June 12, 2023

Dr. Michael Hegedus
School of Engineering
Simon Fraser University
8888 University Drive
British Columbia, V5A 1S6

Re: ENSC 405W Requirement Specifications

Dear Dr. Hegedus,

This requirement specification documentation for the Integrated Fire-Control Optic and Ballistic Solution was prepared by Company 15 in partial fulfillment of requirements for ENSC 405W: Project Design, Management, and Documentation (Capstone A).

This project was inspired out of a need for soldiers to effectively engage targets at unknown ranges with a greater degree of accuracy compared to existing rifle optic solutions. In addition, shooting from unconventional positions changes the trajectory of the projectile relative to the rifle optic and currently requires the soldier to mentally compute their point of aim at certain distances. Integrating a ballistic solution and fire control into the rifle optic itself reduces the amount of information a soldier must process to provide effective fire on target.

This document will address the following items: project scope, existing market, project requirements, engineering standards, safety and environmental concerns, and the deliverables for the poster presentation. Company 15 consists of 5 SFU Engineering students: Braden Choy, Bowie Gian, Mint Luc, Swapnil Patel, and Hong Shi.

Thank you for taking the time to review our requirement specification documentation for the Integrated Fire-Control Optic and Ballistic Solution. If there are any questions or concerns with our product, please contact the Chief Executive and Communications Officer Braden Choy at bchoy@sfu.ca.

Sincerely,

Braden Choy
Chief Executive and Communications Officer
Company 15

Integrated Fire-Control Optic and Ballistic Solution

Requirements Specification for ENSC 405W

Company 15
June 12, 2023

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Abstract

This document presents the requirement specification of the Integrated Fire-Control Optic and Ballistic Solution to be met by Company 15. The requirements include the general and functional specifications and are organized into four sections detailed below. Furthermore, each goal is separated according to the product development cycle: proof-of-concept, engineering prototype, and production version. Development constraints will be presented as well as the engineering standards towards safety and sustainability that must be met. The goal of this document is to give the reader a comprehensive understanding of the device's purpose and its intended operation.

The Integrated Fire-Control Optic and Ballistic Solution can be broken down into two distinct products; a rifle optic and a testbed solution. The rifle optic is designed with a laser rangefinder and accelerometers which measure certain variables and outputs a point of aim to the shooter. The testbed solution provides the user a stable shooting platform while providing data on the positioning of the rifle. Each device enhances the user's ability to make difficult shots in non-ideal situations while being intuitive to use.

The requirements will be presented in four sections corresponding to the major subsystems:

1. General Rifle Optic Requirements
2. General Testbed Requirements
3. Hardware Requirements
4. Software Requirements

Finally, this document outlines the planned deliverable product as a proof-of-concept by the end of August 2023 and the key challenges that must be overcome to meet these goals.

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1 Introduction

The modern battlefield is fought in a wide range of non-permissive environments and unpredictable situations. Each contact with the enemy is a dynamic firefight with varying distances, shooting positions, and mental state. In stressful situations, soldiers may not be capable of making accurate ballistic calculations to make effective hits on target.

Automatically compensating the bullet drop of the soldier’s particular rifle system reduces the amount of information a soldier must mentally process to return effective fire at the enemy. Presenting an intuitive interface with quick computation is necessary when seconds count for their survival. Using a laser rangefinder and accelerometers to measure ballistic variables, our optic system aims to display an accurate point of aim for a shooter in whichever position they find themselves in. Ballistically compensated shooting eliminates the wasteful expenditure of ammunition and reduces the high level of experience required to become an effective shooter.

1.1 Background

Rifle shooting from unconventional positions drastically affects the point of impact of bullets, especially at long ranges. Certain variables such as distance, elevation, rifle cant angle, and muzzle velocity all play a role in the trajectory. Rifle scopes are optical instruments mounted to a rifle with a reticle to show the bullet's impact point. However, accurate bullet drop compensation with a scope is limited to a perfectly upright rifle with a known target distance or the shooter’s ability to account for multiple unknown variables. Our optical device aims to automatically compensate for these ballistic variables and relay an intuitive point of aim to the shooter to enhance their shooting capabilities and effectiveness.

Figure 1 - Shooting Targets at Unknown Distances and Elevation [1]

Our device is primarily marketed towards a professional military but civilian and sport shooters also desire similar requirements. Whether the end user implements the device as a training tool or an essential part of their rifle system on the modern battlefield, we believe our optic can be adopted into a wide range of shooting roles. Our product is intended to be used by individuals who require a rifle optic that enhances their accuracy, situational awareness, and target engagement capabilities in diverse environments.

