EAGLE EYE SYSTEMS

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

RE: ENSC 405/440 Functional Specifications for the Eagle Eye Tracker

Dear Dr. Rawicz,

The following document contains an overview of the functional specifications of our project for ENSC 405/440: the Eagle Eye Tracker. The goal of the project is to create an automated targeting and tracking system. The system will be ideal in locations where aerial security is of utmost importance – such as airports, prisons, and international borders. The Eagle Eye Tracker's design is highly flexible due to its deep learning-based algorithm, and thus has many more potential applications – including pest control, cinematography, and surveillance.

The purpose of the functional specifications is to provide high-level requirements for the project, and to outline the functions that we expect our product to demonstrate. This applies to all stages of the project – the proof of concept, the prototype, and the final marketable product. This document will be used as a reference throughout the development of our project, and each stage of our project will be tested and compared against these requirements to ensure that the functions outlined in this document are indeed demonstrable.

If you have any questions or comments, please direct them to aathwal@sfu.ca.

Sincerely,

Arman Athwal
Chief Communications Officer

EAGLE EYE SYSTEMS

FUNCTIONAL SPECIFICATIONS

Eagle Eye Tracker

Authors
ARMAN ATHWAL (aathwal@sfu.ca 301226860)
MATEEN ULHAQ (mulhaq@sfu.ca 301250828)
MARTIN LEUNG (mml28@sfu.ca 301233998)
BUD YARROW (byarrow@sfu.ca 301230000)
NAIM TEJANI (naimt@sfu.ca 301235623)
VICTOR YUN (vyun@sfu.ca 301229725)

February 21, 2018

Abstract

Object recognition and tracking is a relatively new but well-established field. A variety of approaches exist, each with their own unique benefits and drawbacks — methods like feature identification, color analysis, and optical flow, to name a few. The usefulness of automated object tracking cannot be overstated. A potential application can be thought of as any situation where one or more objects need to be tracked through space and time. This is an exceptionally broad definition. Thus, this problem statement gives rise to a massive array of potential applications. Tracking technology can be implemented across all fields and industries, from medical devices to military defense. However, each tracking method is generally best suited to a specific set of applications where environmental characteristics follow a predictable pattern — thus, the optimal tracking algorithm for intercepting missiles may not be appropriate in tracking small animals for pest control.

The Eagle Eye Tracker is Eagle Eye Systems' answer to this dilemma. We propose a single, unified solution for a wide array of tracking applications — from aerial drone tracking to bird deterrence. Using deep learning, the Tracker will not only be able to track moving objects in real time, but also identify and label objects using a decision-based classification algorithm. Thus, the Tracker is adaptable to the user's needs. The system will be able to distinguish between a face and a plane, for example, and consequently take specific actions based on the parameters provided by the user for their intended application.

This document outlines the functional specifications and requirements of the Eagle Eye Tracker, with the goal of describing at a high level the constraints within which the system will achieve its desired functionality. Initially, we outline the urgency of the problems that the Tracker can address by providing background on some of these issues. We then proceed by breaking the system down into its main subsystems to illustrate its core functionality, and the requirements that need to be met within these subsystems in order to provide this functionality. Further, we state the relevant engineering standards that we intend to follow to ensure that our system possesses the high quality that we envision.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

The last decade has seen massive shifts in the defense industry. Advancements in aerospace technology, specifically small, personal aircraft, have created an underestimated problem for aerial defense and surveillance. Personal drones, which are largely marketed as toys, have become increasingly versatile to satisfy hobbyist customers. This versatility, however, has been discovered by criminals as an effective method of carrying out illegal acts. Security personnel must now deal with personal drones carrying loads of illicit substances, such as drugs or firearms, across international borders, prison walls, and other secure institutions. Due to the compact design of these small aircraft, they are particularly difficult to target. Further, many of these drones are armed with high definition video cameras, creating an alarming void in the privacy sector.

Eagle Eye Systems believes that we can solve all of these issues with a single, versatile product: the Eagle Eye Tracker. Our solution is comprised of two main subsystems. The first is the detection apparatus, which can take many forms. For the purposes of our prototype, we will use a high-speed optical camera. Future generations of the product could feature a combination of different detection modalities, such as radio or LIDAR (Light Detection and Ranging). The information gathered from the sensor(s) is passed to a unique deep learning algorithm, which will be trained on data corresponding to the appropriate detection modality. The deep learning algorithm allows the Tracker to perform real-time analysis of the detection feed (for the prototype, a video feed), and make decisions on what is being seen in the feed. This allows the Tracker to distinguish between a personal drone and a bird, for example, and take different actions based on that decision — completely autonomously.

