July 25, 2021

Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 405W Project Proposal for **Guardian Sight™**

Dear Dr. Scratchley,

Please find attached to this letter the Guardian Sight™, Project Proposal for ENSC 405W in conjunction with ENSC 440. Guardian Sight™ allows for real time feedback on posture and form, providing easy corrective suggestions to the end user. Guardian Sight™ is intended to make accessible the knowledge a personal trainer has to those who may not have access to one. However, Guardian Sight™ should not be taken as a replacement for real professional advice.

This document will provide a high level understanding of Guardian Sight™. This document will go over the project overview, risks, and benefits. It will also cover the market and potential competitors to Guardian Sight™. Details of the team organization, project planning, costs of the project, and potential funding will also be covered.

Tech-Fit is a company of senior engineering students from predominantly computer engineering backgrounds. The team consists of computer engineers: Hamlet Jiang Su, Johnston Yang, Allan Tsai, Andrew Chen, and Luke Gair, as well as engineering physicist Landon Reeves.

We sincerely appreciate the time taken to read the project proposal document for Guardian Sight™ . All questions and concerns can be addressed to our Chief Communication Officer, Landon Reeves, who can be reached at landon_reeves@sfu.ca. Tech-Fit will be happy to address all questions, issues, and concerns.

Regards,

Luke Gair
Chief Executive Officer
Tech-Fit

Guardian Sight™

Tech-fit

Project Proposal

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ENSC 405W: Capstone A

School of Engineering Science

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Last Revision: 2021-07-25

Executive Summary

As more people find that they are able to work from home, the amount of people looking for home workouts is rising. When exercising and working out from home, it is easy to develop improper form, posture, and bad habits from lack of knowledge and experience [1].

Guardian Sight™ by Tech-Fit is a product that aims to improve a user's form and posture when performing at-home workout routines. The purpose of this product is to reduce the number of injuries from improper form. Tech-Fit's Guardian Sight™ prototype uses a feedback system to alert the user in real-time whenever their posture or form is incorrect. This is achieved using the combination of computer vision techniques and sensors to determine the user's posture and related physiological data.

The Guardian Sight™ prototype can be subdivided out into its main components which include the camera system, sensor system, microcontroller system, and the user interface. The camera and sensor system work in tandem with the microcontroller system to output real time feedback to the user.

Guardian Sight™ has a large pre-existing market. Guardian Sight™ takes advantage of shifting market trends, to capture a part of the market that chooses to work out from home. Currently the market for home fitness equipment is projected to reach $14.74 Billion by 2028 [2]. Guardian Sight™ can also work in a commercial gym environment as an affordable alternative to gym members hiring a personal trainer.

This document outlines the company's policies and strategies to avoid and mitigate risks. Major risks described in this document are market analysis failure, analytical failure, and hardware failure.

Tech-Fit hopes to provide an effective alternative to assist people in their personal workout routines, particularly for those who are working out from home. Our team of six engineers has experience in hardware, electronics, and software design and is actively working to develop and improve Guardian Sight™. Tech-Fit provides opportunities for people to exercise safely and effectively from home.

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1 Introduction & Background

1.1 Background

Many people lack the means or availability to contact a professional trainer to ensure that they are working out safely and using proper form. As a result, people are working out in ways that may pose an increased risk of causing a preventable injury [3]. This is directly related to a lack of knowledge on how to prevent these injuries. More people are choosing to do activities that can be done from the comfort of their own homes. Guardian Sight™ is an opportunity for people to fundamentally rethink the way they approach personal fitness and working out, by providing people with the opportunity to work out at home with a lower risk of causing personal injury.

Guardian Sight™ helps people maintain proper form during workouts and exercise routines, all from the comfort of their own homes. Guardian Sight™ has the capability to alert the user through visual and auditory cues when they need to correct their form.

1.2 Document Scope

The purpose of this document is to provide an overview of the Guardian Sight™ product and provide justification of its marketability. Design choices will be provided along with justification for the decisions made.

2 Project Overview

The following section provides a high-level overview of the three major systems that work together to detect, alert, and guide a Guardian™ Sight user in the event of improper form. The systems include a camera that records the user's movements, a microcontroller that processes the camera data to provide feedback, and a system of sensors attached to the user that provide important physiological data. All of this information will be output to a display that will provide feedback in both visual and auditory forms. This information is synthesized in Figure 2.1 below.
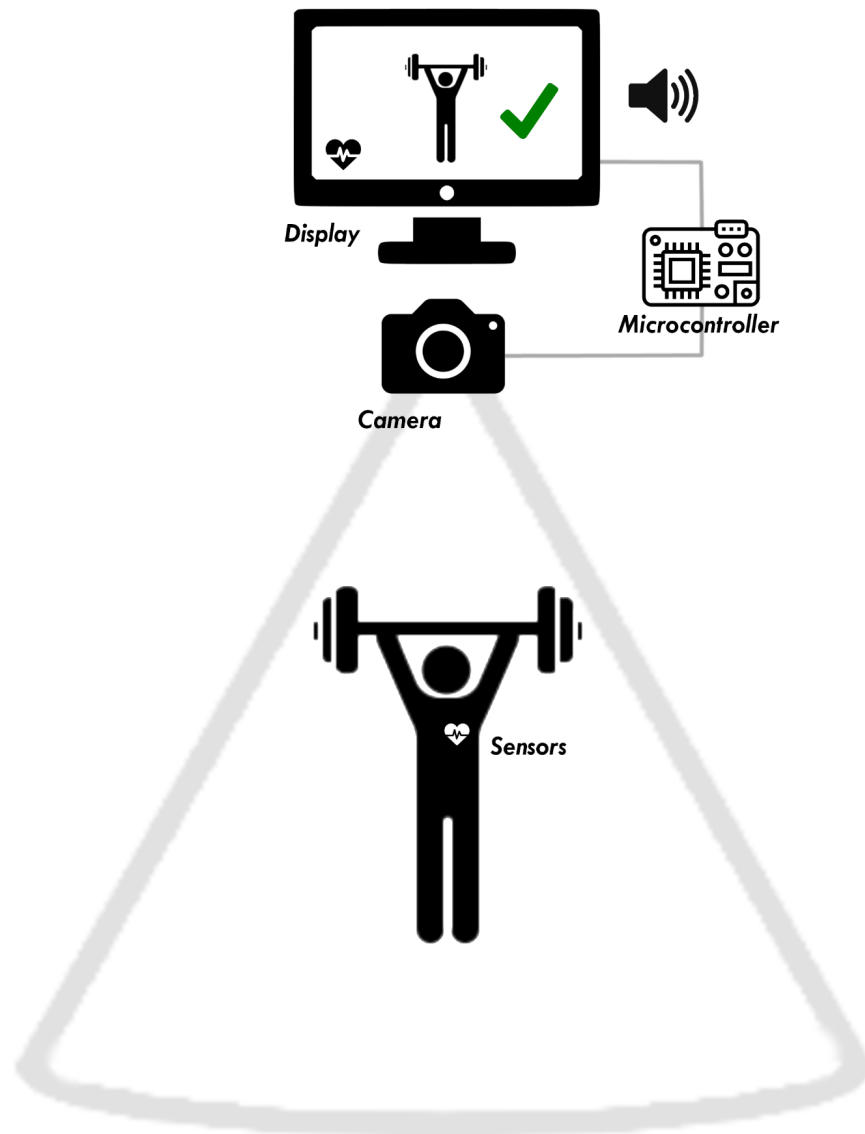
Figure 2.1 - System Setup: including camera, microcontroller, and sensors being output to the display

