Tech-fit

June 14, 2021

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

Re: ENSC 405W Requirement Specifications for **Guardian Sight™** by **Tech-Fit**

Dear Dr. Scratchley,

Please find attached to this letter the 'Guardian Sight™, Requirements Specifications' 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.

The requirements specification document outlines the functional and non-functional requirements of Guardian Sight™. This document provides a high-level overview of the physical, hardware, software, economic, and documentation requirements. Engineering standards, sustainability and safety sections for Guardian Sight™ are also included.

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 our requirements specification document for Guardian Sight™ . All questions and concerns can be directly addressed by contacting 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

Requirement Specifications, Company 6.

Tech-Fit Team:

Andrew Chen

Luke Gair

Hamlet Jiang Su

Landon Reeves

Allan Tsai

Johnston Yang

Presented To:

Dr. Craig Scratchley, P.Eng – ENSC 405W

Dr. Andrew Rawicz, P.Eng – ENSC 440

School of Engineering Science

Simon Fraser University

ENSC 405W: Capstone A

Revised: 2021-06-14

Abstract

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. Guardian Sight™ will use a feedback system to alert the user in real-time whenever their posture or form is incorrect. The product will use a combination of computer vision techniques and sensors to determine the user's posture and related physiological data.

This document aims to outline the requirement specifications of Guardian Sight™ as set out by Tech-Fit. In addition, this document will provide an overview of the high-level systems involved in the production and implementation of Guardian Sight™. Special considerations will be made regarding the safety, sustainability, and engineering standards of Guardian Sight™ to ensure that all proper procedures and regulations are met.

This document will conclude with an acceptance test plan for the alpha stages of the product's development. The acceptance test plan will highlight the deliverables that are expected to be delivered by Tech-Fit at the end of the alpha phase of the project.

Table of Contents

List of Tables and Figures

List of Tables

List of Figures

1 Introduction

2020 and 2021 have led to significant changes in how things are done in our everyday lives due to the COVID-19 pandemic. A significant change is the closure of gyms and other exercise facilities. As a direct result, more people are opting to exercise and work out in their homes [27]. Many of these 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 [27]. This is directly related to a lack of knowledge on how to prevent these injuries. In the time that follows the global pandemic, we will likely bear witness to the advent of more and more people opting to do activities from the comfort of their own homes. We may see an increase in the number of people choosing to continue to work out at home as restrictions begin to ease. The pandemic has created an opportunity for people to fundamentally rethink the way they approach personal fitness and working out. Guardian Sight™ provides people with the opportunity to work out at home with lower risk of causing personal injury.

Guardian Sight™ is an aide to help people achieve proper form during workouts and exercise routines, all from the comfort of their own homes. Guardian Sight™ has the capability to alert the user when it detects that the user needs to correct their form. On display and through an audio cue, the system then prompts the user to correct their posture and/or form using visual and auditory aid.

1.1 Background

1.1.1 Common Workout Injuries

In 2019, the NSC reported that there were 468,315 injuries sustained while exercising [13]. When training or working out alone, not all people can seek out a personal trainer. Development of repetitive strain injuries (RSI) is usually associated with repetitive work tasks in the workplace, this also extends to the performance of repetitive workout routines. Unaddressed, these injuries can get significantly worse [26]. This is entirely preventable and can be corrected by providing real-time feedback. In the absence of professional advice from a personal trainer, people should still be looking for strategies to prevent injury.

While working out, injuries are often sustained over time. These types of injuries are noted as RSI and are caused by continually performing a repetitive task with improper form and poor posture. While not all injuries fall in this set, there are a significant number of them. Some examples of the types of injuries that can be sustained while performing a workout at home are listed below.

- Bursitis
- Muscle Tears and Ruptures
- Patellar Tendon Injuries
- Tendinitis

1.1.2 The Case for Guardian Sight™

Given that many workout injuries sustained in the home are preventable, Guardian Sight™ seeks to reduce the risk of sustaining injury during home workouts by providing real-time feedback so the user can adjust their form and prevent the formation of bad habits that could be causing them harm.

1.1.3 Intended Use

Guardian Sight™ is intended for use in the home but has the potential to expand to use in community gyms in the future. For the best results, it is recommended that Guardian Sight™ be used in a well-lit and open space. It should be noted that Guardian Sight™ is not a replacement for a personal trainer and merely seeks to provide important data for people while they are working out.

2 System Overview

The following section provides a high-level overview of the systems involved with Guardian Sight™. The product will be composed of three major systems that work together to detect, alert, and guide the 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 this information will be output to a display that will provide feedback in both visual and auditory forms. This information is shown in Figure 2.1 below.

