UCF Senior Design 1 Divide and Conquer Group 23
Project ATLAS(Auto.Targeting.Light.Attack.System)

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1.0 Executive Summary

2.0 Project description

The project description consists of an overview of the ATLAS system. The main points of interest for this section is the motivation and background behind how we chose our project. Goals and objectives, specifically our main, advance and stretch goals. Features and functionalities, basically how our system will work. And last but not least any existing products that we gather motivation from.

2.1 Motivation and Background

The ATLAS project is meant to develop a system for automated light arms fire requiring minimal user input. With the ongoing conflicts between modern and technologically equipped nations being fought around the globe it's clear that tech plays a large role in combat.

Sentry turrets that feature automatic targeting systems are still fairly new to the modern military landscape. The first system adopted by the US Navy was the Phalanx CIWS produced by General Dynamics in 1978. This system however is heavy and fires large arm caliber. In fact most automatic targeting systems fire a large arms caliber and therefore are very heavy. There are examples of small arm caliber systems though, such as the Samsung SGR-A1 which fires the widely available 5.56 x 45 mm cartridge.This technology is also fairly new with prototypes being developed in 2006.

We wondered why turrets have not been widely adopted by modern militaries as they seem to be the perfect solution to combating enemies without risking allies. The answer is simple, the sentry turret is not as effective as a human soldier with a rifle. There are many reasons for this but one of them is that turrets can not give the same feedback as a human. A sentry turret is also cumbersome to carry with most systems weighing above 250 pounds.

Knowing that no turret will be able to replace the modern warfighter in terms of cost and efficiency we can then move onto what a turret would be good for. Any defensive position would make a good candidate for turrets as it increases firepower without increasing the manpower required for this firepower. Also turrets are very useful to protect borders and contested zones that are subject to invasion. Similar to the Maginot Line that France built during the 1930s, a defensive line equipped with turrets would be highly effective.

Our project aims to develop a turret system to be lightweight and portable for the user to deploy at their own discretion. The automatic targeting system will be highly accurate and precise but also allow room for the user to have input. We will be utilizing the use of machine learning as well using AI within the design as it seems that most turrets in today's world have yet to implement AI into the system.

That being said, with the introduction of AI into a system that is meant for defensive applications comes a set of ethics that must be regarded. The main issue is the idea that a machine would be targeting humans. With our design however we plan to make sure that the operator can set the parameters of how the machine behaves even though the targeting is automatic. We also plan to include certain safety and procedure settings inside the programmed logic to reduce collateral damage to zero.

In the future automated defense systems will be widespread throughout the world even perhaps breaking into the civilian sector. This technology will have much room to grow with the advancements in AI and machine learning. Our team hopes to tap into some of that development in its infancy.

2.2 Goals and Objectives

Our goal is to build and design a fully functional stationary sentry gun to be able to track and detect object movement with precision firing. With these goals in mind, we strive to create an automated sentry gun that is modernized for the 21st century that can be used in various different situations.

Main Goals

- Automated object detection and tracking in the horizontal plane.
- Targeting and precision aim.
- Automatic firing system.
- Safety and Failures.

Advanced Goals

- Color differentiation.
- Working in the vertical direction.
- Incorporate an RFID tag and sensor to differentiate between subjects/objects.

Stretch Goals

- The capacity to discharge a round with a precision rate of one per second.
- The ability to transport and fire simultaneously.
- Ability to mount multiple weapon systems depending on user

2.2.1 Main Goals

The main goals that we are really stressing to accomplish for our project is to be able to detect and track an object in a 180 degree field of view in the horizontal direction, targeting the object and be able to successfully target and aim at the object, and finally safety and failures for weapon jams or identifying the wrong object.

Detection and Tracking mechanism

The way we are going to be able to detect and track an object is going to be with the use of a DFROBOT HUSKYLENS camera, mounted on top of our shooting mechanism that will be able to identify an object within 30 meters, and track it within 180 degrees. Since our camera is going to only have a field of view of about 60 degrees and we want a maximum angle of 180 degrees if our object is going to move outside of that 60 degree window we must incorporate the use of a motor. The motor we are going to be using is going to be a stepping motor that will help us reach that maximum distance of 180 degrees.

Targeting and precision aim

The targeting and precision aiming system is going to be able to consistently track and aim with high accuracy. Using the DFROBOT HUSKYLENS camera, it will be able to identify the object and follow that object with the use of a stepping motor to allow the following of the object in a 180 degree angle.

Automatic firing system

The use of an automatic firing system is to be used when the system identifies an object and once the system is locked onto the target the automatic firing system will begin firing. With the use of an automated firing system it will confirm that the turret has the ability to be completely autonomous with limited use of manual input such as reloading or a weapon jam.

Safety and failures

Since there is always a risk that we run into certain failures such as a gun jam or running out of bullets we are going to be able to solve this issue with using the LED on the arduino board. Will also use a proximity sensor that will relay the information of how many bullets leaves the weapon to alert when the weapon is getting low or out of rounds. Also with the use of a proximity sensor if there are no rounds coming out of the weapon it will also be able to let the user know that there is potentially an issue with the weapon.

2.2.2 Advanced Goals

The advanced goals that we want to accomplish by the end of senior design 2 are going to be the use of color differentiation as well as working in the vertical direction. With the use of color differentiation it will help the system if we want to set it to a certain color, while working in the vertical direction is going to be good if the object we want to track is flying or in the air.

Color differentiation

The use of color differentiation in our system is going to be used from the DFROBOT HUSKYLENS camera since it has a built in AI aspect which is able to recognize colors as well as objects. This is really powerful if we want to have our system only target certain colors of the object or if we don't know the color of the object it would be able to recognize that and give the feedback.

Working in the vertical direction

Hoping to work in the vertical directions in case of an object in the air that we want to target and engage with. With the use of another stepper motor and the camera that we have selected it will give us the field of view to be able to detect the object and it will be able to look up at that object and engage.

Incorporate an RFID tag and sensor to differentiate subjects and objects

The reason that modern sentry turrets aren't used now in the real world is the fear of not being able to differentiate some objects. The main fear is friendly fire, one way that we would be able to avoid that is the use of an RFID tag or sensor that will let the turret know if it sounds engaged with that target or just keep scanning for another object. If there is an RFID that the system could pick up and not engage with it would be a modernized piece of equipment that could be used in the real world.

2.2.3 Stretch Goals

The capacity to discharge a round with a precision rate of one per second

With the use of a nerf gun we would want to incorporate a motor or some mechanism that will let us fire at a faster rate than a regular nerf gun would let us shoot. With the use of an external battery or even just another added motor that can let us reach a discharge and precision of one round per second.

The ability to transport and fire simultaneously

This system is going to be a stationary turret but there are many capabilities to be able to mount this on another sort of transportation unit, such as a robot that will be able to move into dangerous areas and still achieve the capabilities that we are looking for it to do such as target and track objects as well as rotate by itself and fire. The use of another unit that could have the turret included on it and the units be able to work by themself could lead to the turret firing while the transport unit is moving itself.

Ability to mount multiple weapon systems depending on the user

This system is only going to be able to handle one weapon system at this time. But if it is able to handle multiple weapons at once and still only has to use one camera it can lead to having multiple capabilities. Some of those capabilities could be to target multiple objects at the same time and fire at two different objects at once, which could lead to better efficiency since there might be a group of objects that it needs to engage with but might not be able to fire fast enough or be able to engage with them with only having one weapon system.

2.2.4 Objectives

The objective of the ATLAS sentry turret is to provide precision, efficiency and speed in order to produce a modern day sentry turret. Using recent innovations of technology will allow for a more up to date sentry turret that showcases all the technologies of the modern day. We plan on using modern day advances in order to try to improve a beneficial military product. Artificial intelligence has been a recent innovation of the 21st century and features such as color, facial, and object recognition. Our group's biggest objective is to integrate artificial intelligence and an RFID system in order to prevent accidental fires while incorporating precision, speed and accuracy.

2.3 Features and Functionalities

- Ability to detect using color, facial, and object recognition using artificial intelligence.
- Ability to track an object and stay engaged.
- Discharge of a round with precision and accuracy.
- Ability to differentiate from whom to fire at and whom not to using RFID.
- Rotate the firing mechanism both in an x and y axis.

2.4 Existing products

We found a UCF senior design project from 2016 that worked with Lockheed Martin in order to compete at the battlebot competition. Battlebot was a competition that required students to create a system that competed with opposing systems. The team was named the “Green Team” and consisted of Clayton Cuteri, Corey Nelson, Kyle Nelson, and Alexander Perez. The team was tasked by Lockheed Martin to create a fully autonomous target recognition system. The fully autonomous targeting system synced projectile weapons to hit targets using a webcam, lidar, and ultrasonic sensors. The Green team used the webcam to be the “eyes” of the system, allowing for a live feed. The lidar sensor was used to determine distance by shining a laser and seeing how long it takes to return back to the sensor.The infrared sensor emits a sound pulse that then reflects off of objects back to the sensor’s receiver in order to determine the distance between the object and the battlebot. The webcam, lidar, and ultrasonic sensors all work together with OpenCV. OpenCV is a library used for facial recognition, specifically the local binary pattern histograms algorithm. The local binary pattern histograms algorithm summarizes local structures of an image comparing pixels to the pixels surrounding it. Facial and object recognition/tracking are key aspects to a project as such, allowing for an efficient way to detect, differentiate and track subjects/objects. The Green team had used the Windows platform because of the flexibility of Windows and the availability of systems, and the Arduino environment because of its compatibility with the Windows platform. The Arduino environment has versatility and open source capabilities, allowing for ease of use for various hardware and software. The Green team had used a NERF blaster that was reconfigured to communicate with the system in order to fire at other battlebots.

Figure 1: Image of The Green Team's System

Another UCF senior design project from 2016 also worked with Lockheed Martin to procure a fully autonomous target recognition system to compete in the battlebot competition. Daniel Agudelo, Rachel Gremillion, Aaron Hoyt and Rafael Ramirez were the students a part of this effort. The team had used both a webcam and a lidar lite laser rangefinder that determined the distance of the target and whether or not the system should fire, the lidar lite laser rangefinder had the ability to detect up to 40 meters. The team had used OpenCV and Visionworks library packages in order to procure computer vision algorithms that worked with the webcam and lidar lite laser rangefinder. Various DC motors were used in this system in order to tilt the robot's optical mount and for manual navigation. A stepper motor was incorporated as well in order to provide accurate positioning for the robot. The firing mechanism consisted of two NERF blasters, one for short range and one for long range. The short range NERF blaster had the ability to fire up to 55ft and used three motors in order to fire automatically. The long-range NERF blaster had the capability of firing up to 75 ft using a longer magazine and a 12V fan in order to push the ammunition farther, a flywheel and servo motor was used to control the amount of ammunition shot when necessary.

Figure 2: Image of The 2016 Lockheed Martin's Team's System

2.4.1 Projected Similarities

Both projects from UCF senior design 2016 are efficient systems. Our team plans on using similar parts from the projects. The NERF blaster is a firing mechanism our team aims to use, due to its ability to fire a considerable distance without causing any harm. Webcam is another component we plan on adding to our system to act as the "eyes" of our system in order to relay and communicate with the rest of the components. The lidar sensor is our sensor of choice because of its ability to measure the distance of a subject/object. Our team is going to use several motors as well in order to maneuver our NERF blaster and webcam.

2.5 Engineering Specifications with Quantitative Measures

Table 1 below provides our engineering requirements and specifications. The requirements highlighted in orange are the requirements we expect to demonstrate. The reason we had selected the three highlighted requirements to demonstrate is because we believe those are critical features that are best visually to demonstrate. Detection range, response time and field of view are critical features for that of a sentry turret.

Detection range is a key requirement because it is optimal that our sentry turret can detect from a respectable distance, with modern day technology it would be a disservice to have a short detection range. Response time is also important, a system that takes too long would defeat the purpose of the sentry turret since the sentry turret is prominently a military product. A response time of 300 ms is quick but really showcases the speed of our system and our implementations of advanced technology. Field of view is a critical component of our system. Our group wants to have a wide field of view so that we are able to detect a large area which then leads to a quicker response time.

The other nine specifications are necessary since our highlighted one's work hand in hand with the other nine. Functionality is important, we want to verify that our product functions the way a sentry turret should. Precision is crucial, like any firing system/weapon the user wants a precise system. Creating a system that is not accurate and precise is essentially a non-practical system. Latency for our system needs to be as low as possible, our system should respond as soon as a target is detected, military grade sentry turrets require low latency in the case of urgency. The same applies for power consumption, we desire a lower power consumption, a high-power consumption would require a more power source in turn becomes pricier. Typically, sentry turrets are placed outdoors in all sorts of climates, deserts, mountains, beaches, etc. The ATLAS system should be able to withstand those types of conditions as well, hence the operating conditions of 100 degrees or less. Stability for the ATLAS would require a flat surface, our system consists of a firing mechanism, camera, and sensors which would work optimally on a flat surface.

Specifications	
Functionality:	**Object tracking and shooting to the target**
Detection Range:	**30 meters**
Precision	**At least 90% accuracy**
Response Time	**Around 300 ms**
Field of View	**180°**
Latency	**Less than 500 milliseconds**
Power consumption	**1.15 Watts**
Operating Conditions	**Less than 100° F**
Stability	**Flat surface**

Table 1: Specifications Table

2.6 Hardware Block Diagram

The hardware block diagram is a general breakdown of the hardware components that must go into our ATLAS system. It includes motors for the X and Y axis, power supply, MCU, camera sensor, step motor and sensor for detecting ammunition.

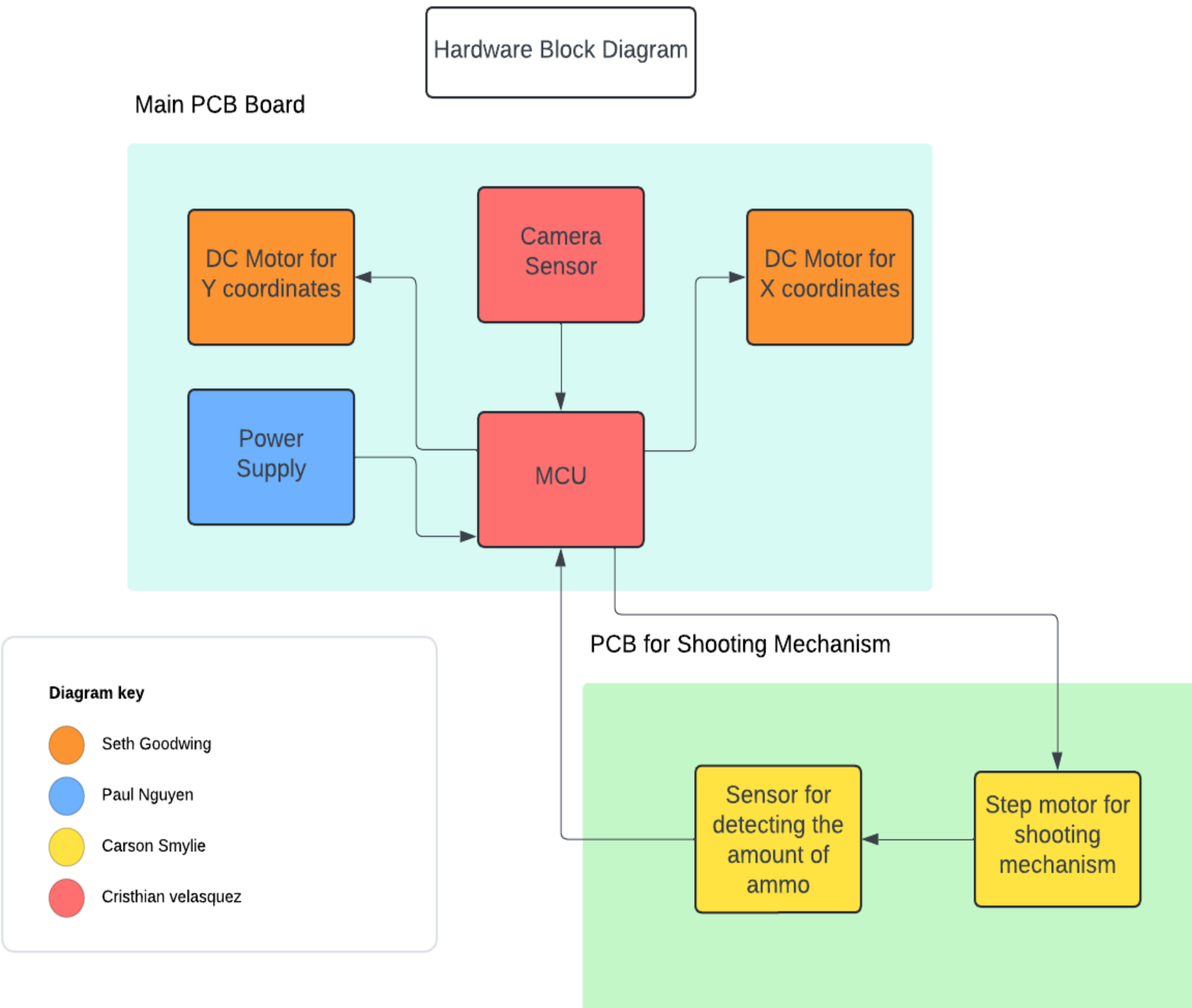

Figure 3: Hardware Diagram

2.7 Software Block Diagram

The software block diagram is a step-by-step process that shows viewers how the overall software system works. Essentially starting with the camera and walking through how the software will comprehend and fire at the target.