A diagram of the interactions between the hardware and software components of the system is shown in Figure 2.2 below.
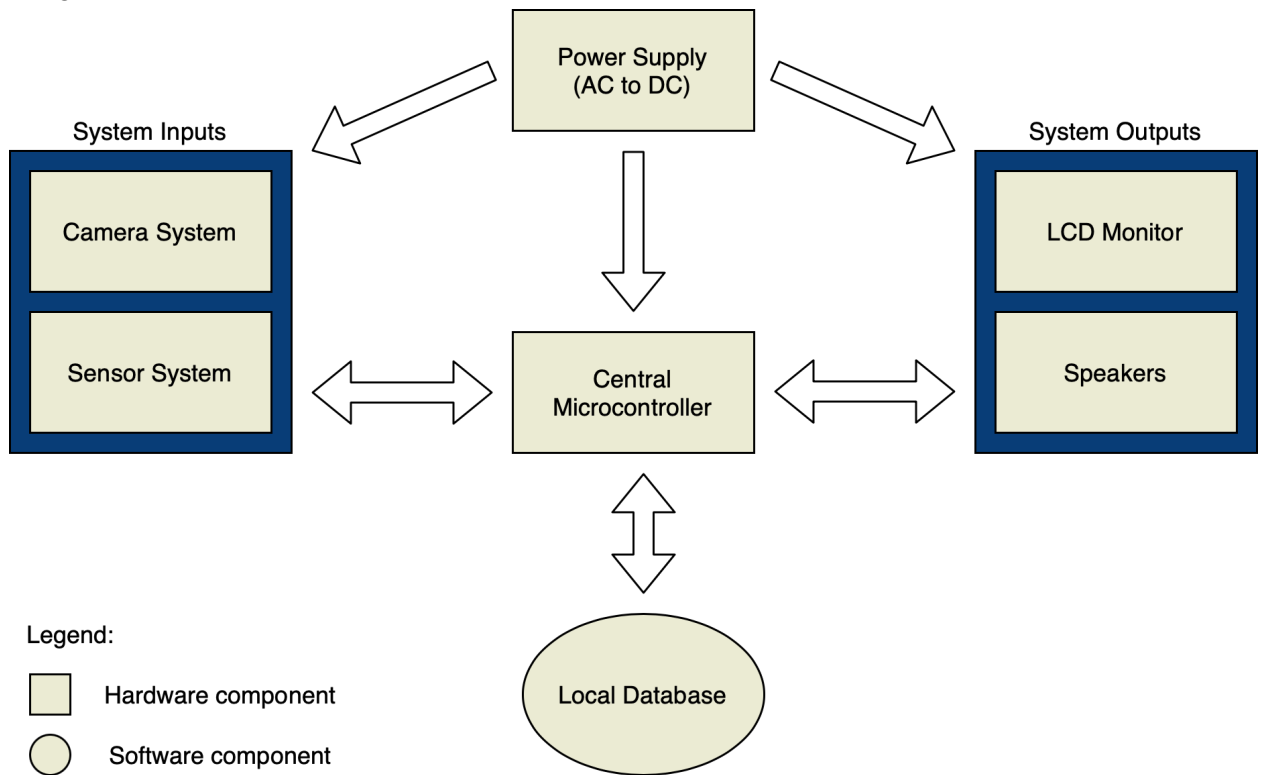
Figure 2.2 - System Block Diagram: detailing interaction between hardware and software components

2.1 Camera System

The purpose of the camera system is to capture information about the user's posture, form, and position during a workout routine. The system uses Google's MediaPipe computer learning algorithm to figure out the user's position. The camera that will be used is the e-CAM30_CUTX1.

2.2 Sensor System

The purpose of the sensor system is to analyze data collected during a user's workout routine. The sensor system will consist of a device that attaches to the user's body and uses a MAX30102 Sensor to measure physiological data. The physiological data includes the user's heart rate, and may also include other metrics such as blood oxygen levels. This data will be visualized on a display where it can be used to judge the quality of the workout routine.

2.3 Microcontroller System

The microcontroller system is responsible for processing the data provided by the camera and sensor systems. Given the inputs, the system will determine the user's current and expected posture, and output visual and auditory feedback through the use of a display and speaker. The main controller system is implemented using the Jetson TX2 Module. The sensor system has its own microcontroller which is implemented using an Arduino Uno Rev 3.