The second subsystem is the tracking apparatus. After an object of interest has been identified, the coordinates of the object in the image plane are converted into angular rotations of two motors, which allow the system to rotate angulary and azimuthally so that the system is aligned directly with the object. This is done for every image frame in the video feed in real time. Thus, for the 60fps camera we will use for the proof of concept, 60 images will be analyzed and translated into motor movements every second. However, the frequency that the motors are able to move is further dependent on the physical motors themselves, as well as the latency of data communication in the system.

These essential functionalities allow the Eagle Eye Tracker to perform a large host of tasks, not just those related to defense applications. A highly precise, highly versatile tracking system can be applied anywhere a user identifies a need. Pest control, high-speed photography/videography, and personnel surveillance are a few diverse applications that the Eagle Eye Tracker would be well suited for. Depending on the application, the specific tracking requirements for the system may differ. To compensate for any such differences, Eagle Eye Systems will supply an Application Programming Interface (API) so that users can modify the system parameters to suit their specific tracking needs.

1.2 Scope

This document outlines the functional requirements and specifications that we expect our product versions to meet. The high level design of the system is presented, as well as relevant engineering standards.

1.3 Classification

The following format is used to describe and organize the requirements listed in this document:

[REQ X.Y.Z-TYPE]

where **REQ** denotes a requirement, **X** denotes the subsection number, **Y** denotes the sub-subsection number, and **Z** denotes the requirement number within the sub-subsection.

TYPE specifies which product version the requirement applies to, and can have a value of **A**, **B**, or **C** (or any combination thereof), which represent **Proof of Concept**, **Prototype**, and **Production Ready**, respectively.

2 System Overview

The Eagle Eye Tracker will provide users with the capability to autonomously identify and track the motion of a target object of their desire. A neural network will be configured to recognize several objects. This will provide the system with the ability to distinguish between a target object and other objects that we must identify, so that the Tracker can ignore these objects. A significant benefit of the neural network is that its database of recognizable objects can be updated constantly. Thus, the Tracker can improve over time without the need for new versions of the entire product.

Once the system is configured to identify the desired objects, the users will install the system in a region where it has a wide open field of view for optimal surveillance. The Tracker will then run in an idle mode, where it pans the imaging system back and forth over the desired field of view. Once a targeted object comes into the field of view, the image detection algorithm will identify the object and provide a bounding box outlining the object in the video feed. The tracking algorithm will then kick in and direct the mechanical system to move to center the targeted object in the camera's field of view and keep it there through adjustments done in feedback to the object's motion. Figure 1 provides a general illustration of this scenario.