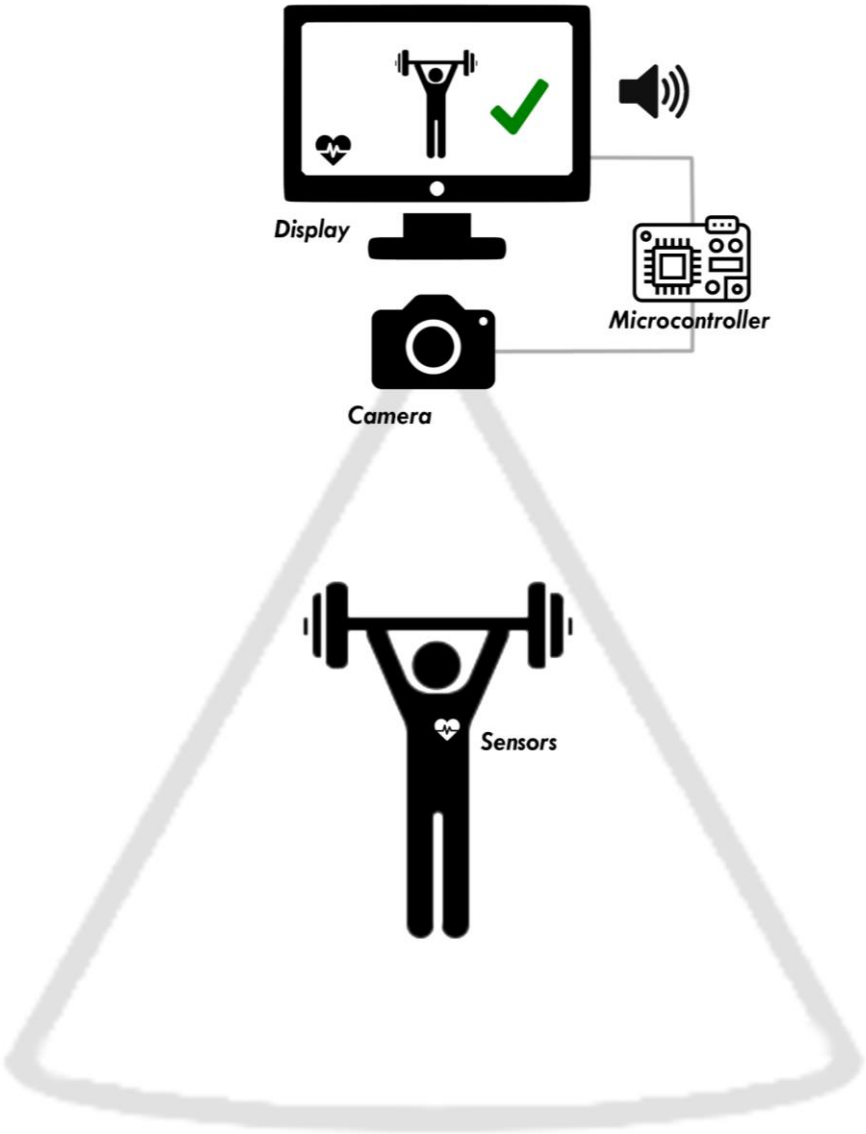

Figure 2.1 - System Setup: including camera, microcontroller, and sensors being output to the display

The system behaviour is synthesized below in Figure 2.

