EAGLE EYE SYSTEMS

Dr. Andrew Rawicz
School of Engineering Science
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RE: ENSC 405/440 Project Proposal for the Eagle Eye Tracker

Dear Dr. Rawicz,

The following proposal contains an overview 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 to counteract illegal actions that are committed using small unmanned aerial vehicles. This 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 versatile due to its deep learning-based algorithm, and thus has many more potential applications – including pest control and photography.

The purpose of the proposal is to provide an overview of the project, a description of the system's high-level functionalities, an outline of the potential risks and benefits, and an exploration of alternatives already existing in the market. Also included is an overview of the implementation schedule, an analysis of the projected budget and sources of funding, and a description of the members' roles in the realization of the project.

Eagle Eye Systems is an innovative organization working to solve several issues with one unified product. Our multidisciplinary team is comprised of six talented and hardworking individuals: Arman Athwal, Bud Yarrow, Martin Leung, Mateen Ulhaq, Naim Tejani, and Victor Yun.

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

Sincerely,

Arman Athwal

Chief Communications Officer

EAGLE EYE SYSTEMS

PROJECT PROPOSAL

# Eagle Eye Tracker

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# 1 Executive Summary

Eagle Eye Systems is proposing an innovative take on the well-established problem of object tracking – the Eagle Eye Tracker. Geared primarily towards government uses of aerial drone tracking, but also suitable for various commercial and personal uses, the Eagle Eye Tracker is a unified solution to tackle any medium to large-scale tracking problem. Designed to use a deep learning algorithm, the Tracker will be able to identify and track various kinds of objects – both ground-based and airborne – with high speed and accuracy.

The system will be designed with an optical sensor – a high resolution, high speed camera – which will convert two-dimensional image coordinates into angular rotations of the motors. The object will be identified and labeled using our deep learning algorithm, and the appropriate image coordinates within the labeled region will be selected to precisely rotate the camera and targeting laser to the corresponding location. Because of the flexibility of the system design, the sensor need not be optical in nature. Modalities such as radar or ultrasound could be used instead, or even in combination with one another for more precise detection. In such cases, the deep learning algorithm would have to be trained on a new data set corresponding to the detection modality and is thus outside of the scope of our prototype – however, it is important to note the wide potential for improvement of this versatile product.

The range of potential applications of the Eagle Eye Tracker is remarkable, and can only grow as technology improves and users explore the benefits of object tracking. Although the system will be an ideal solution for drone tracking, pest removal and high-speed photography are also realistic applications. The prototype will be designed to perform only the core functions of these applications – identification and tracking. However, the system will be designed with the possibility of physical expansion in mind. For example, to take the drone tracker functionality to the next level, a projectile or interference device could be attached to the rotating arm of the device to convert the system into a drone destroyer. For pest control, a low power laser with the appropriate specifications could be attached to shine into the eyes of a target – a safe and humane way to deter pests from areas such as berry farms. With the core tracking functionality perfected and the deep neural network always expanding, the possibilities are truly limitless.

Within the attached proposal, one will find details on the prototype design, market analysis, risk/benefit analysis, implementation schedule, and projected cost of development. We estimate this cost to be between $900 and $1000 CAD for the final prototype. Most of this cost comes from the high-speed camera and motors, with the rest coming from the rotating stage materials, the microprocessor, a USB neural network accelerator, and other minor components. We are currently exploring sources of funding, which include the ESSS and an IEEE grant for photonics projects. We expect to have a functioning, initial prototype by the end of March, with a refined and more robust final prototype tested and debugged by the end of July. We are excited to bring this truly innovative and versatile design to fruition.

# 2 Introduction

In February of 2002, only months after 9/11, the CIA performed the first targeted aerial strike with an armed, multi-million-dollar Predator drone [1] – a type of Unmanned Aerial Vehicle (UAV). Due to the novelty of the technology, the rules of engagement were largely undefined, and thus that night is still shrouded in controversy to this day. Without a doubt, this marked the beginning of a new era in aerospace technology.

Today, only sixteen years later, a teenager can walk into a department store with a few hundred dollars in hand and purchase a state-of-the-art remote-controlled UAV – more commonly known as personal drones. Although a far cry from the vehicles of death used by governments around the world, these smaller aircraft have an underestimated, dangerous potential that few truly appreciate.