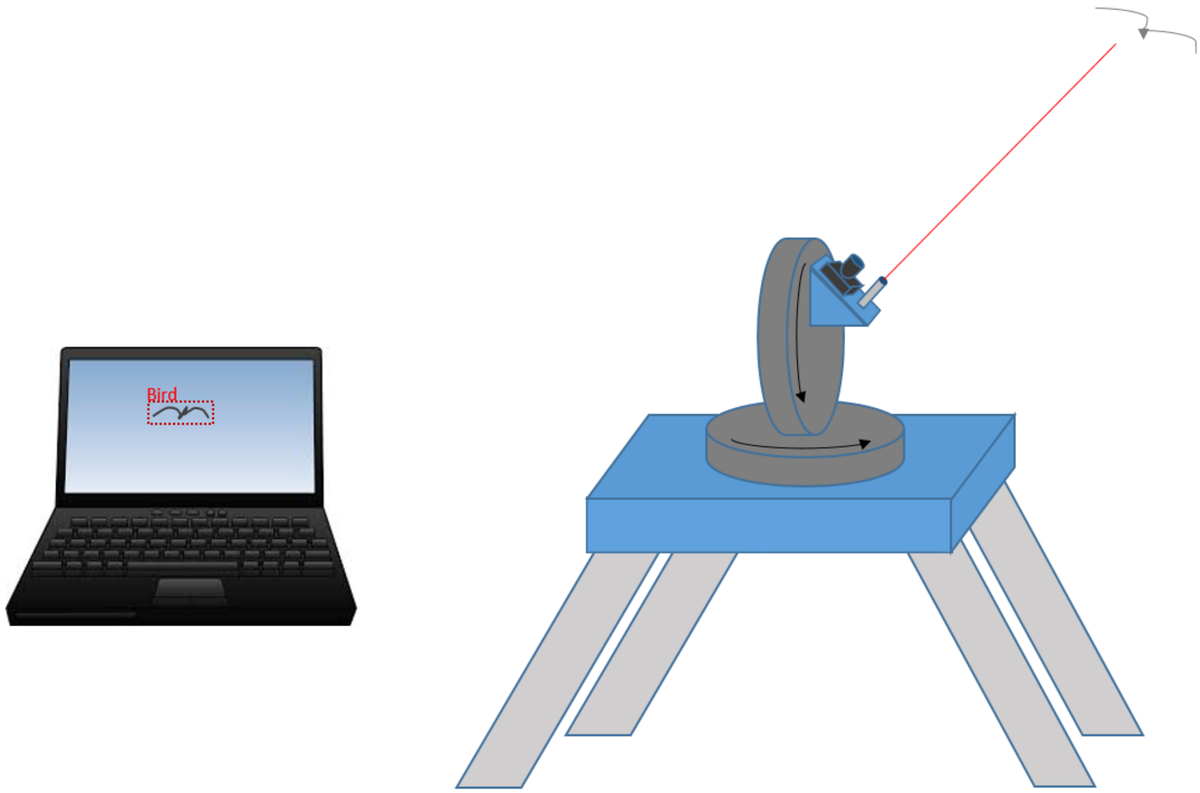

Figure 1: Conceptual diagram visualizing the Eagle Eye Tracker, which looks not entirely unlike our intended finished product.

If programmed to do so, the system will enable a laser pointer to mark the target being tracked as shown in Figure 1 above. Simultaneously, the Eagle Eye Tracker will be programmed to alert the user of a detection, so that they may respond as necessary without delay. The Tracker will also log detections and relevant metrics such as time and tracking duration of objects to provide maximum surveillance information to the user upon their request.

3 System Requirements

There are several strict hardware and software requirements needed to deliver a system effective to the versatile requirements of clients. Below we will distinguish between requirements for different stages of the project. The stage requirements are for the proof-of-concept, prototype, and production version. The functionalities that will be presented for the proof-of-concept during the 405W poster presentation are outlined in the appendix.

3.1 Hardware Requirements

A sophisticated robotic stage is necessary to enable autonomous tracking of the objects. The stage will provide two rotational degrees of freedom necessary to pan the space to search for objects of interest. Once an object of interest has been identified the stage will be controlled to precisely track the object by keeping it in the center of the field of view as outlined in Figure 2. In some cases we will use a laser to mark the object being tracked. In other cases, the system will simply record a video feed of the aforementioned object.

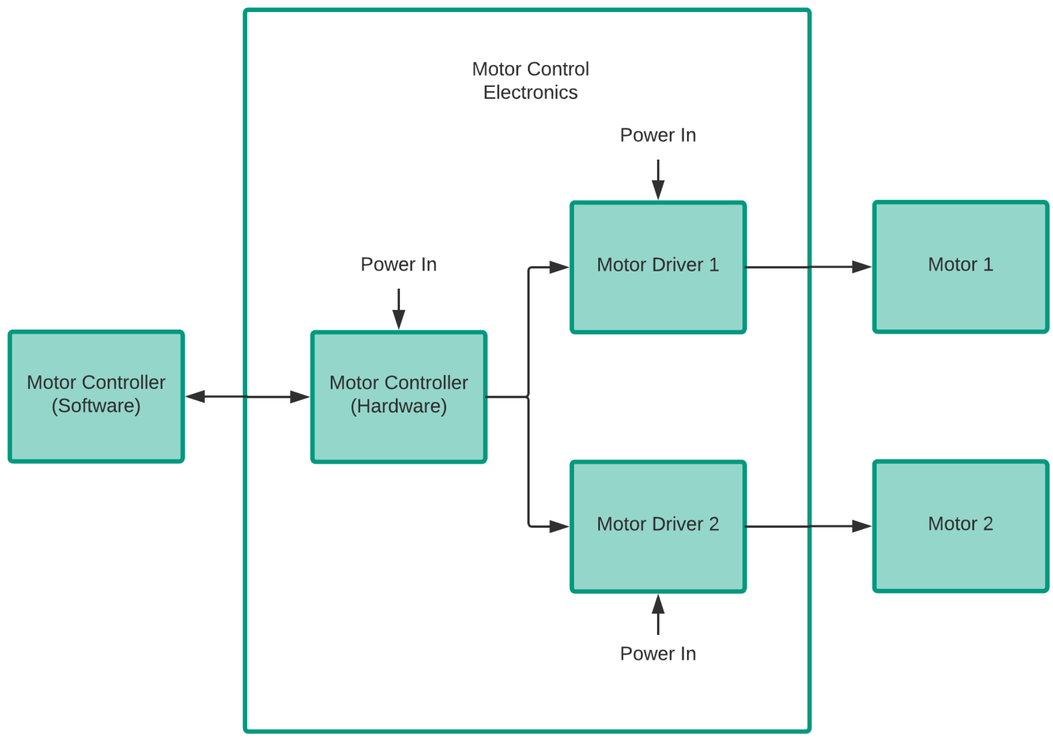

Figure 2: Flowchart illustrating motor control system.