2.4 User Interface

In figure 2.4.1, the menu selection functionality can be observed, where the user cycles through each menu option. When a menu item is selected, it's appearance changes to indicate to the user that their input is having an effect. The design is simple and intuitive with content being easy to find. For early prototypes, the UI can be interfaced with a keyboard and mouse, but a market ready version would have touch screen support.
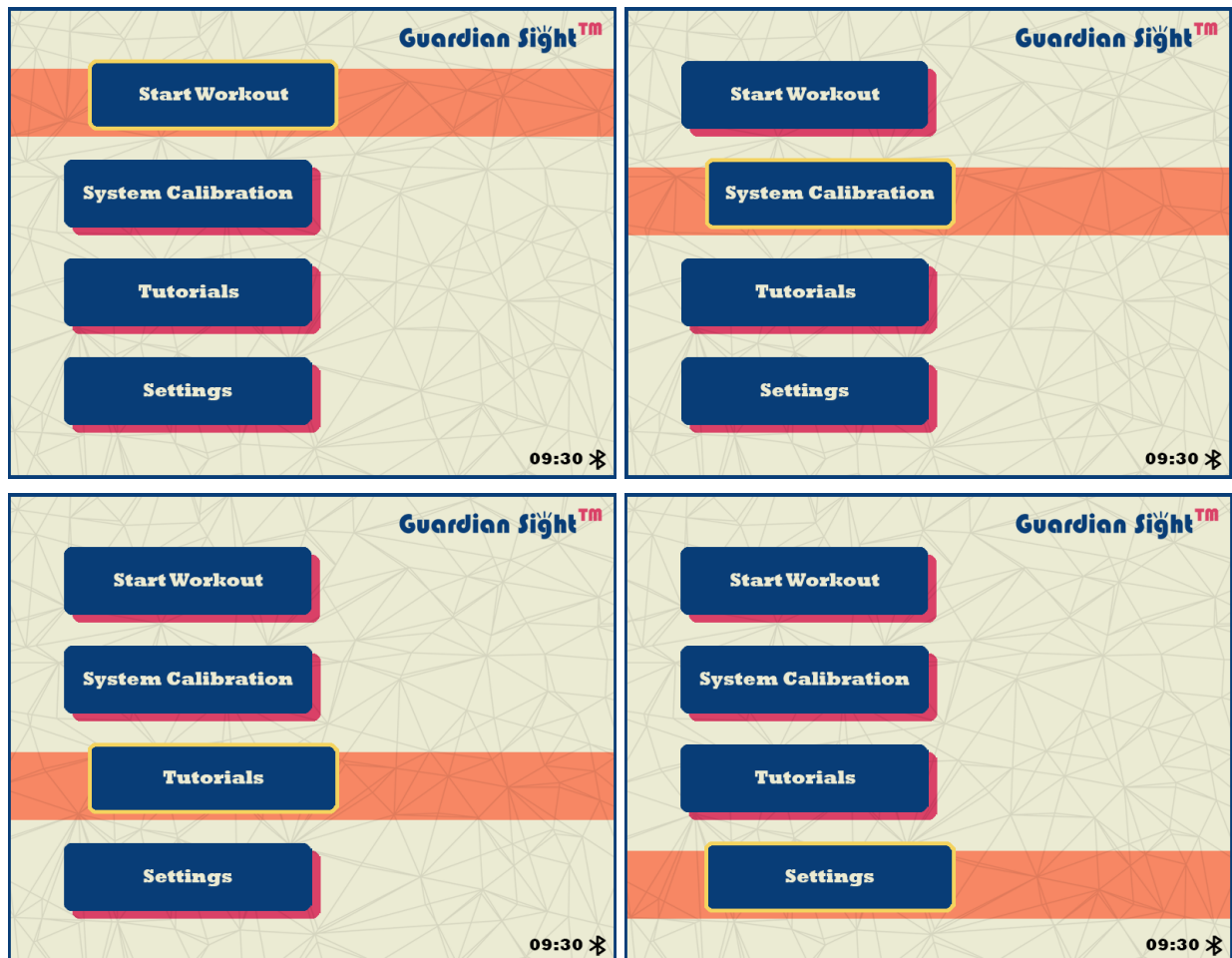
Figure 2.4.1 - Menu Selection: demonstrating the user being able to cycle through menu options
Top Right: Start Workout, Top Left: System Calibration, Bottom Right: Tutorials, Bottom Left: Settings

Figure 2.4.2 demonstrates the functionality of Guardian Sight™ during a workout. An example where good form is being observed is included alongside an example where bad form is being observed. The feedback system relies heavily on existing signifiers that the user should be familiar with. The user being outlined in green and a check mark being displayed indicate a success and the target area being outlined in red and an X being displayed indicate a failure. For accessibility purposes, or because the user may be unable to look at the screen depending on the workout being performed, feedback can also be provided through auditory means.

Figure 2.4.2 - Exercise Feedback Demo: demonstrating behaviour in the case of good and bad form

3 Risks & Benefits

3.1 Risks

Risks are particularly important for a product like Guardian Sight™ and significant effort will be made to ensure that users are made aware of the potential risks of using exercise equipment. Users need to be aware of the extent of liability that Guardian Sight™ assumes in the event of an injury. It is important for users to understand that Guardian Sight™ is not a valid replacement for a personal trainer or other exercise professional.