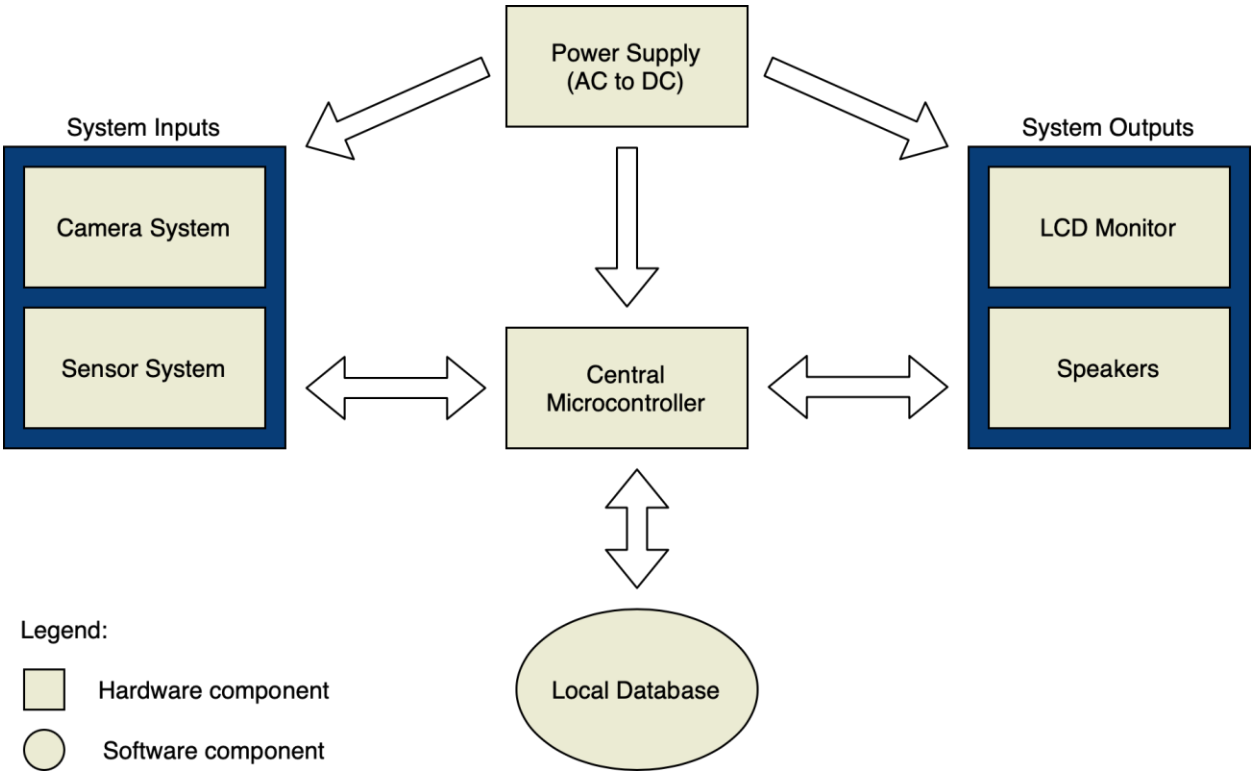

Figure 2.2 - System Block Diagram: detailing interaction between hardware and software component.

The algorithm flow chart for Guardian Sight™ is shown below in Figure 2.3. Implementation phases are shown regarding Guardian Sight's™ development cycle.

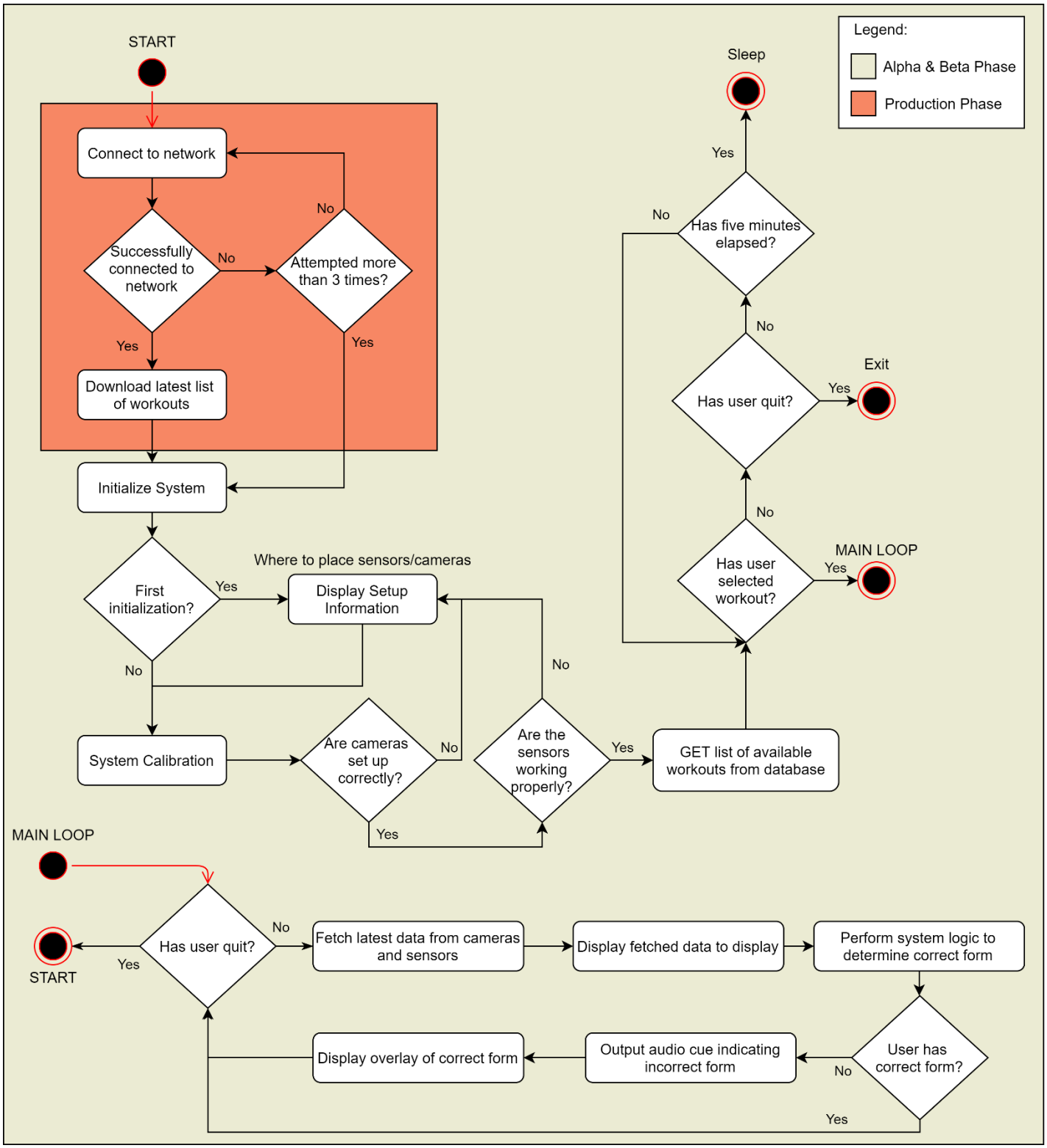

Figure 2.3 - Algorithm Flow Chart

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 will utilize computer vision and machine learning to figure out the user's position. To facilitate more accurate readings, the camera system will be composed of one or more cameras, positioned relative to each other. This will allow Guardian Sight™ to more accurately judge the position of the user, and account for differences and changes in the environment.