3.1.1 Mechanical Requirements

REQ 1.1.1-ABC	Tracker shall have precisely two motors, each corresponding to an angular degree of freedom
REQ 1.1.2-BC	Each angular degree of freedom will have a resolution of at most $0.1°$
REQ 1.1.3-BC	Each motor will be fast enough to move each degree of freedom at least $45°/s$
REQ 1.1.4-BC	Each motor will move smoothly and minimize vibrations induced to system and camera in particular
REQ 1.1.5-BC	Modular product design that allows for easy upgrading

The Eagle Eye Tracker's mechanical design is one of its most important components. Each one of these specifications (Particularly 1.1.1 and 1.1.2) is absolutely crucial to the usability of our product. The rotation of the camera frame must be especially precise as our tracking is intended to work for long range objects. It is for this reason that we are using stepper motors with an extremely small step resolution.

After much thought into this, our team decided that these two degrees of freedom for the system are not only necessary but also sufficient for object detection spanning the upper quadrants of the spherical space.

3.1.2 Electronics Requirements

REQ 1.2.1-BC	Control system for motors will drive motors with smoothness, accuracy and speed required by the mechanical system
REQ 1.2.2-BC	Control system for laser will drive laser as required by software
REQ 1.2.3-C	System will have uninterruptible power supply, regulated to eliminate interruptions
REQ 1.2.4-C	System will have options for solar power or directly from grid, both with battery backup

Our electronic requirements are quite important for intended functionality of our product. Requirements 1.2.1 and 1.2.2 are overall requirements without which our tracker will be unable to perform its intended purpose, especially for far away objects. Requirement 1.2.3, though not necessary for a bare minimum functional product, is necessary for complete and reliable tracking. Requirement 1.2.4 is part of our commitment to providing an environmentally friendly product, and also providing options to the user if the need the system install away from easy connection to electrical grid. To avoid our system going off-line due to power outage, backup sources such as batteries are needed as depicted in Figure 3.

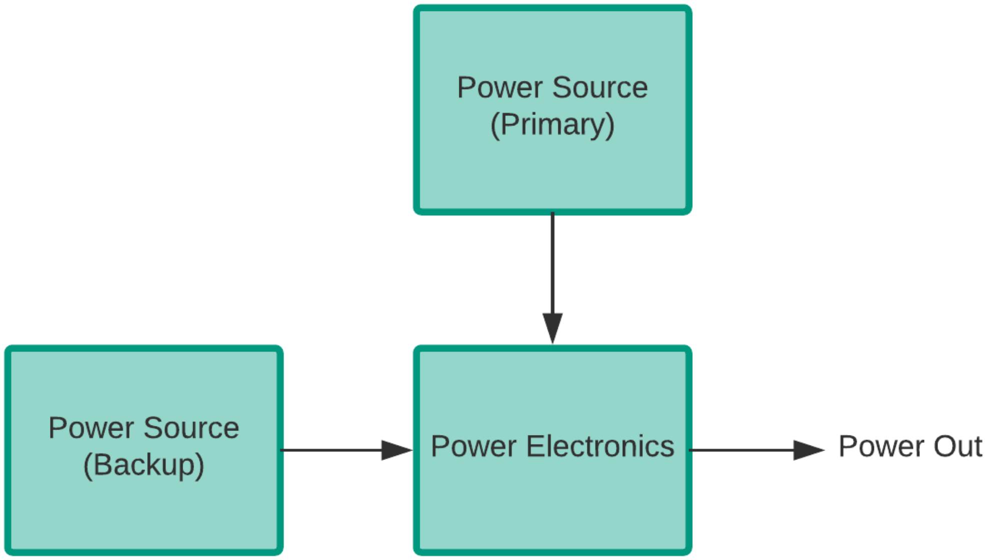

Figure 3: Flowchart illustrating power source. We will use two sources for reliability and portability.

3.1.3 Optical Requirements

A prerequisite to the object identification is having the optics capable of providing the adequate resolution at the distances required. This will define the type of lenses and camera necessary. It may be necessary to have adjustable zoom to provide tracking for distant and close range object detection and tracking. For the most part we will be focusing to infinity, allowing distant objects to be detectable and not worrying about close range objects.

