of the last 50 sample i.e. a new light source being introduced, the system activates the motor which in turn reads as a hit by the clients existing hardware.



The basic circuit diagram can be found below detailing how the components interface with the Raspberry Pi Pico. The SFH 213 photodiodes are connected in parallel and can be extended indefinitely to accommodate a variety of target dimensions. The resistor to the ground can also be changed to adjust the array's sensitivity.



We've also made some updates to software in order to combat false positives and improve the overall accuracy of the system. The script still makes use of a rolling average detection algorithm however we've shifted the trigger to only activate on the falling edge of a spike. In the image below you can see the expected signal behavior of the photodiode array in response to laser pulses in low light and standard environments.



Overall the current system does meet all given requirements however there are still some improvements that could be made in the future should the client choose. Currently, the system only communicates with the client's hardware through physical vibration however in the future the system could be modified to communicate directly with the client's hardware. Another possible improvement could be the design of the acrylic sheet, the basic frosting technique we used was effective however system performance could be improved with a manufactured light diffusing acrylic sheet. Adding a digital potentiometer to the output of the photodiode array would allow for easy adjustment of the sensitivity. Finally, reflective material could also be added to the interior of the enclosure to maximize its light-capturing capabilities.

7 Professional Responsibility

This discussion is with respect to the paper titled "Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment", *International Journal of Engineering Education* Vol. 28, No. 2, pp. 416–424, 2012

7.1 Areas of Responsibility

Pick one of IEEE, ACM, or SE code of ethics. Add a column to Table 1 from the paper corresponding to the society-specific code of ethics selected above. State how it addresses each of the areas of seven professional responsibilities in the table. Briefly describe each entry added to the table in your own words. How does the IEEE, ACM, or SE code of ethics differ from the NSPE version for each area?

7.2 Project Specific Professional Responsibility Areas

For each of the professional responsibility area in Table 1, discuss whether it applies in your project's professional context. Why yes or why not? How well is your team performing (High, Medium, Low, N/A) in each of the seven areas of professional responsibility, again in the context of your project. Justify.

Area of responsibility	Definition	NSPE Canon	IEEE code of Ethics	Importance	Current Importance
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence.	Perform services only in areas of their competence; Avoid deceptive acts.	to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations; Similar stances on only taking on jobs under your field of knowledge with IEEE taking an extra step saying to continuously expand	(Moderate) This project is meant for students to learn new and different systems that they may not have experienced before. However creating a viable product in the end is the ultimate goal and to achieve that some level of competence is necessary.	(High) We have assigned roles that fit into each other's skill sets as much as possible and have continued to learn more about the systems we are utilizing.
Financial Responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees.	to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist As financial responsibility goes IEEE says to avoid conflict wherever possible and unrealizable pricing is an unnecessary conflict	(High) Extremely important to be truthful and honest when it comes to finances with a client.	(High) We hold a High standard of responsibility when it comes to sourcing and acquiring resources to propagate this project.
Communication Honesty	Report work	Issue public statements	to seek, accept, and offer honest criticism of technical	(High) Staying Honest in	(High) Nothing good comes out

	truthfully, without deception, and understand able to stakeholder s	only in an objective and truthful manner; Avoid deceptive acts.	work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others; These two code reiterate the same ideas off of each other by standing by your morals and owning up to and correcting mistakes.	communication and avoiding deception is a key piece of a healthy client relationship	of deceiving a client and being straight forward in conversation will always be beneficial to the team.
Health, Safety, Well-Being	Minimize risks to safety, health, and well-being of stakeholder s.	Hold paramount the safety, health, and welfare of the public.	to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment; Two very similar codes saying that the safety of the public is the number one priority	(High) The safety of the public and trustees are always the number one priority and must be held to strictly.	(Moderate) We have taken into consideration the situations in which this product is used and he has addressed several concerns to mitigate any dangers.
Property Ownership	Respect property, ideas, and information of clients and others.	Act for each employer or client as faithful agents or trustees.	to avoid injuring others, their property, reputation, or employment Also two similar passages except NCPE uses more of a generalized blanket statement to say the same thing.	(Moderate) Owner property is important to be respectful of and managed in a competent manner	(High) We have been given different products from the client and it is important to us to keep each item safe and protect their intellectual property
Sustainability	Protect the environme nt and natural resources locally and globally.		to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, NCPE did not have a sustainability section per say but this would fall into	(Moderate) Protecting the surrounding environment and natural resources used in the project is an important step in creating	(Moderate) We are using our advisors and clients to responsibly source products and be mindful not to waste any material