2.2 Sensor System

The purpose of the sensor system is to analyse data collected during a user's workout routine. The sensor system will consist of a device that attaches to the user's body 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 using a display and speaker. Figure 2.3 above provides a high-level description of the tasks required by the system.

2.4 Requirement Classification

The requirements of this document will follow a specific classification for easy reference. The following format will be used to classify each requirement.

[A.B.C - XX]

A refers to the category of requirement
B refers to the feature type
C refers to the specific feature number

XX refers to the Alpha Phase (AP), Beta Phase (BP), and Production Phase (PP)

3 Functional Requirements

This section defines what each component of the system must do to help the user track and improve their posture.

3.1 Camera System

[3.1.1 - AP] The camera must produce a clear image for posture estimation up to two meters away.
[3.1.2 - AP] The camera must output to a standard image format.
[3.1.3 - AP] The camera must be interfaceable and controllable via a microcontroller.
[3.1.4 - BP] The camera must produce visible light when it is active.
[3.1.5 - PP] The camera must have a rotatable mounting system for auto calibration (if standalone).
[3.1.6 - BP] The camera must have a way to regulate internal temperature.

3.2 Sensor System

[3.2.1 - AP] The sensor system must provide a way to obtain heart rate measurements.
[3.2.2 - BP] The sensor system must attach to the user without hindering their movement.
[3.2.3 - AP] The sensor system must be able to operate for at least 3 hours per session.

3.3 Display

[3.3.1 - AP] The display must be visible by the user from two meters away.
[3.3.2 - AP] The display must show the user's heart rate in real time.
[3.3.3 - AP] The display must show the user's current position in real time.
[3.3.4 - AP] The display must show the expected and proper form as an overlay.

3.4 Wiring and Power

[3.4.1 - BP] The wiring between systems must be out of the user's range of movement.
[3.4.2 - BP] All electric components must be well insulated and protected against external electrical interference.

3.5 Audio Requirements

[3.5.1 - AP] The system must have the ability to provide standalone audio output.
[3.5.2 - BP] The audio output must not exceed 5 to 10 dBm above ambient room noise at any point in time [6].
[3.5.3 - BP] The user must be able to adjust the volume of the audio output.
[3.5.4 - BP] The system must output an audio cue when the user's form is out of the range of the expected form.

3.6 Durability

[3.6.1 - AP] The system must withstand temperatures ranging from 10 to 40 degrees Celsius [14].
[3.6.2 - PP] The sensor system should be IPX4 water resistant [7].
[3.6.3 - AP] The heart rate sensors must be able to withstand a drop from 250cm.

3.7 Safety

[3.7.1 - BP] Each system (camera, sensor, and display) must have proper enclosures.

[3.7.2 - BP] The product and its components must be able to withstand impacts.
[3.7.3 - BP] The product and its components must be able to withstand vibrations.

3.8 Microcontroller

[3.8.1 - AP] The microcontroller must be able to transmit and receive data wirelessly.
[3.8.2 - AP] The microcontroller must have the ability to be reset through physical means (button/switch).
[3.8.3 - AP] The microcontroller must communicate to the sensors and the cameras through standard interfaces.
[3.8.4 - AP] The microcontroller must have methods to output visual data via HDMI standards.
[3.8.5 - AP] The microcontroller must be able to detect if the user is using improper form while doing an exercise.
[3.8.6 - AP] The microcontroller must be able to detect if the user is using proper form while doing an exercise.
[3.8.7 - BP] The microcontroller must have a way to regulate internal temperature.

3.9 Local Database

[3.9.1 - AP] The database table must contain short term sensor data.
[3.9.2 - AP] The database size must exceed 256MB.
[3.9.3 - AP] The database must have read/write capabilities.
[3.9.4 - BP] The database must have a column for average heart rate per session.
[3.9.5 - BP] The database must have a column for the number of incidents per session.
[3.9.6 - BP] The database must have a column to store the time length of each session.
[3.9.7 - BP] The database must have a row associated for each exercise session.
[3.9.8 - BP] The database must support SQL queries.
[3.9.9 - BP] The database SQL must use the DDL command format.

3.10 Economic Requirements

[3.10.1 - PP] Guardian Sight™ must be sold for less than $1500 [16].
[3.10.2 - PP] Guardian Sight™ must have a minimum life expectancy of five years.

3.11 Documentation Requirements

[3.11.1 - BP] The manual must provide information regarding its intended use.
[3.11.2 - BP] The manual must provide instructions on how to set up the Guardian Sight™.
[3.11.3 - BP] The manual must provide troubleshooting steps for common issues.
[3.11.4 - BP] The manual must provide details about the product dimensions.
[3.11.5 - PP] The manual must be available in multiple languages.
[3.11.6 - BP] The manual must inform the user what kind of alerts or sounds Guardian Sight™ may produce while in operation.
[3.11.7 - BP] The manual must provide information regarding collection of user data.
[3.11.8 - BP] The manual must provide information about the potential safety hazards.
[3.11.9 - PP] The manual must state which parts of Guardian Sight™ can be recycled after the end of its lifespan.
[3.11.10 - PP] The manual must provide information about the calibration process of Guardian Sight™.
[3.11.11 - BP] The manual must provide details on how to use each of Guardian Sight's™ functions

4 Non-Functional Requirements

This section specifies criteria to judge the performance and operation of Guardian Sight™.