REQ 1.3.1-BC	Product will be capable of imaging objects 5 to 100 meters away with adequate resolution
REQ 1.3.2-ABC	Objects will be resolved by at least 100 by 100 pixels to make object identification accurate
REQ 1.3.3-C	Option for infrared camera for nighttime detection
REQ 1.3.4-BC	Option for laser pointer to mark target
REQ 1.3.5-C	Option for high power laser to destroy target

For operation in low light levels or low visibility, due to fog for example, it is required to have a infrared camera to allow for object detection and tracking. We may wish to incorporate a laser pointer to mark the target, or deter pests in the case of agricultural applications. A high power laser is needed for the interception and destruction of unwanted objects such as drones. A control system for such lasers is shown in Figure 4.

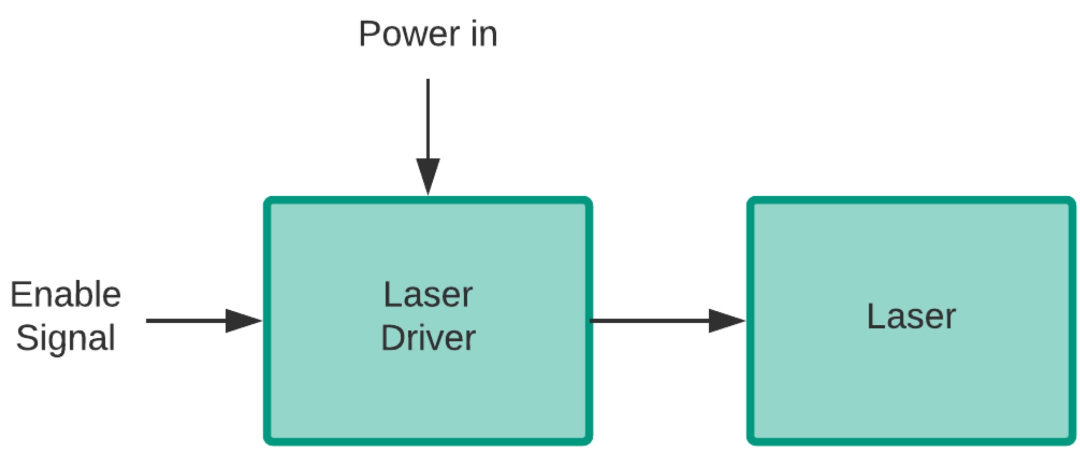

Figure 4: Flowchart illustrating laser control system.

3.2 Software Requirements

The heart of the system relies on identifying the specific targeted object and being able to distinguish between the targeted object and other similar objects. At Eagle Eye Systems our software team led by CTO Mateen Ulhaq will realize this using state of the art deep learning methods to establish the neural network responsible for the identification of all objects of interest. This phase of the software process is contained within the third block of Figure 5.

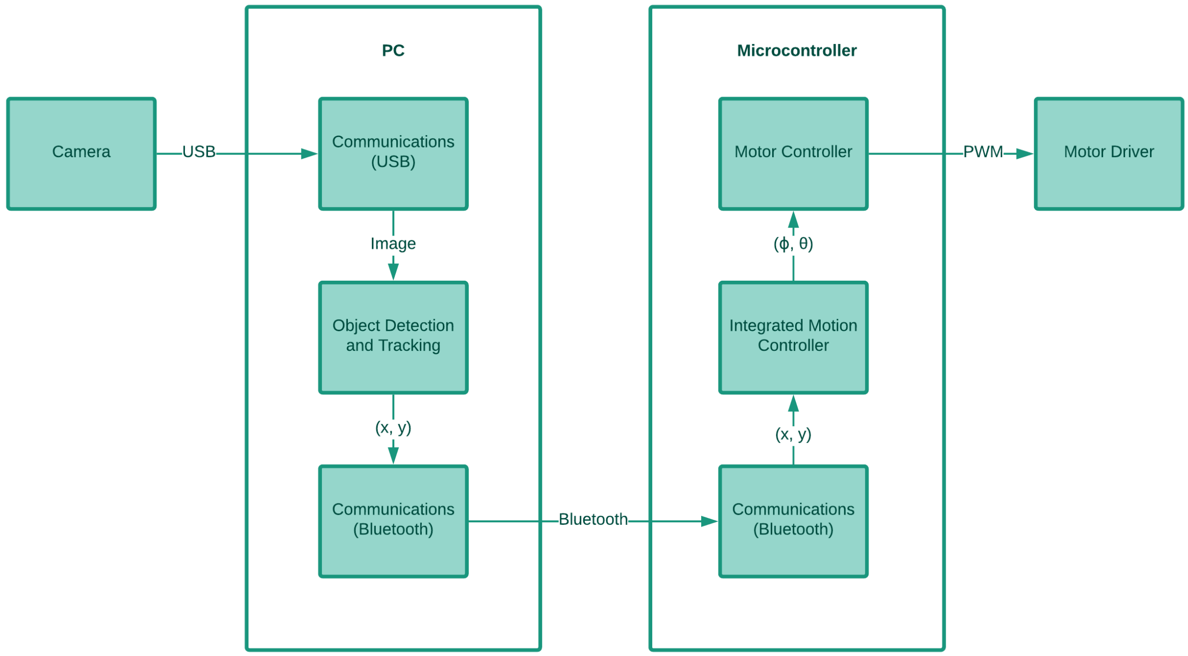

Figure 5: Flowchart illustrating flow of information throughout the required software modules.