Marketed as toys, these devices are deceivingly sophisticated. High definition video recording is now a standard feature, as is long range communication and heavy load-carrying capability. The technology is improving rapidly, yet reliable countermeasures have not been established to account for the ever-growing capabilities of these machines. Legal regulations have attempted to mitigate the issue by restricting the operation of drones in public areas. Yet, such formalities do little to deter those who intend on using these devices for criminal acts. While these sophisticated UAVs improve and become more prevalent, critical security weaknesses have appeared seemingly overnight. Personal drones are being used to smuggle narcotics over international borders [2], drop firearms within prison walls [3], perform illegal surveillance, and have even been involved in several foiled terrorist attacks [4].

**Figure 1:** *Mostly Harmless* Drone.

Eagle Eye Systems has the solution. Our organization proposes a sophisticated, elegant, and safe solution to deal with this security epidemic – the Eagle Eye Tracker. Using our novel object-tracking algorithm, our system will be able to identify an intruding object and precisely track its movements in real time – and if programmed to do so by the operator – terminate the threat using an external projectile or interference-based system that may be mounted onto the Tracker. We recognize that when dealing with such equipment, safety is paramount. Hence, our system uses a deep learning algorithm to distinguish between hostile threats and harmless passers-by – after all, the last thing we want to do is cause a decline in local bird populations.

An added benefit of our deep learning-based tracking algorithm is its wide range of applications. The network will be pre-programmed with knowledge of several objects – drones, birds, and airplanes, to name a few - and this database will be constantly updated. Thus, the application of the Eagle Eye Tracker need not be for target destruction. A potential application is the deterrence of birds in berry farms. A low-power laser may be mounted onto the Tracker to shine directly at the target – a humane way to disperse pests. Pre-existing solutions involve shining several dozen lasers at random angles, a costly and inefficient method. Because of the Tracker's high speed, high accuracy, and low cost, a small network of Trackers may be placed in strategic locations to disperse flocks with remarkable efficiency. This is but one of a wide array of potential applications.

The elegance of the Eagle Eye Tracker lies in the user's ability to set its function to whatever purpose they need fulfilled. Whether if be for aerial defense, pest control, or even hobbyist activities like wildlife photography, the Eagle Eye Tracker is the unified solution for any government, commercial, or personal tracking application.