4.1 Performance

[4.1.1 - AP] Guardian Sight™ should be able to provide feedback of the user's pose to the user within 5 seconds.
[4.1.2 - AP] Guardian Sight™ should be able to provide feedback of the user's heart rate to the user within 5 seconds.
[4.1.3 - AP] The camera system should communicate with the microcontroller with a maximum latency of 1000 milli seconds [15].
[4.1.4 - AP] The sensor system should communicate with the microcontroller with a maximum latency of 1000 milli seconds [15].
[4.1.5 - AP] The display should have a minimum refresh rate of 30Hz.
[4.1.6 - AP] The database should respond to the microcontroller within 5 seconds.
[4.1.7 - AP] The microcontroller should retrieve data from the database within 5 seconds.
[4.1.8 - BP] Audio should be played within 5 seconds to alert the user of their improper form.
[4.1.9 - AP] Guardian Sight™ should display the correct form to the user when Guardian Sight™ detects an improper form within 5 seconds.

4.2 Maintainability

[4.2.1 - PP] The batteries for the sensors should be replaceable with a standard 3-Volt CR2032 lithium battery.
[4.2.2 - PP] The cameras should be easily replaceable in the event of failure.
[4.2.3 - PP] The heart rate sensor(s) should be easily replaceable in the event of failure.
[4.2.4 - PP] The display should be easily replaceable in the event of failure.
[4.2.5 - PP] The microcontroller should be easily replaceable with a new microcontroller in the event of failure.
[4.2.6 - PP] The power supply device should be easily replaceable with a new power supply device in the event of failure.

4.3 Security

[4.3.1 - PP] Guardian Sight™ should sufficiently protect all user collected data.
[4.3.2 - PP] Guardian Sight™ should protect against malicious interception of wireless signals where applicable.

4.4 Usability

[4.4.1 - AP] The heart rate measurement should clearly be legible to the user from 2 metres away from the display.
[4.4.2 - AP] The poses should clearly be visible to the user from 2 metres away from the display.
[4.4.3 - AP] The power on button for Guardian Sight™ should be green.
[4.4.4 - BP] The camera should be able to be easily set up by the user.
[4.4.5 - BP] The display should be wall mountable.
[4.4.6 - AP] The reset button for Guardian Sight™ should be yellow.
[4.4.7 - BP] The sensors and camera systems should provide a calibration tool.

[4.4.8 - BP] The display output should take into consideration colour blindness.
[4.4.9 - AP] The buttons should be properly labelled.
[4.4.10 - AP] The buttons should be easily accessible.
[4.4.11 - AP] The camera should come with an adjustable mounting mechanism.

4.5 Availability

[4.5.1 - PP] Guardian Sight™ should be shipped to buyers in Canada.
[4.5.2 - BP] Guardian Sight™ should still function normally after three hours of use.
[4.5.3 - PP] The manual should be available online.

4.6 Scalability

[4.6.1 - BP] The code should be written such that the inclusion of additional cameras can easily work in tandem with each other.
[4.6.2 - BP] The camera system must allow communication and data transfer through a wireless interface.
[4.6.3 - PP] The user should be able to connect their devices through either Bluetooth or wired connection to play music through Guardian Sight™.

4.7 Size and Weight Requirements

[4.7.1 - BP] The system should not exceed 30 kg.
[4.7.2 - BP] The display should take up no more than fifty percent of the user's field of vision two meters away.
[4.7.3 - BP] The display should be at least 24-inch screen.
[4.7.4 - BP] The dimensions of the camera must not exceed 20 centimetres cubed.
[4.7.5 - BP] The heart rate monitor should not exceed 30 centimetres cubed.
[4.7.6 - PP] The heart rate monitor must not exceed 2.5 centimetres in width, 6 centimetres in length, and 2.5 centimetres in height.
[4.7.7 - BP] The power on button on the Guardian Sight™ should be a circle with a radius no larger than 3 centimetres.
[4.7.8 - BP] The reset button on the microcontroller should be a circle with a radius no larger than 3 centimetres.
[4.7.9 - BP] The microcontroller should not be larger than 20 centimetres cubed.
[4.7.10 - BP] The power supply for Guardian Sight™ should not be larger than 20 centimetres cubed.

5 Engineering Standards

Obtaining the right certification is important. To capture the North American and international markets, the engineering standards that Tech-Fit will adhere to includes Canadian and North American regulations such as CSA and ANSI, as well as international standards like IEC, ISO and IEEE.