3.2.1 General Requirements

REQ 2.1.1-ABC	Real-time video stream must be read in with low latency
REQ 2.1.2-ABC	Integrated motion controller will ensure accurate mapping between detected object position and desired motor angles
REQ 2.1.3-BC	Datasets of target objects used to train neural network will be sufficiently large to form a good internal representation
REQ 2.1.4-C	For portability, the neural network may run on standalone system

The success of the overall product will be heavily dependent on low-latency, continuous flow of data between the software modules. Since our product involves a sequential approach, it is crucial that all of Requirements 2.1.1 to 2.1.3 are met, as inability to do so will lead to failure of the whole system. Requirement 2.1.4 is not necessary for our current design since we will have a PC with a dedicated GPU, but it will be useful for neural network calculations if we decide to encapsulate our system into a portable all-in-one design.

3.2.2 Identification Requirements

REQ 2.2.1-BC	Targets will be identified with minimal false positives
REQ 2.2.2-C	Objects likely to be identified as false positives should be uniquely identified
REQ 2.2.3-BC	Coordinates of object center must be accurately determined
REQ 2.2.4-BC	Object detection must be fast to ensure low latency
REQ 2.2.5-BC	Record position and timing of object identification

Requirement 2.2.1 and 2.2.2 are in place to reduce the chances of misidentification, which can be a serious risk of our product depending on its application. This also ties back to a previous requirement of training a discriminator to identify objects that are more likely to be seen as a false positive. Requirement 2.2.3 is needed to ensure the tracker tracks accurately. Requirement 2.2.4 is important since object detection will be a primary bottleneck which determines a significant portion of the latency. Requirement 2.2.5 is needed to provide a log of the objects' position and time of identification. This information may be helpful for the users record.

3.2.3 Tracking Requirements

REQ 2.3.1-ABC	Target objects must be brought quickly and smoothly to the center of the field of view through feedback control system with motors and camera
REQ 2.3.2-BC	Identified target objects must be held accurately in the center of the field of view through feedback control system with motors and camera
REQ 2.3.3-BC	Log position of object over time for duration of tracking to construct a smooth path of motion
REQ 2.3.4-BC	Motor controller will enhance precision of tracking using prediction

Requirement 2.3.1 is important to ensure low latency. Requirement 2.3.2

is needed to ensure the tracker tracks accurately. Requirement 2.3.3, just like Requirement 2.2.5, is useful for user records and accountability. Requirement 2.3.4 will ensure precise tracking in real-time.

3.3 Environmental and Safety Requirements

REQ 3.0.1-C	Optional solar power for off grid stand alone system
REQ 3.0.2-BC	Product will not incur harmful consequences to natural ecosystems in its vicinity
REQ 3.0.3-C	A discriminator will be trained to help ensure that only actual target is tracked
REQ 3.0.4-BC	Strong, corrosion resistant, environmentally friendly metals will be used in the construction of the stage
REQ 3.0.5-BC	Rugged, environmentally friendly plastics will be used in the construction of the stage
REQ 3.0.6-C	System electronics and mechanics must operate accurately under a broad range of temperatures from -30°C to 60°C
REQ 3.0.7-C	Product will be water resistant
REQ 3.0.8-C	Product shall be sturdy enough to withstand wind gusts of up to 60km/h

As outlined in our Electronics and Environmental Requirements, we plan on our system having the option to use solar power for off-grid stand alone systems. In addition, we need to make sure we do not harm any wildlife. In our animal deterrent application, we plan to undertake extensive tests to ensure that the laser has enough power to deter birds and rodents but is not powerful enough to cause physical harm. The discriminator will ensure that only the desired target object is tracked to avoid unwanted laser exposure to innocent targets.

Furthermore, environmentally safe, non-toxic materials should be used to avoid leaching of toxic materials into ecosystem. Our last three requirements stem from the fact that our product's implementation most of the time will be in an outdoor location. For this reason, we need to be prepared for various harsh conditions.