1.2 Current Market Solutions

There are numerous options available in the current scope market to meet the diverse needs of military and civilian shooters. Rifles may be attached with laser rangefinders to provide accurate distance measurements to calculate for bullet drop. Some models include built-in ballistic calculators that consider environmental factors. A recent example is the US Army's XM157 [2][3], which integrates a laser rangefinder and ballistics calculator, displaying the target's point of aim. This integration takes place within a standard analog rifle scope.

The global market for rifle scopes is expected to increase significantly, rising from USD $765.9 million in 2021 to USD $1,193.6 million in 2028 [4]. Additionally, the US Army's XM157 fire control optic was awarded USD $2.7 billion over the next 10 years with an expected 17,164 units to be delivered by the end of 2023 [5]. As the technology becomes more affordable and proven, many shooters from a wide range of experiences will naturally adopt these devices to reduce the complexities of shooting.

Figure 2 - Vortex XM157 Fire Control Optic [6]

1.3 Scope

This document presents the functional requirements of our Integrated Fire-Control Optic and Ballistic Solution. This includes the general functional requirements that the system must fulfill in its entirety and requirements specific to each individual subsystem. The requirements for each product stage will also be categorized accordingly; proof of concept, engineering prototype, and production version. In addition, this document outlines compliance with current Engineering Standards and efforts towards sustainability and safety.

1.4 Intended Audience

This document is primarily intended to guide the members of Company 15 with the functional requirements necessary to develop the Integrated Fire-Control Optic and Ballistic Solution. Moreover, these specifications are presented towards the company's potential clients and partners, Dr. Mike Hegedus, and the teaching staff.

2 Process Details

2.1 Problem Statement

Modern firearm systems require the shooter to mentally account for ballistic variables and positioning under stress which diminishes their speed and effectiveness. Removing the calculations from distracting the shooter allows them to focus on their shooting fundamentals and increase their hit probability.

2.2 Optic System Overview

The Integrated Fire-Control Optic and Ballistic Solution is designed to be mounted onto modern firearm systems and will be battery powered. Ballistics data is embedded into the optic with customisable values to accommodate a large variety of firearms and projectiles.

The optic system will have sensors to detect the range to the target along with the firearm's cant and elevation. A microprocessor will calculate the point of aim in real time and display it on a transparent display to the user. Additionally, a button can be used to lock the distance measurement. This is necessary because the adjusted point of aim may be off the target, changing the sensor values and generating an incorrect point of aim. A block diagram of the optic system is shown below.