5.1 General Standards

Standard	Description
ISO 14155:2011-Ed.2.0 [17]	Clinical investigation of medical devices for human subjects - Good clinical practice
ISO 13485 [18]	Medical devices - Quality management systems - Requirements for regulatory purposes
ANSI/ASSE Z690.2-2011 (Adopted from ISO 31000) [19]	Risk management principles and guidelines

Table 5.1.1 - General Standards

5.2 Software/Firmware Standards

Standard	Description
IEC 62304:2015-Ed.1.1 [17]	Medical device software - Software life cycle processes
ISO/IEC/IEEE 29119-1:2013 [20]	Software and systems engineering - Software testing - Part 1: Concepts and definitions
ISO/IEC/IEEE 29119-2:2013 [21]	Software and systems engineering - Software testing - Part 2: Test processes
ISO/IEC/IEEE 29119-3:2013 [22]	Software and systems engineering - Software testing - Part 3: Test documentation
ISO/IEC/IEEE 29119-4:2015 [23]	Software and systems engineering - Software testing - Part 4: Test techniques

Table 5.1.2 - Software & Firmware Standards

5.3 Electrical Standards

Standard	Description
IEC 60601-1-11:2010 -Ed 1.0 [17]	Medical electrical equipment - Part 1: General requirements for basic safety and essential performance - Requirements for medical electrical equipment and medical electrical systems used in the home healthcare system
IEC 60601-1-8:2012 -Ed.2.1 [17]	Medical electrical equipment - Part 1-8: General requirements for basic safety and essential performance - Collateral Standards: General requirements, tests and guidance for alarm systems in medical electrical equipment and medical electrical systems
IEC 62366-1:2015-Ed.1.0 [17]	Part 1: Application of usability engineering to medical devices
CAN/CSA C22.2 NO 60601-1-1-14:2014-Ed.3.0 [17]	Medical electrical equipment - Part 1: General requirements for basic safety and essential performance

Table 5.3.1 - Electrical Standards

5.4 Data Standards

Standard	Description
Regulation (EU) 2016/679 [24]	GDPR (General Data Protection Regulation)

Table 5.4.1 Data Standards

6 Sustainability and Safety

The following section will provide some insight on the safety and sustainability factors that will be considered during the creation of Guardian Sight™.

6.1 Sustainability

Tech-Fit is committed to providing a product that is both safe and sustainable. We will follow the Cradle-to-Cradle design philosophy wherever possible. This includes abiding to the Cradle-to-Cradle assessment categories for Material Health, Material Reutilization, Renewable Energy & Carbon Management, Water Stewardship, and Social Fairness [10].

6.1.1 Material Health & Material Reutilization

Tech-Fit will pay close attention to the materials that are used in the production of Guardian Sight™ and will do its best to ensure that the materials can be recycled or reused at end-of-life. The following sections will describe in more detail, the methods that will be used to ensure environmental sustainability.

6.1.1.1 Camera System

Careful consideration will be taken when developing the camera system to ensure that the parts will be recyclable at an electronics recycling depot. Each individual camera will be encased in a housing made of environmentally friendly materials.

6.1.1.2 Sensor System

The sensor system will contain components that attach to the user's body in order to measure physiological data. To accommodate this restriction, the sensor system may need to be powered with batteries. Careful consideration will be made for the type and recyclability of the batteries to reduce the amount of non-recyclable materials. Our goal is to use Lithium-Ion batteries which are both rechargeable and made of recyclable materials.

6.1.1.3 Display System

The display system will be an optional component that the user will be able to include in their purchase of Guardian Sight™. To target sustainability efforts, we will allow the user to use their existing display devices as visual output. We will ensure that the connections to the display are standardized and hope to accommodate as many existing displays as possible using HDMI output.

6.1.1.4 Material Reutilization Plan

Table 6.1.1 describes the material reutilization plan for Guardian Sight™. This table describes the correct disposal methods for each of the potential components used in the implementation of our product

Component	Material	Disposal Method
Enclosures	Plastic	Recycling Depot
Batteries	Lithium-Ion	Call2Recycle Program [25]
Sensors	Electronics (metal, wiring)	Electronics Recycling Depot
Cameras	Electronics (metal, wiring, glass)	Electronics Recycling Depot
Display	Electronics	Electronics Recycling Depot
Microcontroller	Electronics	Electronics Recycling Depot

Table 6.1.1 - Material Reutilization Plan

6.1.2 Renewable Energy & Carbon Management

Tech-Fit will strive to use renewable energy whenever possible to reduce carbon emissions. This includes placing emphasis on the energy efficiency of our products. We will do our best to ensure that Guardian Sight™ follows Canada's Energy Efficiency Act [8] and Canada's Energy Efficiency Regulations [9].

6.1.3 Social Fairness

Tech-Fit holds itself to a high standard when considering social sustainability and fairness. We are committed to the physical and mental well-being of our employees and will ensure that our employees are treated fairly and equitably.

6.2 Safety

Safety and the protection of privacy are important aspects of Guardian Sight™. We are committed to user safety and user privacy.

6.2.1 Product Safety

We will abide by engineering standards to ensure that our product meets the safety standards outlined in Section 5 - Engineering Standards. User manuals and documentation will be provided alongside Guardian Sight™ to ensure proper usage of the product.

Furthermore, we will provide the user with information about potential safety risks that might occur during use. Through this, we hope to provide a safe and reliable product to all of our users.