4 Sustainability

At Eagle Eye Systems, we are committed to ensuring our products are not only effective, but also in line with our commitment to protecting and minimizing harm to the environment. Through modular design elements, we allow component upgrades without the need for replacing the entire system. Additionally, we judiciously acknowledge that tailoring our product specifically to our customers' needs would effectively reduce environmental waste and the inevitable pitfall of obsolescence. Where possible, the Eagle Eye Tracker uses biodegradable and non-toxic materials as well as materials that are easily recyclable. Aluminum and stainless steel are both environmentally friendly and resistant to degradation due to environmental weathering. These will form much of the final product's casing due to the materials' durability. Furthermore, PLA plastics are biodegradable and non-toxic, making it an ideal choice for functional prototyping due to its relatively small ecological footprint compared to ABS plastics.

5 Engineering Standards

5.1 Electrical

The following engineering standards apply to electrical safety. Since the Eagle Eye Tracker uses electrical power, it is vital that these standards are followed to prevent accidental shock. Further, the Tracker has been designed knowing that most applications will place the device outdoors. Hence, it is crucial that the device be resistant to rain and other weather conditions, which is also covered in the standards below. Finally, since the Tracker is constantly recording and processing a video feed, a safety standard regarding video apparatuses has been included as well.

UL 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use — Part 1: General Requirements [1]
UL 60950-1	Information Technology Equipment — Safety — Part 1: General Requirements [2]
IEC 60065:2014	Audio, video and similar electronic apparatus — safety requirements [3]

5.2 Mechanical

The Tracker consists of two moving components — the motors — which can rotate rather quickly. Thus, it is important to consider the following mechanical safety standards in our design. As the system is automated, ergonomic design of the device itself was not considered a pressing concern.

ISO 13854:1996	Minimum gaps to avoid crushing of parts of the human body [4]
ISO 12100:2010	Safety of machinery — general principles for design — risk assessment and risk reduction [5]

5.3 Environmental

Since the Tracker will most often be placed in outdoor settings, the environmental impact of the device is of large concern. The following standards will be adhered to in order to ensure that the Tracker and its components do not have a negative impact on their surrounding environment.

CAN/CSA-ISO 14040-06 (R2016)	Environmental Management — Life Cycle Assessment — Principles and Framework [6]
CAN/CSA-ISO 14044-06 (R2016)	Environmental Management — Life Cycle Assessment — Requirements and Guidelines [7]

6 Conclusion

The requirements and specifications outlined in this document specify the boundaries within which the Eagle Eye Tracker will be constructed. These functional parameters will allow the Tracker to fulfill the purpose that we envision. The Tracker will be ideal for defense and surveillance applications, particularly for use against small Unmanned Aerial Vehicles (UAVs) like personal drones. A network of Trackers can be used to monitor a large area from several angles, making it perfect for use atop perimeter walls such as borders and prisons. With an automated tracking and surveillance system such as this, fortified institutions will be able to deter criminals that attempt to smuggle illicit goods across their perimeters. Further, the Tracker offers institutions such as banks and casinos a more refined and sophisticated surveillance technique than a jungle of standard cameras can offer.

Despite its huge potential in the defense and surveillance industries, the requirements and specifications outlined herein have been designed to allow the Tracker to be much more. As technology progresses, the need for sophisticated and efficient tracking solutions will grow. The Tracker has the potential to improve industries such as sports broadcasting, cinematography, and agriculture - to name a few. The Tracker is algorithmically complex, yet elegantly simple for the end user. This combination of broad application, sophisticated technology, and simplicity for the user will make the Eagle Eye Tracker a true force to be reckoned with.

7 Glossary

Application Programming Interface (API) A collection of subroutines used to interface with external software components.

Artificial neural network A computing model made up of interconnected nodes (neurons) which produces output in response to external inputs. It is inspired by the structure of the brain.

Computer vision A field that explores algorithms for machines to gain visual understanding of images and video.

Deep learning A machine learning technique based on learning data representations using neural networks, typically making use of multiple layers of neurons.

Drone An unmanned aircraft controlled remotely or autonomously.

Graphics Processing Unit (GPU) A processor capable of executing many instructions in parallel; particularly useful for image processing and neural networks.

LIDAR A sensing method that uses light to measure distances [8]

Machine learning A field of computer science and statistics that studies algorithms for learning and improving autonomously from data.

References

[1] UL 61010-1, UL, 2016. [online]. Available at: http://ulstandards.ul.com/standard/?id=61010-1_3. [Accessed 19 February 2018].

[2] UL 60950-1, UL, 2016. [online]. Available at: http://ulstandards.ul.com/standard/?id=60950-1_1. [Accessed 19 February 2018].

[3] IEC 60065:2014, International Electrotechnical Commission, 2018. [online]. Available at: https://webstore.iec.ch/publication/494. [Accessed 19 February 2018].