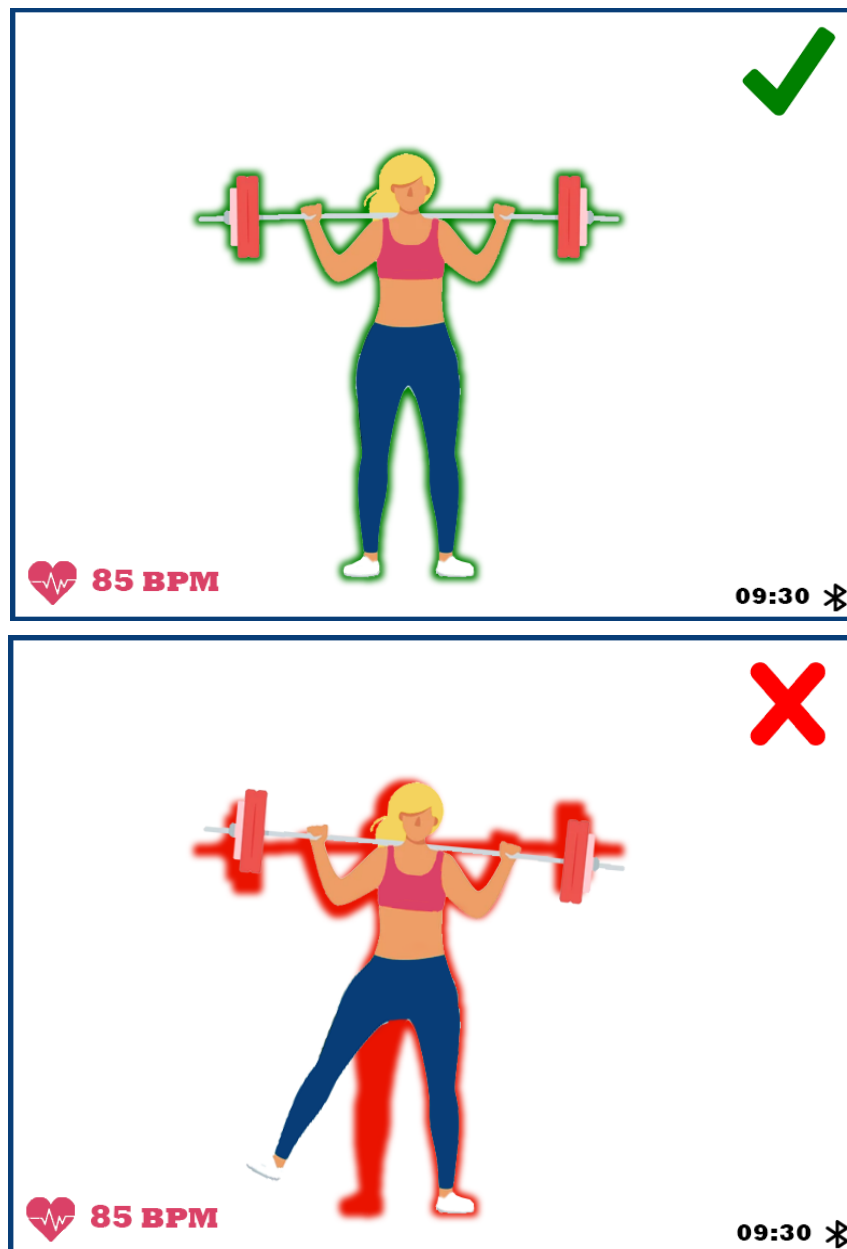### 3.1.1 Analytical Failure

Guardian Sight™ aims to provide a visual aid to assist the end user with their chosen exercise as accurately as possible. However, studies have shown that no software can be completely accurate [4]. Trials and extensive effort will be made to test out the functionality and reduce the chance of error, but it is not possible to remove all risk. To mitigate further risks, the final system will allow users to provide feedback and report issues. Software updates will be provided regularly to improve functionality based on feedback.

3.1.2 Data Security

Tech-Fit aims to provide sustainable long term service to Guardian Sight™ users. The production phase version of Guardian Sight™ will allow users to download new workouts. Since the product stores user data, data security is a top priority. As specified in the requirement specification document, care will be taken to follow the General Data Protection Regulation (GDPR) data standard as proposed by the European Union.

3.1.3 Hardware Failure

There may be risks of hardware failure associated with possible shorting with the heart rate sensor as contact needs to be made between the sensor and the user. From extensive physical activities, excessive sweat may come into contact with the heart rate monitoring device. To mitigate this, the hardware team intends to make the wearable device water resistant.

3.2 Benefits

Guardian Sight™ aims to empower users to work out safely and properly by providing visual and auditory guidance. This section will therefore provide more details on the benefits that Guardian Sight™ offers.

3.2.1 Stakeholders

From the perspective of our stakeholders, the largest cost for Guardian Sight™ is the initial development cost of software and hardware. With sufficient funding to reach the production phase, we anticipate profit from sales to return dividends to investors.

3.2.2 Users

For the end user, Guardian Sight™ is more than just a virtual exercise assistant. Guardian Sight™ promotes a healthier lifestyle by offering convenient assistance for the user. The user is able to exercise with correct form from their own home without the hassle of searching for a personal trainer.

3.2.3 Commercial Gyms

Guardian Sight™ also provides a less costly alternative for commercial gyms by substituting the recurring costs of in-house personal trainers with an initial upfront cost of setup.

4 Market & Competition

Guardian SightTM is a product that offers data-driven solutions to proper physical fitness. It is designed to be easily installed into a chosen area with minimal setup time. It is primarily aimed towards a higher-end market such as commercial gyms and in-home gym setups. According to statistics taken from 77 gyms, the majority of people with a membership fall in the age range of 18 - 54 [5]. As such, marketing will be geared towards adults within that age range.
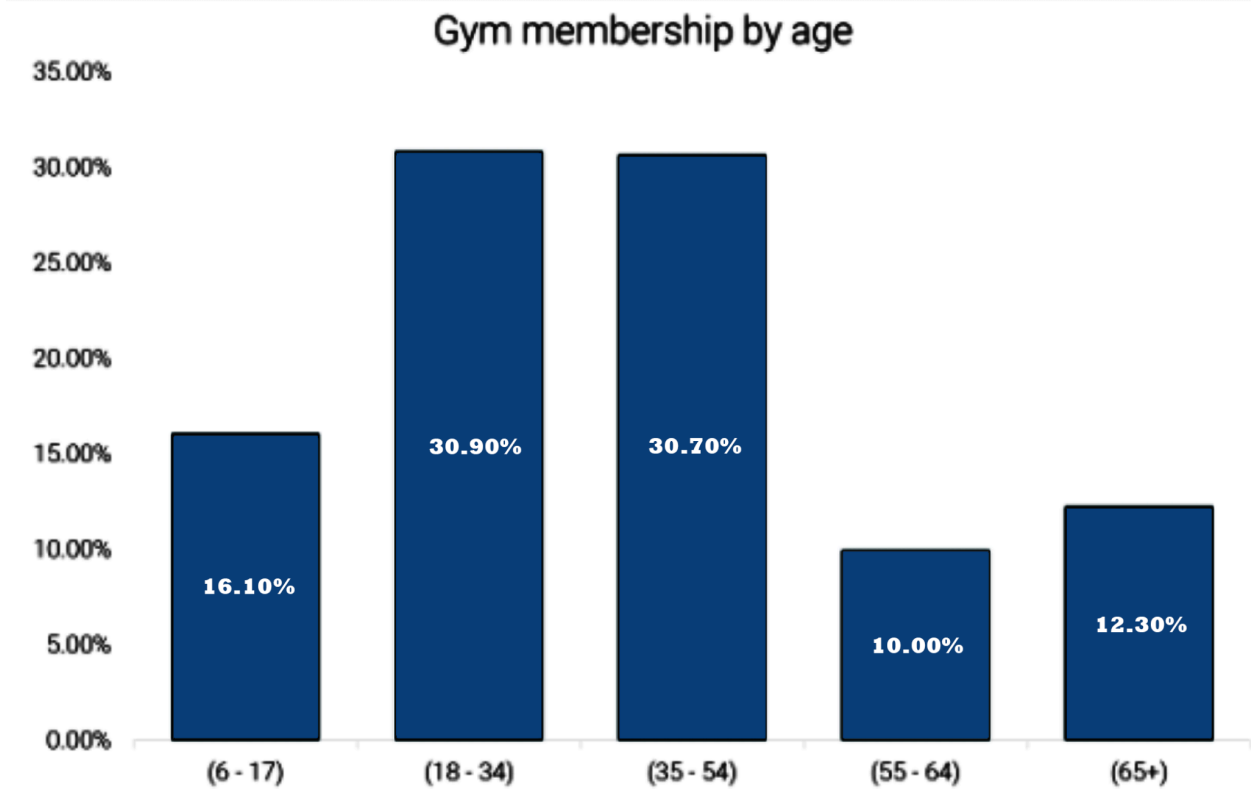
Figure 4.1: Age demographic of gym members [5]

