ENSC 405W Grading Rubric for Design Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the design specifications with appropriate justification for the design approach chosen. Includes descriptions of the physics (or chemistry, biology, geology, meteorology, etc.) underlying the choices.	**/20%**
Technical Correctness	Ideas presented represent design specifications that are expected to be met. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text). Equations and graphs are used to back up/illustrate the science/engineering underlying the design.	**/25%**
Process Details	Specification distinguishes between design details for present project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Numbering of design specs matches up with numbering for requirements specs (as necessary and possible).	**/15%**
Test Plan Appendix	Provides a test plan outlining the requirements for the final project version. Project success for ENSC 405W will be measured against this test plan.	**/10%**
User Interface Appendix	Summarizes requirements for the User Interface (based upon the lectures and the concepts outlined in the Donald Norman textbook).	**Graded Separately**
440 Plan Appendix	Analyses progress in 405W and outlines development plans for 440. Includes an updated timeline, budget, market analysis, and changes in scope. Analyses ongoing problems and proposes solutions.	**Graded Separately**
Conclusion/References	Summarizes functionality. Includes references for information sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow logically.	**/05%**
Format/Correctness/Style	Includes letter of transmittal, title page, abstract, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted. Correct spelling, grammar, and punctuation. Style is clear, concise, and coherent. Uses passive voice judiciously.	**/15%**
Comments		

March 31, 2018

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

Re: ENSC 405W/440 Design Specification for M-Brace

Dear Dr. Rawicz:

The following document contains design specifications for *M-Brace* by ChronoTech Systems, which was prepared as a requirement for the course ENSC 405W. Our goal is to help people who suffer from repetitive movement syndrome and people who are concerned with re-developing the disorder later in life. M-Brace is a lightweight device that monitors pressure being applied on the user's wrist and palm to monitor and to mitigate the symptoms.

This document is meant to provide an outline of the design process for the proof-of-concept and prototype of *M-Brace*. The following specifications include a system overview, a justification of requirements, a list of test plans, an appendix that details the user interface, and an appendix that details what features are to be expected for the prototype in August. This document will serve as a guide during the development of our product.

ChronoTech Systems consists of hardworking engineers with a diverse set of skills and passions that complement one another. Michelle Ho, Ying Hsin Lan, Princess Krizia Macanlalay, and Randel Argel Rivera form the foundation upon which ChronoTech Systems is built.

Thank you for taking the time to review our documentation for *M-Brace*. Please direct any questions or concerns to our Chief Operations Officer, Michelle Ho, by email at mmh12@sfu.ca.

Sincerely,

Randel Argel Rivera
Chief Executive Officer
ChronoTech Systems

Design Specifications for *M-Brace*

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Published Date
March 31, 2018
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Abstract

Many sports players are affected by repetitive motion syndrome (RMS) as their activities often include repeated motions of flexion and extension of the hand and wrist. Some of the best ways to prevent this injury is to take breaks and maintain good posture; however, many people are unaware of their hand behaviour and it is difficult to stop people from performing their daily activities. Therefore, M-Brace is designed to monitor the strain on the user's hand and wrist and to remind the user to take breaks or to correct their posture. The intended user of M-Brace are athletes who wish to prevent further development or re-injury of RMS in their hand.

This document covers the system design specifications, the user interface design, the engineering and safety standards, and the proposed project outline for ENSC 440. M-Brace will be developed in three phases: proof-of-concept (PoC), prototype, and final product. The expected hardware and software design specifications for each phase are discussed in this document, with the differences between each stage highlighted. A set of test cases are identified to help the team test the PoC and utilize the results to improve on the designs for the prototype and final product. Details of the deliverables due in August can also be found in this document.

M-Brace consists of a hardware component and a software component to identify and alert the user of the repetitive strain they are experiencing. In the PoC stage, ChronoTech Systems explores the different sensors to be used for pressure detection, the features of a mobile application, and the integration process of the hardware and software components. The intended prototype design will consist of a wearable module with flexible sensors collecting data at key points on the user's hand. The data collected from the sensors will be sent to an user-friendly smartphone application and will be displayed in an intuitive manner. The user will also have the option to receive instant feedback of their hand status and to set reminders, either at regular intervals or specific times, for taking breaks and performing stretches.

The proof-of-concept will be delivered by April 9, 2018 and a prototype for sports use will be delivered by August 3, 2018. The final product will be further optimized for consumers after the prototype is delivered.

Glossary

Android	An open-source smart device operating system
Brace	A non-restrictive brace that has coverage on the palm and the wrist
CTS	An abbreviation for carpal tunnel syndrome - a chronic disorder that causes pain in the hands due to excessive pressure on the median nerve
FSR	An abbreviation for force sensing resistor
GUI	Graphical User Interface
IEC	An abbreviation for International Electrotechnical Commission
IEEE	An abbreviation for Institution of Electrical and Electronics Engineers
iOS	A smart device operating system released by Apple Inc.
ISO	An abbreviation for International Organization for Standardization
Median Nerve	A nerve from the brachial plexus that passes through the carpal tunnel
Microcontroller	A computer on an integrated circuit dedicated to execute a specific task
PCB	An abbreviation for printed circuit board
PoC	An abbreviation for proof-of-concept, which is sample product assembled to explore the feasibility of a concept
Prototype	A preliminary model or release of a product
RMS	An abbreviation for repetitive movement syndrome
SI Units	An abbreviation for International System of Units - used in this document
UI	An abbreviation for user interface

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1.0 Introduction

Many people are unaware of their gripping habits while doing repetitive hand movements. When people perform such habits on a daily basis, they become prone to developing repetitive movement syndromes (RMS). A common RMS is carpal tunnel syndrome (CTS), which is caused by excessive pressure exerted on the median nerve. Currently, there are a few options for assisting the disorder. One common solution is wrist splinting, which is only effective in the early stages of RMS. Although surgery and medication do exist as well, these treatments are only temporary methods for controlling the numbness and pain caused by RMS.

ChronoTech Systems envisions a wearable device, M-Brace, to assist sports enthusiasts and professional athletes who need to do repetitive hand movements throughout the day. The purpose of M-Brace is to remind users to take frequent breaks, to encourage users to exercise with counter-movements, and to notify the user of the pressure exerted on their median nerve. Similar to training supersets in the gym, the trainee should complete triceps extension after a biceps curl; this allows the trainee to perform with opposing muscle groups. For example, if the M-Brace user is constantly flexing their wrist during their daily routine, the user interface would recommend the user to extend the wrist after a certain extended period.

1.1 Scope

The target development for M-Brace will occur over three main phases. ChronoTech Systems promises to produce a proof-of-concept (PoC) by April 9, 2018 and a prototype for sports use by August 3, 2018. Further analysis with medical professionals is needed to improve on the data reliability and accuracy of the prototype for the assembly of the final product.

This document outlines the system overview and the design specifications of M-Brace in the initial two phases. The design specifications are proposed and tested based on the requirement specifications documentation, which must be met by its proposed deadline for a successful completion of M-Brace. Furthermore, ChronoTech Systems has included detailed test plans, with which the company aims to achieve with M-Brace.

1.2 Intended Audience

This documentation is intended to be reviewed by the team members of ChronoTech Systems and by other experts interested in the product, M-Brace. The design specifications will be referenced by the firmware, hardware, and software design engineers throughout the research and development phase of M-Brace. The quality of M-Brace will be validated by ensuring all engineering standards and safety, sustainability and design requirements and specifications are met by the ChronoTech Systems design team.

2.0 System Design Overview

M-Brace monitors the amount of pressure exerted to the user's wrist and palm. The product design has been divided into three main categories: the physical wearable component, the hardware component, and the user interface component. The design of the wearable component must be able to collect data in regard to the strain on the user's wrist and the pressure on the user's palm. In the prototype, this data would be transmitted wirelessly to a user interface, where the user can intuitively track the graphical data, as illustrated in Figure 1.

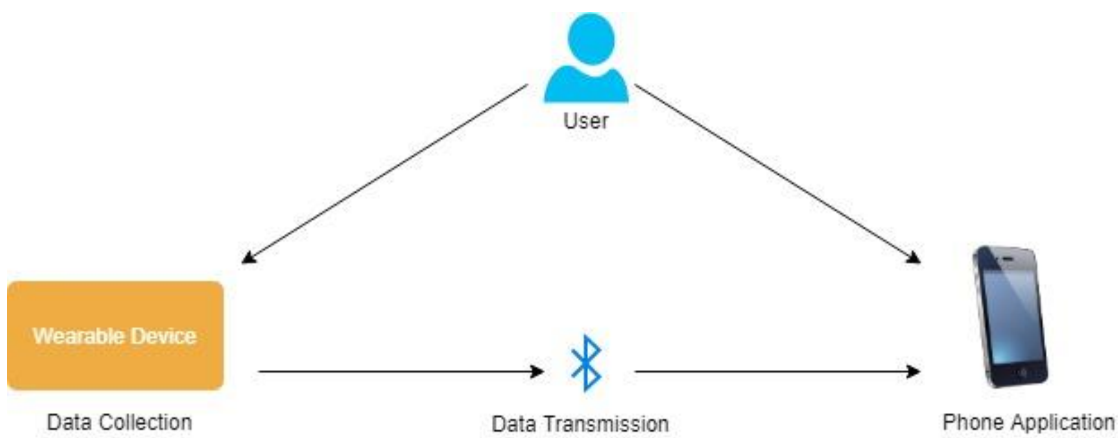

Figure 1 Conceptual Overview of the System

In order to properly monitor the pressure on the user's palm and wrist, the user is required to wear M-Brace while completing tasks. Thus, M-Brace is designed to have minimal mobility restriction. The module will be lightweight, the wearable fabric will be breathable, and the sensors will be flexible. The target demographic of the product will be sports enthusiasts and professional athletes.