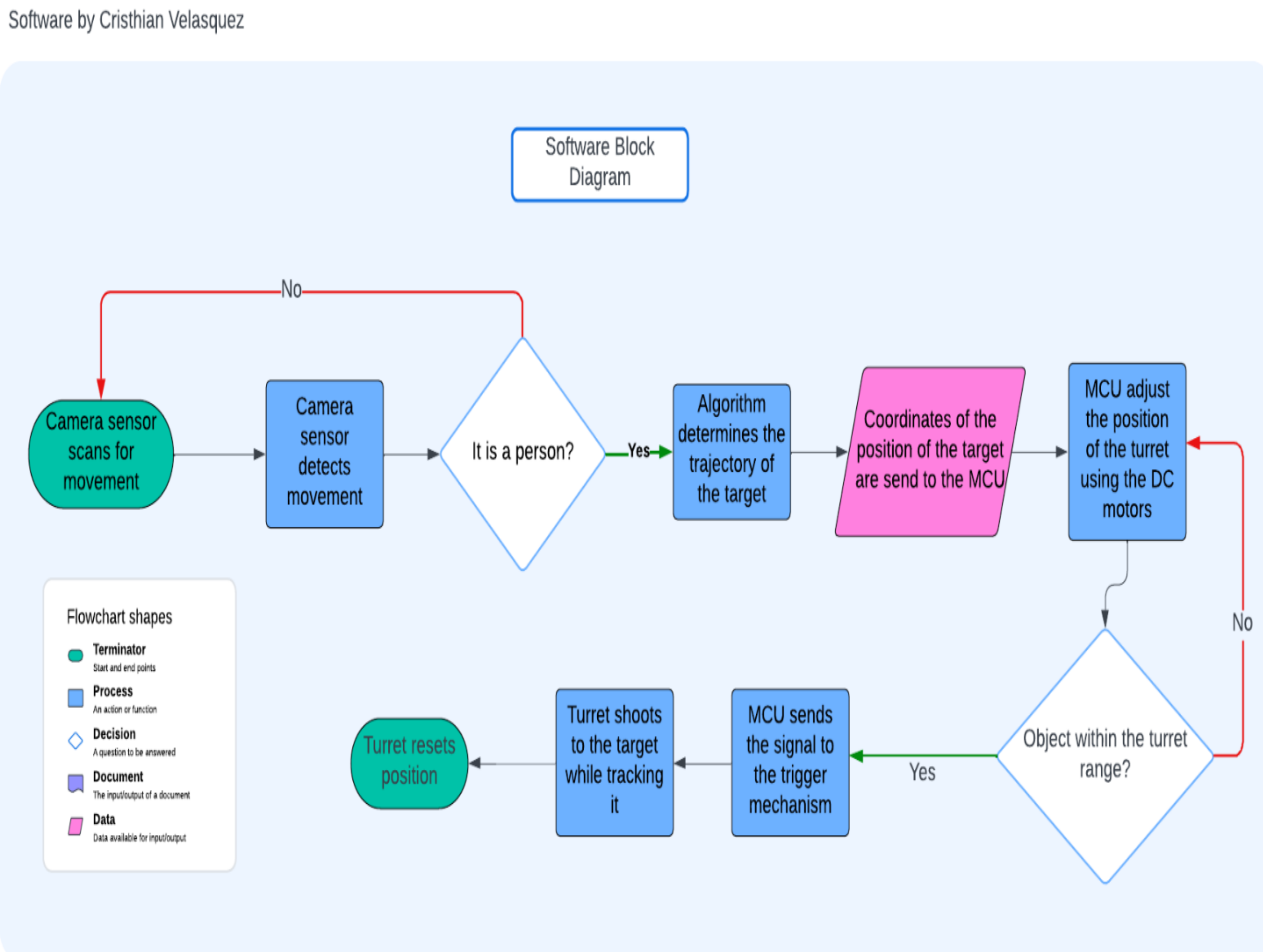

Figure 4: Software Diagram

2.8 House of quality

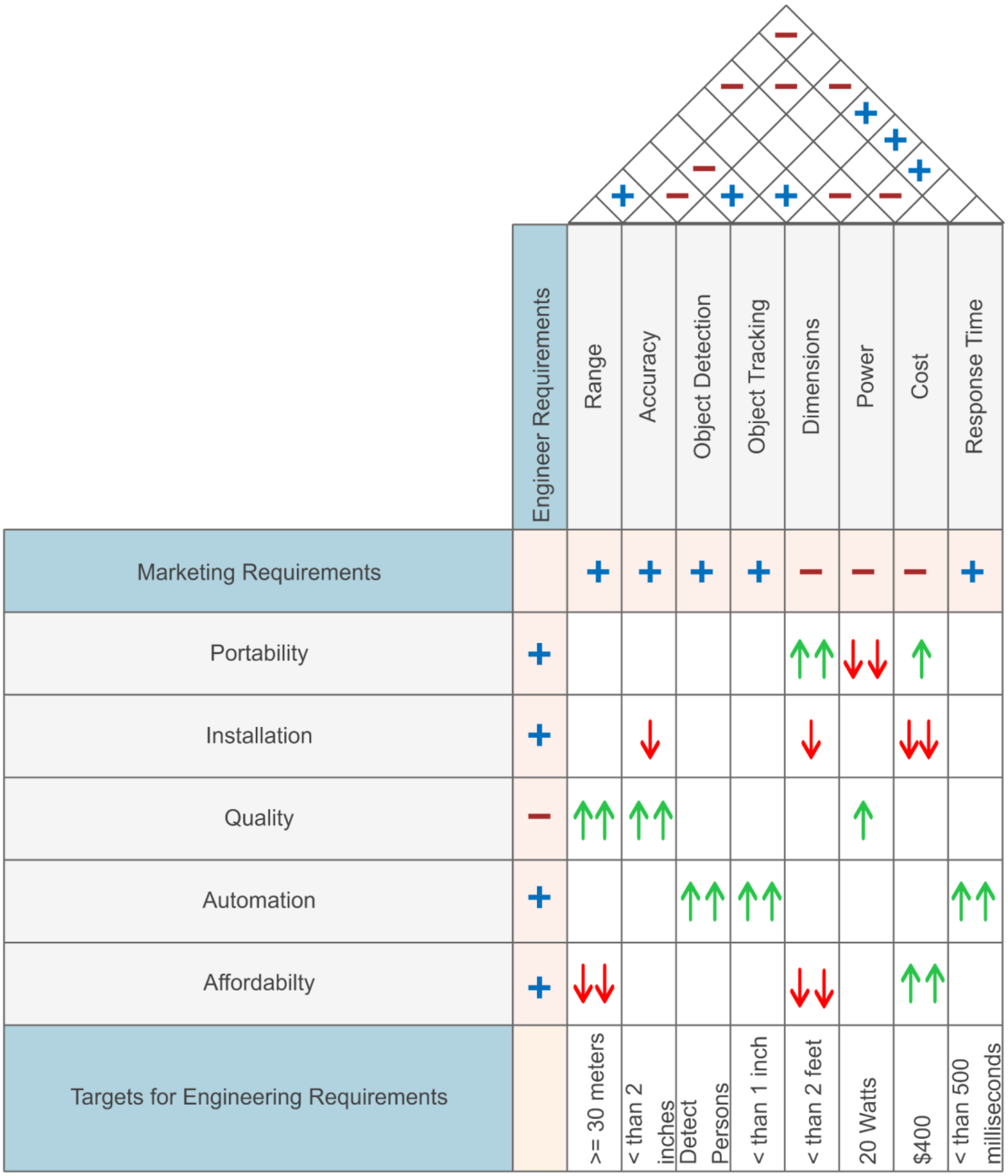

Figure 5: House of Quality

3.0 Research and Investigation

In the research and investigation section we will be discussing technology and part comparison. Technology comparison consists of comparing potential technologies we will be using, comparing MCU vs FPGA, different types of motors, sensors and power supplies. In the part comparison we will be finding specific parts and comparing which part is best for our system.

3.1 Technology Comparison

In the technology comparison we are comparing MCU vs FPGA to see which approach would be better. Wireless or wired power supplies are another technological aspect we will research and compare. Different types of motors and sensors as well will be assessed.

3.1.1 MCU vs FPGA

Depending on the scenario or type of project, the MCU and FPGA can be used according to the necessities of the user. A microcontroller unit (MCU) is a compact integrated circuit designed to perform a specific operation in an embedded system. On the other hand, a field-programmable gate array (FPGA) is a semiconductor device that can be programmed post-manufacturing to perform a variety of more complex tasks while having multiple peripherals connected to it. One of the key features that the MCU offers is that it can be programmed using high-level languages like C or C++, while the FPGA can be programmed only using hardware description languages like VHDL and Verilog. One major difference between the two is that the MCU is usually cheaper for simple tasks that requires a low-power consumption (suitable for battery-operated devices) while the FPGA since it has a higher rate for performance and multitasking, tends to be more expensive since in most cases is used for complex computations. Overall, MCUs are great for low-power, cost-sensitive applications that require straightforward processing control and very little number of peripherals. FPGAs excel in performance-intensive multitasking scenarios needing flexibility and parallel processing capabilities.

3.1.1.1 Why Did We Choose MCU?

The main reasons why we have chosen a MCU for our project, are because of the flexibility that MCUs can provide at the moment of building a custom PCB, programmability is more reliable and simpler, cost is very low, and power consumption is suitable for battery powered devices like the one we are trying to build. Thanks to the architecture of MCUs that typically have a CPU, memory (RAM and Flash), and peripherals (I/O ports, timers, ADCs) all on a single chip, makes easier and more cost effective the amount of PCBs required for the project (1 or 2 PCBs). One MCU can control up to 2 peripherals at the same time with the use of the input and output ports, this makes it ideal for our project since it will consist of the data obtained from the camera in order to control the position in the X and Y coordinates of the turret using the DC motors.

3.1.2 Power Supply (Wireless Vs Wired)

A sentry turret must have a power supply in order for it to function. Without a power supply an electrical system is rendered useless. When it comes to the sentry turret the question at hand for the power supply is whether to use a wireless or a wired power supply. Both the wireless and wired have their own pros and cons. Wireless power supplies such as power banks and portable battery packs have the advantage of being portable. The ability of being portable allows the sentry turret to be placed anywhere, mountain, desert, forest, etc. Portability is a key component in not just military products but all sorts of technologies of the 21st century. The convenience provided with wireless power supplies is a strong factor. The disadvantages of wireless power supplies are the capacity and efficiency. Capacity of the wireless power supplies is a very limited factor; the wireless power supply must be charged before use and must be recharged when power is gone. The total energy that can be supplied all relies on the battery's capacity. Having to constantly charge the wireless power supply can be an inconvenience if the sentry turret is placed out in the desert or an isolated area. A wireless power supply is not as efficient as a wired power supply, energy conversion and storage can eventually lead to energy leaks and losses. Wireless power supplies must have a very large capacity in order to power on a large system.

Wired power supplies allow for reliable and continuous power. Wired power supplies use an outlet to apply power to a system leading to a large power capacity which is essentially unlimited if the power from the outlet is constant. Power loss is not an issue with wired power supplies compared to wireless power supplies that lose energy when the battery is charged and recharged. Despite the large power and efficiency wired power supplies provide; the wired power supply uses cables/wires and requires an outlet in order to function at all. Wired power supplies have very limited mobility because they require an outlet, this means that it does not have the ability to be used in deserts, forests, isolated areas, etc.

Feature	Wireless Power Supply	Wired Power Supply
Reliability	Requires recharge after use.	Reliable as long as there is constant power from a power source (ex. Outlet).
Mobility	Portable, can be used anywhere.	Requires an electrical outlet.
Efficiency	Energy decrease occurs as charging and draining the battery continues.	Direct energy transfer, very efficient.
Capacity	Limited to the power supply's battery	Limitless power as long as connected to an

	capacity.	electrical outlet.
Size/Weight	Lightweight	Lightweight
Power Output	Best for low/medium power devices.	Able to power supply for low, medium and high power devices.
Convenience	Portable and can be taken anywhere.	Stationary use is ideal, otherwise inconvenient.

Table 2: Comparison Between Wired and Wireless Power Supply

3.1.3 Motor Technology

There are multiple factors to consider when choosing a motor to control the sentry turret. These factors are included but not limited to size, weight, speed, precision, torque, and the limitations imposed by the actual design of the sentry turret. Ideally, we would like to select a motor that provides smooth rotation, speed, and high precision. The motors we will be looking at for comparison are stepper motors, servo motors, and a DC motor with encoder.

The stepper motor is a device that uses DC power in order to divide a full rotation into equal steps that can be accurately controlled with no need for a feedback mechanism.

The strong points of using a stepper motor are the speed control, precise positioning, and repeatability of movement. The precise positioning and speed come from the stepper motor control system itself. Because it functions off of dividing the movement into individual steps which means that the motor will move by a fixed number of degrees.

The stepper motor is also highly reliable. This is something to consider when trying to eliminate the possibility of having a failure. This also helps the end-user as having the motor being reliable will decrease the maintenance and knowledge that the end-user would have to perform on the turret.

Variable reluctance rotors have a core made of iron core that also aligns with the magnetic field. The pros of having a variable reluctance rotor are that we reach fast speeds and resolution. However, the torque is lower for application.

Hybrid rotors are a mixture of permanent magnet rotors and variable reluctance rotors. There are two caps within the rotor with alternating teeth and are also magnetized axially. This configuration gives us high resolution, speed, and torque. With this performance boost however also comes a higher cost than any of the other stepper motors.

When controlling the stepper motor we use a pre-driver and transistor bridge to interface with the MCU. We can combine this Pre-Driver and the transistor bridge into a single device that we call the Driver. The transistor bridge will control the electrical connection of the motor coils.

There are also multiple techniques we can use to drive the stepper motor. The wave mode will only energize a single phase at a time. The full-step mode has two phases that will remain energized at the same time which means we get higher torque. Half-step mode combines wave and full step mode but this mode will result in an inconsistent torque. Micro stepping reduces the steps even smaller based on current. This mode however needs a complex driver.

The stepper motor does not require a sensor to position its motor. The control method is extremely simple as well and has good static torque. Despite this ease of control, the stepper motor can miss a step when the load torque is too high. They also always have a high-power draw which can cause overheating problems within the motor. Also the stepper motor is known to have low torque at high speeds. We will consider all of this when comparing the stepper to the other motor options.

Servo motors will produce torque and velocity based on the supplied current and voltage. The closed loop system provides these features utilizing a feedback device to close the loop. The motor relies on three important electronics: motor, a feedback device, and control electronics.

Servo motors can come in many different shapes and sizes. Motors can be AC or DC, brushed or brushless, rotary or linear. Feedback devices can be potentiometer or any other sensor. The control electronics power the motor and are responsible for the feedback data and command reference to make sure the servo motor is operating as commanded.

Servo motors also typically run on 5-7 volts while stepper motors and DC motors operate on 12 volts or more. Also compared to stepper motors the servo motor will have higher torque. Servo motors have precise motion and high power density when compared to the stepper motor.
As mentioned previously the servo motor operates on a closed loop control system. The closed loop control system, even though it’s more complicated when comparing it to the control of the stepper motor, will provide us with even better accuracy, response times, and load control. With this enhanced capability comes drawbacks.

The more we increase the system complexity we increase the investment to be made into the motor system. The motor system will need fine tuning and maintenance of the feedback system to the controller. This tuning leads to a different torque-speed characteristic than the stepper motor.

This is because the servo motor draws power proportional to the load they're driving while the stepper motor will consume power continuously even while not moving. Power efficiency is something we must consider since our power supply will be powering multiple electronics and motors.

Another characteristic of a servo motor is that they operate quietly. A smooth torque results in the motor sound level being at a lower decibel level than that of other motor options like the stepper. The lack of noise and vibration is critical for making electronics that move precisely and for electronics that require stability.

Our last option is a DC motor with encoder. When we use a DC motor by itself we can't control it like a servo motor or a stepper motor. When you interface a DC motor with an encoder that's when we can use a DC motor for our application.

The encoder will watch the magnetic field created by the magnet attached to the DC motor shaft. When the motor rotates the encoder will give outputs based on the motion. For example, Output A will trigger when the magnet spins clockwise and Output B will trigger when the magnet spins counterclockwise.

The DC motor with encoder will require a more complex control setup than the other motors. We will have to implement a closed loop control system to translate encoder feedback. We will have to tune the PID parameters to our needs. This tuning can become very complicated quickly. Compared to the servo motor which already has built in feedback control this will be tougher.

Also, the DC motor with encoder will need a motor driver to control speed and direction because a DC motor with encoder can't interface directly with a microcontroller. The hardware complexity will only increase when using the DC motor with encoder.