			other areas of safety and public interest.	sustainable projects	given to us.
Social Responsibility	Produce products and services that benefit society and communities.	Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.	to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies These two codes say that is the duties of IEEE members to advance society and technology in all aspects as to raise the standard of the profession as a whole	(High) Always improving in technology and all areas of work will bring a great benefit to users and the greater society.	(High) We as a team will always see to it that our advancement will be used in lawful and purposeful means to further advance society.

7.3 Most Applicable Professional Responsibility Area

Communication and honesty is the most important responsibility area when it comes to client projects. Sometimes roadblocks come up in which it would possibly be easier to keep people in the dark and not tell them about but that is not the right and ethical way of conducting business. which in the long run ethical conduct is the only way of conducting business and ourselves as engineers.

8 Closing Material

8.1 Discussion

Discuss the main results of your project – for a product, discuss if the requirements are met, for experiments oriented project – what are the results of the experiment, if you were validating a hypothesis – did it work?

At this time, we have developed a working prototype which meets our client's given requirements however further improvements could be made in the future. Our current implementation involves a circuit which utilizes resistors, photodiodes, and a Raspberry Pi Pico as the logical basis. The physical build of this prototype uses a plastic housing with one transparent side and an acrylic plate to diffuse the light to the photodiodes.

In brief, our design works by using the photodiodes as detectors, which should receive the diffused laser light. This change in voltage is detected by the Raspberry Pi, which is currently programmed to trigger a motor which vibrates upon detection. This motor is attached to the vibration receiver, which lowers the flag when vibration is sensed.

Regarding the validation of each part of our design, we were able to get most of them to function correctly. The only part of our initial plan that caused unforeseeable problems was the acrylic plate. During testing, we found that it did not diffuse as expected. We were able to work past this problem by doing things such as increasing the roughness of the plate texture and surrounding the module with more compactly spaced photodiodes.

8.2 Conclusion

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals. What constrained you from achieving these goals (if something did)? What could be done differently in a future design/implementation iteration to achieve these goals?

Goals:

1. Design a way to detect light on a target with roughly 1 ft by 1 ft dimensions.
2. Determine a threshold of light to accurately determine when a laser is shone upon the target.
3. Constantly poll for this information and collect data in a software program.
4. Utilize a vibrational motor to trigger the client's receiver and lower the target flag upon detection.
5. Ensure through testing that this design is feasible under various weather and room conditions.

Solutions and Obstacles Observed For Each Goal:

1. Our current design utilizes an acrylic plate to diffuse the laser beam into a larger surface area. This will allow for the photodiodes to detect the laser regardless of their location on the plate. During the testing of this part, we encountered problems achieving such light diffusion. We found that the light, when shone straight onto the plate, went straight through. If the laser was at a slight angle, some light was diffracted within the plate, but not enough to achieve our goal. We achieved diffusion by applying a frosted effect to one side of the acrylic plate which led to the light being diffused an acceptable amount.
2. During testing, we were able to read the voltage output on the Raspberry Pi Pico software when the photodiode was exposed to natural light and the more intense laser light. Then, the resistor paired with this photodiode could be adjusted to alter the sensitivity of the detection. We also found that this sensitivity could be adjusted in the software as well.
3. This was simply part of our software program in Arduino/Raspberry Pi, which constantly read in photodiode voltage inputs and averaged values within a particularly short time range.
4. This did not end up being possible and as such we needed to come up with another solution. This meant that we needed to physically trigger the existing module. We decided

using a small motor to simulate an object hitting the target was the approach we wanted to use. This ended up being effective and consistently triggered a hit.

5. The testing of this portion has been minimal. Our current testing conditions have been in rooms with a fair amount of natural and artificial light. Our new design takes into account the issues of weather and lighting conditions by being flexible on light intensity detection and by protecting the sensitive components with a durable shell.