4.1 Market for Smart Gyms Devices

Smart fitness devices are a relatively new technology that is advancing by the day. The market for smart home gym equipment is anticipated to grow at a compound annual growth rate of 9.2% between 2020 and 2026 [6]. With current trends, even non-fitness enthusiasts are giving more importance to their health and fitness [7]. In figure 4.1.1, the expected market size for all home fitness equipment can be seen to increase.
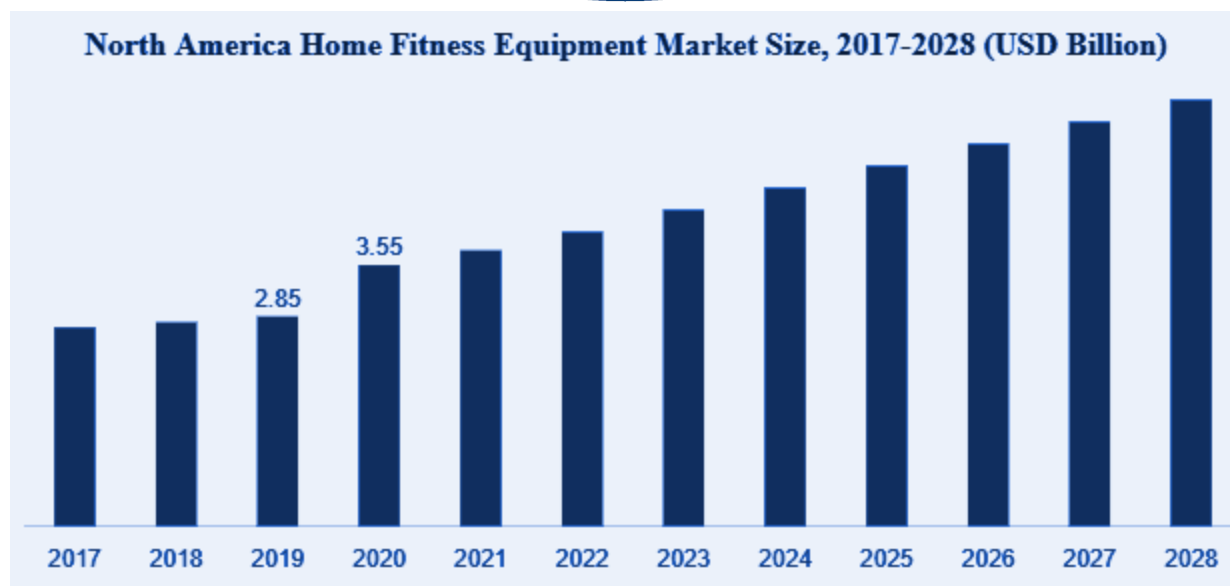
Figure 4.1.1: Expected Home Fitness Equipment Market Size [7]

There are many driving factors contributing to this rise in market size. There has been a significant increase in healthcare spending and health consciousness. Other factors such as a comfortable environment at home, personalized exercise programs, and consumer health awareness continue to drive the home fitness market[8].

4.2 Market for Users

4.2.1 Commercial Gyms

Health club memberships in America have been steadily increasing over the decade. Between 2018 and 2020 alone, it increased by 5.5% [5]. From an online survey taken in America, roughly 77% of people go to the gym alone [9]. Depending on the exercise, there are disadvantages to going to a gym alone. For exercises that require proper form, such as squats or a deadlift, it is impossible to accurately check form using only a mirror.

Gyms that offer Guardian Sight^{TM} can be more attractive to individuals that go to gyms alone, and would like feedback about their form. Members will have the opportunity to perform their daily routine without needing assistance.

From a cost standpoint, Guardian Sight^{TM} will reduce the costs of maintaining the gym. The average personal trainer in 2018 cost $40,000 USD per year [10]. Guardian Sight^{TM} can serve as a supplement to personal trainer guidance and reduce the amount of personal trainers needed on the gym floor at one time.

4.2.2 Home Gyms

As mentioned earlier in section 4.1, there are many driving forces behind the need for home fitness equipment. The convenience of being able to perform a workout at home decreases the time spent commuting. This is especially true for city dwellers that rely on transit where there may not be a gym easily accessible by transit. With Guardian Sight™, people will be able to perform workouts the correct way without needing to go to a gym in person or be in a video call with an expert.

4.3 Competition

4.3.1 VERA by Reflexion Health

A likely competitor for Guardian Sight™ is VERA by Reflexion Health. VERA is different in that it provides a platform for connecting with therapists who monitor the patient from recorded video clips [2]. However, Guardian Sight™ has a broader audience and use case and has utility in both commercial gym and home workout environments [11].

4.3.2 Tempo Studio by Tempo

A potential competitor is Tempo Studio by Tempo. Tempo uses a single 3D sensor camera to capture every nuance of a person's movement while they work out. Their product has a built-in monitor and stand that can hold Tempo weights, as well as a mobile app to plan training on the go [12]. The key difference between Guardian Sight™ and Tempo Studio is that Tempo does not provide feedback on how to correct posture. It displays a model of how the exercise should be done and indicates where improper posture is, but does not clearly indicate how much adjustment needs to be made.