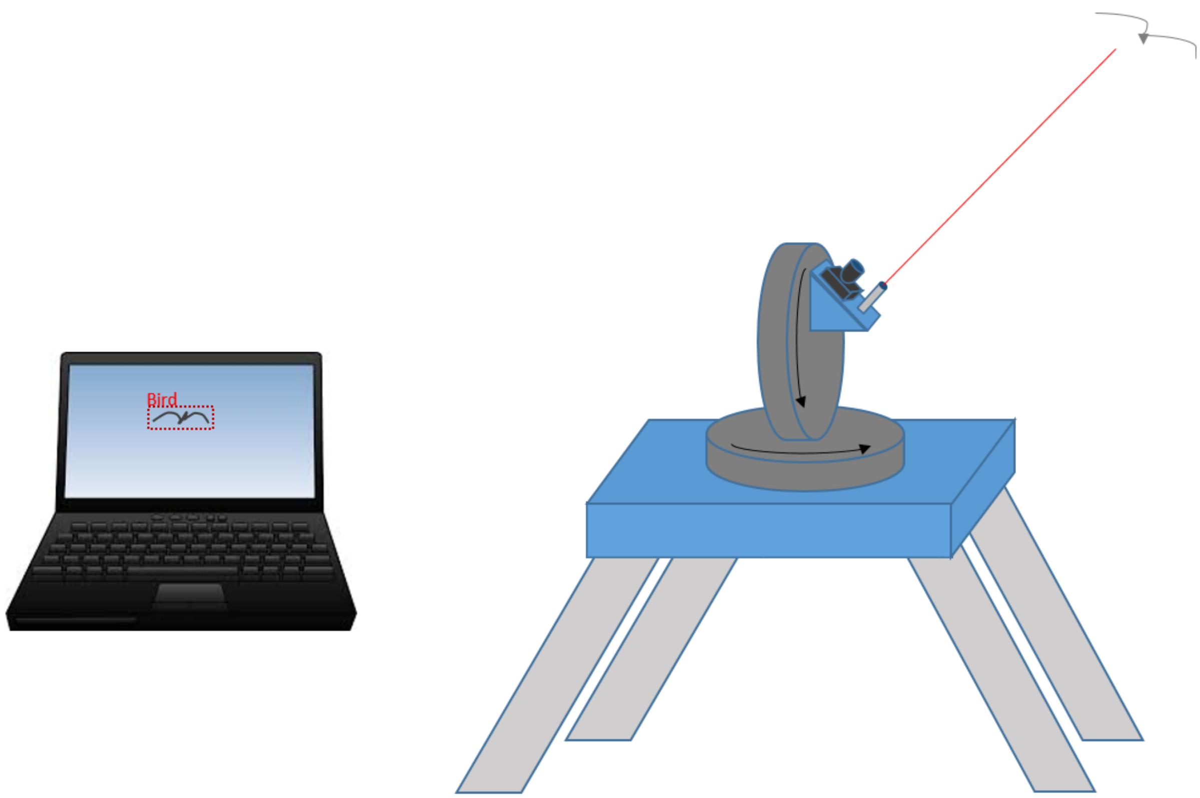



**Figure 2:** Conceptual diagram visualizing the Eagle Eye Tracker, which looks not entirely unlike our intended finished product.

# 3 Scope

The goal of our product is to detect and track distinct objects in the sky. The Eagle Eye Tracker will be able to automatically perform accurate image recognition on its targets (drones and various animals), retrieve their coordinates, and track the target by moving the camera and laser to point directly at the target.

1. Detect and recognize distinct objects (including drones and birds)
2. Retrieve coordinates in image
3. Send desired coordinates to motor (for tracking) to move camera and laser

All of these steps need to be performed in real-time in order for effective tracking to take place. Low latency and accurate coordinate retrieval are essential requirements for a competitive product.

## 3.1 Benefits

The Eagle Eye Tracker will have various benefits depending on the industry and its usage. Its flexibility is in itself a notable benefit: the detection and tracking algorithm can be customized to accommodate the specific needs of the end user. By generalizing the capabilities of the system, the Eagle Eye Tracker will not be constrained by a single application and can therefore continue to evolve as object tracking becomes more widespread. We envision that there will be innovative uses for this technology that have yet to be explored.

With respect to current issues, the Eagle Eye Tracker can provide benefits to a wide range of industries from agriculture to defense. For example, wildlife such as birds are an ongoing problem for farms, causing substantial damage to crops every year [5]. The Eagle Eye Tracker can be used in conjunction with an approved laser in order to harmlessly fend off birds, rather than more obtrusive methods such as netting or using loud noises.

Alternatively, the Eagle Eye Tracker can provide facilities such as government buildings and prisons with a solution to track drones that pose a threat to public safety or are used for criminal activity. By mitigating the security and privacy risks that drones possess, the Eagle Eye Tracker can further promote the proper use of UAV technology while ensuring the safety of all those involved.

The advanced algorithms integrated into the Eagle Eye Tracker will fully automate the process of detecting and tracking. Using deep learning methods for recognition will also enable highly accurate results. Unlike application-specific algorithms, neural networks can be trained more flexibly with arbitrary datasets to tailor functionality to the customer's needs. Lastly, the lightweight and compact design of the Eagle Eye Tracker will fulfill its goal of being a portable solution. Installation will require minimal effort and will support a variety of environments.

## 3.2 Risks

Misidentification is a significant risk of object tracking, and could lead to unfavorable outcomes. For example, birds and drones follow similar characteristics when viewed from afar. Thus, it is crucial for the system to be able to differentiate between them. To mitigate this, the Eagle Eye Tracker will use state-of-the-art deep learning methods in order to fine-tune the recognition algorithm to be as robust as possible. Recent research stemming from the IEEE International Conference on Advanced Video and Signal-based Surveillance has provided many solutions to the problem of "drone versus bird detection". Results have shown that deep learning can effectively differentiate the two in video sequences with high accuracy [6].

Another notable risk would be latency. High latency between camera input and motor actuation leads to inaccurate tracking. With the numerous processes involved in the operation of the Eagle Eye Tracker, from tracking of the object to the rotation of the motors, many factors may lead to delays in data flow. In order to ensure reliable performance, we must divide Eagle Eye Tracker into many stages. Focus should be on optimizing individual aspects of the overall product, such as camera specifications and GPU performance.