This subsection discusses the overview of hardware, firmware, and software aspects that need to be implemented for M-Brace through each development phase. Section 3.0 explains the details of the design progress.

2.1 Proof-of-Concept Deliverables

Based on the various tests conducted, as outlined in Appendix A, the hardware team presents a simple brace with sensors placed inside the fabric. The wearable components consist of four sensors for PoC, as shown in Figure 2. Two 0.2" single point FSR are located on the palmar side of the hand to measure the pressure exerted on the palm. Two flex sensors are placed on the two sides of the wrist to measure the flexion and hyperextension. Alternatively, we may replace the flex sensors with two analog hall effect sensors to minimize wrist movement restrictions.

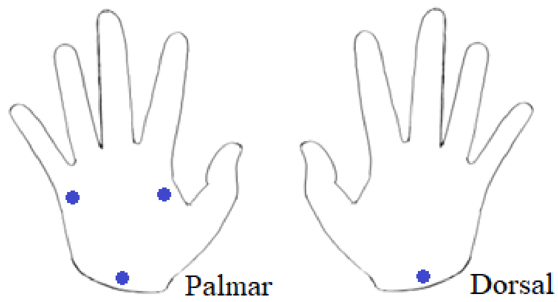

Figure 2 PoC Sensor Placement

The microcontroller used in the PoC stage is the Arduino Uno - R3 due to its low level programming ability. The Arduino Uno is used to collect the data from the sensors through jumper wires and transfer the information to a computer through serial port. On the macOS, ChronoTech Systems' chosen operating system environment, the terminal console is used to communicate with the serial port. The terminal uses a screen log command to store the data into a text file on the computer.

The emulated version of an iOS companion application running on Xcode would display the sensor points on their respective plots over time. The mobile application, developed by the software design team, runs on an emulated version of the iPhone 8 with iOS 10. Referring to the block diagram in figure 3, sensor data would be obtained via wired connection to a computer running macOS. The computer will locally host a TCP Server where it will send sensor data to requesting clients. The emulated iPhone will continuously request data from this server. The deliverable for this phase would be available on April 9, 2018.

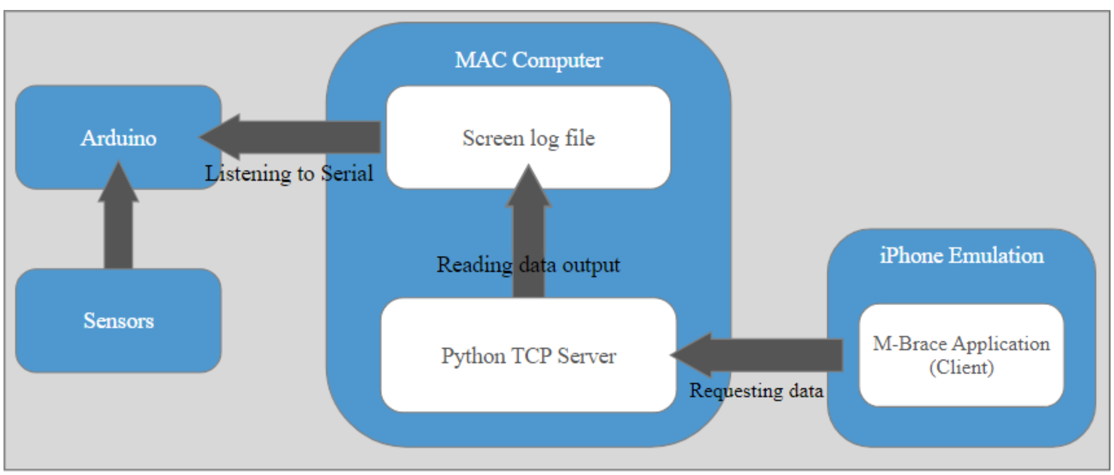

Figure 3 Block Diagram of Sensor Data Connection

2.2 Prototype Deliverables

For the prototype, a Cypress Semiconductor microcontroller will be used to collect data from the sensors through thin wires. Since M-Brace requires low voltage to be applied to the sensors and the microcontroller, a removable battery is attached to a custom PCB with a power isolation circuit and a voltage regulator. For safety concerns, the microcontroller unit and its battery are stored in an enclosed plastic box. Figure 4 below shows a conceptual relation between each component.

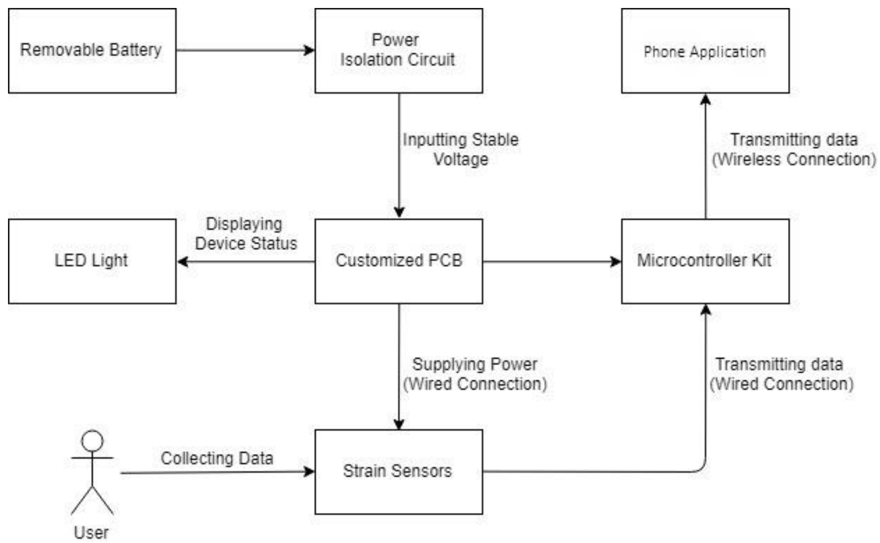

Figure 4 Conceptual Diagram of the Hardware Design Overview

M-Brace's physical module can be paired wirelessly to a companion application, which will run on a smart device with either the iOS or Android interface. Figure 5 is a use case diagram of the user interface design overview.

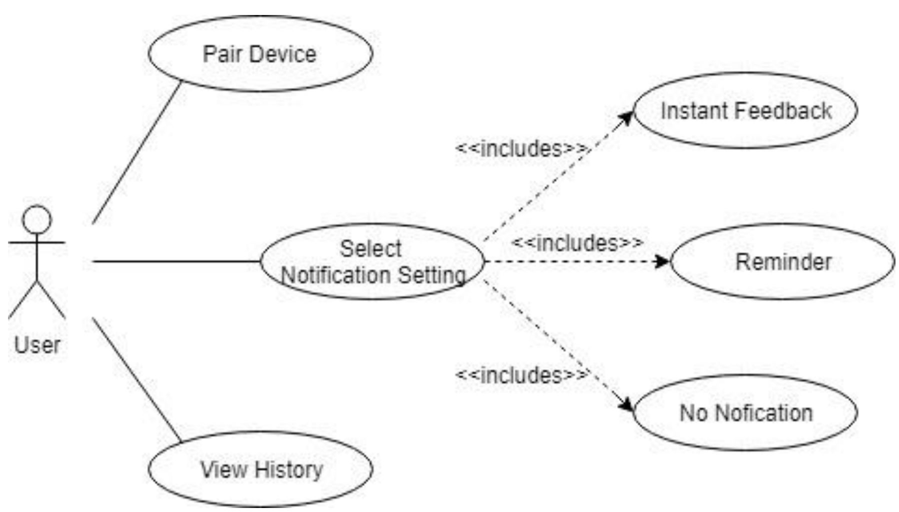

Figure 5 Use Case Diagram of the Software Design Overview

The user can view a real-time graphical feedback of the pressures applied on different sensors. The application provides a linear colour feedback based on the pressure of the sensors; green representing no pressure to an acceptable amount of pressure applied, and red representing an excess amount of pressure applied.

At this stage, the application should also alert the user whenever their hands have been in the same position or have been repeating the same motion for an extended period of time. The recommended alert setting allows for instant automatic notification when too much tension is applied. This helps remind the user to lessen their grip on an item or to assist in the correction of their posture. If the task requires the user to exert more pressure over an extended period, the user may choose the other settings, which allows the user to set a regular interval reminder for counter-movement exercises.

The aim for the prototype is to create an intuitive and user-friendly interface for users of any technical background. The application should be able to display the collected data on a colour map superimposed on the emulated hands.

The deliverable for this phase would be August 2018. Appendix D includes a detailed outline of the tasks, timeline, and budget planning for M-Brace between April 2018 to August 2018.