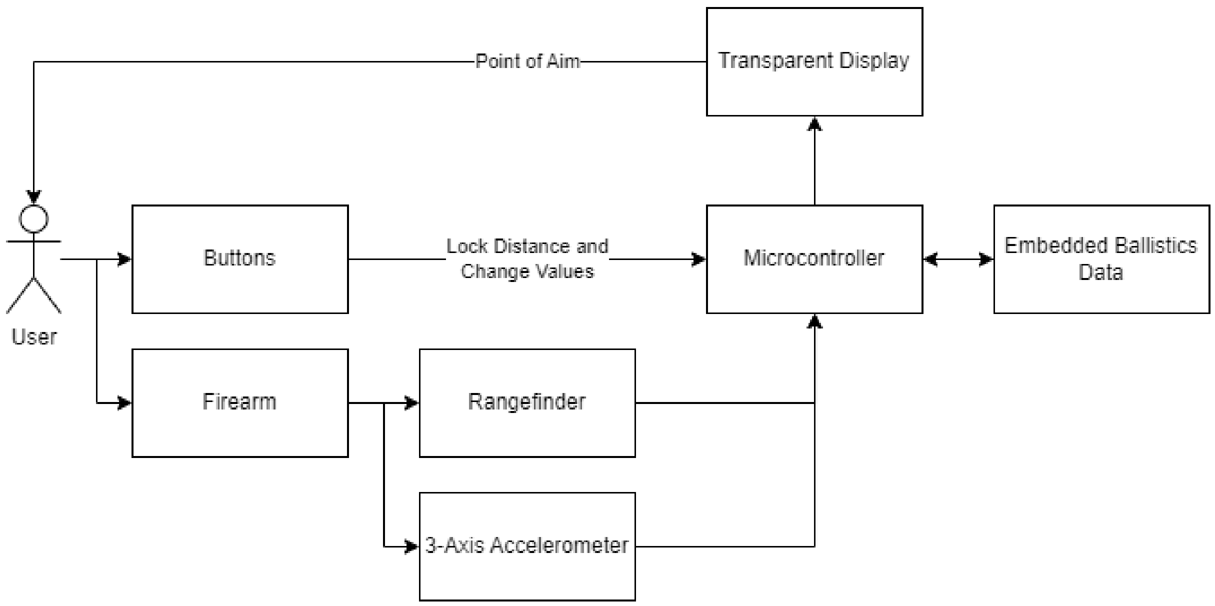

Figure 3 - Fire Control Optic Block Diagram

2.3 Testbed System Overview

In addition to the fire control optic will be a testbed system, used to calibrate and verify the optic. The testbed will securely hold the firearm while displaying real time measurements about the firearm's positioning. The user can adjust and lock the cant and elevation of the firearm. A manual trigger control will be included to reduce the movement of the firearm while pulling the trigger. A block diagram of the testbed system is shown below.

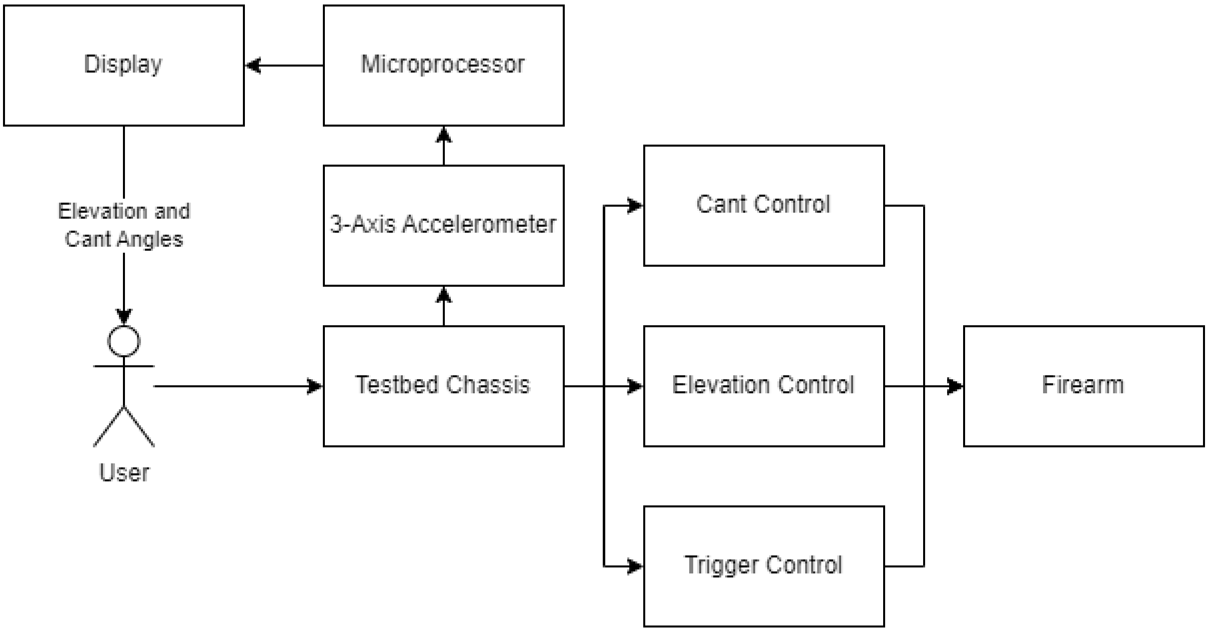

Figure 4 - Testbed Block Diagram

3 Requirements

3.1 Requirement Types and Classification

The requirement categories are organized into four sections: General Rifle Optic, General Testbed, Hardware, and Software. Each requirement will be labeled in compliance with the following convention:

Req {Section}.{Subsection}.{Requirement Number}

Three further subclassifications are designated based on when each requirement is to be met in the product's development cycle.

Project Tag	Project Stage
A	Proof of Concept
B	Engineering Prototype
C	Production Version

Table 1 - Development Stage Encoding

3.2 General Rifle Optic Requirements

The following table outlines the general requirements of the rifle optic system.