6.2.2 Privacy and Data Collection Safety

Tech-Fit is committed to being fully transparent with regards to the collection of user data. During the development of Guardian Sight™, efforts will be made to minimize the amount of user collected data. Any user collected data that is required for the core functionality will be stored securely on the device. Furthermore, users will be clearly informed about the data that is collected and how it will be use

7 Conclusion

Tech-Fit's requirement specification document outlines the functional and non-functional requirements for the Guardian Sight™ product. 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.

The COVID-19 pandemic has fundamentally changed how people choose to spend their lives and has shown people what is possible when working from home. Guardian Sight™ seeks to leverage this time of significant change to give consumers the power to rethink how they exercise from home by providing real-time feedback to the user about their form during workouts. Our end goal is to reduce the risk of injury when working out at home so people can feel safe and healthy.

This document also serves as a timeline for when specific features will be implemented, with the alpha phase being completed in August 2021 and the beta phase being completed in December 2021. The appendix included at the end of this document outlines the acceptance test plan for the alpha phase of development.

8 Glossary

Term	Definition
AC	Alternating Current.
ANSI	American National Standards Institute.
Bursitis	Bursitis is the inflammation of the bursa sac. These sacs can be found around many of the major joints in the body and serve to lubricate them and to ease friction and irritation on site.
CSA	Canadian Standards Association.
DC	Direct Current.
DDL	Data Definition Language.
HDMI	High-Definition Multimedia Interface.
IEC	International Electrotechnical Commission.
IEEE	Institute of Electrical and Electronics Engineers.
ISO	International Organization for Standardization.
LCD	Liquid Crystal Display.
Muscle Ruptures and Tears	This injury can be sustained anywhere on the body where muscle mass can be found and involves the separation of muscle tissue from itself.
NSC	National Safety Code.
Patellar Knee Injury	An injury where the tendon detaches or tears from its anchor point on the knee cap.
RSI	Repetitive Strain Injury.
SQL	Structured Query Language. It is the standard language for relational database management systems.
Tendinitis	Tendinitis is the inflammation of a tendon. The tendon connects surrounding muscle tissue and anchors it to the bone.

9 References

[1] H. Tu, C. Wang, and W. Zeng, “VoxelPose: Towards Multi-Camera 3D Human Pose Estimation in Wild Environment,” *arXiv.org*, 24-Aug-2020. [Online]. Available: https://arxiv.org/abs/2004.06239. [Accessed: 14-Jun-2021].

[2] “Pose,” *mediapipe*. [Online]. Available: https://google.github.io/mediapipe/solutions/pose. [Accessed: 14-Jun-2021].

[3] C. E. Quatman, G. D. Myer, J. Khoury, E. J. Wall, and T. E. Hewett, “Sex differences in ‘weightlifting’ injuries presenting to United States emergency rooms,” *Journal of strength and conditioning research*, Oct-2009. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2770173/. [Accessed: 14-Jun-2021].

[4] S. E. Gray and C. F. Finch, “The causes of injuries sustained at fitness facilities presenting to Victorian emergency departments - identifying the main culprits,” *Injury epidemiology*, Dec-2015. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5005555/. [Accessed: 14-Jun-2021].

[5] “Product List,” CSA Group, 02-Jun-2021. [Online]. Available: https://www.csagroup.org/store/product-list/telecommunications-audio-and-video-engineering/a0K1I000002IWMyUAO/. [Accessed: 14-Jun-2021].

[6] “Harmful Noise Levels,” *HealthLink BC*. [Online]. Available: https://www.healthlinkbc.ca/health-topics/tf4173. [Accessed: 15-Jun-2021].

[7] Element, “Guide to Ingress Protection Testing,” *Element*, 10-Oct-2016. [Online]. Available: https://www.element.com/nucleus/2016/guide-to-ingress-protection-testing. [Accessed: 14-Jun-2021].

[8] L. S. Branch, “Consolidated federal laws of canada, Energy Efficiency Act,” *Energy Efficiency Act*, 27-May-2021. [Online]. Available: https://laws-lois.justice.gc.ca/eng/acts/e-6.4/page-1.html. [Accessed: 14-Jun-2021].

[9] N. R. Canada, “Government of Canada,” *Natural Resources Canada*, 13-Feb-2020. [Online]. Available: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/guide-canadas-energy-efficiency-regulations/6861. [Accessed: 14-Jun-2021].

[10] *What is Cradle to Cradle Certified®? - Get Certified - Cradle to Cradle Products Innovation Institute*. [Online]. Available: https://www.c2ccertified.org/get-certified/product-certification. [Accessed: 14-Jun-2021].

[11] P. & Me, “Improper Exercise Leads to Injury,” PT ME, 29-Jan-2015. [Online]. Available: https://ptandme.com/improper-exercise-leads-to-injury/. [Accessed: 07-Jun-2021]

[12] S. E. Gray and C. F. Finch, “The causes of injuries sustained at fitness facilities presenting to Victorian emergency departments - identifying the main culprits,” Injury epidemiology, Dec-2015. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5005555/. [Accessed: 07-Jun-2021]

[13] “Facts + Statistics: Sports injuries,” III. [Online]. Available: https://www.iii.org/fact-statistic/facts-statistics-sports-injuries. [Accessed: 07-Jun-2021]

[14] “Data.org,” *Climate*. [Online]. Available: https://en.climate-data.org/north-america/canada/british-columbia/vancouver-963/. [Accessed: 14-Jun-2021].