2.3 Final Product Deliverables

The final product should be designed to allow for mass production. Varied sizes should be constructed to fit a wide range of adult hand and wrist sizes. The wiring on the wearable component should be switched to conductive threads. A single microcontroller chip should be used instead of a Cypress Semiconductor microcontroller kit because this would reduce the weight of the device, the amount of unnecessary hardware components, the size of the PCB, and the power required for the hardware system. Furthermore, the application for the final product should be available on all major platforms and will have access to a cloud-based server to securely store user data.

3.0 System Design Specifications

This section discusses the system design based on the functional requirements as listed in the Requirement Specification Documentation at each development phase. Each functional requirement is denoted with the following system coding scheme convention:

[R <Section Code>.<Identification Code> - <Phase Code>]

The first letter ***R*** is an abbreviation for requirements. The **<*Section Code*>** follows the hierarchical order of the Requirement Specification document. Table 1 below provides a legend of all sections containing functional requirement specifications.

<Section Code>	Section Title
3.1	Physical Design Requirement
3.2	Hardware Requirement
3.3	Software Requirement
3.4	Miscellaneous Requirement
5.0	Safety Requirement

Table 1 Section Code with Corresponding Section Description

Furthermore, the **<*Identification Code*>** is an integer assigned to each requirement, while the **<*Phase Code*>** corresponds to the development phase at which the function requirement is expected to be met. Table 2 outlines the three main phase codes of M-Brace.

<Phase Code>	Development Phase Description
I	The requirement applies to the proof-of-concept
II	The requirement applies to the prototype
III	The requirement applies to the final product

Table 2 Phase Code with Corresponding Phase Description

Note: Requirements marked with '' are not carried over into subsequent development phases*

3.1 Hardware and Firmware Design Specifications

As the project was initially inspired by people who are at risk of developing CTS, the preliminary placement decisions were based on the concerned pressure points for CTS patients. This medical condition is caused by pressure exerted on the median nerve. The median nerve starts at the brachial plexus, located in the upper limb, and travels down the arm into the palm, where it ends on either side of the index and middle fingers, and the thumb-side of the ring finger [1]. The primary affected area of the pinched median nerve is the wrist, as shown in Figure 6.

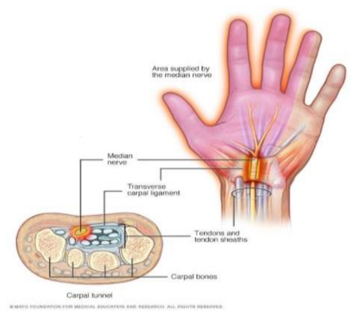

Figure 6 A Visual of A Pinched Median Nerve Provided by Mayo Clinic [2]

Therefore, the sensors inside the wearable must be able to collect information regarding the strain experienced on the user's palm and the tension applied on the user's wrist during flexion and hyperextension, as shown in Figure 7.

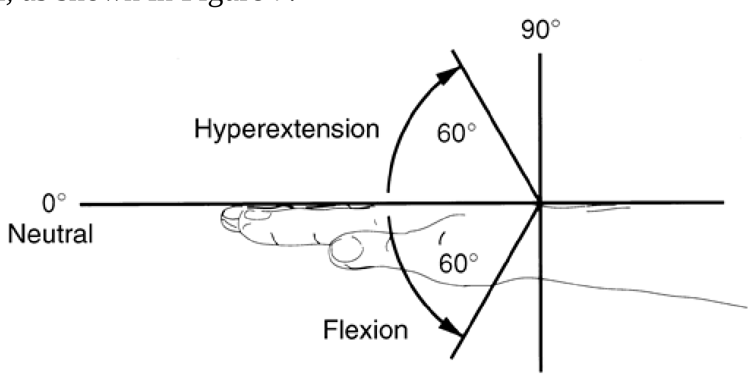

Figure 7 Range of Wrist Joint Movement for Flexion-Extension and Hyperextension [3]

The team tested with sensors that would works at the points highlighted in blue dots in Figure 8.

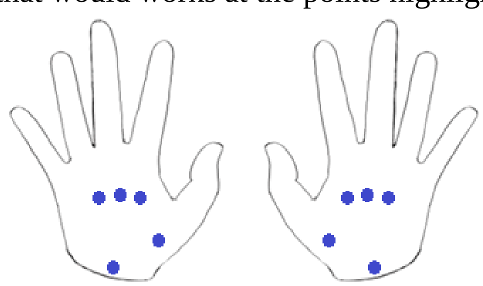

Figure 8 Preliminary Sensor Placement Design

The following section discusses the design process, the experiments conducted, the chosen design for PoC, proposed design for prototype, and justifications for possible further improvements.

3.1.1 Hardware and Firmware PoC Design Specifications

Following the preliminary design, the hardware and firmware design team has conducted experiments for each of the following categories: sensors, microcontroller, and other circuit component design. Appendix B contains the test plans for PoC to confirm the validity of the functionalities for the hardware and firmware design.

PoC: Sensor Design

Based on the requirement specifications documentation, the design team has listed out the specifications that are related to sensor choices and placement, as shown in Table 3.

Requirement ID	Sensors Design Requirement Description - PoC
[R 3.1.1 - I]	The device should not restrict wrist movement by having flexible sensors
[R 3.1.2 - I]	The sensors should be minimally intrusive to the user
[R 3.2.29 - I]	The sensors should be able to detect the force pressure variance
[R 3.2.30 - I]	Sensor should not exceed ±3% single part force repeatability
[R 3.2.31 - I]	The collected data should be consistent to ensure the precision of the device
[R 3.2.35 - I]	The functionality of the tension sensors should be tested by bending the brace in a manner that mimics a hand flex or extension (Refer to Figure 7)

Table 3 A List of Sensor Design Requirements for PoC

Because the sensor placement on the device is crucial to the goal of monitoring RMS, the hardware team ran a series of tests, outlined in Appendix A, to find a rough estimation for where to put the sensors in the brace. For the sensors located on the palm, Interlink FSRs were chosen for their flexibility, relatively low actuation force, and price. The reliability of the FSR was determined by placing the sensor on surfaces of different firmness. The sensor was first attached to a breadboard and then placed on top of a different sports ball for each test. The ball was then firmly grasped, and the corresponding data was collected via the Arduino UNO. Although these tests initially yielded promising results, the FSR could not handle excess forces for too long. Under the advisement of a consultant on the project, the hardware team smothered several pieces of sports equipment and firmly grasped the gear to see which areas of the hand had the most contact with the equipment when gripped. The locations the powder stuck to on the palm provided the team with more information as to where the sensors should go.

To monitor the flexion and hyperextension in the wrist, two types of sensors were considered, simple flex sensors, and the hall effect sensor. Flex sensors were ultimately chosen to be used in the proof of concept for their ease of use and sensitivity. The circuit for the flex sensors can be found in Figure 9.

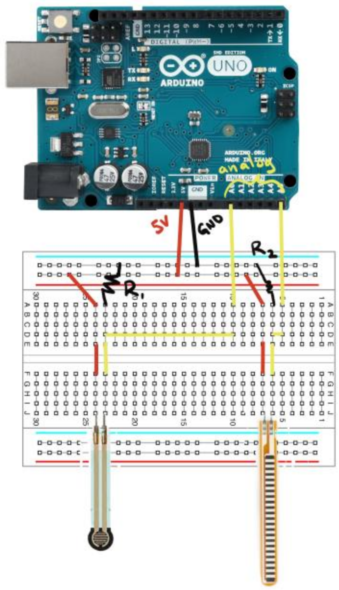

Figure 9 PoC Circuit with R1 = ~22kΩ and R2 = ~12kΩ

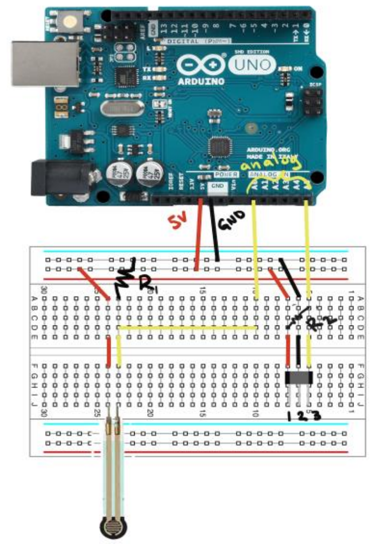

Figure 10 PoC Circuit with R1 = ~22kΩ and R2 = ~1kΩ

The second type of sensor that was considered for the wrist was the Hall effect sensor. This is a special microelectronic component found in devices like cell phones and can detect changes in magnetic fields. The digital Hall effect sensor (US1881) tested is a bipolar latch that has an OFF-state and ON-state. Figure 10 shows the circuit built for this test.

From the figures mentioned above, we gathered that the digital Hall effect sensor is a switch whose state is determined by the polarity of the magnetic field within its vicinity. This feature, along with the US1881's very miniscule activation distance, was not ideal for M-Brace.