3.1.3 Why Did We Choose Servo Motor?

Our team decided to go with a servo motor for a variety of reasons. The turret will always require solid torque output in order to snap onto targets. Also, the use of the feedback system with the servo motor means we can precisely control the motor.

The stepper operates on an open loop system which gives us precise control since it moves in fixed controlled steps. The DC motor with encoder operates on a closed loop system but the feedback and control part is external to the motor. The servo operates on a closed loop system that has built-in feedback to the motor. This built-in feedback makes it easier for us to control the motor to fit our needs. The stepper motor has torque that is good at low speeds but starts to drop when speed increases. The torque of the servo motor is constant throughout the movement regardless of the speed of the motor. The DC motor with encoder has a high torque and can achieve even higher torque with an added gearbox. For our project we will require a motor that has torque at all speeds even high speed. With this condition we could either consider the servo or the DC motor with encoder. Because the DC motor with encoder would require external setup we will choose the servo in this category for its utility.

The precision of the motor matters as well. All three of the motors have very high precision. The stepper operates on fixed steps that leads to this high precision and also leads to reliability. The servo has high precision due to its integral feedback control system. The DC motor with encoder has high precision as well but requires external PID control. For the turret, we could either select the stepper or the servo in this category.

The stepper motor has a simple control system since it only requires pulses to operate. The servo motor has the easiest to use control system since it only requires a PWM signal and has a feedback loop that makes controls easier. The DC motor with encoder is the most complex to control which is the main drawback of using this motor. If we had picked the DC motor with encoder, we would have to have a driver and extensively tune PID settings which are complex.

We will also consider power efficiency for each of these motors. The stepper motor will always consume power regardless of the load and because of this we can have higher heat production and less efficiency. The servo motor will only consume power proportional to the load that they are driving. A DC motor with encoder will draw high power whenever it is moving at high speeds or using high torque.

Our turret requires a good power efficiency, easy setup, good torque and speed, and precise control. The motor that best suits these needs is the servo motor. Each of the other motors has a drawback that would be solved by using the servo motor. The servo motor delivers precision with built-in feedback as well as solid torque output throughout all speed ranges. If our application required higher speed, then the DC motor with encoder would be a better pick. Or if our turret did not have speed as a priority, we could use the stepper motor.

Characteristic	Stepper Motor	Servo Motor	DC Motor with Encoder
Control Method	Open-Loop	Closed-Loop	Closed-Loop
Torque	High at low speeds, Low at high speeds	Consistent torque at all speeds	High torque(can add gearbox for higher torque)
Ease of Use	Simple control mechanism	Easiest to use	Complex(PID tuning)
Power	Moderate	Low	High at high

consumption			speeds and torque
Cost	$10-$50	$10-$60	$15-$100+

Table 3: Comparison of Motor Technology

3.1.4 Sensor technology

Photoelectric, ultrasonic, and magnetic sensors will be discussed in this section. Doing so will allow us to pick the best sensor for our project and gather a better understanding as we research.

3.1.4.1 Photoelectric Sensors

A photoelectric sensor is a type of sensor that can detect the presence of an object as well as be able to find distance by the use of emitting light. The sensor uses both a transmitter and a receiver for the light aspect, it is able to use visible or non-visible light. There are three different types of photoelectric sensors which are thru-beam, retro-reflective and diffuse-reflective sensors. A thru beam sensor will have the transmitter and receiver in separate housings. The beam will be able to be shined from the transmitter to the receiver and if an object (in our project a nerf ball) passes through the beam it will be able to sense that an object has passed. A retro-reflective sensor works in the same way with a transmitter and receiver but both of them are in the same housing and the light will need the use of a reflector to shine the light back to the receiver. If an object passes through the light won't make it to the reflector and won't send it back to the receiver which will let the sensor know that an object passed through. A diffuse reflective sensor works almost just like a retro-reflective sensor in the fact that the transmitter and receiver are in the same housing, but instead of the light having to reflect off the reflector the light for this sensor will reflect off of the object and back to the receiver. These sensors will all have pros and cons, for the thru-beam sensor some of the pros are that they are the most accurate and have a fast response time, but the cons are that they are the most expensive, complex installations and alignment issues due two separate housings. Retro-reflective sensors pros are that they aren't as complex to set up, have a fast response time as well as cost effective while some cons are alignment issues, false readings as well as external interference such as light or other factors. For a diffuse-reflective sensor the pros are easy installation, cost effective, compact and high sensitivity while some cons are less accurate, reading can be affected by color, texture of the object. For this project we think the best sensor for the photoelectric sensors would be a retro-reflective sensor since we will still be able to get some accurate reading without the high cost of a thru beam sensor.

3.1.4.2 Ultrasonic Sensors

An ultrasonic sensor is a type of sensor that will emit high frequency sound waves and once the object is hit, the sound wave will reflect back to the sensor. Most ultrasonic sensors are used for multiple different applications such as measuring water height, distance measurements, and detection such as object detection.

There are multiple pros and cons for using an ultrasonic sensor. There are a lot of pros that would be a good fit for what we are looking for but the cons outweigh the pros for these sensors. A few of the pros that would be helpful to our product is it can work in various different lighting conditions; it is very versatile when it comes to what objects it can detect and it is also affordable. Some of the cons are that some materials could affect the sensor's reading, slow response time, and external effects can affect readings such as temperature and sound can affect readings.

3.1.4.3 Magnetic (magnetometer) Sensor

Magnetometer sensors are a type of sensor that use a magnetic field to detect objects, there are multiple different types of magnetic sensors. The way magnetometer sensors work is stated as "work by detecting and measuring magnetic fields, specifically their strength (magnetic flux density) and direction." [29]. Magnetic sensors are used in a lot of different applications such as vehicles, phones, healthcare and security systems. Some of the most common types of magnetic sensors are Hall effect sensors, magneto resistive sensors, giant magneto resistive, and fluxgate.

Hall effect sensors are a type of magnetic sensor that can be used for sensing, positioning, speed detection and current sensing. The way Hall effect sensors work is stated as "Using semiconductors (such as silicon), Hall effect sensors work by measuring the changing voltage when the device is placed in a magnetic field. In other words, once a Hall effect sensor detects that it is now in a magnetic field, it is able to sense the position of objects." [28]. There are some pros and cons of using this type of sensor for our project, some of the pros are that they have the capability to work with high speed and also they can be accurate. Some of the cons are that it is magnet dependent, power consumption, and the limited range.

A magneto resistive sensor can detect changes in a magnetic field using the magneto resistive effect. The magneto resistive effect is described as "a phenomenon where the electrical resistance of a material changes in response to an applied magnetic field." [34]. While a magneto resistive sensor is a good sensor it comes with some pros and cons, some of the pros include its versatility, sensitivity, and compact size. While some of the cons include power consumption, cost and calibration requirements.

3.1.4.4 What Sensor Did We Choose?

For our project the use of a sensor is going to be to detect the ball when it leaves the barrel and to count how many bullets have been fired and how many are left to let the user or system know when the turret is running out of ammo. Since the sensor is going to have to detect a small foam ball at a fast rate leaving the barrel of the nerf gun, we have to compare all three different sensors and decide which sensor would be best for our application. After looking at all the different sensors we have decided that the best sensor for our application is a photoelectric through beam sensor.

The reason that we have decided to go with a through beam sensor is based on how the sensor works. Since this is going to be detecting a nerf bullet leaving the barrel of a nerf gun, we are going to need an accurate non-contact sensor that can also detect at a fast response time. While the other sensors would be able to work with our application it isn't as reliable as a through beam sensor. The magnetic sensor won't work since it is depended on a magnet and the nerf bullets are foam and the only way that you would be able to use a magnet is if you put a magnet inside the ball or on the outside and that isn't a realistic goal unless you modify every bullet. An ultrasonic sensor would be the only other viable type of sensor to use but after looking at the sensor it wouldn't be as good of a sensor because it emits ultrasonic waves, and it has some considerations we had to take into account. Since we want the best performance for our system the use of an ultrasonic sensor would lead to some decrease in the performance since the bullet is going to be a small spherical foam ball, this could lead to some issues such as missed or false readings, and also foam is usually a material that will absorb waves which isn't good for a ultrasonic sensor that is depended on reading the sound waves off an object to detect it.

Feature	Photoelectric through beam sensor	Magnetic sensor	Ultrasonic sensor
Detection	Light beam to detect interruption	Changes in magnetic field	Sound waves
Response time	Very fast	Fast	Medium
Power consumption	Low	Very low	Moderate
Cost	Moderate	Low	Moderate to high
Size	Compact	Very compact	Moderate
Range	Short to medium	Very short	Medium to long

Table 4: Comparison of Sensor Technology

3.2 Part Comparison

In this section we will find various parts based on the technology we had chosen and discuss different parts in order to see which parts work best for our system. We will be considering several factors with price being the biggest factor.

3.2.1 Motor Part Comparison

For this section we will be looking at three motor options for the servo motor selection. The ATLAS Project requires fast speed, high precision, and good torque. The reason we chose a servo motor is because the servo motor fulfills these requirements since it is a very well-balanced motor. The servo motor we choose should also be economical. We can choose industrial grade servo motors to meet our needs, but these motors would be far too expensive to self-fund and acquire. Luckily the motor we need can be acquired through various hobby websites for a much cheaper price.

The 4 motors we will take a look at are the Tower Pro MG995, Futaba S-U300, Hitec HS-645MG, and the Hitec HS-805BB. The features of each of these that are of particular interest to us are the torque, speed, weight, cost, and power consumption.

3.2.1.1 TowerPro MG995

The TowerPro MG995 is the most famous servo motor made by TowerPro. It is a very popular choice for RC cars and has lots of resources online. It has a conventional standard-sized metal geared servo. They offer medium torque, good speed, and low cost.

The TowerPro MG995 is however a heavy motor. Because of this extra weight added to the motor it will overshoot. Overshoot is when you give the servo an instruction to move to a certain angle and it moves past then angle then moves back to the correct position. This overshoot is not something we desire when looking for a precision motor to aim the gun.

The speed is a little slower than the other models but is still fast for the size. A key feature of this motor is the cost. The price is very low at around $10. This means we can acquire multiple of these motors for the price of a single Hitec motor.

The TowerPro can be controlled much like the other servo motors on the list by connecting the servo to the Arduino or Raspberry Pi with the ground wire and the correct GPIO pin on the board. We will not require a driver or pre-driver to control the TowerPro.

In order to power the TowerPro we are using a DC battery source which will be able to provide 6V of DC to the motor. This will be enough to power the motor and get good torque and speed but if the quality of the internal components is compromised then the motor could lead to poor power efficiency.

The internal servo amplifier of the TowerPro gives us faster response times than analog servos since it uses a microprocessor inside to send voltage pulses to the motor. The higher frequency also lends to the faster response times of the servo.

Even though the TowerPro has an attractive price tag and fast response times we must be wary of the actual quality of the motor. Using this motor with a system that has vibration, and noise can cause the unsupported wires inside to fray and connections become loose. Once these wires are loose the motor can become quite unreliable causing overshoots and such.

We will need a motor that has a higher internal build quality since a large part of the ATLAS is the reliability and lack of maintenance. If we want this turret to be reliable, we will have to pick a different motor that is able to hold up in the field.

3.2.1.2 Futaba S-U300

The Futaba S3003 is a standard type servo motor. It is a digital version of the Futaba S3003 which has been discontinued. The torque at 6V is medium. The motor comes from a reputable manufacturer as well.

The performance of the Futaba S-U300 is very reliable. It has high resolution since it is a digital servo so we get the fast response times of the TowerPro but with a higher quality internal mechanism from Futaba.

The problem with the Futaba S-U300 is that it has lower torque than we would ideally want. The torque is lower than the other motors but is highly reliable. Our payload however is not light enough for the Futaba. If we wanted to swap the nerf gun for another projectile launching device such as a paintball gun or airsoft gun the motor would not have good torque.

If our project had a lighter payload or if we preferred a mainstream servo, the Futaba S-U300 would be a solid choice. Our project however has a heavier payload and requires as much torque as we can have in a small package. For this reason, the Futaba S-U300 is not fit for the ATLAS.

3.2.1.3 Hitec HS-645 MG

The Hitec HS-645 MG is a high-torque metal gear servo. The servo comes with a metal gear set, plastic case set, and applicable horns. The operating range is 4.8V-6V which will suit our needs.

The torque of this motor is much greater than the Futaba and operates at around the same torque of the TowerPro. Even though the Hitec 645MG has the same torque of the TowerPro it outperforms it in the quality of the motor. The internals of the Hitec are as reliable and well known as the Futaba motor. With the Hitec we can expect longer life and higher quality components.

We expect our turret to be on the heavier side with added weight from the gun and camera system. This option would give us the best balance of torque and reliability. If we wanted to do an option more budget friendly, we could pick the TowerPro but we would be compromised by the quality of this motor.

3.2.1.4 Hitec HS-805BB

The last motor for comparison is the Hitec HS-805BB. This motor comes from the same manufacturer as the previous motor. With the same manufacturer we get the same quality brand as before. The main difference between this motor and the HS-645 MG is the size.

The Hitec HS-805BB is our largest motor by far. It has a minimum weight of 152 grams compared to the much smaller HS-645 MG which is 55.2 grams. The dimensions of this motor are also larger than the other motors as well.

The ideology of picking a larger motor is simple. We want to make sure the amount of torque will be enough for the load. Once we start adding the camera, gun, sensor, and any other materials it will be more load on the motor. This motor is heavier than the other motors but only by 200 grams total. That's only 7 more ounces of weight. With this added weight we will gain much more performance than choosing any of the other motors.

The torque of this motor is in a different league than the torque of the other motors. The other motors are seen to be more suited for small hobby applications, but this motor is designed for large/heavier hobby projects and even industrial applications. Other than torque, speed is another feature that this motor excels in. The fastest this motor can move is 0.14(sec/60 degrees) and the second fastest motor on this list can move 0.20(sec/60 degrees). Picking up 0.6(sec/60 degrees) will mean a faster and more precise turret.

The price difference between this motor and the others is noticeable. With this motor being around $30 more expensive than our cheapest motor selection but only $5 more expensive than the HS-645MG which is the next best option. The cheapest option we would consider is the Futaba motor which is $20 less expensive but has much less torque.

This motor is absolutely feature packed for a higher torque motor. Even though this motor will be delivering much more torque than the other options it is at a reasonable price. By picking this motor we would have enough torque for a heavier load.

3.2.1.5 Final Motor Part Selection: Hitec HS-805BB

The motor we will be selecting is the Hitec HS-805BB. This motor will be a powerful addition to the turret that will only improve reliability, precision, and speed. The other motors available would be sufficient but only with lighter duty turrets that do not have the same features as the ATLAS.

***Torque and Speed are assuming 6V DC source**

Motor	Torque (kg *cm)	Speed (sec/600)	Cost	Weight(g)
TowerPro MG995	9.4	0.2	$10	55.0

Futaba S-U300	3.2	0.19	$20	35.7
Hitec HS-645MG	9.6	0.2	$35	55.2
Hitec HS-805BB	19.8	0.14	$41	152.0

Table 5: Comparison of Motors

3.2.2 Tracking Mechanism (Camera Sensor)

The tracking mechanism will be the most essential part for the entire device, it will have the features of tracking the object as well as being able to recognize them by what type of object is and differentiate them by the color. Depending on how good the object recognition and tracking is, the accuracy will be higher as we expect it to be greater than 90 percent in most of the cases.

For the tracking mechanism, we want to implement a 3D camera sensor with AI capabilities that will help for the accurate detection and recognition of the target. ATLAS will have the capability to use object recognition, like what type of object is in range and use this as a form to detect if it is a person in order to track it down. Also, ATLAS will be able to differentiate colors as well as face recognition. In order to implement all these features, we decided to compare multiple 3D cameras that will work under the environment of Arduino and most of these cameras will include the AI algorithms required for all the features mentioned above.

3.2.2.1 DFROBOT: HUSKYLENS Smart Vision Sensor

The HUSKYLENS camera sensor is a simple to use AI device vision sensor that is equipped with multiple AI features like object tracking, face recognition, object recognition, color recognition and tag recognition. It makes use of the protocol UART/I2C to connect to the environments of Arduino and micro:bit. It uses an integrated LCD display that helps for the setting and selection of the different features that the camera can provide.

The vision sensor makes use of the AI chip Kendryte K210 which is a system-on-chip (SoC) that integrates machine vision and machine hearing. This chip uses the 28nm ultra-low-power advanced process with a dual-core 64-bit processor for better power consumption, stability and reliability. With the machine vision capabilities, the Kendryte K210 can perform convolutional neural network calculations in low power situations which make it ideal for the type of project our team is trying to develop.

Thanks to the implementation of this chip, the HUSKYLENS camera sensor is able to capture fast-moving objects which in our case is ideal since the target will be in motion and ATLAS must be sufficiently fast to detect the object and track it in order to shoot. Having the use of this integrated chip with the camera sensor it helps with the computation pipeline for the MCU we want to use for the entire body of the device, this means that the computation for the tracking mechanism will be done by the camera with its own chip and it will just send the signals to the main MCU to control the X and Y motors for the mechanical movement as well for the shooting mechanism.