There are laws and regulations that limit the Eagle Eye Tracker's applicability to drones and animals, which could influence the marketability of our product. For instance, laws surrounding destruction of aircraft limit the potential usage of counter-drone technologies [7]. For now, full use of this technology may only be reserved for the government. It is uncertain whether this will change in the future. However, recent activity in the industry has shown a favorable trend towards further adoption of these systems, such as increased investments in drone-defense companies [8]. Though the main selling point of the Eagle Eye Tracker will be its detection and tracking capabilities, it will still be important for us to understand and consult the end user with respect to their intended usages of our product.

# 4 Market and Competition Analysis

The largest selling factor of our product is its wide range of applications. The Eagle Eye Tracker uses deep learning for recognition of a variety of objects and animals. As a result, our market includes governments, farmers, state-owned enterprises, private businesses, and individual citizens. Another feature of our device is the immediate countermeasures it takes against drones. The markets for various applications are described below.

## 4.1 Drone Detection

The usage of drones for illegal purposes is increasing. As a result, governments feel increasing pressure to find solutions for law enforcement. Recently, a news article published by CTV News Vancouver reported that a drone had dropped a package containing $26,500 worth of prohibited goods into a medium-security prison [9]. Smuggling of narcotics and weapons across borders and into prisons is an act to be taken very seriously and for this reason, we believe that governments will take a serious interest in our product. In particular, a country's border, prison walls, or public events could benefit from anti-drone technology.

A similar market is for state-owned enterprises, where provincial or state governments have significant ownership over the enterprise but do not control its day-to-day decisions. These are the kinds of companies that own and operate public venues such as BC Place Stadium. Such venues are often targets of terrorist attacks because of the overwhelmingly large quantity of people attending the events. The Eagle Eye Tracker seeks to improve the safety of the public by installing our product at these venues.

Typical drone tracking and detection systems do not include the full functionality of our system. For instance, current solutions do not use any form of automated countermeasures. A company named DeTect has developed a technology called DroneWatcherRF [10] which detects only commercially available drones in a 1-2 mile radius. DroneWatcher RF is an electric box that is installed around the perimeter of a facility and requires the user to take action once an intrusive drone is identified.

## 4.2 Bird/Animal Deterrent

For generations, farmers have been using scarecrows to deter harmful birds from their farms. With modern technology, more effective solutions exist. In addition to drone detection, our solution is flexible enough to have such agricultural applications. Our product will aim a low power laser towards the birds' eyes to scare them away.

**Figure 3:** Birds can be mostly harmful to crops.

This application can also be implemented at outdoor venues. Unwanted bird excretion can be very problematic at outdoor events. For this reason, we are marketing our product to event organizers. Other industries that may be interested in bird deterrence include aviation, industrial sites, and oil and gas fields.

The company Bird Control Group has developed multiple solutions for this very niche market. Unfortunately, since it is a multinational organization, its products are extremely expensive. A farmer may not have the funds to purchase such technology, nor would a young couple wanting to cut costs by opting for an outdoor summer wedding. In addition to this, low-tech solutions exist such as scarecrows, or kites resembling birds of prey. Unfortunately, these methods often underestimate the intelligence of many birds. Birds quickly realize that these scarecrows and kites do not represent real threats. Our fully automated system will not encounter such a problem because although birds may realize the laser does not pose direct harm, the lasers will act as a temporary vision impairing deterrent.

The Eagle Eye Tracker can be further extended as a general animal repellent. For an example application, look no further than the SFU campus! Raccoons are frequently entering SFU buildings and wreaking havoc by spreading diseases and knocking over garbage cans in search of food. A company named HavaHart has developed a series of electronic animal repellents. However, these devices need to be manually aimed properly. In contrast, our product is fully automated in recognition and aiming.

# 5 Budget

We have determined that the prototyping budget requires $660 and the final product budget requires $1000. Possible optional systems may also be considered if we feel they add value to the product.

| **Item** | **Cost** | **Prototyping** | **Final Product** | **Optional** |
|---|---|---|---|---|
| Arduino | $25 | | ✓ | |
| Bluetooth module | $30 | | ✓ | |
| Camera | $400 | | ✓ | |
| Laser pointer | $5 | | ✓ | |
| Motors (x2) | $200 | | ✓ | |
| Stage materials | $100 | | ✓ | |
| Mindstorms kit | $500 | ✓ | | |
| Intel Movidius DNN USB | $80 | | | ✓ |
| Mirrorcle laser system | $8000 | | | ✓ |
| RADAR | $2000 | | | ✓ |
| Rotating stage | $800 | | | ✓ |
| **Subtotal:** | | $500 | $760 | |
| **Tax (12%):** | | $60 | $90 | |
| **Contingency (20%):** | | $100 | $150 | |
| **Total:** | | $660 | $1000 | |