Lastly, the team was able to test an analog Hall effect sensor. The SS495A is a bipolar sensor with a linear derivative when there is a magnet in its vicinity. The voltage across the analog Hall effect sensor is determined by the following equation, where I is the current, B is the magnetic field, n is the charge density, t is the thickness of the sensor and e is the charge of the electrons [4].

$$V_H = \frac{I_x B_z}{nte}$$

During the initial tests, it was found that the voltage across the sensor reached the desired value when the magnet was within 3.5mm of the sensor's range, but after further testing and investigation, it was found that the sensor was able to start detecting a change in the magnetic field from as far away as 9cm. This result was promising and became the main factor when considering sensors for the proof of concept and subsequently the prototype. The team has decided to provide two versions of M-Brace to be presented for proof of concept, one with flex sensors and another with the Hall effect sensors to detect the flexion/hyperextension of the wrist.

PoC: Microcontroller

The design team has listed out the requirement specifications that are related to microcontroller design, as shown in Table 4.

Requirement ID	Microcontroller Design Requirement Description - PoC
[R 3.2.9 - I]	The device should be running on an Arduino Uno - R3 for easier testing *
[R 3.2.10 - I]	The microcontroller should have at least 5 I/O ports for connecting to sensors
[R 3.2.11 - I]	The microcontroller should be able to collect data from sensors
[R 3.2.12 - I]	The microcontroller should send the data via serial port for testing purposes
[R 3.2.19 - I]	The device should be powered via serial port for better cord management *
[R 3.2.21 - I]	The input voltage from Arduino UNO to the device should not exceed 5V *
[R 3.2.13 - I]	Real-time data transmission should be provided for allowing instant feedback

Table 4 A List of Microcontroller Design Requirements for PoC

For testing the feasibility of the concept and the sensors, the firmware design team has chosen to use the Arduino Uno - R3, as shown in Figure 11.

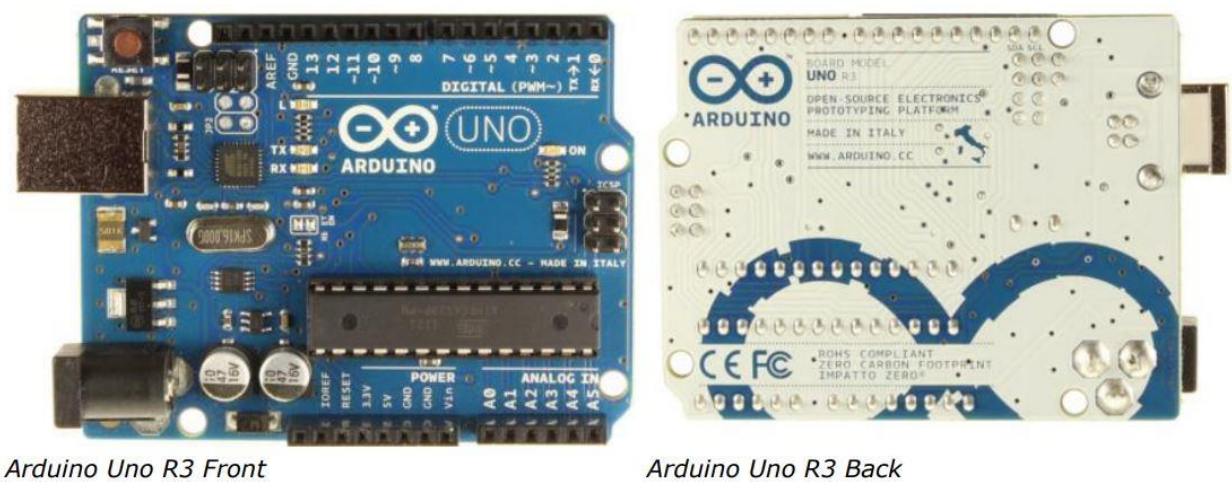

Figure 11 The front and back of Arduino Uno - R3 [5]

Because one of the requirements for the monitoring device is to gather continuous data, this would require analog input pins for each of the sensors at the four points mentioned in Figure 2. The key concept is to test the functionality of the two different sensors, thus a minimum of two analog input pins are needed to collect data from the 0.2” single point FSR and either the flex sensor or the analog hall effect sensor. The Arduino Uno uses the microcontroller ATmega328, which allows for a total of 6 analog input pins and fulfills the requirement [R 3.2.10 - I].

The Arduino UNO can also be powered by USB when connected to the computer. The input voltage from the computer to the Arduino UNO is between 7V to 12V; however, the operating voltage is either 3.3V or 5V. Thus, the sensors on the device are powered at the operating voltage. This also allows real-time data to be transmitted to the computer via serial port.

PoC: Circuit Design

The design team has listed out the requirement specifications that are related to other circuit components, as shown in Table 5.

Requirement ID	Circuit Design Requirement Description - PoC
[R 3.2.1 - I]	The circuit should be able to withstand drastic changes in current and voltage
[R 3.2.2 - I]	The circuit should include thermal management to prevent overheating
[R 3.2.3 - I]	The circuit should have at least one LED to indicate system status
[R 3.2.4 - I]	The wires should be insulated and grounded for safety
[R 3.2.20 - I]	The device should have enough current to power all the sensors
[R 3.2.22 - I]	The power consumption should not exceed 0.05W
[R 3.2.32 - I]	The main circuit should be tested on a standard breadboard
[R 3.2.33 - I]	The currents and voltages applied to each component should comply with its respective datasheet to minimize risks of failure
[R 3.2.34 - I]	The functionality of the force sensors should be tested with a dome-shaped padding to substitute human testing
[R 5.0.1 - I]	The current limit should not exceed 10mA to avoid shocking the user
[R 5.0.2 - I]	The device’s electrical connections should be contained

Table 5 A List of Circuit Design Requirements for PoC

The circuits to be presented for the PoC will be built on a breadboard and powered by an Arduino UNO via the serial port. A pressure sensor and a wrist sensor will be sending their respective data. The pressure sensor will consist of a .2” FSR in series with a voltage divider. The output of said voltage divider will be used as input for the companion application.

There will be two different designs of the wrist sensor, one with a flex sensor and one with a Hall effect sensor. Similar to the pressure sensor, the flex version will have a flex sensor in series with a voltage divider and the voltage output will be used as the input to the companion application. This circuit can be found in Figure 9. The Hall effect sensor version will be attached to the analog port of the Arduino board. This circuit is depicted in Figure 12. The actual circuit will be constructed on a mannequin hand to provide an accurate representation of how the circuit will work in real life.

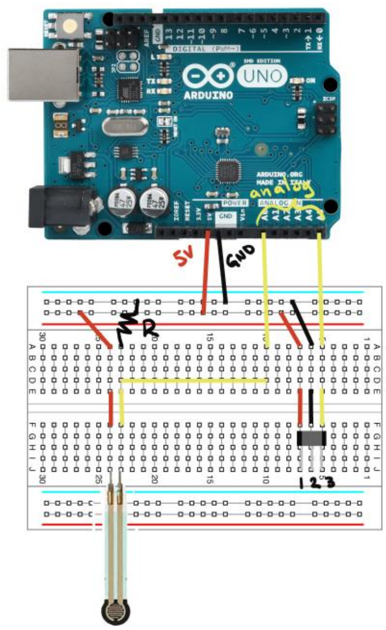

Figure 12 Wrist Sensor Hall Effect Version

3.1.2 Hardware and Firmware Prototype Design Specifications

To further improve the M-Brace product design, the hardware and firmware design team has made changes based on the PoC design. This section describes the changes made to suit the prototype design requirement specifications under the following categories: sensors, microcontroller, circuit components, PCB, and wearable design.

Prototype: Sensor Design

All the requirement specifications listed in Table 3 for PoC will be carried over to the prototype phase. There are no additional requirements; however, the design team has introduced new sensors to improve the data accuracy and comfort.

ChronoTech Systems wants to add an inertial measurement unit (IMU), MPU-9250 Breakout board, for detecting the position and the orientation of the wrist. The IMU would be connected to the microcontroller through the sensor Inter-Integrated Circuit (I2C) bus, as shown on the top row of Figure 13. The sensor data - X, Y, Z, roll, pitch, and yaw, is updated at the interrupt of the microcontroller, which is controlled by the clock speed. The clock accuracy for the IMU is dependent on the clock speed and directly affects the performance of the Digital Motion Processor.

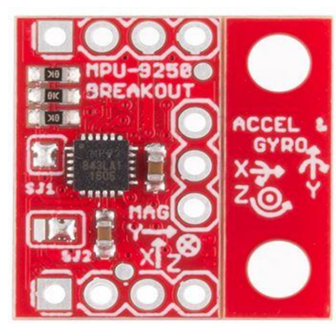

Figure 13 MPU-9250 Breakout Board [6]

Furthermore, to improve on the comfortability of the wearable module, the hardware design team would attempt to replace the flex sensor with stretchy resistance variable fabric, such as the EeonTex™ LTT-SLPA-20K [7]. In addition to flexion and hyperextension, we also want to detect abduction and adduction movement. This may be accomplished by adding two extra sensors on the sides of the wrist. Another design modification would be to substitute the 0.2” single point FSR with non-woven conductive fabric, such as the EeonTex™ NW170-SLPA-2K, on the palm. [8]

Prototype: Microcontroller

The design team has listed out the requirement specifications that are related to microcontroller in Table 6.