[15] World Leaders in Research-Based User Experience, “Response Time Limits: Article by Jakob Nielsen,” *Nielsen Norman Group*. [Online]. Available: https://www.nngroup.com/articles/response-times-3-important-limits/. [Accessed: 14-Jun-2021].

[16] Coop, “How Much Does a Home Gym Actually Cost in 2021,” *Garage Gym Reviews*, 30-Nov--1. [Online]. Available: https://www.garagegymreviews.com/how-much-does-home-gym-cost. [Accessed: 14-Jun-2021].

[17] H. Canada, “Government of Canada,” *Canada.ca*, 07-May-2021. [Online]. Available: https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/standards/list-recognized-standards-medical-devices-guidance.html. [Accessed: 14-Jun-2021].

[18] “ISO 13485:2016,” *ISO*, 21-Jan-2020. [Online]. Available: https://iso.org/standard/59752.html. [Accessed: 14-Jun-2021].

[19] “Books & Standards,” *ASQ*. [Online]. Available: https://asq.org/quality-press. [Accessed: 14-Jun-2021].

[20] “ISO/IEC/IEEE 29119-1:2013,” *ISO*, 11-Jun-2020. [Online]. Available: https://www.iso.org/standard/45142.html. [Accessed: 14-Jun-2021].

[21] “ISO/IEC/IEEE 29119-2:2013,” *ISO*, 03-Sep-2019. [Online]. Available: https://www.iso.org/standard/56736.html. [Accessed: 14-Jun-2021].

[22] “ISO/IEC/IEEE 29119-3:2013,” *ISO*, 03-Sep-2019. [Online]. Available: https://www.iso.org/standard/56737.html. [Accessed: 14-Jun-2021].

[23] “ISO/IEC/IEEE 29119-4:2015,” *ISO*, 03-Sep-2019. [Online]. Available: https://www.iso.org/standard/60245.html. [Accessed: 14-Jun-2021].

[24] “Lex Access to European Union law,” *EUR*. [Online]. Available: https://eur-lex.europa.eu/eli/reg/2016/679/oj. [Accessed: 14-Jun-2021].

[25] Ministry of Environment and Climate Change Strategy, “Recycle Batteries (Household),” *Province of British Columbia*, 09-Aug-2018. [Online]. Available: https://www2.gov.bc.ca/gov/content/environment/waste-management/recycling/extended-producer-responsibility/electronics-and-electrical/batteries. [Accessed: 14-Jun-2021].

[26] B. A. O'Neil, M. E. Forsythe, and W. D. Stanish, “Chronic occupational repetitive strain injury,” *Canadian family physician Medecin de famille canadien*, Feb-2001. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2016244/. [Accessed: 14-Jun-2021].

[27] I. Advanced Solutions International, “Overuse Injury,” *Preventing Overuse Injuries | Overuse Injury Diagnosis & Prevention*. [Online]. Available: https://www.stopsportsinjuries.org/STOP/Prevent_Injuries/Overuse_Injury.aspx. [Accessed: 14-Jun-2021

10 Appendix

10.1 Acceptance Test Plan for Alpha Prototype

Table 10.1.1 below shows a high-level test plan to demonstrate the functionalities of the alpha phase prototype.

Purpose	Test Description	Acceptance Criteria
Camera output image valid up to 2 meters distance	Take pictures of an object at varying distances	The camera must produce a clear image of the target
Validate heart rate sensor system	Increase a person's heart rate through stimulation. Test the system on one arm, compare against third party sensors on the other arm	The system's sensors must match other sensors within a range of 5 beats per minute
Validate microcontroller can detect if the user has improper form	User does an exercise with improper form and have the microcontroller detect if the user has improper form	The microcontroller must be able to detect if the user has the incorrect form. Verify output results from the system with Kinesiology.
Validate microcontroller can detect if the user has proper form	User does an exercise with proper form and have the microcontroller detect if the user has proper form	The microcontroller must be able to detect if the user has the correct form. Verify output results from the system with Kinesiology.
Validate wireless connection between heart rate sensor and microcontroller	Connect sensor to microcontroller	The proper heart rate must be shown on the display while the sensor is connected
Validate battery life of heart rate sensors	Leave on heart rate sensor and measure how accurate the heart rate measurement is	Use the heart rate system for 3 hours straight and compare the measurement from when the user started to the measurement after 3 hours
Validate system can output audio	The system will output audio depending on whether the user has done the exercise correctly or incorrectly	User does exercise incorrectly and must hear the audio cue
Validate heart rate sensors durability	Drop the heart rate sensor, varying heights, 250cm maximum. Compare the heart rate to a third-party sensor to determine the accuracy.	The heart rate sensor can survive a drop from up to 250cm. The heart rate sensor is within the third-party heart rate sensor by 5 beats per minute.

Table 10.1.1 - High Level Acceptance Test Plan: Alpha Prototype