Another point of difference between the two products is the price point. Tempo Studio has three bundles to choose from ranging between $2495 USD to $3995 USD, or $3139 to $5025 CAD [12]. A detailed cost analysis is laid out in section 7 of this report. It is our hope that after considering economies of scale, a production phase version of Guardian Sight™ would be comparable in cost.

5 Company Details

5.1 Team Members

Luke Gair (CEO) - Chief Executive Officer

As a fifth year Computer Engineering student, Luke is highly interested in software development as well as hardware and electronic design, enabling functional code to run more effectively on embedded systems. Luke has experience in the workforce as a full stack developer in laravel and MySQL for web platforms as well as as a verification and validation test engineering for medical devices. Luke has experience with requirements engineering design and documentation. These skills allow Luke to manage group resources effectively as CEO.

Hamlet Jiang Su (CTO) - Chief Technology Officer

Hamlet is a fifth year Computer Engineering student. His interest lies in web development and low level hardware design. Hamlet has experience in project management and creating responsive web applications using Javascript frameworks from his past co-ops. These skills will be useful for the development of Guardian Sight™. As CTO, Hamlet is responsible for ensuring the technological needs of the team are met.

Johnston Yang (CFO) - Chief Financial Officer

Johnston is a fifth year Computer Engineering student. He has experience in designing User Interfaces for programs and software development experience from personal projects and from the industry. These experiences will come in handy when working on the Guardian Sight™ project. As CFO, Johnston is in charge of managing and planning financial decisions.

Andrew Chen (COO) - Chief Operating Officer

Andrew Is a fifth year Computer Engineering student. He has interests in learning more techniques for CAD design. From his past co-op semesters, he has experience working with motion sensors and controlling a wireless robot using computer vision. This experience will come in handy since Guardian Sight™ also uses computer vision.

Allan Tsai (CAO) - Chief Analytics Officer

Allan is a fifth year Computer Engineering student at Simon Fraser University with a strong interest in computer graphics and software development. He has accomplished co-op experiences at Sierra Wireless as a software test engineer and at SAP as a web developer. These experiences will be applied to ensure that operations at Tech-Fit will function correctly and smoothly.

Landon Reeves (CCO) - Chief Communications Officer

Landon is in his final year of an Engineering Physics degree. He is passionate about both social and environmental issues. Landon has extensive experience in project management through his involvement in extracurricular activities. He also has extensive experience with graphic design which has been very useful when creating mock ups of the UI and developing a consistent brand for Tech-Fit. As CCO, Landon is responsible for communicating with the administrative team and ensuring proper communication amongst team members.

5.2 Team Organization

In Table 5.2.1 below, the three different teams of Tech-Fit are shown. The three teams are the Computer Vision Team which is lead by Allan Tsai, the Hardware Interface Team which is lead by Hamlet Jiang Su, and the Technical Exercise Knowledge Team which is lead by Landon Reeves. These teams are tentative, and people will move around based on need in any given week.

Table 5.2.1 - Tech-Fit Teams

Team	Members
Computer Vision	Luke Gair Hamlet Jiang Su Johnston Yang Andrew Chen Allan Tsai - Team Lead
Hardware Interface	Luke Gair Hamlet Jiang Su - Team Lead Landon Reeves
Technical Exercise Knowledge	Johnston Yang Andrew Chen Landon Reeves - Team Lead

Figure 5.2.1 shows a Gantt Chart showing the expected relative duration that each individual team will need to be active during the prototyping process. Since computer vision is fundamental to the project, the time at the beginning of the project is dedicated to it. As progress is made, the hardware interface team will begin to attempt to integrate their work with the work being done by the computer vision team. After a functioning prototype that can detect body postures is achieved, the technical exercise team will consult with professionals to ensure that Guardian Sight™ can provide accurate feedback about correct form to the user during workouts.
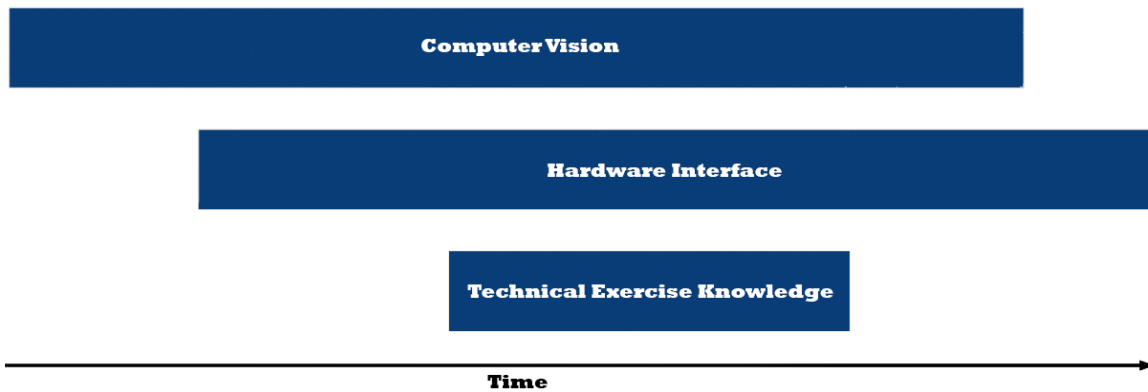

Figure 5.2.1 - Team Activity Timeline: Gantt Chart showing the expected duration each team will be active

6 Project Planning

Guardian Sight™ will consist of two stages of design. This includes an alpha prototype and a beta prototype.

The alpha phase of the project will place a major focus on developing a prototype that achieves the basic scope outlined in the requirement and design specification documents. The alpha phase will be completed by the end of ENSC 405W in August 2021. The alpha prototype of Guardian Sight™ will contain functionality such as:

- Detecting and displaying the posture/form of a user to an external monitor
- Basic algorithms to detect the correctness of a user's form with some margin of error
- Detecting and displaying heart rate information to an external monitor
- Functional user interface for a user to select an assortment of exercises
- Appearance prototype to show how the final product would look like

The beta phase of the project will be completed by the end of ENSC 440 in Fall 2021. This prototype will contain further improvements and refinements of the alpha prototype. The beta prototype will contain functionality such as:

- Usage of more powerful hardware if necessary
- Improvements to the computer vision and pose detection algorithms on multiple exercises
- Addition of audio cues for user and refinement of the user interface
- Improvements and miniaturization of the sensor system to fit on a user
- Improved enclosures to contain all the hardware used for Guardian Sight™

For each figure shown below, the bolded text with the blue background refers to the milestone and any activities below that are the tasks within the milestone.