8.3 References

List technical references and related work / market survey references. Do professional citation style (ex. IEEE).

"Photodiode basics," Wavelength Electronics, 11-Feb-2020. [Online]. Available: https://www.teamwavelength.com/photodiode-basics/. [Accessed: 01-Dec-2022].

E. Ramos, "Arduino basics," *SpringerLink*, 01-Jan-1970. [Online]. Available: https://link.springer.com/chapter/10.1007/978-1-4302-4168-3_1. [Accessed: 29-Nov-2022].

"IEEE SA - IEEE Guide for Safety Specification of laser transmission in high-power industrial laser systems," *IEEE Standards Association*. [Online]. Available: https://standards.ieee.org/ieee/2066/7327/. [Accessed: 02-Dec-2022].

8.4 Appendices

Appendix 1: Instructions for Product Use

1) Power on the Raspberry Pi Pico using the power button

2) Download and open the Trigger Interactive App

3) Turn Bluetooth on in your phone settings to connect to the module

4) Turn on the Smart Target Attachment modules, including the main hub and all other target hubs

5) Sync all modules via bluetooth by connecting each target one by one

(Hold the power button for one second and release to activate pairing mode, this must be done at the same time for each target and the main hub. Repeat with remaining targets.)

6) Set the targets a sufficient distance away, depending on the difficulty level you desire

7) Choose a training option, such as Basic Combat and press start

8) When training, wait for the flag to raise, then point the laser at the target

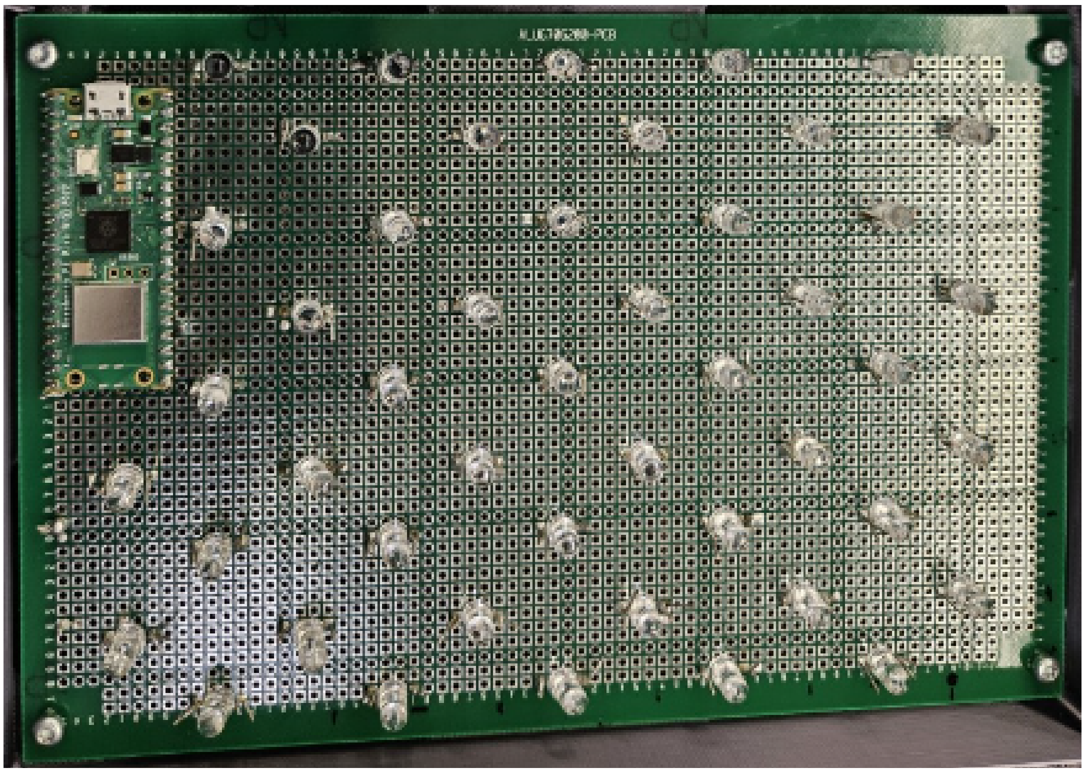
You should notice that the flag lowers once the target is hit by the laser