The main functions that we want to implement in ATLAS are face recognition, color recognition, object recognition and finally object tracking. HUSKYLENS provides all these functions already integrated into its own chip:

- Face Recognition: by default, the camera sensor is set to detect any face contour and track the learned face. With the help of the integrated LCD display, the user can see when a face is detected and save it for the tracking functionality.

Figure 6: Face recognition After It Was Previously Learned.(Permission Requested from DFRobot)

One important feature from the HUSKYLENS sensor is that it has the ability to detect multiple faces at the same time. This helps for our project since we can implement the function to track a specific target when a group of people is in the vision range of the sentry turret.

- Object Tracking: same as the face recognition, the camera sensor can learn how to track an object when it is detected by the camera, and it will follow it whether it keeps in the vision range of the camera.

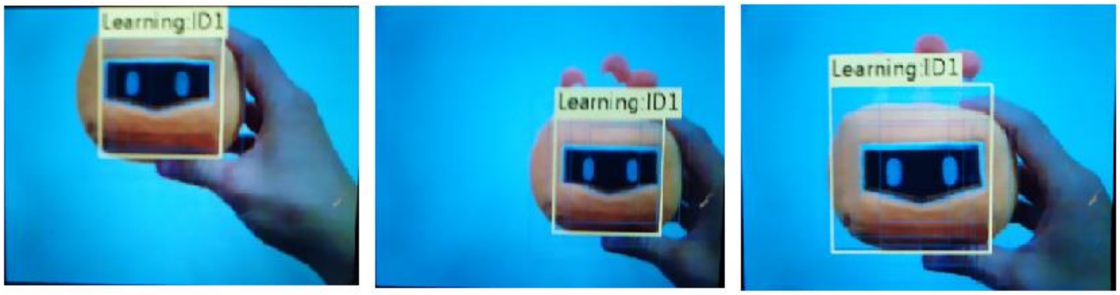

Figure 7: Tracking an Object After It Was Previously Learned and Autosaved (Permission requested from DFRobot)

- Color Recognition: with this function, the camera sensor can learn, recognize and track a specific color. Same as the previous features, the HUSKYLENS camera can learn any color that is in the vision range and once it's been saved, then it will recognize and track the color that the user has taught to the camera.

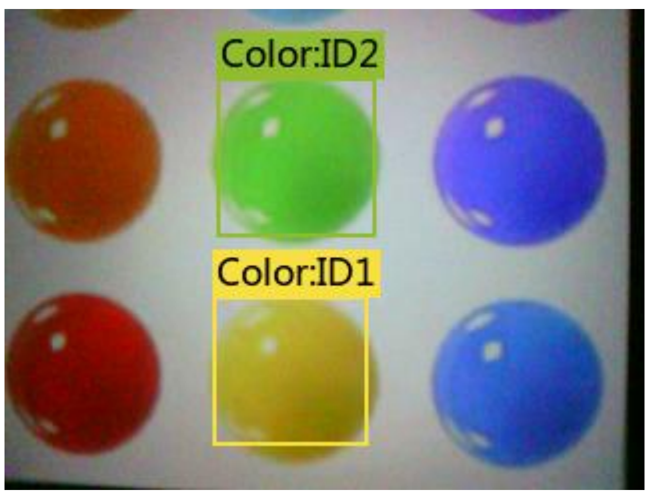

Figure 8: Color Recognition After It Was Previously Learned by The Camera Sensor (Permission requested from DFRobot)

3.2.2.2 Pixy2 Smart Vision Sensor

The Pixy2 vision sensor is the second version of the original Pixy, it is faster, smaller and more capable compared to its predecessor. It has an improved framerate of 60 frames per second, it can detect lines and small barcodes, also it comes with the tracking algorithms that are color-based object detection. It has an improved library for the Arduino environment as well for Raspberry Pi and LEGO Mindstorms EV3. It can communicate with the interfaces of SPI, I2C, UART, USB or analog/digital output.

Pixy2 pairs with the powerful and efficient processor NXP LPC4330 that processes the images from the image sensor and only sends the useful information to the microcontroller (coordinates of the position of the tracked object) and it does all of these at a frame rate of 60 Hz. This processor is a dual-core ARM cortex that has a frequency of 204 MHz with a 234 Kb SRAM for code and data use. This processor makes the Pixy2 faster and more responsive with the different AI algorithms that can be implemented along with the connectivity of Arduino processors or Raspberry pi.

Pixy2 uses a color-based algorithm called the Color Connected Components (CCC) that helps to calculate the color (hue) and saturation on each RGB pixel from the image sensor and uses these as the primary filtering parameters. This algorithm has the capability to remember up to 7 different color signatures, this helps to identify an object surrounded by multiple different objects each with a distinguished color.

The user can teach Pixy2 to identify the objects that he or she is interested in, this is done by pressing the learning button in the camera sensor and it will be stored in flash, it will then use this statistical model to find objects with similar color signatures and its frame from then on.
Once Pixy 2 detects a new object, it will add it to the table of objects that is currently tracking and assign a tracking index. It will then attempt to find the object and every other object in the table in the next frame by finding its best match.

Another feature that Pixy2 vision sensor provides is the color code feature, this feature allows Pixy2 to detect and recognize 2 or more color tags placed together. This can be used as a way to tag special objects that might be surrounded by any other objects with the same similarities. The color code scheme with 2 tags and 4 different colors can differentiate up to 12 unique objects.

Figure 9: Color Code Tag Detected and Recognized by Pixy2 (Permission Requested From Charmed Labs and Carnegie Mellon)

3.2.2.3 Hiwonder WonderMV Smart Vision Sensor

The WonderMV is an open-source AI vision module that provides robust and reliable functionality. The module is built with the processor K210 chip, which allows it to boast features like color recognition, road sign recognition, vision line following, and face recognition. It integrates a serial port and an I2C port allowing for easy connectivity with various sensors and expanded functionality, also it is equipped with a 200W HD high-transparency vision camera which allows it to make use of all the computer vision capabilities already mentioned.

WonderMV is able to identify the presence of a human face. Once the face is successfully detected, the module outlines the human face on the built-in LCD screen and provides the position information. Thanks to its complex face recognition algorithm, the module can also mark key facial features such as the eyes, nose and mouth using star symbols. This feature allows the module to be able to identify if the person is wearing a mask.

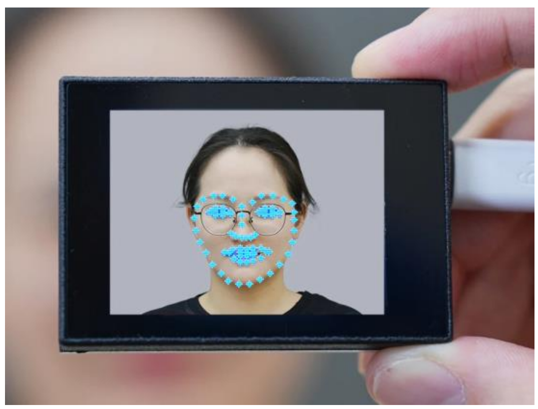

Figure 10: WonderMV Key Facial Recognition (Permission Requested from Hiwonder)

The module sensor has the capability to identify up to 20 different types of objects. Within these types of objects, it can be mentioned that it is capable of distinguishing between animals, non-living objects and humans. It also has the capability of autonomous learning that allows it to capture multiple pictures of a single object to extract the same features or characteristics, then it can autonomously learn and classify the objects.

Along with the object recognition, the WonderMV can accurately identify the color of objects and outline them. This allows the module to be able to track the object when the color has been detected while it is in his range of view.

Make	Angle of View (Degrees)	Interface	Dimensions(inches)	Voltage and Current Consumption (Volts and milliamps)	Price ($USD)

HUSKYLENS Smart Vision Sensor	50x30	UART, I2C	20.5 x 1.75	320mA @ 3.3V, 230mA @ 5.0V	$65
Pixy2 Smart Vision Sensor	60x40	UART, I2C, SPI, Analog, Digital	1.5 x 1.65	6.0 V - 10 V 140 mA typical	$68
WonderMV Smart Vision Sensor	60x40	USB-C, UART, I2C	2.32 x 1.6	5.0V @ 300 mA	$59

Table 6: Comparison of Vision Sensors

3.2.2.4 Final Camera Sensor Selection

The camera module that we decided to choose is the HUSKYLENS Smart Vision Sensor. The main reason is because of the different built-in features that the sensor provides as well as the versatile LCD display where the user can select different configurations and be able to see what the camera is looking at without the necessity of connecting the camera to a PC. Another reason is because we consider that the different algorithms that the camera provides are well designed and responsive, which make it more suitable for our design since we are looking for fast responsiveness and high accuracy.

3.2.3 Microcontrollers (MCUs)

The microcontroller will be used to connect the electrical subsystems together, which in our case, we are having two subsystems: the main system which will consist of the camera module, DC motors for x and y coordinates and power supply. The second subsystem will consist of the firing mechanism that includes the sensor to calculate the amount of ammo left in the nerf gun and the step motor to shoot the gun.

Since the camera module we want to use for our project works directly with Arduino boards, we have focused our search on microcontrollers available for this type of platform. With the use of the Arduino Software, the Arduino microcontrollers are programmable in C++ language which make them more efficient and reliable since C++ is more popular among software developers. Since our main goal is to build a light and portable device, a list of potential compact microcontrollers can be found in the table below.

Development Board	Arduino UNO REV3	Arduino Micro	Arduino Nano
MCU	Atmega328P	Atmega32U4	Atmega168

SRAM	2 KB	2.5 KB	2 KB
Size	2.7 in x 2.1	1.9 in x 0.7 in	1.7 in x 0.7 in
Digital I/O Pins	14	20	14
Analog input pins	6	12	8
Price	$27	$24	$25

Table 7: Comparison of Microcontrollers

All three microcontrollers share the same architecture as well the same clock frequency, flash memory and operating voltage. In terms of size, which is a key feature for our project, the Arduino nano seems to be most suitable, however, since we are planning to design a custom PCB, we are not going to use the development board, in fact what is more suitable for our device is the amount of digital I/O pins as well the analog input pins that the MCU offers. Therefore, we found the Atmega32U4 more suitable because it offers more SRAM and a slightly higher number of digital and analog pins.

3.2.4 Firing Mechanism

A sentry turret must consist of an accurate firing mechanism, an imprecise firing mechanism will essentially render the whole system useless. Unlike firearms we see in civilian everyday life, where humans need to interact with the firearm in order to manually aim and pull the trigger, a sentry turret must autonomously aim and fire with high precision. The firing mechanism will be working with other components such as a tracking mechanism, motors and sensors in order to track, aim and fire which is why we need a very precise firing mechanism, we will not have the ability to look through a scope and aim the firing mechanism ourselves like a typical gun. The firing mechanism must be able to account for several factors, making sure each shot is accurate and effective. The factors we will be looking into consist of target distance, timing, and trajectory. Additionally, the firing mechanism must have a moderate recoil force, a recoil force that is too strong can lead to our whole system falling over and must be able to fire without having ammunition reload issues. The firing mechanism that comes in most nerf guns are spring powered, but they also have pump action as well as flywheel systems. A standard Nerf Spring gun is a type that you would pull part of the gun back (handle or slide) to extend the spring and then when you pull the trigger it would release the spring and would fire the bullet, this spring fired mechanisms are very reliable and don't require any external power. Another type of nerf gun is a pump action; this type of gun would be used with air such as when you pump it would build up air and when the trigger is pulled instead of a spring being released all the air that is built up will propel the bullet forward and to exit the weapon. The final type of nerf guns are flywheel firing; these types of guns are always going to be battery powered since power needs to be supplied to the motors to be able to spin the flywheels. A flywheel system has two rotating wheels in front of each other that will spin at a high rate of speed from the use of a motor. With this type of system you will have two different triggers, one will be used to be able engage the motors and start spinning the flywheels, the other trigger will be used to fire the weapon. When the trigger is pulled a bullet will enter the firing chamber and once it passes the flywheels, the flywheels will accelerate the bullet, and it will be fired at a high rate of speed.

3.2.4.1 NERF Gun

A NERF gun is known for being a child's toy, surprisingly it is a great option for low harm, precise, and quick firing. The NERF gun is known for safety, reliability and ease of use. The NERF gun offers multiple different types of bullets and guns. Nerf has regular foam bullets and then they have a new ball type of foam bullet. The regular nerf bullets are typically made of foam that have an orange plastic tip on the end of it. While the new rival bullets are a spherical shaped foam yellow ball. The original nerf bullets are used more in regular nerf guns that are either pump fired or in some cases used with an automatic firing nerf gun. The new rival bullets are better for all automatic firing weapons that will provide a different type of guns and the firing velocity is much better. When we compare the two of them the foam ball is going to provide a more reliable, rapid, and accurate shot. Since the bullet is a ball shape it will also give us a faster shooting velocity when the weapon is fired as well as not cause as many issues while feeding the gun as the regular nerf bullets would. There are three types of nerf guns that would fit our project since it is fully autonomous, all these guns will have an automatic flywheel which can be incorporated with an electric trigger to provide full autonomous firing.

Nerf N-strike Elite Stryfe Blaster

The Nerf N-strike Elite Stryfe Blaster is described as a "one of the most popular and versatile Nerf blasters in the N-Strike Elite series. Known for its simplicity, ease of use, and performance" [36]. This gun has the dimensions of 2.9''x10.1''x16.6'' with a weight of about 0.8 pounds without the batteries or the clip inserted. The N-strike Elite Stryfe Blaster is an electric semi-automatic dart firing weapon, it uses a flywheel that is powered by the 4 AA batteries in the gun. With the ammo type of nerf darts they are lightweight made up of a foam base and a rubber tip. The way the flywheel works in this weapon is that there is a button that you hold down that will start powering the motor which will make the flywheels start spinning, once the trigger is pulled it will lead to a bullet being fed into the chamber and later fired, once the trigger is released and pulled again the same thing will happen to make the gun fire again. The maximum magazine capacity of this weapon is 6 darts but can also work with different magazines to be able to store more ammo capacity if needed. Some of the specifications of this gun are that it has a firing rate of 3-4 per second and has a firing range of up to 90 feet, with decent accuracy due to how used the batteries and flywheels are.

Nerf Rival Nemesis MXVII-10K

The Nerf Rival Nemesis MXVII-10K is one of the more powerful nerf guns and can be described as “a high-capacity, fully automatic blaster in the Rival series, designed for intense Nerf battles with its rapid-fire capabilities and accuracy.” [37]. The rival nemesis is fairly big in size with the dimensions of 29’’x 12’’x 4.5’’ and weighs roughly 5 pounds. The reason this nerf gun is so big is due to its large high-capacity hopper as well as the power source which uses 6 D type batteries. The Nemesis uses a hopper fed magazine which uses gravity to help the rounds reach the firing chamber, the hopper holds 100 rounds of rival’s high impact rounds, which are spherical foam balls. The use of the rival rounds will improve the accuracy, range, exit velocity, and less weapon jams. Since this weapon is fully automatic the power source for this gun is 6 D-type batteries which will supply power to the flywheel and firing mechanism of the weapon. The Nemesis can fire at a rate of 4 rounds per second with the velocity of up to 100 feet per second, with the range of up to 100 feet.

Nerf Rival Khaos MXVI-4000

The Nerf Rival Khaos is also a part of the Nerf rival series that fires the same high-impact Rival rounds and is described as “a fully automatic, high-capacity blaster that features a 40-round magazine and a motorized flywheel system, delivering rapid-fire foam rounds.” [38]. The Khaos is on the bigger size of weapons with the dimensions of 29’’x 10.5’’x 4.5’’ and a weight of 5.3 pounds. This weapon has an insane fire rate of up to 12 rounds per second, but it has a limited magazine capacity of 40 rounds. With a range of up to 100 feet and an exit velocity up to 100 feet per second. This weapon is powered by either a nerf battery pack or 6 D-type batteries, this will be to power the motors in order to help the flywheels reach its peak performance. The gun also has an easy reloading system that with a push of a button will help the mag eject so it's easier to change magazines when the gun runs out of rounds.