Requirement ID	Microcontroller Design Requirement Description - Prototype
[R 3.2.14 - II]	The device should be running on a microcontroller kit that allows for flexible configurations and function implementations *
[R 3.2.15 - II]	The microcontroller should have wireless capability to allow greater range of user mobility
[R 3.2.16 - II]	The device should have a sampling rate and transmit rate of at least 30Hz *

Table 6 A List of Microcontroller Design Requirements for Prototype

To introduce a more customized design, the hardware team has switched to the Cypress Semiconductor CY8CKIT-043 PSoC® 4 M-Series Prototyping Kit. The kit consists of two parts: Cypress KitProg and the main board of the PSoC 4200M Target, as shown in Figure 14.

The block diagram, shown in Figure 15, shows the theory of operation for the prototyping kit. The main board of PSoC 4200M uses ARM Cortex-M0 CPU with the CY8C4247AZI-M485. The microcontroller chip receives the sensor data through its input pins and the IMU breakout board through I2C. During the development phase, the data would be sent to the KitProg through UART. The KitProg enables onboard programming, debugging, bridging functionality, and powering via the PCB USB connector J6.

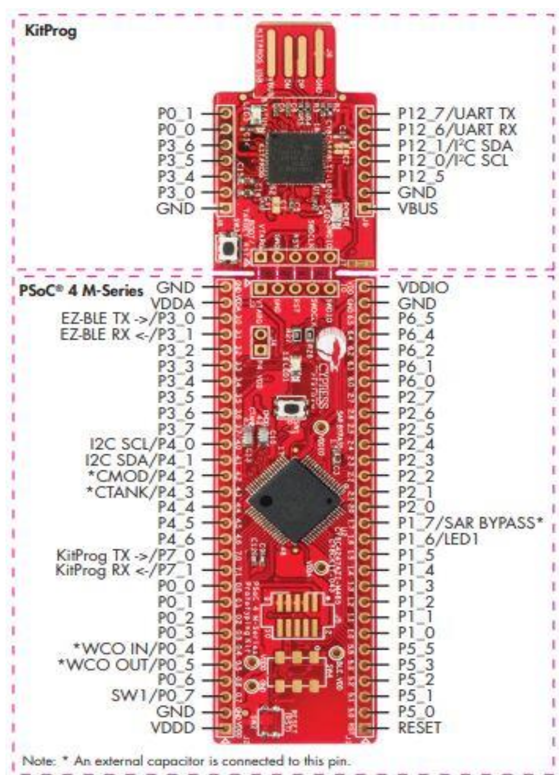

Figure 14 Prototyping Kit Pin Details [9]

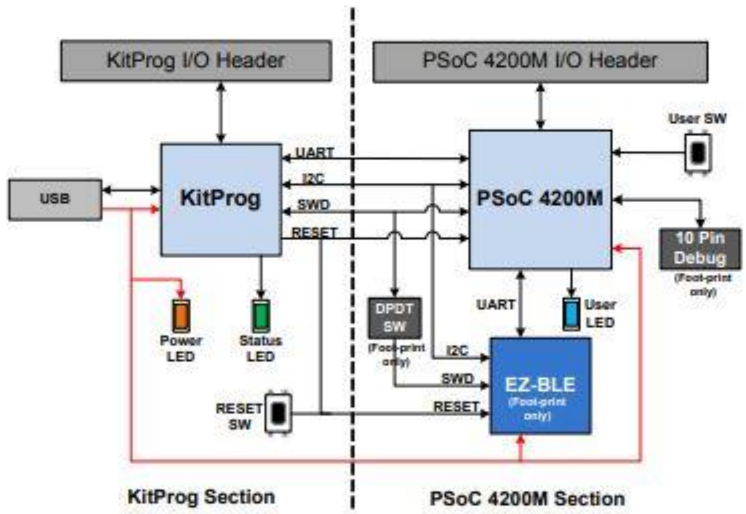

Figure 15 Block Diagram of PSoC 4 M-Series Prototype Kit [9]

As shown in Figure 15, the Cypress microcontroller kit board includes a footprint for mounting an EZ-BLE PRoC Module. The footprint allows for the addition of a Cypress EZ-BLE module of the size: 10mm x 10mm x 1.8mm. This includes the module CYBLE-022001-00, which is connected to the main chip through UART and I2C with its integrated pins and allows for Bluetooth connectivity with other devices [10].

However, ChronoTech Systems has limited resources. All parts require assembly with handheld soldering iron; thus, we are unable to mount the EZ-BLE module during the prototyping phase. Alternatively, the design team has decided to use the Expressif ESP8266 Wi-Fi microchip instead. The ESP8266, as shown in Figure 16, would be powered by the Cypress prototyping kit at 3.3V. The data would be transmitted from the Cypress microcontroller to the add-on module through UART.

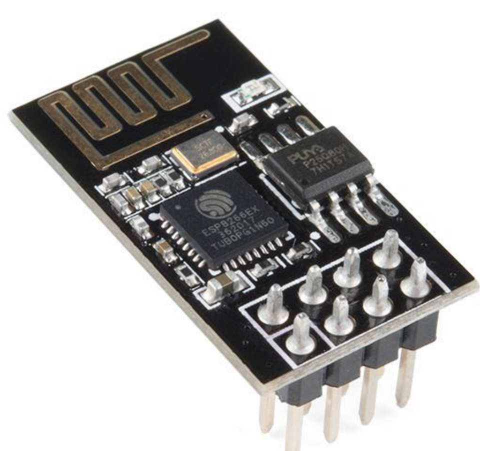

Figure 16 Expressif ESP8266 Wi-Fi module [11]

Prototype: Circuit Design

The design team has listed out the requirement specifications that are related to other circuit components for the prototype, as shown in Table 7.

Requirement ID	Circuit Design Requirement Description - Prototype
[R 3.1.10 - II]	The sensor and the microcontroller must be connected with robust wires of less than 2.54mm in diameter *
[R 3.2.23 - II]	The input voltage from a removable battery should not exceed 5V
[R 3.2.24 - II]	The device should have a runtime of at least 2 hours on a full charge in order to test all the functionality of the prototype requirements *
[R 3.2.25 - II]	The battery should be stored and fitted in a enclosed compartment
[R 3.2.26 - II]	The device can be turned on and off with a mechanical switch for each microcontroller for convenience and for safety
[R 5.0.5 - II]	The device should have a thermal control component to reduce overheating and prevent risks of burns to user
[R 5.0.6 - II]	The device should shut down within 1ms with a mechanical switch
[R 5.0.7 - II]	The hardware should be enclosed in a rigid plastic case to restrict the user's access to any crucial electronic components

Table 7 A List of Circuit Design Requirements for Prototype

The circuit will be relatively similar in both of the PoC and the Prototype stages. Aside from the chosen sensors, the circuit will consist of a voltage divider; the output for which will be the input to the companion application. Based on the test for new components, the team may opt to use fabric sensor for the wrist and pressure sensors to avoid compromising comfort while still allowing the brace to go passed the distal transverse arch. If the fabric sensors prove to not be useful, the wrist sensor will have four flex sensors to detect flexion, hyperextension, abduction and adduction. The team will also add another FSR to have a more active area when monitoring pressure.

The circuit will be powered by a Lithium polymer (LiPo) battery and will be attached to a Cypress microcontroller mounted on a custom PCB. To conserve power when the device is not in use, a power slide switch would be added to control the power to the device. The power would then pass through a power regulator before reaching to the microcontroller. Finally, the entire hardware module will be in an enclosed case attached to the brace.

Prototype: Printed Circuit Board Design

Table 8 includes a list of requirement specifications that are related to the PCB for the prototype.

Requirement ID	Printed Circuit Board Design Requirement Description - Prototype
[R 3.1.11 - II]	The maximum size for the PCB should be 4cm by 9cm to fit on the user's forearm and to avoid impeding movement *
[R 3.2.5 - II]	The PCB should be customized for the circuit
[R 3.2.6 - II]	The PCB circuit design should be compatible with the microcontroller

Table 8 A List of PCB Design Requirements for Prototype

Instead of using a breadboard for the circuit design, ChronoTech Systems would design a 2-layer PCB layout on EAGLE 8.2.2. The circuit design would include sensor pins, power input pins, and Cypress microcontroller kit pins; thus, the PCB size is mainly limited by the size of the Cypress prototyping kit.

All the other components, such as resistors for the voltage divider, LED light for status, and power switch for the LiPo battery, would be surface mount. The design will be sent to third party PCB manufacture, such as OSHPark, for printing. The hardware design team will then assemble all the components onto the board with handheld soldering irons.

Prototype: Wearable Design

Table 9 includes a list of requirement specifications that are related to the wearable component.

Requirement ID	Wearable Design Requirement Description - Prototype
[R 3.1.4 - II]	The brace should be easy to set up for users of all technical backgrounds
[R 3.1.6 - II]	The brace should have a wrist circumference of 15cm to 22cm in order to fit the majority of the ChronoTech Systems team for testing the comfortability *
[R 3.1.8 - II]	The device should be secured to the user's wrist and palm
[R 3.1.9 - II]	Sensor movement should be minimized to $\pm$0.5cm when pinpointing the wrist and each part of the hand for minimal error in data collection
[R 3.1.3 - II]	The brace should not pass the distal transverse arch
[R 3.1.5 - II]	The device should be comfortable to wear for extended periods of time
[R 3.1.7 - II]	The weight of the device should not exceed 200g for easy transportation *
[R 3.4.1 - II]	The brace should not strain, compress, or discomfort the user's wrist and hand
[R 5.0.3 - II]	The device should be free of hazardous or toxic materials and chemicals
[R 5.0.4 - II]	The brace and its electrical components should not have sharp edges

Table 9 A List of Wearable Design Requirements for Prototype

Since M-Brace is intended to be used for an extended period of time, the team proposes a more secure design that resembles a wrist brace, where the wrist and half of the palm be would covered, as shown in Figure 17. Minimal technical background would be required for the setup as anyone who can put on a generic wrist brace should be able to wear M-Brace.