ID	Tag	Requirement Description
Req 3.2.01	A	Optic will be modular and integrate via standard rifle attachments
Req 3.2.02	A	Calibration and setup process is intuitive to the user
Req 3.2.03	B	Optic will weigh under 2.5 pounds
Req 3.2.04	B	Optic will be no larger in size than a conventional rifle scope
Req 3.2.05	B	Optic placement on the rifle will minimize torque load to the shooter
Req 3.2.06	C	Final product will cost under $500
Req 3.2.07	C	Optic will operate for longer than 100 hours with one battery charge
Req 3.2.08	C	Optic will display a high resolution point of aim that is easy for the shooter to identify the target
Req 3.2.09	C	Optic will be in compliance with military standards

Table 2 - General Rifle Optic Requirements

3.3 General Testbed Requirements

The following table outlines the general requirements of the testbed system.

ID	Tag	Requirement Description
Req 3.3.01	A	Testbed will hold a firearm securely under recoil
Req 3.3.02	A	Testbed will have two degrees of freedom
Req 3.3.03	A	Testbed will allow adjustment of firing position based off a closed loop feedback system with the optic
Req 3.3.04	A	Testbed will accurately measure and quantify performance of the optic
Req 3.3.05	A	Calibration process is intuitive to the user
Req 3.3.06	B	Testbed deployment will take less than 60 seconds
Req 3.3.07	C	Testbed will weigh under 10 pounds

Table 3 - General Testbed Requirements

3.4 Hardware Requirements

The following table outlines the general requirements of the system hardware.

ID	Tag	Requirement Description
Req 3.4.01	A	All optic hardware will be mounted on a firearm
Req 3.4.02	A	The rangefinder needs to operate over 100m
Req 3.4.03	A	Hardware will not obstruct the user
Req 3.4.04	B	All hardware will be powered by battery
Req 3.4.05	C	All hardware will be durable or protected from the elements
Req 3.4.05	C	Optic will compensate for parallax

Table 4 - Hardware requirements

3.5 Software Requirements

The following table outlines the general requirements of the system software.

ID	Tag	Requirement Description
Req 3.5.01	A	Software will receive range data from a sensor
Req 3.5.02	A	Software will receive acceleration data from a sensor
Req 3.5.03	A	Ballistic calculations are done within the micro-controller
Req 3.5.04	A	Calculated point of aim will be output as pitch angle
Req 3.5.05	B	Software will receive tilt angle from sensor and added to calculation

Req 3.5.06	B	User can lock the current distance measurement
Req 3.5.07	B	Simple interface to display bullet trajectory to user
Req 3.5.08	C	Current distance and tilt are displayed to the user
Req 3.5.09	C	Calculation will take less than 100ms to be displayed to the user

Table 5 - Software Requirements

3.6 Constraints

The biggest constraint to our fire control and ballistic solution will be a balance between budget and performance. Laser rangefinders can cost from $250 upwards to $10000. Even at the lowest end, the majority of our limited budget will be spent on a laser range finder. Additionally the inability to purchase higher resolution sensors and extra computational power will affect computational time and accuracy.

Another consideration will be the weight and size of the optic. Soldiers deploying this system will be burdened with an additional load when firing. We plan to minimize the absolute weight by researching different housing materials and minimize the effective weight of the optic by optimizing ergonomics. Research on the impact of recoil due to additional loads will be required.

Lastly, we will have to consider test bed constraints. Testing and reproducibility of the optic will largely rely on the accuracy of the test bed. A closed loop system between the testbed and optic will be required to minimize setup and calibration errors.

4 CEAB Outcomes

4.1 Responsibilities of an Engineer

The engineering responsibilities for the project involve various crucial aspects throughout the development and production process of the product. Engineers have a critical responsibility to ensure the highest level of reliability in terms of accuracy, as the scope may be used in high-stress survival situations. Accuracy is critical because it has a direct impact on the effectiveness and success of the product.

4.2 Standards

4.2.1 Electrical Standards

The following table outlines the electrical standards for our project.

Standard	Description
CSA C22.2 NO. 0:20	Canadian Electrical Code General Requirements
CSA C22.2 NO. 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
ISO 12233	Methods for measuring the resolution and the SFR of electronic still-picture cameras
IEEE 1481	Delay and power calculation for integrated circuit design with support for modelling logical behaviour and signal integrity
ANSI/ISA-12.12.01	Minimum requirements for the design, construction, and marking of electrical parts for use in hazardous locations.

Table 6 - Electrical Standards

4.2.2 Software Standards

The following table outlines the software standards for our project.

Standard	Description
IEC 61508	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems

Table 7 - Software Standards

4.2.3 Military Defense Standard

The following table outlines the military standards for our project.