Feature	N-strike Elite Stryfe Blaster	Rival Nemesis MXVII-10K	Rival Khaos MXVI-4000
Type	Electric semi-automatic	Motorized Automatic	Motorized Automatic
Firing mechanism	Flywheel	Hopper-fed flywheel	Magazine fed flywheel
Range	Up to 90 feet	Up to 100 feet	Up to 100 feet
Dart type	Nerf Darts	Rival Rounds (foam balls)	Rival Rounds (foam balls)
Magazine Capacity	6- dart clip	100-round hopper	40-round magazine

Battery Requirement	4 AA batteries	Nerf Battery or 6 D-type batteries	Nerf Battery or 6 D-type batteries
Price	$20	$60	$70
Firing Rate	Semi-Automatic	5 rounds per second	12 rounds per second
Weight	1.5 pounds	5 pounds	5.3 pounds

Table 8: Comparison of Nerf Guns

3.2.4.2 Final Nerf Gun Choice

The nerf gun that we decided to go with is the Rival Nemesis MXVII-10K. The reason that we chose this nerf gun over the others is that it provides a lot of what we are looking for to make an automatic turret, we wanted something that can be portable, lightweight, autonomous, as well as powerful and that is what we get in this nerf gun. Obviously, the Nemesis is a little heavy but everything else about the weapon is what would work best for our project, the fact that is has 100 round hopper fed capacity magazine, combined with its automatic firing of four rounds per second with high accuracy at short to medium ranges, with the capability to fire up to 100 feet. Since the Nemesis and the Khaos use the same firing system we had to compare the two and fire out which one would be a better fit for our turret. We decided it would be better to use the Nemesis, due to the fact that it is a little lighter, has a greater magazine capacity, the ability to reload the weapon, and the cost of the weapon. Even though the Khaos has a great firing rate, it also has a smaller magazine capacity that would run out of ammo faster. The magazine size is also a big factor in this, the Nemesis has a capacity of 100 rounds while the Khaos has a capacity of only 40 rounds. While we want this turret to be autonomous, we know we are going to have to reload it at some point which is why the hopper fed magazine is the better fit, with the window on top to be able to reload the Nemesis while the Khaos we would have to replace the magazine. The cost difference isn't a lot, but we figured that with the extra money we would be able to add other components which would make our turret better.

3.2.5 Power Supply

A power supply is a necessity for any technological device and the continuous operation of the components. The power supply will supply our whole system power. Motors typically range from 5V to 12V, microcontrollers typically operate at 5V, so choosing a power supply that can supply up to 12V would be ideal. Our goal for our sentry turret is for it to be lightweight and portable, so ideally a power supply that does not need to plug into an outlet would be ideal. We plan on using two different power supplies, one to power low/medium power devices and another to power high power devices. This section will differentiate the options available for powering our system.

3.2.5.1 12V Wall Adapter Power Supply

A 12V wall adapter power supply is a great option for a motorized sentry turret. It can supply consistent power without having to recharge or swap batteries and would ultimately be the cheapest option in the long run. A voltage regulator could always be applied to bring the voltage down. The 12V wall adapter is reliable and ideal for supplying stable power to our motors, microcontroller, essentially our whole system. Although the 12V wall adapter is great for supplying constant power, it does require the system to be plugged into an AC power supply such as an outlet. Having to plug the system into an outlet is good for most household items, but for a sentry turret which is known for being a military product out in the desert, mountains etc. there are no outlets available, hence not ideal for a sentry turret. The whole goal for our sentry turret is for it to be lightweight and portable, having to plug our whole system into an outlet would contradict the ability to be portable.

Figure 11: Example of a 12 V wall adapter

3.2.5.2 4 x AA Battery Holder

A 4 x AA battery holder is another great option for a motorized sentry turret. It is portable which is what is needed for a system such as a sentry turret as a sentry turret must have the ability to be placed in isolated conditions. A 4 x AA battery holder has the ability to power high power devices such as sensors and motors, this is because the output can output 6V. The 4 x AA battery holder also has a switch which allows users to turn off the system whenever it is not being used to allow the batteries not to drain.

Figure 12: Example of a 4 x AA battery holder

3.2.5.3 2 x AA Battery Holder

Another power source would be the 2 x AA battery holder. It is very similar to the 4 x AA battery holder but is smaller. It has the ability to be portable which is important for our sentry turret as we would like to make the whole system portable and mobile. The 2 x AA battery holder is also lightweight, not causing any weight issues that could overwhelm our system. The only downside is that it can only produce 3V output which is not desired for high power components. It is more desirable if we were to use it with low power components.

Component	12V Wall Adapter Power Supply	4 x AA battery holder	2 x AA battery holder
Output Voltage (V)	12 V	6 V	3 V
Output Current (A)	5 A max	Depends on batteries and load	Depends on batteries and load
Weight (oz.)	5.29 oz	2.39 oz	0.21 oz
Dimensions (inches)	4.72 x 1.57 x 1.18 in	6.7 x 4.8 x 0.8 in	2.28 x 1.29 x 0.55 in

Table 9: Comparison of Wall Adapter and Alkaline Battery Holder

For our sentry turret system, we have decided to use a 6V output 4 x AA battery holder over the 12V wall adapter and the 2 x AA battery holder. The reasoning behind this is the ability to be portable, does not require another power source (ex. Electrical Outlet), and its ability to produce the desired voltage output. It has the ability to supply power to our high-power components.

3.2.5.2 USB Power Bank

The Anker PowerCore 20100 USB power bank is ideal for low-power components such as the microcontroller. It is lightweight coming in at 12.5 oz, it can output 5V/4.8A which is ideal for most microcontrollers and has a capacity of 20,100 mAh. The power bank has ports for USB-A outputs and micro-USB input. The power bank would be hooked up to the microcontroller to power on the microcontroller only since it is ideal for low-power components. The power bank is a great choice because it is small, lightweight and portable. It does not require an outlet in order to function, we would be able to charge it up to turn on the microcontroller and then just recharge it when it runs out of power. Although the power bank can not supply power to the whole system, it is relatively cheap and can be recharged at any time which makes it a great product for powering on low-power components such as the microcontroller.

Figure 13: Anker PowerCore 20100 USB Power Bank (Permission from Anker)

Another USB Power bank considered was the Pxwaxpy Portable Charger 36800mAh. Considering it is a cheaper option coming in at $29.95 and is good for low power components we had considered the product. The Pxwaxpy Portable Charger 36800mAh has the ability to store 36,800 milli-amperes per hour which is enough to power on low power components. It has the ability to output 5V and 2.1A which is more than enough for our low power components such as the MCU and webcam. It is lightweight (13.44 oz.) and small in size, this is ideal for a sentry turret because the lighter the device is the quicker it can move.

The last power bank we were considering is the Anker Prime 20,000 mAh Power Bank. This power bank is portable and wireless which is essential for the sentry turret. It has a digital display on the screen that allows for information regarding battery capacity and power output. With 200W output it can charge low power components quickly and efficiently. The only downside is that it is $129.99 which is too high for our budget. With a 5V and 2.4A output, this device has the ability to provide for low power components efficiently.

We will compare the Anker PowerCore 20100 and the Pxwaxpy Portable Charger 36800mAh power banks in the table below.

Component	Anker PowerCore 20100	Pxwaxpy Portable Charger 36800mAh	Anker Prime 20,000 mAh
mAh	20,100 mAh	36,800 mAh	20,000 mAh
Output Current (A)	4.8 A	2.1 A	2.4A
Weight (oz.)	12.5	13.44	13
Dimensions (inches)	6.5 x 2.3 x 0.9in	6.1 x 3.1 x 0.87in	4.9 x 2.1 1.9in
Price	$49.99	$29.95	$129.99

Table 10: Comparison of Power Banks

After considerations, we decided to go with the Pxwaxpy Portable Charger 36800mAh. It is a lot cheaper than the Anker PowerCore, but it does weigh a little more and produce not as much current output but will get the job done for the low power components. The purpose of the power bank is to provide power to low power components such as the webcam and microcontroller which needs 5V to power. It has a high mAh allowing for a higher electrical charge in the battery and will essentially last longer than the Anker PowerCore. It weighs slightly heavier but not enough where it will significantly impact our whole system.

3.2.6 Sensors

The use of a sensor is going to be used in the firing aspect of our project. The use of a through beam sensor will be used to sense when a bullet is fired out of the gun and keep track and let the user or system know when the weapon is low on ammo. The sensor that is the best fit for this type of application is a through beam sensor since it has a fast response time, able to detect objects no matter the material, easy adjustments, and non-contact sensing ability.

3.2.6.1 E18-D80NK

The E18-D80NK is an infrared photoelectric sensor that is used for object detection. This type of sensor “emits infrared light from an LED and detects the reflection of that light from nearby objects. When an object enters its sensing range, the sensor outputs a signal.” [39.] While this sensor operates at 5 Volt it would be able to work directly with the Arduino since the Arduino will be able to provide the 5 volts needed. The detection range is from 10cm to up to 80cm and when an object is detected it will provide an output of on or off with a response time of one to two milliseconds. Most of these types of sensors are easy to incorporate with our project since we will be able to connect it to the Arduino, as well as the easy installation.

3.2.6.2 M18 Infrared Photoelectric Sensor Switch

The M18 infrared photoelectric sensor uses a detection method which is through a beam that has two different components of the system, one is a transmitter and the other is a receiver. This sensor has a detection range of up to 5 meters with an operating voltage of 6 to 36 volts. It also uses the NPN NO output configuration which uses an NPN transistor and is normally open, which means that if it is not detecting an object that it is an open circuit, and no current will flow through. This sensor will have a detection speed of 1-3 milliseconds. This sensor would fit our project since it has a fast response time, we would be able to adjust the sensitivity, and it is easy to install onto the weapon and works well with the board.

3.2.6.3 IR Break Beam Sensor

An IR break beam sensor is a “simple and effective sensor used for detecting the interruption of an infrared beam.” [40]. The sensor uses an infrared emitter and an infrared receiver to be able to tell if there is a break in the beam. The sensor also comes with the option to use a 3mm or 5mm LED. It would be more beneficial to use the 5mm LED so we have a further range of this sensor if needed, even though this will consume more power we have external battery packs just in case it is needed. This type of sensor is a good fit for an Arduino since most types of these sensors are made specifically for an Arduino. To power this sensor, it will need 3.3 to 5 volts, which will be provided by the Arduino board. This sensor will give us an output of high or low which is based on if the sensor is being broken by an object or not.

Features	M18 infrared photoelectric sensor switch	E18-D80NK	IR break beam sensor
Type	Through beam	Proximity	Break beam
Detection range	Up to 5 meters	Up to 80 centimeters	Up to 1 meter
Power	DC 6-36 V	DC 3-24V	5V

Response time	5 - 10 ms	1 - 5 ms	1 - 5 ms
Output	NPN NO	Digital	Digital

Table 11: Comparison of Sensors

3.2.6.4 Final Sensor Part Selection

The sensor that we decided to go with is the M18 infrared photoelectric sensor. The reason that we decided to go with this sensor rather than the other sensors is based on the fact that a through beam sensor would be a better fit for our project, the reason that a through beam sensor would be better is because of the fact that the ball is small and is traveling at a high rate of speed and we need a sensor that is very accurate and reliable when it comes to sensing fast moving objects. Even though an IR break beam and a photoelectric switch are both good options, the photoelectric switch might have some difficulty detecting the ball when it goes past the sensor since there isn't a receiver that would be able to see if there is a break between the beam since it is depended on the reflection of the LED. We are also going to compare the M18 and the IR break beam sensor when we start building our turret to see which sensor gives us better performance once everything is working.

3.2.7 Housing/Base

The housing and base of our turret is going to be a 3D printed base and legs. 3D printing is “a process used to create three-dimensional objects by building them layer by layer from a digital model.” [24]. There are multiple types of 3D printing such as FDM (Fused Deposition Modeling) which uses melted plastic layer by layer to build the object, SLA (stereolithography) which uses UV light to cure liquid resin into a solid layer and SLS (Selective Laser Sintering) which uses a laser to fuse powder material into a solid object. The type of printer we are using for the housing and base of our turret is a FDM printer. The type of printer that we are using is an Ender 3 created by creality. We will be using a PLA type filament which is a polylactic acid filament. The use of a 3D printer will help us achieve the exact look and design of the turret that we want, with full functionality of the design it will also help us be able to make our turret compact and portable. We have created a rendering in AutoCAD of what the turret is going to look like.

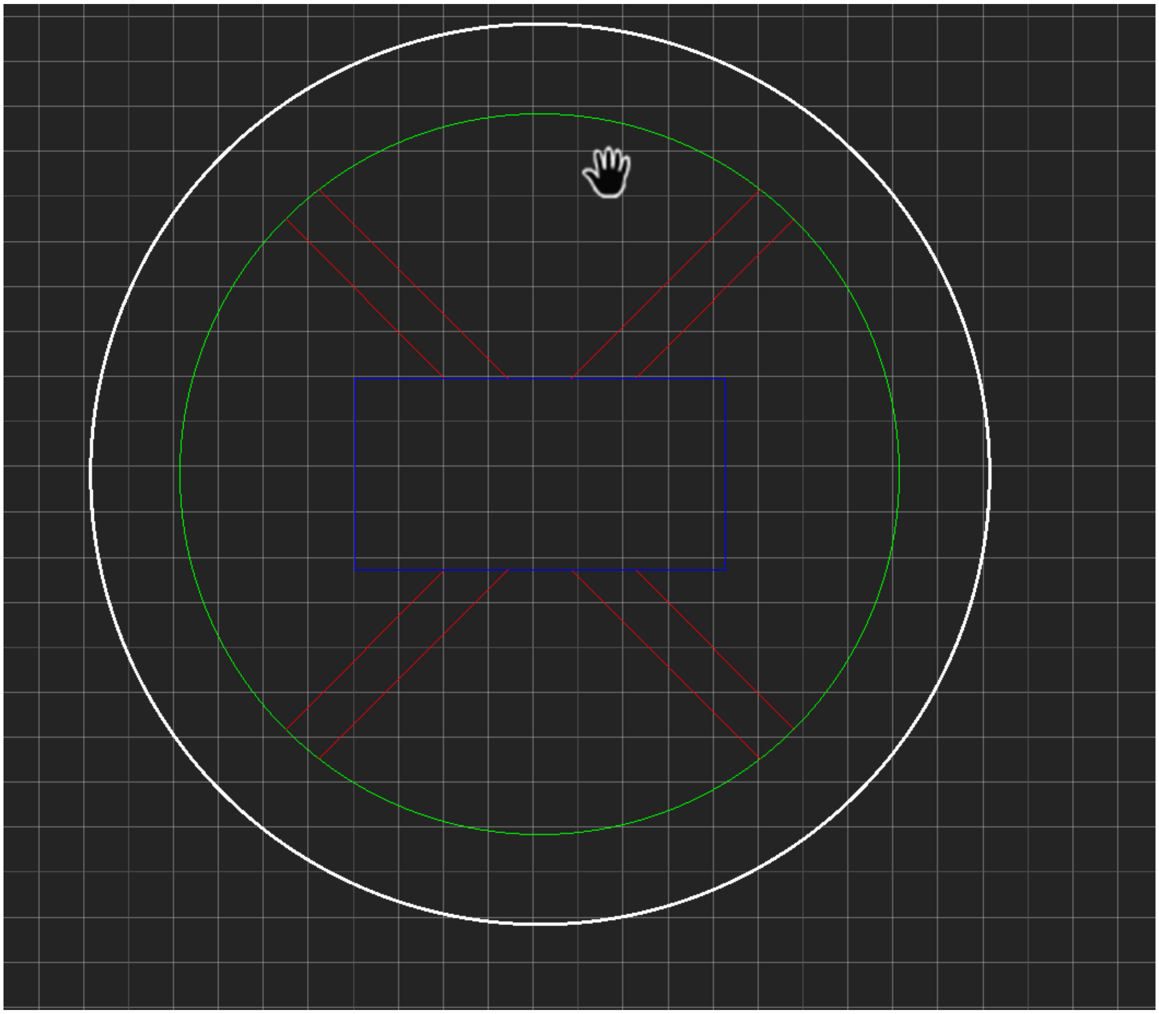

Figure 14: Top View

With this top view we can see the multiple colors which all identify as parts of the turret. The blue is the nerf gun itself, the red are the upright legs to be able to hold the nerf gun in place, the green is the inner compartment which will be able to hold all our electronic components, and the white is the outside base of the turret which will be stationary. The green inner circle will be used to also spin and rotate to be able to achieve full functionality of the rotation.