Figure 17 Wrist Brace Design [12]

The distal transverse arch is formed by the metacarpophalangeal (MCP) joints, as illustrated in red in Figure 18. As the thumb and the four fingers fold at the MCP joints, any fabric or material on the distal transverse arch would impede movements, such as gripping on an object. Therefore, the wrist brace, designed in the prototype development phase, will not extend beyond the distal transverse arch to minimize mobility restrictions.

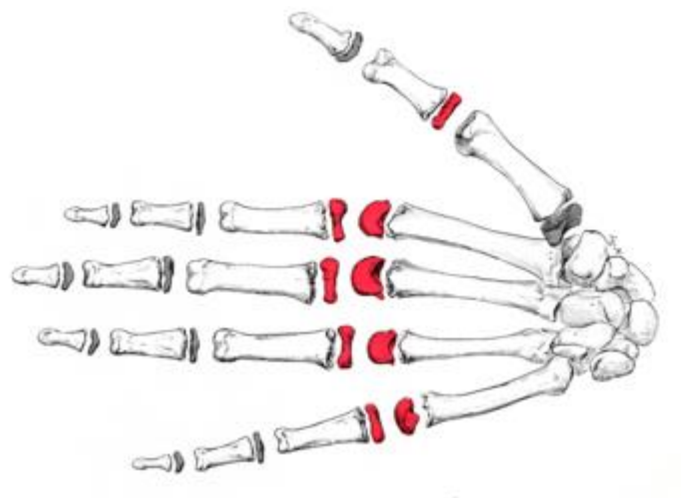

Figure 18 Metacarpophalangeal Joint [13]

3.1.3 Hardware and Firmware Final Product Design Specifications

In order for M-Brace to become a commercialized product, further improvements are required to be made. This section describes the changes made under the following categories: general circuit components, PCB, and the wearable design.

Final Product: Circuit Design

The design team has listed out the requirement specifications that are related to the general circuit for final product of M-Brace, as shown in Table 10.

Requirement ID	Circuit Design Requirement Description - Final Production
[R 3.2.17 - III]	The device should be running on a single microcontroller chip without unnecessary hardware components
[R 3.2.18 - III]	The device should have a sampling rate and transmit rate of at least 1kHz as the product will eventually be marketed to medical professionals
[R 3.2.27 - III]	The battery size should not exceed the PCB size to minimize the footprint
[R 3.2.28 - III]	The device should have a runtime of at least 4 hours on a full charge in order for the user to play the full-length of a common sports game
[R 3.1.14 - III]	The sensor and the microcontroller must be connected with conductive thread of less than 0.4mm in thickness

Table 10 A List of Circuit Design Requirements for Final Production

The final circuit that goes to market will be powered by a battery that can last for about 4 hours on a full charge, so the user can have it working through most of their work session. The circuit should be on a more compact microcontroller with only the essential features to minimize cost and optimize space.

Final Product: PCB Design

The design team has listed out the requirement specifications that are related to the PCB design for the final product, as shown in Table 11.

Requirement ID	Printed Circuit Board Design Requirement Description - Final Production
[R 3.1.15 - III]	The maximum size for the PCB should be 4cm by 5cm to fit on the dorsal side of the user's hand and to avoid extending beyond the hand
[R 3.2.7 - III]	The circuit should be mass-produced to lower production costs
[R 3.2.8 - III]	The circuit design should be optimized for space on the PCB

Table 11 A List of PCB Design Requirements for Final Production

To mass produce M-Brace, ChronoTech Ssytems will be purchasing an ultra-compact wave solder machine, such as the C350 wave solder machine [14]. With this machine, the hardware design team will can replace the Cypress prototyping kit with a single microcontroller chip. This would drastically reduce the PCB footprint and the production cost. Furthermore, the company would can add the EZ-BLE module on the PCB with the solder machine.

Final Product: Wearable Design

The design team has listed out the requirement specifications that are related to the wearable component for the final product, as shown in Table 12.

Requirement ID	Wearable Design Requirement Description - Final Production
[R 3.1.13 - III]	The weight of the device should not exceed 120g to put less strain on the user
[R 3.1.12 - III]	The brace should be available in different sizes for adults with wrist circumferences between 15cm to 24cm
[R 5.0.8 - III]	The fabric of the brace should consist of allergen-free material
[R 5.0.9 - III]	The brace should be water resistant to eliminate risks of electric shock

Table 12 A List of Wearable Design Requirements for Final Production

The wearable design for the prototype only has one size, which fits the majority of the ChronoTech Systems engineers. For the final product, ChronoTech Systems would like to commercialize M-Brace by producing braces of various sizes. Each of the brace size would need to undergo various testing to ensure the data collection is still precious prior to hitting the market.

3.2 Software Design Specifications

The software design consists of the implementation to send and receive data between the microcontroller and the phone application. This section will elaborate on how the PoC and prototype will send and receive sensor data between the independent components. Additionally, the software design also focuses on how the data will be represented graphically. The PoC will only display real-time data. For the prototype, there will be sensor data analysis and data logic functions. This section will go into depth with the functions that are to be implemented for the prototype software application.

3.2.1 Software PoC Design Specifications

Following the preliminary design, the software design team has divided the specifications into the following categories: GUI, sensor data receiving, and software testing. Appendix B contains the software test plans for PoC to confirm the validity of the functionalities.

PoC: GUI

The design team has listed out the requirement specifications that are related to the software UI for the proof of concept of M-Brace, as shown in Table 13.

Requirement ID	GUI Design Requirement Description - PoC
[R 3.3.1 - I]	The sensor data can be accessed from an emulation of a phone
[R 3.3.2 - I]	The application should provide numerical feedback of the sensor readings
[R 3.3.3 - I]	The application should be available on iOS for the ease of accessibility
[R 3.3.4 - I]	The application should provide timestamps, based on the clock of the user's phone, for each data packet received from the device

Table 13 A List of GUI Design Requirements for PoC

As the ChronoTech Systems software team was more familiar with the iOS user interface, Xcode was the chosen development environment for the front and back end development of the software application. Furthermore, Xcode has the ability to generate a mobile app simulation for the proof of concept and poster presentation demo.

The GUI for the software application is a graph display from an open source Charts library [15]. As a result, the app shows a multiple line chart with each line corresponding to the sensor that it was read from. The sensor data is accessed by requesting the data from a server on the local host computer that is emulating the phone.

Despite the requirement, [R 3.3.4 - I] the sensor data is not plotted against time because the Arduino microcontroller does not have an internal clock to keep track of the sensor outputs. Since this problem may recur in the prototype phase, the solution proposed is to have the microcontroller with an internal clock so it is possible to determine the time since the microcontroller was powered on. This would allow the data to be sent to the computer with a time reference.

PoC: Data Receiving

The design team has listed out the requirement specifications that are related to the software UI for the proof of concept of M-Brace, as shown in Table 14.

Requirement ID	Data Receiving Design Requirement Description - PoC
[R 3.3.18 - I]	The software should consistently receive data packets from microcontroller
[R 3.3.19 - I]	The emulation of the phone should receive data packets via serial port

Table 14 A List of Data Receiving Design Requirements for PoC

To receive the sensor data from the Arduino microcontroller, the Arduino will output the sensor values to its console. The Mac computer, which is connected to the microcontroller, will listen to its serial port and output the values into a text file called screen log. Simultaneously, the Mac computer will also locally host a TCP Server using Python. The server reads the data values line by line in the screen log file and sends it to requesting clients. The sole client is the emulated iPhone 8 application running on iOS 10. Once the client receives the data, the software application can graph the sensor values onto a plot.

PoC: Testing

The design team has listed out the requirement specifications that are related to the testing of the software application for the proof of concept of M-Brace, as shown in Table 15.

Requirement ID	Testing Requirement Description - PoC
[R 3.3.24 - I]	The software should receive data at a consistent sampling rate
[R 3.3.25 - I]	The received data should be consistent to ensure the precision of the device
[R 3.3.26 - I]	The numerical output should match the received data values
[R 3.3.27 - I]	White box testing should be performed by at least 2 team members

Table 15 A List of Testing Design Requirements for PoC

The above test requirements are to be met by the software application and will be tested by procedures outlined in the Appendix B for test cases.

3.2.2 Software Prototype Design Specifications

Based on the PoC design, the software design team has improved upon the following categories: GUI, sensor data receiving, and software testing.

Prototype: GUI

The design team has listed out the requirement specifications that are related to the software UI for the prototype of M-Brace, as shown in Table 16.