Standard	Description
MIL-STD-810H	Considering the influences that environmental stresses have on materiel throughout all phases of its service life
MIL-STD-1913	methods of dimensioning accessory mounting rails for small arms weapon systems (Picatinny rail)
MIL-STD-1472	human engineering criteria for design and development of military systems
SAAMI Z299.3	Performance standards for pressure and velocity of ammunition

Table 8 - Military Standards

5 Sustainability and Safety

Our design goal is to emphasize modularity and size, enabling us to create a product that is not only efficient but environmentally friendly. A modular approach ensures that our optics can be easily repaired and upgraded, reducing the need for frequent replacements and minimizing electronic waste. Additionally, our focus on size optimization reduces the amount of raw materials required during production.

We will integrate military considerations to ensure reliability and durability. By designing our products with robustness as a priority, we create solutions that are less likely to break and require replacements, thus reducing the overall waste generated. Our audience will notice an extension of lifespan in day-to-day use, minimizing the environmental impact associated with frequent optic replacements.

Additionally by conforming to military standards, we are able to develop a product that meets the highest safety requirements.

The following table outlines the sustainability and safety considerations for our project.

ID	Tag	Requirement Description
Req 5.1.01	A	All exposed wires have insulative protection
Req 5.1.02	A	Sufficient isolation between sensitive electronics and user
Req 5.1.03	C	Ability to operate in low power scenarios
Req 5.1.04	C	Shock and vibration resistance
Req 5.1.05	C	Water and environmental resistance

Table 9 - Safety/Sustainability Requirements

6 Conclusion

In conclusion, our objective is to develop a scope that revolutionizes accuracy and enhances the shooting experience for both military and civilian shooters. Our primary focus is to provide shooters with a highly precise and reliable product that enables them to improve their performance. Through the integration of advanced features such as rangefinders, ballistics calculators, and high-resolution point-of-aim displays, our scope transforms into a sophisticated tool that assists shooters in making precise aiming adjustments. Ultimately, scopes serve as indispensable tools that empower shooters to achieve exceptional accuracy and outstanding performance in their shooting experience.

7 Appendix

7.1 Proof of Concept Deliverables

This section outlines the key functionalities of our optic that will be presented at the proof of concept poster presentation in August 2023:

- The optic will detect the range of the target and the position of the firearm
- The calculated point of aim will be given as the angle of elevation
- The optic will be battery powered and mounted on a prop firearm
- The testbed will hold a prop firearm securely
- The testbed will allow adjustment and locking of two degrees of freedom, elevation and cant
- The testbed will display the firearm’s cant and elevation angles

7.2 Key Problems to be Addressed

In order to achieve the proof of concept product listed above, these key problems need to be addressed:

- Precise alignment of the optic along with its sensors on the firearm
- Testing the ballistics calculation
- The rangefinder’s maximum range
- Compatibility between components

8 References

[1] T. 1 Group, “1000m unknown distance (UKD) range,” T1G, https://t1g.com/project/1000m-unknown-distance-ukd-range/ (accessed Jun. 11, 2023).

[2] T. South, “Army finally picks an optic for next generation squad weapon,” Army Times, https://www.armytimes.com/news/your-army/2022/01/07/army-finally-picks-an-optic-for-next-generation-squad-weapon/ (accessed May 25, 2023).

[3] P. Suciu, “Army selects optics for Next Generation Squad Weapon,” The National Interest, https://nationalinterest.org/blog/buzz/army-selects-optics-next-generation-squad-weapon-200255 (accessed May 26, 2023).

[4] “Rifle Scopes market size, share & covid-19 impact analysis, by magnification (1-8x, 8-15X, and greater than 15x), by sight type (telescopic and reflective), by end-use (commercial and defense), and Regional Forecast, 2021-2028,” Rifle Scopes Market Size, Share, Growth and Forecast, 2028, https://www.fortunebusinessinsights.com/riflescopes-market-105869 (accessed Jun. 11, 2023).

[5] C. Eger, “More on SIG’s $4.5 billion Army rifle, machine gun contract,” Guns.com, https://www.guns.com/news/2022/04/22/more-on-sigs-45-billion-army-rifle-machine-gun-contract (accessed Jun. 11, 2023).

[6] G. J. Sagi, “Vortex Selected To Produce Army NGSW Fire Control Optic,” American Rifleman, https://www.americanrifleman.org/ (accessed Jun. 11, 2023).