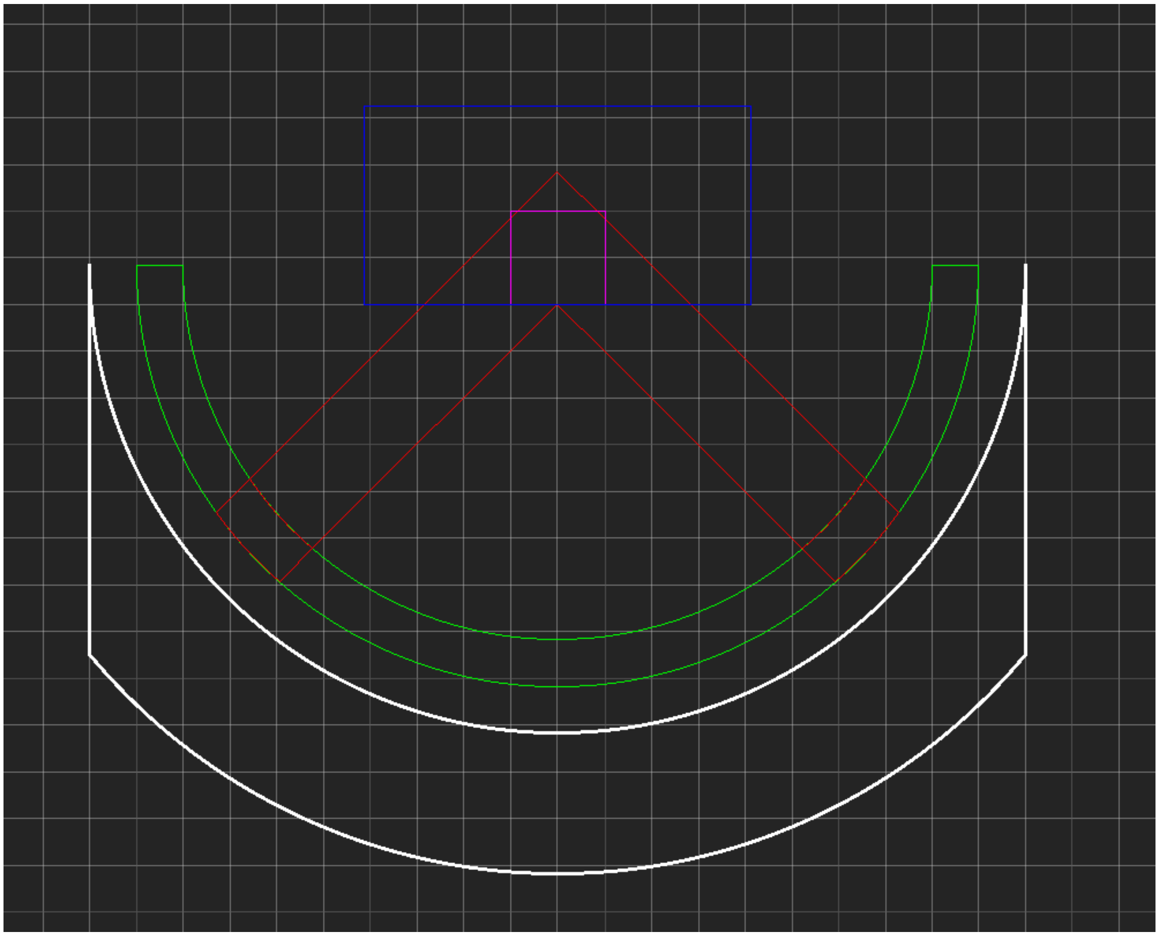

Figure 15: Side View

From this image you can see the white lines which are the base, this will give us a sturdy base to hold all of the components as well as be able to hold the turret itself. The green lines are going to be a lazy Susan that is going to be sitting above all of our components. With the use of the Lazy Susan it is going to allow us to use a motor to be able to rotate the turret by itself in the X plane. The red are still the legs that will have an L bracket that will help the turret attach to the lazy Susan and it is going to hold the nerf gun up. The pink lines are for the motor that will help the turret aim in the y plane. The blue lines are for the nerf gun we plan to use.

3.2.8 Lazy Susan

A Lazy Susan is described as, “A Lazy Susan is a rotating tray or platform, typically used to facilitate easy access to items placed on it by allowing them to be rotated. It is commonly used on tables, countertops, or in cabinets to make it easier to reach objects like condiments, spices, or food without having to physically move around” [27]. We are only going to use the component of the lazy susan which is made out of metal and has a circular shape in the middle that has small metal ball bearings to help it spin around. Which is going to be in between two pieces of wood, the bottom piece of wood is going to be mounted onto the top base and the lazy susan will be drilled into that piece of wood and the top Piece of wood is going to be where the turret is going to sit.

3.3 Software

The main software that will control the sentry turret will be directly transferred to the MCU using the Arduino IDE which allows it to connect directly to the MCU using Windows PC or a macOS computer in order to include the necessary libraries for the peripherals that the MCU will be responsible for. This software will mainly be composed by the interaction between the camera module and the dc motors for the x and y coordinates. A portion of the software in the MCU will be responsible for the movement of the turret at the moment that the camera module detects and tracks the target. The other portion will be responsible for the firing mechanism which will be connected directly to the board into the nerf gun using a digital trigger.

Since the main purpose of the entire project is to detect, track and attack a target, computer vision algorithms are necessary to perform all this task. Thanks to the evolution of technology in the last years, more and more camera modules are now integrated with their own chips and with all the necessary algorithms to perform all these tasks as well as more features are integrated like face recognition and color recognition. The Huskylens camera module is already integrated with the algorithms of object recognition and tracking, therefore the camera module is responsible to send the coordinates of the position of the target using the computer vision algorithms that it has already preloaded. The MCU will receive these coordinates and send the signals to the motors to adjust the position of the turret and keep tracking and attacking the target at the same time with the least possible lag or delay.

3.3.1 Object Recognition

Object recognition is a fundamental task in computer vision, where the primary goal is to identify and categorize objects in images or video frames. The main principle behind object recognition is to enable a machine to understand visual content, typically by detecting, and localizing objects within a frame. There are several stages that involve the process for object recognition: image pre-processing, feature extraction, classification, and localization or segmentation.

In the stage of image pre-processing, before the image can be processed, it is often pre-processed to improve recognition accuracy, this might involve tasks like resizing, normalization, noise reduction or color conversion (RGB to grayscale). It also standardizes the input images for subsequent processing, ensuring that variations in illumination, orientation, or scale does not affect the recognition process too much.

Feature extraction is the process of transforming raw image data into a compact and informative representation that captures the key patterns or unique characteristics of the object. There are two major types of features used in the process of object recognition: handcrafted features and learned features or deep learning.

Hand crafted features are traditional object recognition features systems or techniques that use manually designed features like: SIFT (Scale-Invariant Feature Transform) that detects and describes local features in images, robust to changes in scale and rotation. SURF(Speeded Up Robust Features) which is a faster alternative to SIFT but focusing on distinctive points in the image (unique points of reference). HOG(Histogram of Oriented Gradients) captures the gradient structure (edges or corners) of an image, commonly used for detecting humans and other objects. And finally, LBP (Local Binary Patterns) describes the texture of an image by thresholding pixel neighborhoods.

With learned features or deep learning, modern object recognition relies heavily on deep learning models, particularly convolutional neural networks (CNNs), which automatically learn relevant features directly from the data. CNNs use convolutional layers to capture spatial hierarchies in the image, where lower layers learn basic features like edges and textures, while deep layers capture complex features such as patterns and object parts. Finally, the output obtained by these layers is a high-level feature representation that is used for classification.

For the stage of object classification, once the features are extracted from the convolutional layers, they are fed into a classifier to determine the object category or class. The most common classifiers include: traditional classifiers which include, Support Vector Machines (SVMs) that finds a hyperplane that separates different object categories based on the extracted features, K-nearest Neighbors that classifies objects by finding the majority class among the k nearest neighbor in the feature space. Deep Learning classifiers include; Softmax Function, which is the final layer of many neural networks, it is often used to output the probabilities for each class label, determining which category the object belongs to. Fully Connected Layers are used to perform object classification after the convolutional layers extracted the features.

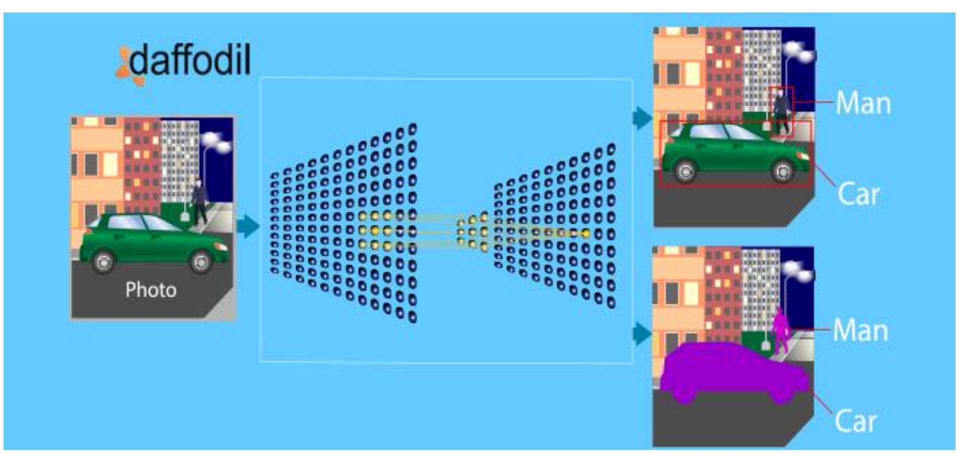

Figure 16: Example of object classification process[17]

In the object localization stage, it is often necessary to localize them within an image, for example, draw bounding boxes around the detected objects. Some of the most popular object detection algorithms that combine recognition and localization include: R-CNN (Regions with CNN) which are a family of algorithms that first propose regions of interest and then use the convolutional networks to classify these regions. YOLO (You Only Look Once) which is a real time object detection algorithm that directly predicts both the bounding box and the object class from the image in a single pass. Finally, SDD (Single Shot Detection) is similar to YOLO that detects the objects in the single pass making them also suitable for real time applications.

Within the object localization stage, object segmentation can be added as another approach. Instead of just detecting and recognizing objects, object segmentation can identify the precise pixel boundaries of the objects. There are two types of object segmentation, Semantic Segmentation classifies each pixel in the image into an object category like sky, car, tree, human, toy, etc. Instance Segmentation detects and delineates each object instance in an image, such as segmenting multiple overlapping objects.

3.3.2 Object Tracking

Object tracking is referred to as the process of making continuous inferences about a target status in a video sequence, which can be simply regarded as recognizing and tracking the object's movement within the visual range of the camera module. This can be achieved by the following key principles: detection, feature extraction, motion and appearance model, data association, handling occlusions, update and feedback.

The key of detection involves detecting the object of interest in each frame, this can be done by using a varios techniques, such as: background subtraction, which compares the current frames obtained by the camera module to a static or dynamic background model to identify moving objects. This is why it is so important that the camera modules support a higher frame rate since it helps to identify objects more accurately and faster since the background subtraction can be applied to a higher number of frames. Some of the common algorithms that use this principle are Gaussian Mixture Model and the K-means clustering. Another technique is the color-based detection, which utilizes the color information to segment the objects. Machine learning is a technique that uses classifiers trained on labeled data to detect the objects. Deep learning objects like YOLO (You Only Look Once) provide real-time detection.

The feature extraction occurs after the object has been detected, then the most important features of the object are extracted, such as: the color histogram that represents the distribution of color within the object, shape of the object like the contour or corners, and key points which can be a unique feature that the object has.

The motion model estimates where the object is likely to move in the next frame. It can use simple techniques like constant velocity or more complex methods like

Kalman filters and particle filters to predict the object’s trajectory. The constant velocity technique is a simple yet widely used motion model in computer vision, it assumes that the object maintains a constant speed and direction over time, and this assumption is used to predict the object's location in the next frame or time step. Kalman filters make use of the constant velocity technique to be particularly effective in predicting linear motion and handling Gaussian noise. On the other hand, particle filters are suited for more complex motion dynamics since they can handle unpredictable motion patterns such as sudden changes in speed, direction and when dealing with noisy measurements.
Appearance model describes what the object looks like or its visual characteristics. With the use of algorithms that make use of color histogram, texture and deep learning that are embedded from a neural network, it will model the object appearance in order to distinguish the object from the background or similar looking objects.

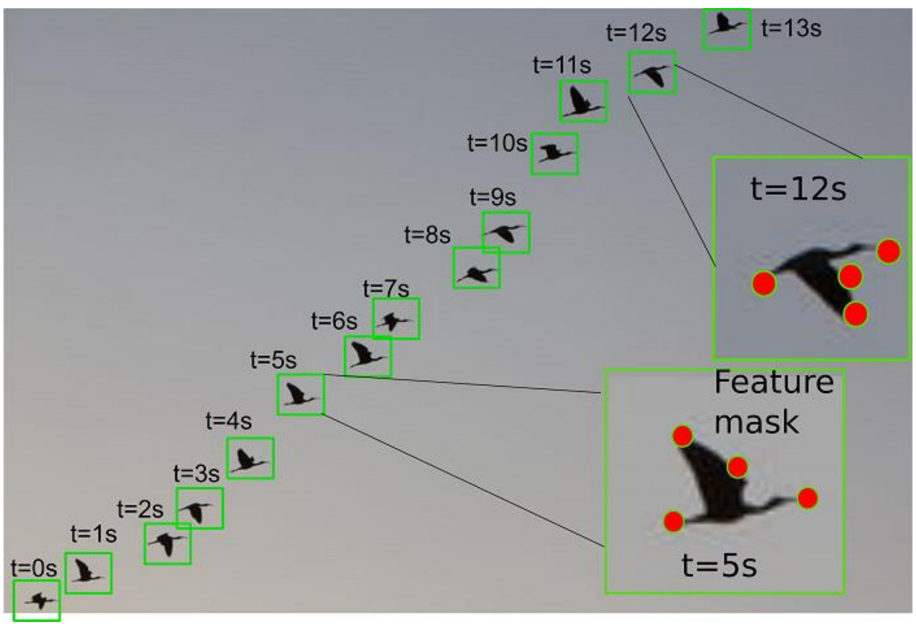

Figure 17: Example of object motion prediction

The data association consists of associating each detected object with a unique identifier in each frame. It involves matching the detected objects between consecutives frames based on their appearance and motion. The three most common data association methods are the Hungarian algorithm, IoU (Intersection over Union), and optical flow. Hungarian algorithm is used to find the optimal assignment of tasks to objects such that the total cost is minimized, ensuring that each task is assigned to exactly one object, this ensures that every detected object(from sensor or frames) is correctly matched with tracked objects, ensuring each detection is correctly matched to the corresponding object. Intersection over Union measures the overlap between two bounding boxes (detected and predicted) and matches them based on the maximum overlap. Optical flow tracks pixels across frames based on their movement.

Handling occlusion consists of when the object gets partially or fully occluded by other objects or the scene's background. To avoid this, the long-term technique is used to remember the object's features and re-detect it after the occlusion. Another technique to avoid the occlusion effect consists in the use of predictive models to estimate the object position while it is being occluded by other or multiple objects.

Lastly with the update and feedback key principle, once the object's new position is predicted by using one of the techniques already mentioned above, it is updated and refined in the current frame; if the object moves unpredictable or the scene changes, the tracker should correct itself using new observations. Kalman filters is the best algorithm that helps to correct the predicted location by combining the predicted motion with the actual observed motion in the frame.

3.3.3 Facial Recognition

Facial recognition is a technology that enables machines to identify or verify a person based on their facial unique features. It is a specific type of biometric identification system, similar to fingerprint or iris recognition. The process involves several steps or stages including image acquisition, facial detection, feature extraction and matching which are generally followed by sophisticated machine learning and deep learning models.

In the step of image acquisition, the system captures an image or video stream of a person's face, this data can be collected from cameras, smartphones or any other device that implements any type of camera sensor. Once the face is obtained from the input data, the image may be processed to improve its quality. This could include resizing, adjusting the lightning, noise reduction or aligning the key features for the face to ensure it is properly oriented.

During the stage of face detection, the system identifies and locates the face in the image by using various methods. These methods are divided into two categories that include: traditional methods like Viola-Jones algorithm, which is one of the early and widely used face detection algorithms. This algorithm uses a cascade of simple classifiers based on Haar features (which are squared-shaped functions to extract specific patterns in an image) to detect the face efficiently. Another traditional method is the Histogram of Oriented Gradients (HOG), it detects faces baes on the gradient structure of the image, which captures the facial edges and shapes.

The category of Deep Learning methods includes the Convolutional Neural Networks (CNNs) which have the ability to detect faces under varying conditions like different lighting, occlusion and head poses. Once the face is detected after using any of the methods mentioned above, the system typically crops the region containing the face to focus on it for further analysis.

The next step in the facial recognition process is the face alignment. Aligning the face in the canonical form helps the recognition process by standardizing variations in pose, orientation and scale. The system finds key points or landmarks on the face, such as the eyes, nose, and mouth, and uses them to adjust the face's orientation. This step ensures that the facial features are aligned consistently across different images.

Once the system has aligned the face, the feature extraction stage occurs. In this stage the system extracts a set of unique features that describe the face. These features serve as a representation to consider that the face is unique. There are two main types of features, the traditional handcrafted features that include the Local Binary Patterns which captures texture by encoding the relationship of neighboring pixels, and the eigenfaces (PCA) which is a statistical method that reduces the dimensionality of facial data by projecting it into a lower-dimensional space, capturing the most significant variations in the face. The Deep Learning features consist mostly of the use of convolutional layers in CNNs to learn hierarchical representations of the face. These features are more robust and invariant to changes in lighting, pose, and expression.

After the feature extraction, the step of face matching matches the extracted facial features with known faces stored in a database. Some of the matching methods in this step includes Distance-based Matching, in which the facial features are represented as vectors in a high-dimensional space, and recognition is performed by calculating the distance between the vectors of the input face and the faces stored in the database. Some examples of distance-based matching are the Euclidean distance, which is commonly used in systems like FaceNet to compare feature vectors. The closer the distance between two vectors, the more similar the faces. Cosine similarity, another method that measures the angle between two vectors, determining how similar they are regardless of their magnitude.

Finally, in the stage of face recognition output, the system compares the input face with all the faces in the database and returns the identity of the person if the face is recognized. Also, the system can compare checks whether the input face matches a specific identity.