9) Repeat step 8 until the training is over and observe your score and reaction time on the app

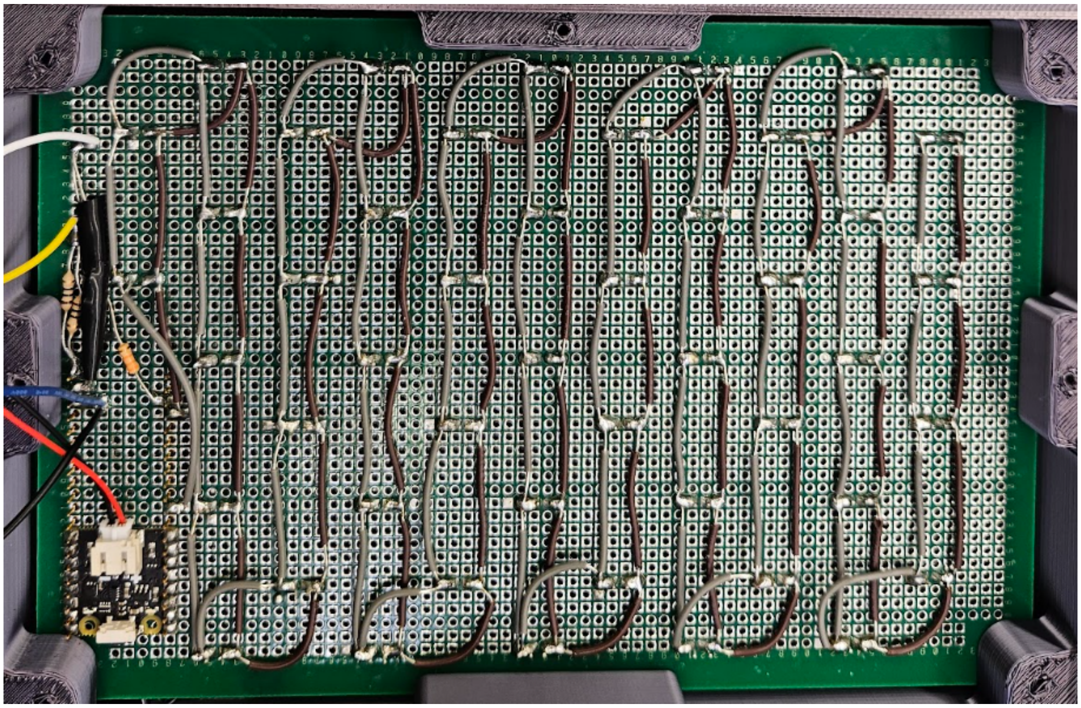
10) Once you are done testing, turn off the Pico in the same way as in step 1 to save battery life

Appendix 2: Additional Information, Images, and Code

Front of PCB:



Back of PCB:



Raspberry Pi Pico Main Code:

```
while True:  # loop indefinitely
    sensor_value = sensor_pin.read_u16()  # read sensor value
    current_average = calculate_rolling_average(sensor_value)  # calculate rolling average
    data_line = 'sensor value: %d' % sensor_value  # create data line string
    print(data_line)  # print data line to console

    if sensor_value > current_average + alpha_rise:  # if a rising edge is detected
        if not hit_detected:  # if a hit has not already been detected
            spike_timer += 0.01  # increment the spike timer

            if spike_timer <= max_spike_duration:  # if the spike timer is within the maximum duration
                hit_detected = True  # a hit has been detected
                motor1_pin.on()
#                 motor2_pin.on()
                print('Hit')
                time.sleep(0.5)
        else:  # if a hit has already been detected
            if sensor_value <= current_average + alpha_fall:
                hit_detected = False  # reset the hit detection flag
                motor1_pin.off()
#                 motor2_pin.off()
                spike_timer = 0  # reset the spike timer

    else:  # if no rising edge is detected
         if hit_detected and sensor_value <= current_average + alpha_fall:  # if a falling edge is detected after a hit
             hit_detected = False  # reset the hit detection flag
             motor1_pin.off()
#               motor2_pin.off()
             spike_timer = 0  # reset the spike timer

    time.sleep(0.01)  # wait for 0.01 seconds before the next iteration
```