Requirement ID	GUI Design Requirement Description - Prototype
[R 3.3.5 - II]	The sensor data can be access from a phone running on iOS
[R 3.3.6 - II]	The application should have an intuitive UI design for the ease of operation
[R 3.3.7 - II]	The application should provide graphical feedback of the sensor readings
[R 3.3.8 - II]	The UI should display the location of the sensors that correspond to where they are physically located on the device
[R 3.3.9 - II]	The application should notify the user upon successful connection with device
[R 3.3.10 - II]	The application should notify the user when it detects excessive pressure
[R 3.3.11 - II]	The application should notify the user when it detects that their hand has been performing the same movements for an extended period
[R 3.3.12 - II]	The application should have the option to set reminders
[R 3.3.13 - II]	The collected data should be saved onto the user's phone and be kept in data logs for a week to avoid filling up the phone's memory *
[R 3.3.14 - II]	The application should load the user's data within 2s of the request

Table 16 A List of User Interface Design Requirements for Prototype

The GUI in the prototype stage will feature an iOS application on the phone. The application will have user-friendly interface design elements with an intuitive design of an emulated hand to display sensor data that corresponds to each sensor on the wearable. The simulated hand model in the application will show the sensor positions that match the placement in the brace. There will be four views of the hands in the application, two front views and two back views of the left and right hands. The user will still be given the option to change from viewing the sensors on a hand simulation back to viewing the data in graph form. The application will also provide the user with the option to set reminders for themselves to take breaks. Another user interface feature new to the prototype will be notifications. The phone app will notify the user when connection is successfully established with the wearable device. Upon sensor detection of excess pressure on the hand or the detection of repetitive motion of the hand for extended periods of time, the mobile application will also send the user an alert.

Prototype: Data Receiving

The design team has listed out the requirement specifications that are related to the software data receiving for the prototype of M-Brace, as shown in Table 17.

Requirement ID	Data Receiving Requirement Description - Prototype
[R 3.3.20 - II]	The application should obtain data within 4m of distance via wireless connectivity *
[R 3.3.21 - II]	The maximum latency between receiving and displaying data should be 1s *

Table 17 A List of Data Receiving Design Requirements for Prototype

In the prototype, ChronoTech Systems will ensure the mobile application can successfully connect to the microcontroller unit wirelessly. In regard to the wireless connection, Wi-Fi will be used instead of Bluetooth connection. This is due to the significant price difference between the Wi-Fi module and the pre-soldered Bluetooth kits and the soldering limitations of available Bluetooth modules. As the team changes from wired connectivity to wireless connectivity, the time for data transfer will be timed to ensure the maximum delay in receiving the sensor information and displaying the data on the mobile application is no more than 1 second.

Prototype: Testing

The design team has listed out the requirement specifications that are related to the testing of the software application for the prototype of M-Brace, as shown in Table 18.

Requirement ID	Testing Requirement Description - Prototype
[R 3.3.28 - II]	All functionalities should be operational before hardware integration
[R 3.3.29 - II]	All functionalities should be operational after hardware integration
[R 3.3.30 - II]	The device should be able to establish and maintain a stable wireless connection in stress tests
[R 3.3.31 - II]	The error tolerance for colour mapping should not exceed 1% (Appendix B)
[R 3.3.33 - II]	Black box testing should be conducted on software components to verify functional requirements are correctly implemented
[R 3.3.34 - II]	Stress testing by placing weights (1kg – 5kg) on the device while it transmits the data to the application for 24+ hours
[R 3.3.35 - II]	Regression testing should be performed when new features are added to the application to check if the new code affects more than intended

Table 18 A List of Testing Design Requirements for Prototype

M-Brace will consist of multiple independent components that each performs their own major tasks and features. Thus, it is important to ensure all software features and integrations work correctly before integrating with hardware. Linear interpolation will be used to calculate the colour mapping of each sensor, where green is minimal pressure and red is intense pressure. Using sample data and the sensor results from stress ball testing, the colour mapping will have a justifiable and meaningful range.

M-Brace is intended to be used for up to 4 hours. To ensure stable performance of data transfer from the device to the mobile application even under stressful conditions, the team will conduct stability testing by placing a heavy object on the device for 24 hours. When a new feature is added, the team will conduct regression and integration testing to ensure that both old and new features are not affected by the addition.

3.2.3 Software Final Product Design Specifications

For better UI, the software design team has made further improvements for the following categories: GUI, sensor data receving, and software testing.

Final Product: GUI

The design team has listed out the requirement specifications that are related to the software UI for the final product of M-Brace, as shown in Table 19.

Requirement ID	GUI Design Requirement Description - Final Production
[R 3.3.15 - III]	The application should be available on iOS, Android, and desktops via a framework to optimize time on the development and accessibility to user
[R 3.3.16 - III]	The application should allow cloud service for data storage scalability
[R 3.3.17 - III]	The application should require a login authentication to protect user information

Table 19 A List of User Interface Design Requirements for Final Production

The software application will be available on various platforms. It is possible to use a framework to develop the application for iOS, Android, and desktop accessibility. The application will include cloud service for data storage. For use data protection, the final product will also ask for login authentication.

Final Product: Data Receiving

Requirement ID	Data Receiving Requirement Description - Final Production
[R 3.3.22 - III]	The data should be wirelessly transmitted to increase device coverage
[R 3.3.23 - III]	The maximum latency between receiving and displaying data should be 0.1s

Table 20 A List of Data Receiving Design Requirements for Final Production

The final product aims to transmit data wirelessly and test for increased device coverage. There will also be timed testing of receiving and displaying data.

Final Product: Testing

The only requirement under testing for the final product is [R 3.3.36 - III]. The software application and device will be given to end-users for user testing. The details of the UI testing is expanded on Appendix C.

4.0 Conclusion

The idea of creating M-Brace was originally influenced by family members, who are suffering with Carpal Tunnel Syndrome (CTS). ChronoTech Systems is motivated to help people at risk of developing Repetitive Motion Syndrome (RMS), which CTS is a type of. The excessive pressure exerted on the median nerve will lead to the gradual development of CTS. RMS, also known as repetitive strain injury, is caused by overuse of the muscles and poor posture. ChronoTech Systems proposes a lightweight and practical solution that monitors and alerts the user of their hand and wrist posture. M-Brace will be beneficial for athletes who wish to prevent either the further development of RMS or the return of the injury in their hands.

ChronoTech Systems has divided the teams into two departments: the hardware department and the software department. The hardware department is in charge of designing the wearable components, the hardware components, and the firmware, while the software department is in charge of the graphical representation on the smart device as well as the data transfer from the hardware device to the mobile application. The proposed design features by both departments are based on the requirement specification documentation.

This document has covered the system overview, device requirements, and proposed design for M-Brace. The design specifications define the expected capabilities and requirements of the M-Brace device at the PoC, prototype, and final product phases. The PoC will be delivered by April 9, 2018 and a prototype will be delivered by early August 2018. The final product will be further customized for medical use in the future. The user's safety is top priority and the product will be designed to meet power regulations and other risk managements specified by the engineering standards of IEC, IEEE, and ISO, as expended upon in Appendix C and Appendix D. Our company plans to utilize the functional requirements proposed for each stage of the project in this document to deliver a safe, reliable, and user-friendly product with an ergonomic design and sustainable materials.

Appendix A: Experiment Details

The hardware team has conducted a series of tests and experiments to determine the ideal location and placement for the potential sensors. A summary of the baby powder testing is included under Section 2.1 Hardware and Firmware Design Overview.

Under the advisement of Dr. Andy Hoffer, the team smothered various sports equipment with baby powder. The following pictures are the results of the tests. The smothered parts were firmly grasped, and wherever the powder stuck to the hand was a good estimation of where the FSRs should be placed.

Figure A1 shows the test with a medicine ball. The power is transferred onto the majority of the palm, except for the corners near the wrist. The hardware testing team has repeated the test to other spherical objects with different firmness. The results are all similar.

Aside from the round spherical objects, the powder stuck to the MCP joints - which were the areas of the palm the team initially wanted to avoid for discomfort issues - and right under the distal transverse arch. The object tested are a cane, a tennis racket, and a hockey stick respectively. Figure A2 shows the result with a cane. Thus, the team decided to investigate the stretchable and uncomforted sensor materials on the palm to reduce the discomfort if the sensor were to be placed at those critical area.

Figure A 1 Power Test with Ball

Figure A 2 Power Test with Cane

Appendix B: Test Plans

The following software test cases will be conducted and cover unit testing, integration testing, regression testing, and system testing.

Test Case		The server receives data from the sensors consistently without errors.	
Requirement(s) covered		3.3.18, 3.3.25, 3.3.27	
Step	Action	Expected Result	Actual Results (P/F and comments)
1	Position the sensor on “rest” mode and check the graphed data. Record the value.	The graphed output is the “rest” mode.	
2	Apply pressure on sensor and check the graphed data. Record the value.	The plotted output should differ from the value recorded in step 1.	
3	Return to “rest” mode and check the graphed data. Record the value.	The plotted output should show the graph returning to “neutral” or “rest” mode and matches the value recorded in step 1.	
4	Apply same amount of pressure on the sensor and check the graphed data.	The plotted output should match the value recorded in step 2.	