Some popular facial recognition models and techniques include:

- FaceNet**:** One of the most well-known facial recognition systems, FaceNet uses deep learning to map faces to a compact Euclidean space where facial similarity is directly proportional to the distance between feature vectors.
- DeepFace (Facebook)**:** Trained on a massive dataset, this system uses a deep neural network to learn highly discriminative facial features.
- VGG-Face**:** A CNN-based model that extracts high-level features from faces and is commonly used in research and applications.
- Dlib (Face Recognition Library)**:** Dlib is a popular open-source library that provides a simple API for face recognition tasks, implementing various state-of-the-art methods.

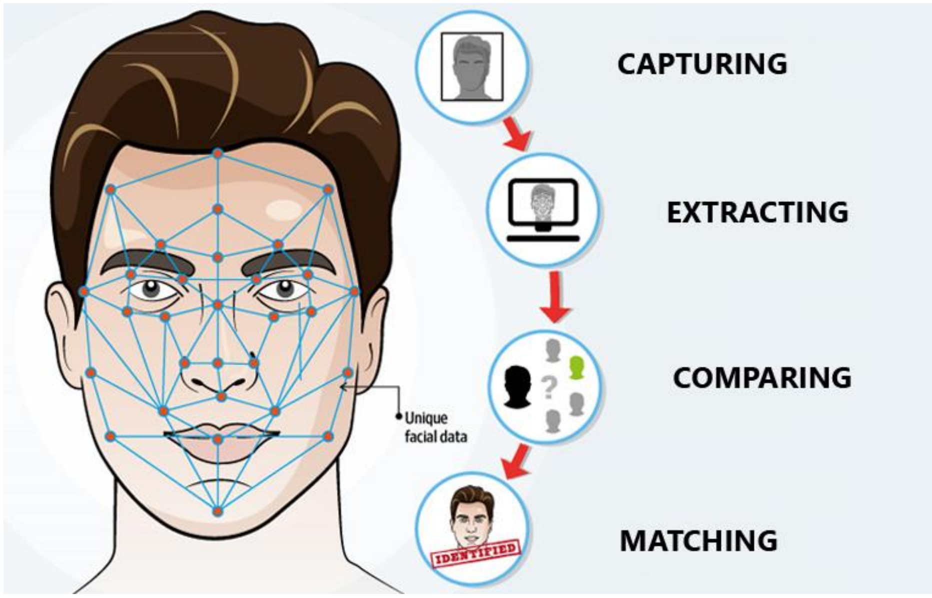

Figure 18: Facial Recognition Process [22]

4.0 Design Constraints and Standards

Standards and design constraints have been around for centuries, they are ethics that people follow in order to move forward and grow. The United States of America (USA) is a prime example of standards and constraints. The USA had set the Bill of Rights and the Constitution which essentially are standards and constraints that the USA and people have followed ever since the start of the country. Being engineering students and future engineers, we also have a set of standards to follow that have been recognized by the Institute of Electrical and Electronics Engineers Standard Association (IEEE). These sets of standards recognized by IEEE are essentially a set of standards and ethics that are used by engineers and future engineers in order to progress the engineering community in a positive direction. Design constraints are another factor that must be considered when creating a system. Design constraints can consist of environmental constraints, weight constraints, safety constraints, etc. Design constraints need to be factored when designing systems, doing so will allow efficiency and functionality in a system. Design constraints are restricting factors that allow our group to come up with a solution in order to produce a system that we want.

4.1 Standards and Design Impact

For our project, we have found plenty of standards that can be compared to our design, each standard is fully analyzed and explained how it can impact our project. Standards are placed in order to provide best practices and motives for several fields that fall under the IEEE realm. The fields that fall under the IEEE realm would consist of engineering fields such as electrical engineering, electronics engineer, and software engineering just to name a few. IEEE standards set in place consists of a wide variety of industries, industries that fall under IEEE would be energy and power systems, telecommunications, networking, information technology and computing, aerospace, defense, and education and media just to name a couple. With our project being a sentry turret, not all standards would apply to us. The standards that we can relate to would be ISO 13849-1, IPC 2221, MISRA C, IEC 60204-1, and IEC 62133.

The first standard for our project is related to the safety of the device, ISO 13849-1: Safety of Machinery, is a safety standard that is related to the general principles for design risk and assessment. It provides principles and guidance on how to ensure that machines can perform their intended safety functions in various operational and failure scenarios. Since our project consists of building an automated sentry turret, it means that is has the capability to shoot some sort of projectile to a person or object, even though we are using a NERF gun which is essentially a gun toy, it does not mean that it cannot harm a person at all, this is why our project must follow this standard in order to make sure it will be one hundred percent safe during the final presentation to the committee. Our group has decided to integrate an AI camera in order to detect and target moving items to fire at, for safety procedures we will provide software code that will tell the camera to only target at objects that are moving, the AI camera has facial recognition features which is something that we will use so that if the AI camera detects a face it will not fire at that subject in order to take safety measures and not cause anyone bodily harm.

The next standard related to our design is IPC 2221: General Standard for Printed Circuit Boards (PCBs) issued by the IPC (Association Connecting Electronics Industries), which is a standard that helps with layout rules, ensuring proper spacing for high-power circuits and signal integrity. It provides essential guidelines and best practices for designing printed circuit boards that are reliable, manufacturable and compliant with industry standards. This standard will help us to design and print a proper and functional custom PCB for our project, since we are not using a pre-built board for the project, we must follow the guidelines for this standard at the moment of creating the schematics and designing the board itself.

Another standard related to our project is MISRA C++, which is a set of coding standards developed by the Motor Industry Software Reliability Association (MISRA) to improve safety, reliability and portability of software written in the C or C++ programming language, particularly in embedded systems used in automotive and other safety-critical industries. The main key objective of this standard is to encourage the use of safe, structured programming techniques to avoid common pitfalls such as undefined behavior, memory corruption, code redundancy and side effects. This standard is very important for our project since the software part is responsible for several types of functionalities in the design, like the communication of the camera module and the MCU for a proper synchronization with the DC motors. The synchronization of the camera module and MCU with the DC motors is critical, the synchronization process will allow the system to receive the proper coordinates that the sentry turret must follow in order to shoot to the target. If the software is not coded following the MISRA C standard, we can encounter multiple problems like lagging. Lagging in our system would lead to the intended target to not be hit at the right time making the whole system inaccurate which is not desired for an automated sentry turret. Slowing down the movement of the turret itself is another issue, with the improper coding measurements our whole project could be moving at an imprecise pace which will lead to inaccuracies as well. A significant delay at the moment of opening fire to the target is another issue that could arise, essentially making the accuracy very low. Miscommunication is another issue that could arise if the proper MISRA C standard, miscommunications for a system such as a sentry turret is undesired. A system as a sentry turret has so many components that work with one another, if the code is improper the system may fire three shots off instead of 1, it may not be tracking properly, and it could ultimately drain the power supply if the code is working the components within the system when it is not needed.

Since our project makes use of DC motors, the standard IEC 60204-1: Electrical Equipment of Machines, is a very important standard that our design must follow, it provides guidelines and requirements for the electrical equipment of machines, focusing on ensuring the safety of electrical systems used in machinery such as DC motors. It mainly protects people, machinery and electrical installations from electrical hazards such as shock, fire and equipment malfunction. Following this standard will prevent any type of malfunction when installing the DC motors to the turret. It is very important that the motors work correctly since they are the most important mechanical aspect of the turret. Placing the motors correctly and well connected to the main board is very important in order for the ATLAS to be able to track the target with the least possible delay. Another component to consider within this standard is the power supply. The power supply is a live electrical component that has potential electrical hazards during testing procedures and even after the project is complete. It is important to try to minimize the risk of electrical hazards when using a power supply, a power supply has enough voltage and current to do serious harm to humans. Not taking proper protocols with a power supply can also lead to fires, fires can not only destroy our entire ATLAS system but can also cause harm to humans. Although our ATLAS system is using wireless power supplies such as an USB power bank and a 6V battery pack holder which is considered fairly low power and voltage, it is always better to take safety protocols to decrease any potential risks.

One more important standard for our project is the IEC 62133 for battery safety, since ATLAS will be powered mainly by batteries, this standard specifies the requirements of safe design, manufacturing, and testing of portable sealed rechargeable batteries, such as lithium batteries and nickel batteries. The main goal of this standard is to protect against potential hazards such as overheating, fire, and explosions that can occur due to battery malfunction or misuse. This standard is very important since our project will be running with a power bank, and a battery holder that consists of 4 AA batteries and we want to be sure that the battery pack will not be overheating due to improper connection or design in our custom PCB. We will also take proper precautions to ensure and prevent any bodily harm when testing the power supply components, since electrical shock can cause a lot of harm to individuals. Not taking proper protocols can lead to the power supply burning up or even shorting our whole system, which could lead to a fire which would be very undesirable considering the time frame and work our group has put into the project.

Table 12 contains other reliable standards with a scope, publish date, and description.

Standard Number	Scope	Publish Date	Description
IEC 61508	Logic Controllers	04/30/2010	Provides guidelines for developing safety-related systems, particularly for programmable logic controllers (PLCs) and MCUs.

ISO 2768	General Tolerances	1989	Important for machining and fabrication if you're building the physical structure of the turret.
IEC 60364	Low- Voltage Electrical Installations	11/29/2005	General requirements for electrical installations, including low-voltage DC systems commonly used in MCUs and sensors.
ISO 17296	3D Printing Parts	01/2015	Guidelines for materials, processes, and properties of 3D-printed parts.
IEC 62061	Testing Debugging	03/22/2021	Specifies requirements and makes recommendations for the design, integration and validation of safety-related control systems (SCS) for machines.

Table 12: Table of Related Standards and Descriptions

4.2 Design Constraints

Design constraints consist of restrictions that can/have impacted our project. Design constraints can have all types of restrictions, whether that be technical, functional or even timing. Our group has evaluated all sorts of constraints as designers in order to find the proper solution to whatever constraints there could be. The constraints we will be discussing are time constraints, economic constraints, environmental constraints, ethical constraints, safety constraints, size constraints, power constraints, weight constraints, and accuracy constraints. All of the constraints will be discussed down below.

4.2.1 Time Constraints

Time constraints consist of aspects such as deadlines and individual schedules that require our group to work efficiently in order to finish our project and create a complete system. The amount of time we have to work on the project was predetermined by our professors and the university. Our project is split into two semesters, with the first semester consisting more of a planning approach. The first semester consists of brainstorming what we want our project to be, researching the proper components and technologies, curating schematics and overall preparing to build the project. In the first semester we spend time finding the proper components we need to curate and work efficiently in order to create our system. The second semester consists of building and crafting the actual project that we had researched in the first semester. The second semester also consists of testing our project, making sure the components work together properly, evaluating any issues with our project, troubleshooting any components that may be broken or does not work, etc. Both semesters have several deadlines set by the professor in order to stay on track to create and finish our system in time. Having the two-semester time constraint limits the group to pick a project that is possible within the two semester time span, we cannot try to do an elaborate project that takes too much time. Another time constraint would be the time schedules of each individual team member. Whether it is extracurricular activities, work, or other academic courses, each individual team member has time constraints that must be worked around. With individual time constraints means that each member may work on the project at different times and may affect the project as we progress. We must consider the varying individual time schedules to make sure everyone has enough time to do their work. The individual time schedules also plays a factor with our meeting times, we have had to have meetings at odd times due to time constraints. The deadlines for certain pages counts placed by our professors are time constraints that must be considered as well. We have had a Divide and Conquer (D&C), a 60-page count and 120-page count deadlines placed by our professor. So as a group we must work around our own individual schedules in order to find time to write our page counts to meet the proper deadlines. The deadlines placed by our professors are beneficial, it ensures that the project is completed promptly allowing students to finish the project in time. The time constraint also affects when to purchase material for our project, as a group we cannot just wait until the last minute to purchase our material because we have to showcase our components and how they function at the end of the first semester. To ensure that we work well under the time constraints, we all must plan appropriately. Our project milestone schedule is a good resource that we have made in order to create a proficient agenda that allows us to plan and execute accordingly. The project milestone essentially lists all of the deadlines and time constraints set by the professors that requires our group to stay on track.

4.2.2 Economic Constraints

Economic constraints consist of factors such as money and budgeting. As we started narrowing down our project idea, economic constraints were a factor that was considered crucially. We had to pick a project idea that would not cost too much money. The first issue that we ran into was our overall budget, as a group that did not choose a sponsored project it meant that we must provide our own finances in order to purchase the material that we needed for our project. As college students we had to make sure that the total budget was relatively reasonable. We had decided our total budget would roughly be $373.00. The budget has dictated the types of motors, camera, power supply, sensors and MCU's that we chose. Of course, we could pick a really expensive material but due to the budget we had to find the best option for our budget. Resource availability was also considered under economic constraints. We had decided to order our components in advance to guarantee we had the necessary components when needed. As a group, we had avoided any component that took too long to ship due to manufacturing issues, or items that are out of stock. If we had chosen a component that was really cheap but took too long to ship we would not have it in time, rather we chose a moderately priced alternative that could be shipped quicker. Motors is a great example in regard to economic constraints. Our group had found various motors that were priced fairly, the only downside was that it would take months to ship which due to time constraints was not a viable option. Hence, that is why we decided to pay a little bit more for a motor that is better in quality and ships quicker. A component such as a power supply is a component that has a vast range of product types with many manufacturers. That is why the power supply was a component that we did not have to pay a premium on and stress about the availability. Oue 3D printed mount is another example of a component that is not affected heavily by economic constraints. The 3D printer uses plastic that can be found in an abundance. The 3D printer can design and create our mount within hours and is relatively cheap for the plastic materials needed.

4.2.3 Environmental Constraints

Environmental constraints are essential for a sentry turret. A sentry turret is a military device that is placed in environments such as deserts and forests. The varying climate types require the system to be versatile. Deserts consist of hot climates that would require a sentry turret to be able to withstand heat that exceeds 100 degrees. The desert can cause overheating to electronic components within a sentry turret that can lead to malfunctions and shorter life spans for the components. The desert also has dust and sand particles that can get into the components leading to malfunctions and shorter life spans. A proper housing unit would be required in order to prevent dust and sand particles from entering and damaging the components of the system. We had decided to use a 3D printed housing and mounting unit in order to create a unified structure to protect the sentry turret system. Another environmental constraint would be windy conditions, with a windy condition our system would need to stay stabilized and precise. Rain and humidity in forests would be another environmental constraint. Exposure to rain and humidity can lead the electrical components inside to short. Having a housing unit that is sealed, and waterproof would be very beneficial. Our 3D printed housing unit is going to enclose the components and prevent moisture and humidity from getting inside.

4.2.4 Ethical and Safety Constraints

Ethical constraints are essentially restrictions based on a moral understanding, preventing any type of harm, ensuring that there is fairness, and protecting the wellbeing of humans, animals and environments. Safety constraints are restrictions that ensure a system, product or procedure operates without harming humans, the environment or even artifacts. Both ethical and safety constraints are somewhat similar and go hand in hand. Ethical constraints that correlate to our project would be the intentions to test out our project on objects rather than humans. Our system consists of an automated firing system that fires soft foam balls as the project tracks moving personnel, although the balls are soft and foam it would ethically be wrong to test our project on humans. For ethical reasons we will be testing our project out by firing at objects. This is done to make sure that the welfare of humans such as members of our group are not compromised. Animals would also be another ethical constraint, just because animals are not humans it is still morally wrong to test our system on them. Animals are living species that are no less important than humans from an ethical standpoint. Firing and testing our project on animals could lead to bodily harm if the system would fire and strike the animal. Safety constraints is another factor we as a group need to consider. A lot of the safety constraints tie in with the ethical ones. When testing out our system safety is the number one concern for our team members. With an automated system that fires projectiles we will make sure to take safety procedures such as wearing safety goggles to ensure no one accidentally gets shot in the eye if there is a malfunction when testing our system. Testing our system with a spacious area and not a lot of foot traffic is also ideal, ensuring a spacious area allows us to test the distance and accuracy of our system while maintaining a safe distance from the system. Testing our system in a location without a lot of foot traffic is also important, doing so will ensure that there is less personnel and reduces the risk of our device accidentally firing and harming someone. It is important to consider ethical and safety constraints as it will help limit any risks and harm that could be induced. With an automated system that is being built from the ground up will require a lot of trial and error, with trial of the system brings occasions that could lead malfunctions while testing and factoring in ethical and safety constraints is the only way to keep accidents minimal.