Method of Calculating the Rolling Average:

```
def calculate_rolling_average(new_value):  # define function to calculate the rolling average
    global count, cursor, data, rolling_average  # use global variables
    rolling_average *= count  # multiply rolling average by number of data points
    if count < data_set_size:  # if the data set is not full yet
        count += 1  # increment the count
    else:
        rolling_average -= data[cursor]  # subtract the oldest value from the rolling average
    data[cursor] = new_value  # add the new value to the data set
    rolling_average += new_value  # add the new value to the rolling average
    cursor = (cursor + 1) % data_set_size  # update the cursor position
    if count > 0:  # if there are data points in the data set
        rolling_average /= count  # divide rolling average by number of data points
    return rolling_average  # return the rolling average value
```

8.4.1 Team Contract

Team Members:

1) _Akash Patel ______________________ 2) __Elijah Bryant____________________
3) _Lincoln Khongmaly ________________ 4) __Neftali Medina_________________
5) _Adam Runde______________________ 6) __Sydney Stowe_________________

Team Procedures

1. *Day, time, and location (face-to-face or virtual) for regular team meetings:*
   Meet every Wednesday at 3:00pm at TLA
2. *Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):*
   Snapchat, Email
3. *Decision-making policy (e.g., consensus, majority vote):*
   Majority Vote
4. *Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):*
   Google Docs

Participation Expectations

1. *Expected individual attendance, punctuality, and participation at all team meetings:*
   Make every meeting. communicate if you will be late or can not make it.

2. *Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:*
   Team members to complete all tasks that are agreed upon by the date agreed upon.

3. *Expected level of communication with other team members:*
   Whenever something comes up, the team must be notified. Other than that, we can communicate during meetings or on needs based.

4. *Expected level of commitment to team decisions and tasks:*
   Attend meetings, get work done, stay updated.

Leadership

1. *Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):*

   Lincoln: Advisor Meetings
   Akash Patel: Take minutes and communicate with the team.
   Neftali: Client Meetings
   Adam: Design
   Elijah Bryant: Testing
   Sidney Stowe: Timeline Management

2. *Strategies for supporting and guiding the work of all team members:*
   Keep google doc of tasks and discussion. This will have the deadlines and members assigned to the task.

3. *Strategies for recognizing the contributions of all team members:*
   Crisp High Five after completing a task.

Collaboration and Inclusion

1. *Describe the skills, expertise, and unique perspectives each team member brings to the team.*
   Sidney Stowe: Software/robotic experience
   Lincoln: Presentation Skills
   Akash: 8 year military, leadership, software
   Elijah: Component Design
   Adam: Client interaction and power system design
   Neftali: analog/digital communications knowledge (EE)

2. *Strategies for encouraging and supporting contributions and ideas from all team members:*
   Be open minded to ideas, everyone has different perspectives.

3. *Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?)*
   Full team meeting about the issue and if no resolution, then meet with the professor.

Goal-Setting, Planning, and Execution

1. *Team goals for this semester:*
   Have a strong design laid out for the product.

2. *Strategies for planning and assigning individual and team work:*
   Weekly meetings dedicated to delegating work to individual members and checking in on how work is going from the previous week.

3. *Strategies for keeping on task:*
   Weekly meetings and advisor meetings. Keep each other in check.

Consequences for Not Adhering to Team Contract

1. *How will you handle infractions of any of the obligations of this team contract?*
   3 Strike method

2. *What will your team do if the infractions continue?*
   We will go to the professor and they will decide what to do.

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a) *I participated in formulating the standards, roles, and procedures as stated in this contract.*
b) *I understand that I am obligated to abide by these terms and conditions.*
c) *I understand that if I do not abide by these terms and conditions, I will suffer the consequences as stated in this contract.*
1) Lincoln Khongmaly________________________________ DATE _9/19/2022________
2) Neftali Medina____________________________________ DATE _9/19/2022________
3) Elijah Bryant______________________________________ DATE _9/19/2022________
4) Akash Patel_______________________________________ DATE _9/19/2022________
5) Sidney Stowe______________________________________ DATE _9/19/2022________
6) Adam Runde_______________________________________ DATE _9/19/2022________