**Table 1:** Budget. Prototyping and Final Product costs are totalled independently.

## 5.1 Funding

Sources of funding for our project are still currently being explored, with the primary options being the Engineering Science Student Endowment Fund and IEEE Student Project Funds; the parts library from the ESSS may also have useful materials that we may choose to borrow. Alternatives such as the Wighton Engineering Development Fund are also being considered. Inquiries and applications for these funds will be completed promptly in order to ensure that we have a solid understanding of our financial plans going forward. Any outstanding expenses will be distributed evenly amongst the team members; as many of the parts are perfectly operational independently, they can be seen as an investment and used in future projects as well.

# 6 Time Schedule

In order to reduce development time, we have divided ourselves into teams to work on separate subsystems in parallel. The main categories include hardware and software, which will be done in parallel by software and hardware teams. System integration will follow, leaving adequate time for testing and debugging. The detailed proposed timeline can be seen in the Gantt chart in Figure 4.

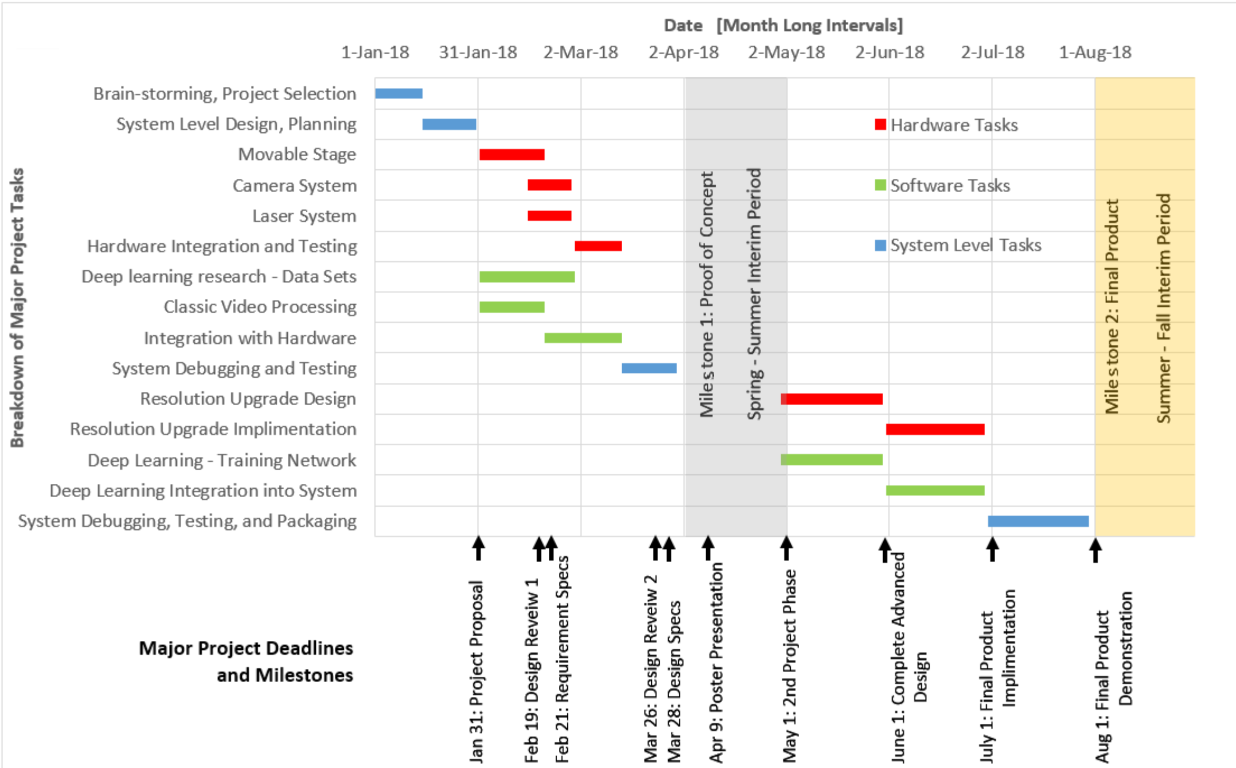



**Figure 4:** Gantt chart outlining schedule of major project tasks, deadlines, and milestones which are incredibly highly likely to be met on time.