[4] ISO 13854:1996, International Organization for Standardization, [online]. Available at: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=22598. [Accessed 20 February 2018].

[5] ISO 12100:2010, International Organization for Standardization, [online]. Available at: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=51528. [Accessed 20 February 2018].

[6] CAN/CSA-ISO 14040-06 (R2016) - Environmental Management - Life Cycle Assessment - Principles and Framework (Adopted ISO 14040:2006, second edition, 2006-07-01), CSA, Mississauga, 2016, [online]. Available at: https://www.iso.org/standard/37456.html. [Accessed 21 February 2018].

[7] CAN/CSA-ISO 14044-06 (R2016) - Environmental Management - Life Cycle Assessment - Requirements and Guidelines (Adopted ISO 14044:2006, first edition, 2006-07-01), CSA, Mississauga, 2016, [online]. Available at: https://www.iso.org/standard/38498.html. [Accessed 21 February 2018].

[8] National Oceanic and Atmospheric Administration; US Department of Commmerce. [online] Available at: https://oceanservice.noaa.gov/facts/lidar.html. [Accessed 21 February 2018].

Appendix: Proof-of-Concept Functionalities

For our Proof of Concept, we will use a LEGO Mindstorms kit, containing two rotational degrees of freedom. A camera will be mounted onto the LEGO stage, positioned in the general direction of an object. A screen will display the live video feed from the camera. We plan on having automated motion of the system for object tracking following the live video input read by the PC via USB. This will be performed by retrieving object coordinates in the image, then transmitting them from the PC to microcontroller using Bluetooth, after which the integrated motion controller will translate image coordinates from Cartesian (x, y) to spherical (ϕ, θ). Figure 6 shows our fully assembled proof-of-concept made from a Mindstorms LEGO kit. This is what we will present with our poster presentation in April.

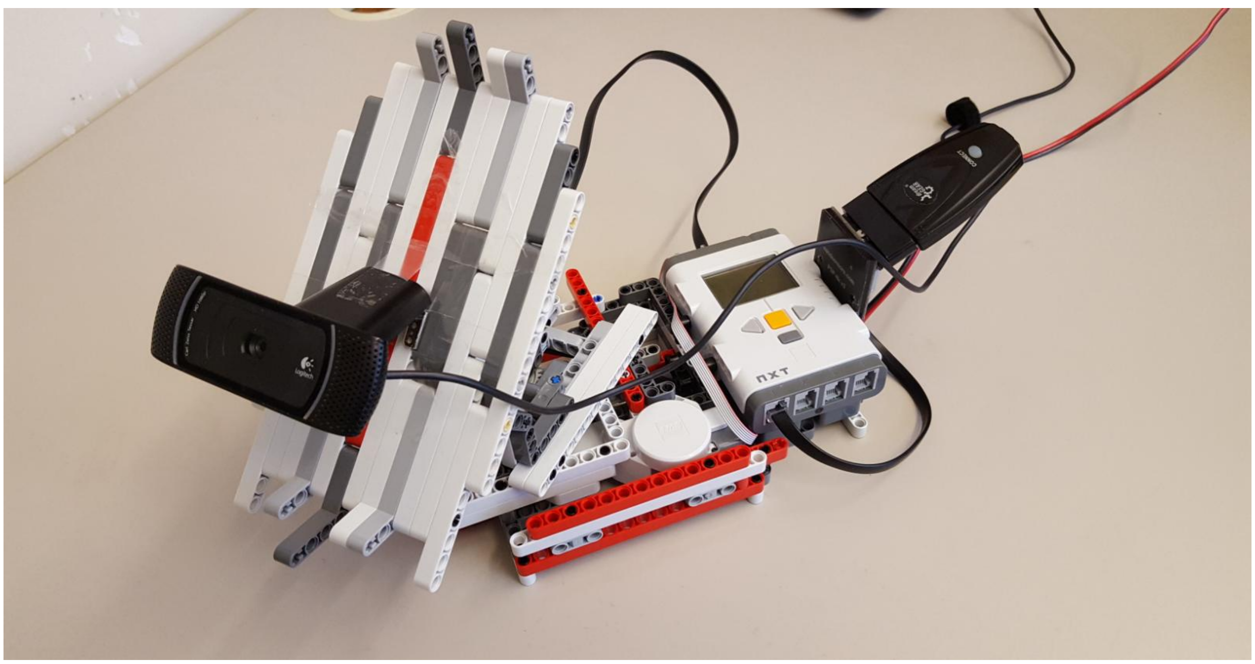

Figure 6: Our proof-of-concept Eagle Eye Tracker.