4.2.5 Size Constraints

Size constraint is an issue that must be considered our ATLAS system. Size constraints refer to any limitations that require the system to be a certain dimension, whether it is due to design or operation restrictions. Size constraints are factored into objects we see in our everyday lives, whether that be furniture to make sure they fit through doors and rooms, smartphones to make sure they fit in pant pockets or purses, and grocery items to make sure they fit into grocery bags. A sentry turret is a firing system used in the military, meaning that the system would be taken to deserts and forests, so the overall size is not necessarily an issue. The issue is that our ATLAS system aims to be lightweight and portable, meaning the overall dimensions must be relatively small so that anyone has the ability to carry it and move it around. With these size constraints we have factored these constraints in when picking our components/parts and how we will supply power in order to achieve a lightweight and portable system. We had decided to use relatively smaller and lighter motors, nothing too big and heavy. Our camera and NERF gun have also been considered, we had chosen a small AI camera and moderately sized NERF gun. The NERF gun that was chosen is big enough to provide accuracy and distance when firing but small enough to keep the overall system lightweight and portable. Our power supply was chosen to consist of portable and lightweight components. If we were to use a wall mount power supply, it would be lightweight, but would require an electrical outlet in order to create and provide any sort of power which would not allow our system to be portable. Our power supply consists of portable power supplies, a portable power bank to power low power components and a 6V battery pack to supply power to our higher power components. Overall, we had factored size constraints into our component research to guarantee that our whole system is lightweight and portable.

4.2.6 Power Constraints

Power constraints is a restriction that was considered vastly when researching our project. Power constraints refer to the confinements of energy in a system, and how much that can be used. Restricting how much energy a system can use allows for the system to operate efficiently and reliably. Power constraints in everyday life would be how much output our outlets can provide, providing too much voltage or power can lead to overheating, component damage and even shorting a circuit which can ultimately lead to fires. The ATLAS system uses batteries in order to power the system. Using batteries will limit the energy and power capacity to the capacities that the battery contains. Ensuring that the system has enough power, our group has decided to use a power bank which will be used for low power components since power banks have lower battery capacities and output voltage/current. For our higher power components, we will use a 4 x AA battery holder which uses AA batteries and outputs 6V which is efficient for our motors and sensors. The reason why we are using a power bank and 4 x AA battery holder is that it is lightweight and will not be too heavy and overwhelming for the overall system. If we were to use a power source with a bigger power capacity it could be too heavy and overwhelm our system, which would lead to a slower, immobile sentry turret.

4.2.7 Weight Constraints

Weight constraints refer to any restrictions in regard to the weight of any particular component or system. Weight constraints are a very common restriction that many people see every day without even considering it. Cars must be a certain weight in order to prevent collapsing roads and bridges, elevators have weight constraints so that they do not snap the wires, even washing machines have weight limits to make sure that the wear and tear on the components inside the washer is minimal. A military grade sentry turret also has weight constraints. A sentry turret is built on a base foundation that can only withstand a certain amount of weight, each sentry turret is different and can consist of a different weight limit. The reason the base has a weight limit is due to the structure of the system, if there is too much weight the whole system could collapse, essentially exceeding the structural integrity. Another weight constraint with the sentry turret is mobility and portability purposes. If the system is too heavy the whole system could be too slow when reacting, decrease the range of the entire system and is essentially inefficient. If the overall sentry turret system is too heavy it could lead to airplanes and ships transporting the system to be unstable, and even expend more fuel transporting the system.

4.2.8 Accuracy constraints

In our sentry turret one of our main goals is to achieve an accurate turret, with this being said there will still be some accuracy constraints we will need to look at such as stability, motor precision, tracking, camera accuracy. Accuracy constraints are impacts to the accuracy and precision of our system, which will help us see how close we can achieve the outcome of targeting and firing at the object that has been detected.

One of the main constraints for our system is the stability of our system. Since we are building a portable and lightweight system we have to make sure that the stability of the system is still strong since the turret will be standing alone without the help of a human to keep the turret upright. If the nerf gun has any sort of kickback or recoil that will affect how the turret is standing upright, it will cause our system to become less accurate, which can lead to the nerf gun not looking in the right direction such as looking too far up or down which will lead to the camera not being able to detect the object if that object isn't in the field of view of the camera. Since this is going to be a 3D printed base we need to make sure that it will be able to withstand the harsh conditions that the nerf gun might cause. To take this into consideration we will be make the base and the legs of the system large enough to hold the turret upright and not be affected by the kickback or recoil of the nerf gun

The next constraint of the system that we are going to look at is going to be the motor precision. This constraint will consider how the motors speed, torque and precision would affect our systems accuracy. With the use of motors, we need to make sure that we don't overshoot or undershoot the target. If the motor speed or torque is too much it can lead to overshooting the target, which is when the system goes past the designated location of the target which can lead to multiple shots missed too far in front of the target. If the system does not reach the location of the target and is too far behind the target it can lead to missed shots behind the target and this can be from the motor and torque not reaching to the target.

Since we are using a camera to detect the objects some of the constraints of the camera are the field of view, frame rate, resolution and latency. Field of view can affect our system accuracy if the camera can't pick up objects outside of the field of view which can lead to the system not being able fire at the objects. Another constraint that will affect the accuracy of the system is if the camera has a low frame rate, which is how many frames the system can capture per second. With a low frame rate, it can lead to the system not being able to pick up fast moving objects and that would mean that our system wouldn't fire at the object and that could also decrease our accuracy. The final constraint of the camera is the resolution, resolution is the number of pixels the camera can capture. If the resolution of the camera isn't high enough it will affect the distance, and object detection. If our system is unable to detect the correct object and it locks onto an object that we don't want it to and we miss the target, then the accuracy of the system isn't accurate at all. latency, which is the delay between when the camera captures the image to when the system will be able to track the image or the object that it is trying to identify. Since this camera is going to be used to identify the object as well as track the object, we need to make sure that the latency is very minimal so that way it will be able to transfer the image, so it is able to be tracked. After the camera has located the object that it is going to track it needs to send the data to the motors so that way the base of the turret can start rotating to be able to track the object. If we have too much latency time between the time the camera senses the object to when the turret starts moving, it can lead to our system not being able to keep up with the object. If we cannot keep up to the object and cant get it to engage with the object the accuracy of our system will decrease since we want the turret to be able to properly follow the object and fully engage to where the nerf gun will fire at that object.

5.0 ChatGPT

ChatGPT is an artificial intelligence language model by OpenAI, developed in the 21st century, it is a relatively new model. It allows users to ask the model questions, and it searches the internet, books, websites and articles to find the best possible answer. There are various benefits to using ChatGPT. ChatGPT can answer a wide range of questions at the click of a simple button, allowing users a quick and swift answer. With quick answers allows the user to save a lot of time not having to look through resources themselves which enhances productivity and allows the user to spend more time elsewhere. Not only are ChatGPT's answers quick, but they are accurate as well since ChatGPT uses various sources such as websites, articles, books, and forums. ChatGPT is also nonbiased, allowing for answers to be straight forward and not swayed a certain way when asking questions regarding theories and concepts. ChatGPT is online 24/7, meaning users have the ability to access an array of information at any time needed. Despite the benefits of ChatGPT, there is always a con to anything.

The cons of ChatGPT consist of the availability, although you can access ChatGPT 24/7 with the internet, without internet access ChatGPT is essentially rendered useless. If you do not have internet access you cannot use ChatGPT and would need to use physical resources such as textbooks, newspapers, etc. ChatGPT checks a lot of sources to search for answers to the user's questions, but ChatGPT can still provide inaccurate answers due to its lack of real time data or even just provide the wrong answer in general. The reason ChatGPT provides wrong answers can also depend on other factors such as not understanding the user's prompt and the inability to critically think. ChatGPT requires the user to critically think and analyze the situation and concerns on their own, ChatGPT is essentially just a quicker search engine. Despite all of these cons, ChatGPT is just in the initial phase and has been a great innovation of the 21st century. ChatGPT will only progress and improve from this point on, it is essentially the future for information.

5.1 ChatGPT Examples

After evaluating the pros and cons of ChatGPT, here are some examples of ChatGPT. We will be evaluating ChatGPT using 3 examples, the first example being the ability to provide an accurate response regarding history, second example the ability to calculate a mathematical problem and the third is a bias test. The last portion will be assessing why ChatGPT may take longer to respond during one request versus another.

First example will just test how accurate ChatGPT is, we will ask ChatGPT to provide a brief summary of sentry turrets to see how accurate it is. The prompt used was "Give me a brief summary of the history of Sentry Turrets in the military." Here is ChatGPT's response. "Sentry turrets in the military have evolved as automated defense systems designed to detect, track, and engage targets with minimal human intervention.

Early Development: The concept of automated defense systems dates back to the 20th century, with early models like stationary machine gun turrets being manually operated or triggered remotely.

Modern Advancements: With advancements in technology, particularly in **sensors, tracking systems, and AI**, automated sentry turrets have become more sophisticated. They can now autonomously detect targets using **radar, infrared, and optical sensors**. The **Phalanx CIWS** (Close-In Weapon System), deployed by the U.S. Navy in the 1980s, is a notable example, designed to protect ships from missile threats.

AI Integration: In recent years, military forces worldwide, including South Korea's **SGR-A1** and Israel's **Iron Dome**, have integrated AI-driven systems for improved target acquisition and engagement. These turrets are designed for **border security**, **base defense**, and **air defense**, reducing the need for human operators in high-risk environments.

While AI-driven sentry turrets offer greater efficiency and accuracy, ethical concerns about autonomous lethal systems remain a topic of debate in modern warfare." (ChatGPT)

The information provided in regard to sentry turrets are correct. The reason accuracy must be tested with ChatGPT is because at times, ChatGPT provides wrong answers. The reason at times it does provide incorrect answers is because ChatGPT has limited access to information, it does not have information that is up to date and only has the ability to access information up to 2021, hence why there may be inaccurate answers at times. ChatGPT could also be overwhelmed if the user exceeds its token limit, ultimately overwhelming ChatGPT and not allowing it to operate at its best capacity.

Second example is a simple electrical engineering problem. This is to test how accurate the ability to perform mathematical problems is. The prompt chosen was "4x + 32= 42(x/14) find x". ChatGPT's response is "The solution to the equation 4x+32=42(x/14) is x= −32."(ChatGPT). The answer is correct, this shows that ChatGPT has the ability to do an algebra problem. Another mathematical problem that is electrical engineering oriented is as such "If there are 110 Volts and 700 milliamps, what should the resistance be." ChatGPT responded with "You can calculate the resistance using **Ohm's Law**:

V=I·R

Where:

- V is the voltage (110 volts),
- I is the current (700 milliamps or 0.7 amps),
- R is the resistance (what we want to find).

Rearranging the formula to solve for resistance RRR:

R=V/I

Now, plug in the values:

R=110/0.7≈157.14 ohmsR

So, the resistance should be approximately **157.14 ohms**."(ChatGPT).

The answer is correct, both mathematical problems have the correct answer from ChatGPT. This shows ChatGPT's ability to do mathematical problems in a diverse field not only that of mathematical problems, but engineering, statistical, business and medical problems as well.

Third example is a question to test the bias of ChatGPT and if there is any. The prompt provided was "What is the best engineering degree to get?" ChatGPT's response was "The "best" engineering degree depends on your interests, career goals, and the industries you want to work in. Here's a brief overview of some of the most in-demand and versatile engineering degrees:

1. Electrical Engineering

- **Best for**: Those interested in electronics, power systems, telecommunications, and renewable energy.
- **Career Prospects**: High demand in industries like energy, robotics, telecommunications, and electronics.

2. Mechanical Engineering

- **Best for**: People who enjoy designing, building, and analyzing machines and mechanical systems.
- **Career Prospects**: Broadest field with opportunities in automotive, aerospace, manufacturing, and robotics.

3. Computer Engineering

- **Best for**: Those who like working with hardware and software, particularly in computing systems, networks, and AI.
- **Career Prospects**: High demand in tech sectors like AI, cybersecurity, and software development.

4. Civil Engineering

- **Best for**: Individuals interested in infrastructure, construction, and urban development.
- **Career Prospects**: Opportunities in construction, transportation, urban planning, and environmental projects.

5. Software Engineering

- **Best for**: People passionate about coding, algorithms, and software systems.
- **Career Prospects**: Booming in tech industries, startups, and big tech companies.

6. Aerospace Engineering

- **Best for**: Those fascinated by aircraft, spacecraft, and defense technologies.
- **Career Prospects**: Growing demand in space exploration, aviation, and defense sectors.

7. Chemical Engineering

- **Best for**: Individuals interested in chemistry, pharmaceuticals, and process engineering.
- **Career Prospects**: Strong demand in energy, biotechnology, and manufacturing industries.

8. Biomedical Engineering

- **Best for**: Those who want to blend engineering with healthcare and medical device development.
- **Career Prospects**: Growing demand in healthcare technology, diagnostics, and medical equipment.

9. Environmental Engineering

- **Best for**: People passionate about sustainability and environmental protection.
- **Career Prospects**: Demand in renewable energy, water resources, and environmental impact assessment.

Ultimately, the best engineering degree for you is the one that aligns with your passion and the areas where you see yourself thriving."(ChatGPT).

As can be seen here, we had asked ChatGPT a potentially biased question. If you were to ask an electrical engineer which engineering field is best, that person may be biased to say electrical engineering. The test was to see if ChatGPT is biased or not and it is clearly not. ChatGPT decided not to give a straightforward answer but rather provide brief summaries of different engineering fields. ChatGPT not being biased is essential, it is not in the platform's best interest to show any bias as it can lead to backlash and less credibility.

ChatGPT is known for being very quick, and users can all agree. Despite this, there are times when ChatGPT takes longer, why is that? The reason ChatGPT may take a long time to respond is a variety of different components. First off, if the server is overwhelmed and there are a lot of users online at the time, ChatGPT may be experiencing a slower response time. Latency is another factor, if a user is too far from the server that hosts ChatGPT then it takes longer to transmit data from the server to the user, ultimately slowing down the response time. Another issue could be that the user is asking too much, if the user is asking too much, that can overwhelm ChatGPT and would take time to process what the user is asking in order to source and send the proper response and data. Network conditions is another issue, if the user is having network conditions that are not standard such as poor network conditions, then ChatGPT would take longer or perhaps not even work, this is not an issue caused by ChatGPT though.

Overall, ChatGPT is a very beneficial system. The ability to provide quick answers to the user allows for a lot of time saved. ChatGPT at times can be slow, but this is due to latency, server traffic and network issues, things that are not necessarily ChatGPT's fault. ChatGPT whilst not 100% accurate is for the most part very accurate and can provide good sources and related subjects for the user to expand upon. ChatGPT is not biased which is very beneficial for users to not be swayed a certain way, in our case ChatGPT will not suggest items from a specific brand because they invested in ChatGPT. ChatGPT has the ability to perform mathematical problems and provide accurate information, this is good for our group because we can rely on ChatGPT to research and assist us in our research, saving our group a lot of time.

10.0 Administrative

The administrative section consists of an overview of management content. This section has the budget and financing estimates of our parts, the actual bill of materials of our parts and the total cost, and our project milestones which is essentially a schedule that has our goals and dates laid out for us to follow throughout senior design 1 and senior design 2.

10.1 Budget and Financing

The budget for the project will be funded by the group. The estimated costs presented in the table above are subject to change depending on how the development of the device goes, this means that some parts may require less or more quantity than expected. Some electric components may be obtained for free from the senior design lab.

The main PCB for the project will include most of the circuit components like the MCU, power supply, and the pin headers for the connection of the peripherals like the camera sensor, step motors and the secondary PCB for the trigger mechanism, which will include the proximity sensor for ammunition left in the gun and the step motor to pull the trigger and shoot to the target.

For the actual base or housing of the turret, we are planning to design it and print it using a 3D printer, this way we can make a more custom design for the project.

Part Description	Quantity	Estimated Cost	Total Cost
HUSKYLENS Sensor Camera	1	$65.00	$65.00
Power Supply	1	$35.00	$35.00
Servo Motor	3	$19.00	$57.00
Nerf Gun	1	$50.00	$50.00
3D Print Case Mount	1	$20.00	$20.00
Micro-Controller Unit	1	$10.00	$10.00
Gears	2	$15.00	$30.00
PCB board	2	$50.00	$100.00
Proximity Sensor	1	$6.00	$6.00
Grand Total			$373.00

Table : Budget Table

10.2 Project Milestones for SD1 and SD2

Senior Design 1		
Week	**Description**	**Due Date**
1-2	Project Idea and Groups formation	
3	Write Divide and Conquer Document and Committee formation form	9/06/24
4	Begin 60-page document draft, Meeting with SD Coordinators to discuss project idea	09/09/24
5	Finish forming a committee and begin research into components	09/27/24
6	Start Elementary Testing	
7-9	Continue testing and writing the 60-page draft	
10	Submit 60-page draft	10/25/24
11	60-page draft feedback meeting with SD1 coordinators	11/08/24
12	Begin working on 120-page Report	
13-14	Start Designing the required PCB for the project and continue working on final report	
15	Submit 120-page Senior Design 1 document and mini demo video	11/26/24

Table : Senior Design Scheduling Table

Senior Design 2		
Week	**Description**	**Due Date**
1-3	Begin working on Full PCB and research methods of putting the device together	
4	Print prototype PCB and construct the project prototype	TBD
5	Test Prototype	
6-7	Research Solutions to any Malfunctions or potential Issues	
8	Continue researching for solutions	

9-10	Test the full prototype	TBD
11	Continue Testing and identifying possible issues	
12-13	Optimize the device	
14-15	Demonstrate final Project to SD Coordinators and Dean	TBD

Table : Senior Design 2 Scheduling Table

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