## 6.1 High-Level System Design

In this phase, we plan the technologies we will use for the different subsystems. We also determine how various subsystems will cohesively fit together. We also designate team roles and divide up into hardware and software teams.

## 6.2 Hardware Design and Prototyping

With respect to the hardware, the first development phase will involve prototyping the stage to support the imaging and targeting hardware. The stage will include a base connected through a series of 2 motors to the top platform of the stage. The motors will provide 2 orthogonal rotational degrees of freedom to function as the basis for panning the camera's field of view over the desired range and to target objects of interest.

Following the acquisition of the appropriate camera, it will be incorporated onto the stage and connected properly to the computer used to do the required video display and processing.

The laser system will be comprised of a simple laser pointer to paint the target of interest and will be affixed next to the camera and calibrated to be pointing at the center of the camera's field of view.

## 6.3 Software Research and Development

The software development will occur in parallel to the hardware development. One component of this will focus on the application of deep learning in this project. This will focus mainly on research and looking at data sets for training and suitable models for this project.

The main software development component will focus on video processing using classical methods to identify moving objects. The algorithm development will be followed by integration into the system.

The full system prototype will be tested and debugged in preparation for the first milestone: demoing a proof of concept prototype.

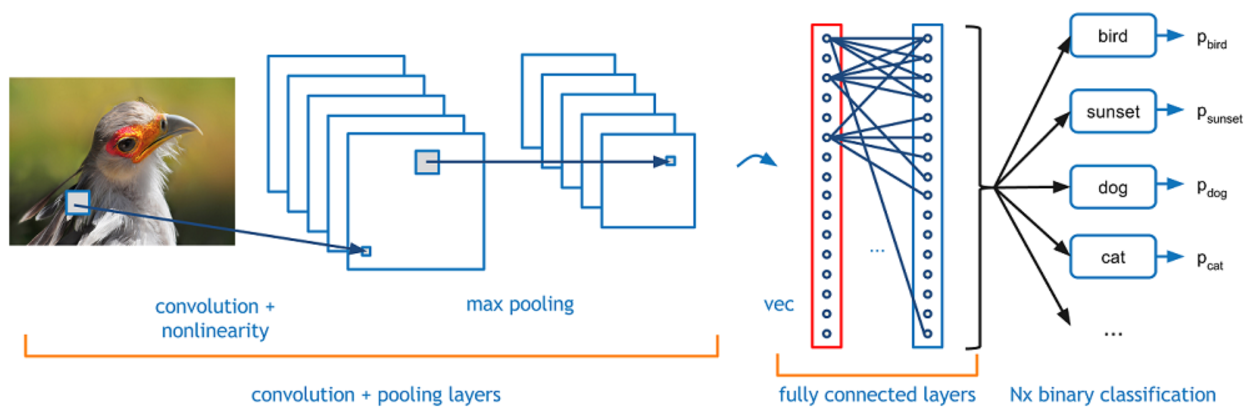



**Figure 5:** Convolutional neural network. Takes an input image and classifies it. The input image in this case appears to be a bird of some kind.

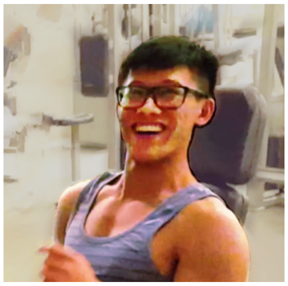
## 6.4 Product Design and Development

Following the completion of the prototype, the upgrade to a full product will be set in motion starting in the summer semester. In terms of hardware, this potentially involves upgrading the resolution of camera and zoom as required to target more distant objects. In software, there will be a big transition from pure classical video processing to incorporating deep learning networks to detect and differentiate between objects such as drones, birds, planes, etc.

# 7 Company Overview

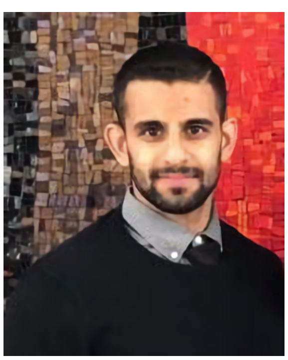
**Arman Athwal** is a fifth year Biomedical Engineering student at Simon Fraser University. He has experience in image processing, deep learning, and biomedical technology. He also has expertise in writing technical engineering documents. Having worked at Engineers and Geoscientists BC, as well as Simon Fraser University's Biomedical Optics Research Group, he has written several high profile engineering documents, including a patent application and several research papers. Nominated as Chief Communications Officer (CCO) of Eagle Eye Systems, he will be leading the production of all documents pertaining to the development process, and will be working on the computer vision, deep learning, tracking, and physical motor aspects of the project.