Figure 6.1 outlines the current progress of Guardian Sight™ for the alpha phase. The main milestones in Figure 6.1 are project idea conceptualization, progress review meeting I, requirements specifications, and progress review meeting II. The project idea conceptualization milestone is where the team brainstormed ideas and determined which project the team wanted to pursue. The progress review meeting I is when the team first presented the idea of Guardian Sight™ to the teaching team. The requirements specification milestone is where Tech-fit determined the specifications Guardian Sight™ would have. Finally, the progress review meeting II is when the team showed a demonstration of our progress up to that point.
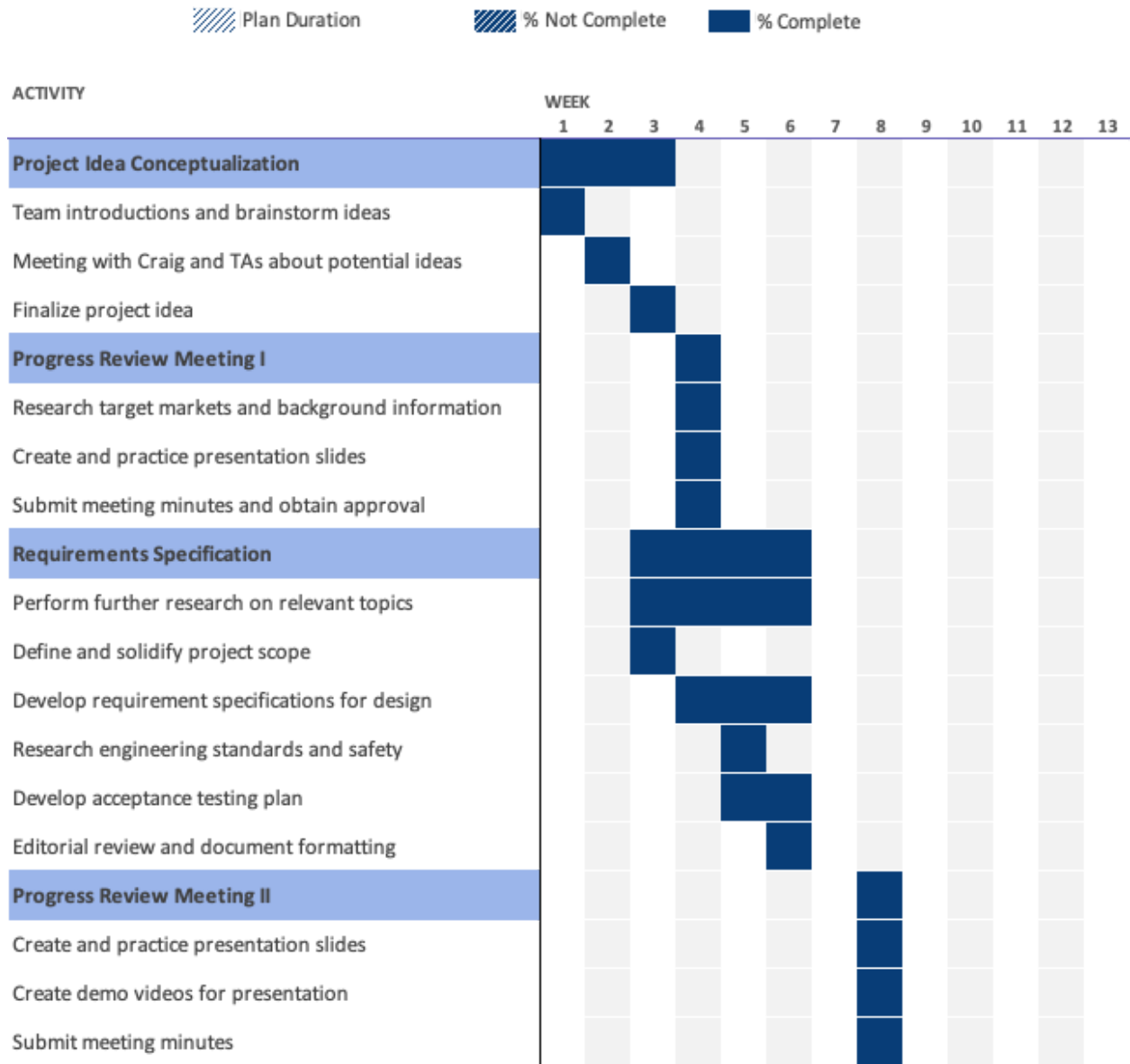
Figure 6.1 First Alpha Phase Milestone Chart

Figure 6.2 below outlines more milestones for the alpha phase of Guardian Sight™. The main milestones are design specification document, proposal document, alpha prototype implementation, and proof of concept presentation. The design specification document milestone is where the team decides how the requirements specified in the requirements document will be achieved, create test plans, and create a User Interface (UI). The alpha prototype implementation milestone describes what Tech-fit will do to make an early prototype of Guardian Sight™. Finally, the proof of concept presentation will show the professor and teaching assistant the completed alpha prototype of Guardian Sight™.