**Bud Yarrow** is a fifth year Engineering Physics student and Researcher at Simon Fraser University. He has expertise in the field of semiconductors and solid-state electronics with over 2 years of combined industrial and academic experience. Bud has a high-level knowledge of optics stemming from his work experience, specialized courses, and projects he has partaken in throughout his undergraduate career. He has a keen interest in applying his expertise to the development of Eagle Eye Tracker. Nominated as Chief Executive Officer (CEO) of Eagle Eye Systems, he aims to work alongside his bright colleagues to ensure completion of a product that will meet the versatile requirements of clients for a competitive price that will not compromise quality.

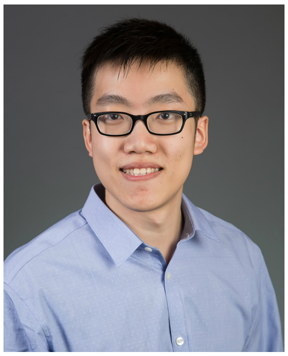


**Martin Leung** is a fifth year Electronics Engineering student at Simon Fraser University. He enjoys researching, working with electronics, and programming in C++. He will be working on optics, motors, electronics. As Chief Operating Officer (COO) of Eagle Eye Systems, Martin always puts the company first, and is excited to be part of the Eagle Eye Tracker development team.

**Mateen Ulhaq** is a fourth year Engineering Physics and Mathematics student at Simon Fraser University. In his last NSERC USRA position, he worked on a mixture of image processing and app development. Loves programming and some languages he typically uses include Python, C++, C#, Java, and Bash. He also has some robotics experience with Mindstorms, VEX, and Arduino. Recently, he became interested in pursuing the exciting, ever-evolving field of deep learning. He will be working on computer vision, deep learning, and tracking. As Chief Technical Officer (CTO) of Eagle Eye Systems, he will manage all technical aspects of the project and the integration of various subsystems between different teams.



**Naim Tejani** is a fifth year Engineering Physics and Economics student at Simon Fraser University. Previously, he has worked at Tantalus, where he worked as a hardware test engineer with a heavy focus in microsequence assembly code. He is also proficient in MATLAB and C++. He has experience with microelectronics, semiconductors, physics, economics, and marketing. He will be working on Solidworks, optics, motors, electronics. Naim has been appointed Chief Financial Officer (CFO) of Eagle Eye Systems, where he will use his knowledge of economics and finance to oversee the funding and costs of the Eagle Eye Tracker.



**Victor Yun** is a fifth year computer engineering student currently attending Simon Fraser University. He has held previous co-op positions as a software developer, and has learned a lot about the development lifecycle on the way. He holds a keen interest for programming and is experienced with languages such as C, C++, and Java. As Chief Information Officer (CIO) of Eagle Eye Systems, he will bring a well-rounded skill set and work on the software components that are vital for the completion of this project, including the computer vision and integration aspects. He will also ensure proper maintenance and documentation of the processes.


**Figure 6:** Great team dynamics! Dilligent meetings!

# 8 Conclusion

As the average cost of recreational drones decreases over time and they become more common, this raises the need for governments to set rules that protect people, places, and aircraft. Flying drones can be a fun hobby, but it can also be a means of carrying out nefarious activities. There are many instances of criminals using recreational drones to smuggle contraband into prisons, and the growing issue of illegal substances being smuggled across borders using drones.

Our team at Eagle Eye Systems sees the need for enforcement of these rules surrounding recreational drones. Our product, the Eagle Eye Tracker will revolutionize the way prisons and borders are monitored through fully automated and highly accurate object recognition and tracking. Utilizing deep learning is the unique selling point of our Eagle Eye Tracker and sets us apart from other similar products on the market. It gives the Tracker the ability to quickly and accurately discriminate its target from the surroundings. Using an image dataset for the target, the Eagle Eye Tracker's neural network can be trained to track that target. This means that the Eagle Eye Tracker can not only recognize drones, but practically anything. We are proud of the Eagle Eye Tracker's versatility, which gives it a wide breadth of applications from bird and drone deterrence to automated camera operation.

# 9 Glossary

**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.

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

**Pre-programmed** To be programmed before it is programmed.

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