Figure 6.2 Second Alpha Phase Milestone Chart

The milestone chart for the beta prototype is shown in Figure 6.3. The milestone here is to improve Guardian Sight™ from alpha prototype to beta prototype. Some activities here include switching to NVIDIA Jetson TX2, adding SpO2 measurements, refining the MediaPipe implementation, and refining the user interface.
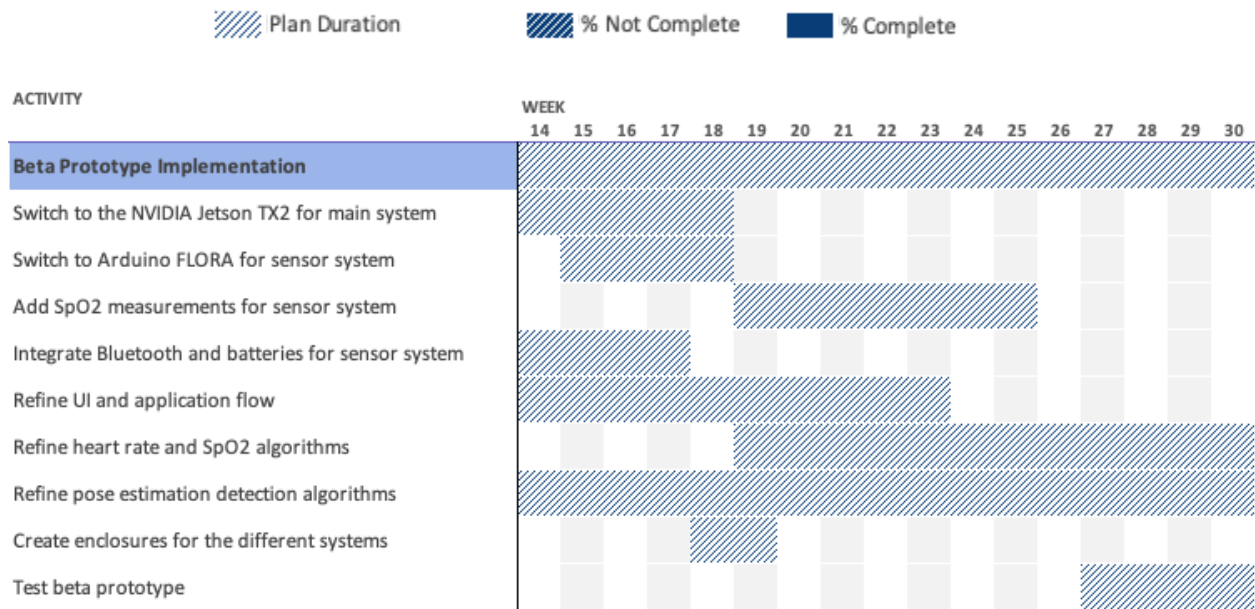

Figure 6.3 Beta Phase Milestone Chart

7 Cost Considerations

7.1 Cost Estimate

Table 7.1 and 7.2 shows the estimated costs for the proof of concept prototype and beta prototype respectively. Components which are re-used from the proof of concept prototype will not be displayed in Table 7.2. It should be noted that these prices would not reflect a real-world production phase version of the product, as economies of scale would significantly lower the price of many of the components.

Table 7.1 Proof of Concept Prototype Estimated Cost of Components

Component	Description	Total Cost (CAD)
Raspberry Pi Model 4 [13]	The Raspberry Pi is used to display the form to the user on a display, power the camera, and run MediaPipe.	$47.45
Microsoft LifeCam Studio (Q2F-00013) [14]	The camera is used to capture the form of the user and allow MediaPipe to determine whether the form of the user is correct.	$76.94
Heart Rate Sensor (MAX30102) [15]	The heart rate sensor is used to display the heart beat to the user while Guardian Sight™ is in use.	$14.45
Arduino Uno [16]	The Adruino will provide the logic and power on the heart rate sensor that was mentioned above.	$28.83
Monitor Display (Acer T232HL) [17]	This is where all the data coming from the Raspberry Pi Model 4 will be displayed to the user.	$389.98
Total Cost		**$557.65**

Table 7.2 Beta Prototype Estimated Cost of Components

Component	Description	Total Cost (CAD)
Nvidia Jetson TX2 Development Kit[1] [18]	The Nvidia Jetson TX2 is used as the main microcontroller for Guardian Sight™ and is used to run MediaPipe, and run the user application on an external display.	$1,170.42
Arduino FLORA [19]	The Arduino FLORA is used as the microcontroller for the heart rate sensor. It contains a smaller form factor to allow the sensor system to be used as a wearable device.	$25.03
e-CAM30_CUTX1 [20]	The e-CAM30_CUTX1 is the camera for Guardian Sight™. This camera is supported on the Nvidia Jetson TX2. Allows for clearer video feed for MediaPipe	$287.73
Bluetooth Module (Flora Wearable Bluefruit LE Module) [21]	The bluetooth module is responsible for transmitting the information from the Arduino FLORA to the Jetson TX2 for display on the screen.	$21.99
Rechargeable Battery (Lithium Ion Polymer Battery) [22]	The battery is used in conjunction with the Arduino FLORA to provide power to the microcontroller without requiring the use of cables.	$18.78
Enclosures	Enclosures for the sensor system, main microcontroller, and the camera system.	$2.78
Total Cost		**$1526.73**

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[1] For production versions of Guardian Sight™ the development kit will not be used, drastically reducing the cost and maintaining affordability.

7.2 Funding

There are two potential funding sources. Those are the Engineering Science Student Endowment Fund (ESSEF) and the Wighton Development Fund (WDF).

7.2.1 Engineering Science Student Endowment Fund

The Engineering Science Student Endowment Fund or ESSEF is a fund provided by the Engineering Science Student Society or ESSS. There are four categories that projects can fall under: competition, entrepreneurial, class, or miscellaneous. For Guardian Sight™, it would fall under Category C - Class. According to the document provided by ESSS, the ESSEF criteria under Category C requires that the project is original, usable, and team oriented [23]. Guardian Sight™ fulfills all the criteria. Guardian Sight™ is an original idea by combining computer vision with working out by providing feedback on their form to the user. Guardian Sight™ can be used by anyone at home planning to workout. The project has a team of six people working behind Guardian Sight™ to provide the best possible version of Guardian Sight™.

7.2.2 Wighton Development Fund

The Wighton Development Fund is a fund provided by Dr. Andrew Rawicz. Guardian Sight™ must satisfy Wighton's requirement of practicality. Preferential treatment is given to projects that benefit society [24]. Guardian Sight™ can help users striving to live healthier lifestyles safely.

8 Conclusion

Guardian Sight™ uses computer vision to assess the user's form and provide real time feedback that can aid in the prevention of injuries. The feedback is provided in real-time in both auditory and visual formats. Our end goal is to reduce the risk of injury when working out at home so people can feel safe and healthy.

This document outlined concerns about analytical failure, hardware failure, and data security, as well as efforts that have been made to mitigate the risk of each of these. The document also defined the primary market of Guardian Sight™, which will be targeted towards people looking to work out in the safety of their own homes. Lastly, the document went through the costs of the components required for each of the prototypes of Guardian Sight™, and some potential sources of funding to cover the costs.

9 References

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