Test Case		The iOS application receives from the server and plots the collected data points with minimal delay (<1s) relative to the changes in sensor values from the microcontroller.	
Requirement(s) covered		3.3.1, 3.3.2, 3.3.3, 3.3.4, 3.3.19	
Step	Action	Expected Result	Actual Results (P/F and comments)
1	Run the emulation for starting the iOS app	Simulated application pops up.	
2	Click on the start button to start plotting the points.	See plot on emulated screen with multiple lines, coloured coded by sensor number. Confirm that the delay between real-time change in the sensors is less than one second.	

Test Case		The text file data is the same as the sensor values plotted in the app. Confirm the plot accurately represents the sensor readings.	
Requirement(s) covered		3.3.19, 3.3.26	
Step	Action	Expected Result	Actual Results (P/F and comments)
1	Open the text file that was logged by the terminal.	Text file contains the values read live from the sensors.	
2	Compare the plotted data with the collected sensor values stored in the text file and confirm both are same.	Values of plotted points are the same as the values from the text file.	

Appendix C: User Interface Design

1.0 Introduction

M-Brace is a combination of a flexible sensor glove and a software phone application to monitor repetitive motion syndrome. The user interface (UI) consists of designing the wearable glove, which specifically focuses on the comfort, safety and appearance to the user. For the phone application, the UI consists of designing the graphical appearance such that an average smartphone user can intuitively understand and use with little instructions. ChronoTech Systems aims to design a product that will maximize usability and the user experience while still meeting its functional requirements.

1.1 Purpose

The purpose of this document is to specify both the hardware and software UI design of the proof-of-concept and the prototype versions of M-Brace.

1.2 Scope

This document focuses on the required user knowledge and restrictions, engineering and safety standards, and usability testing for designers and end users of M-Brace. This section will also consider the seven fundamental principles in the UI design, as outlined from Don Norman's *The Design of Everyday Things.*

2.0 User Analysis

The targeted demographic of M-Brace are sports enthusiasts and professional athletes. In our current generation, using technology has become common for monitoring vitals and athletic growth in the sports industry.

Ideally, the intended users of M-Brace should at least already have previous experience with smartphones. While the GUI of the M-Brace phone application will have a simple and intuitive design, background experience with smartphone conventions is necessary to use the application instinctively for the first time. In the case that users are still beginners in using a smartphone, this issue can be managed by providing a step-to-step instruction booklet for M-Brace. It will include detailed instructions for the phone application and its features.

An additional requirement is that the users must also have experience in wearing gloves or braces. In order to avoid difficulty with the device setup, the brace component design of M-Brace should be as simple as putting on a glove. There will also be a switch to power the device on and off. It will be labelled with universal power symbols to clearly indicate its function.

The current restrictions we have for the prototype is that the user is required to have access to a smartphone to be able to observe the data collected from the glove device. Wi-Fi setup for the brace component is also necessary, and instructions will be provided in the instructional manual. For the PoC, there will be no Wi-Fi connection, as the project will be wired. Additionally, access to XCode is required to emulate the iOS mobile phone and run the application.

Hardware restrictions include the knowledge of removing the electronic components to wash the glove and the knowledge to re-assemble the glove after cleaning the fabric. The instructions to separate electrical component pouch from the wearable glove and properly put them back together will also be provided in an instruction manual.

3.0 Graphical Representation

This section covers the conceptual designs of the prototype and the current representations for the PoC, for both the glove component and the software application component of M-Brace.

Figure C 1 Testing Mock-Up for the PoC

For the PoC, the glove is only a mock-up, consisting of a mannequin hand with moveable joints combined with a latex glove and silicon padding. Sensors will be placed with tape or Velcro onto the mock-up. Figure C1 shows the separate components that will be used to build the mock-up glove.

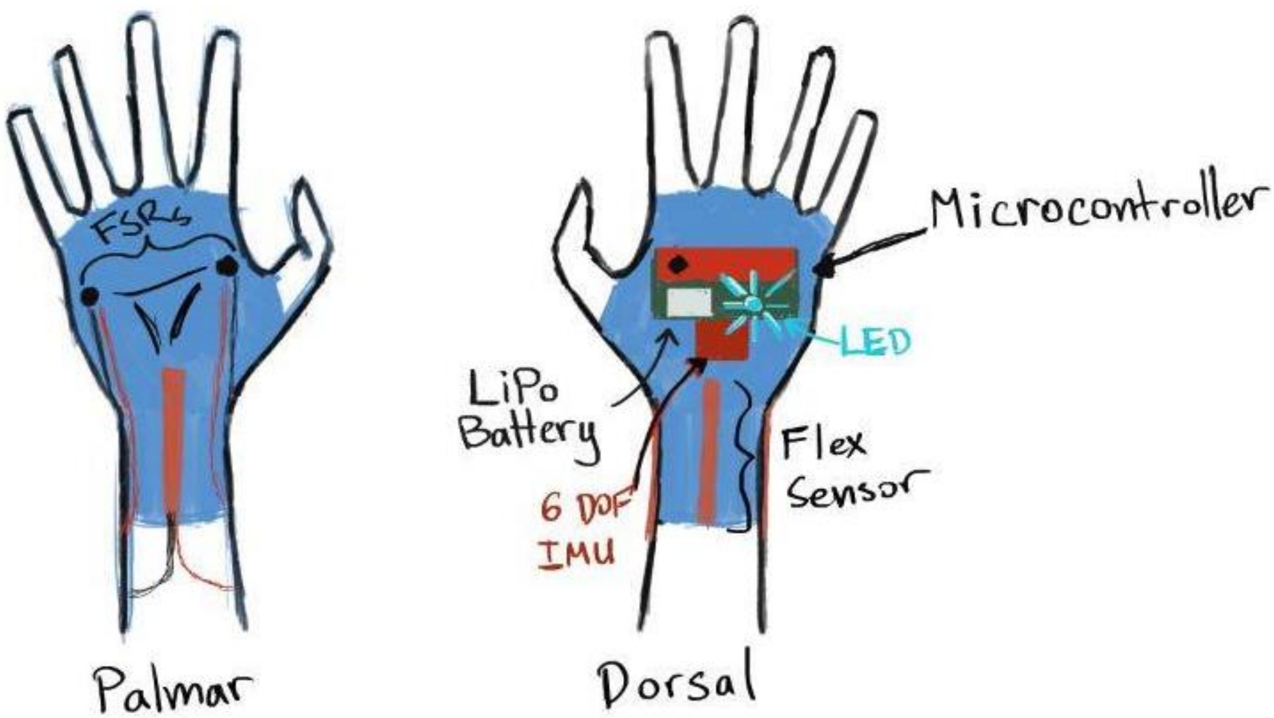

Figure C 2 Sketch of the Prototype for the brace component of M-Brace

The concept of the prototype brace component is a comfortable and flexible fingerless glove that covers about a few inches below the wrist. The larger electrical components will be located at the back of the hand, as shown in Figure C2.

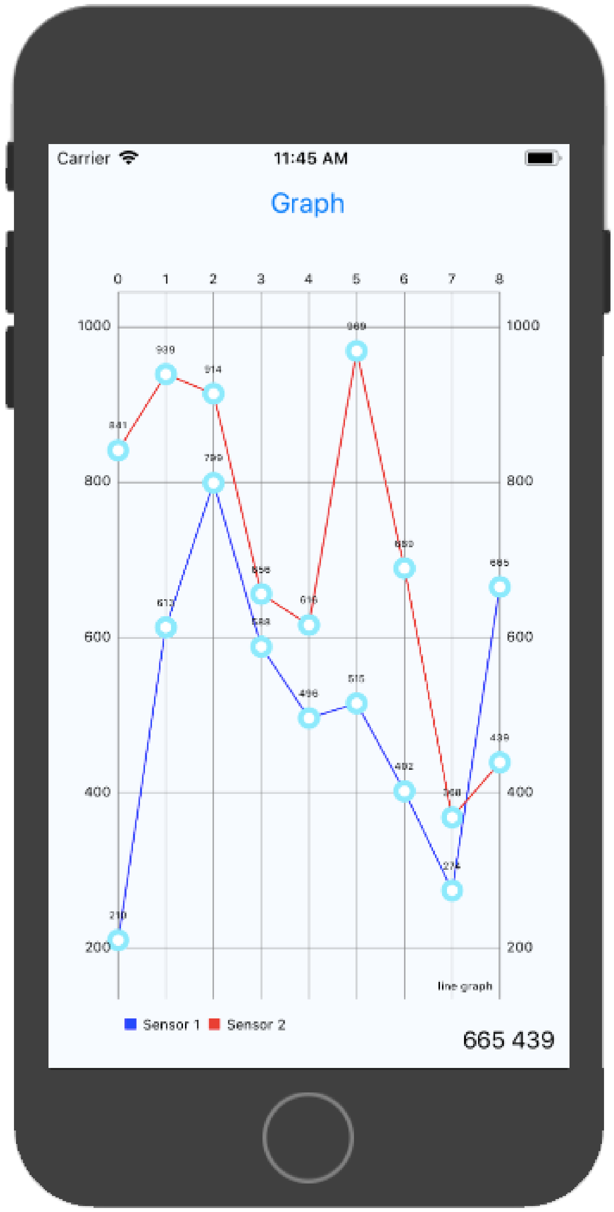

Figure C 3 GUI of the PoC

For the PoC, we have designed an iOS application that displays a graph of plotted sensor data, which each line representing one sensor. Figure C3 is an example of the simulated application graphing two sensors.

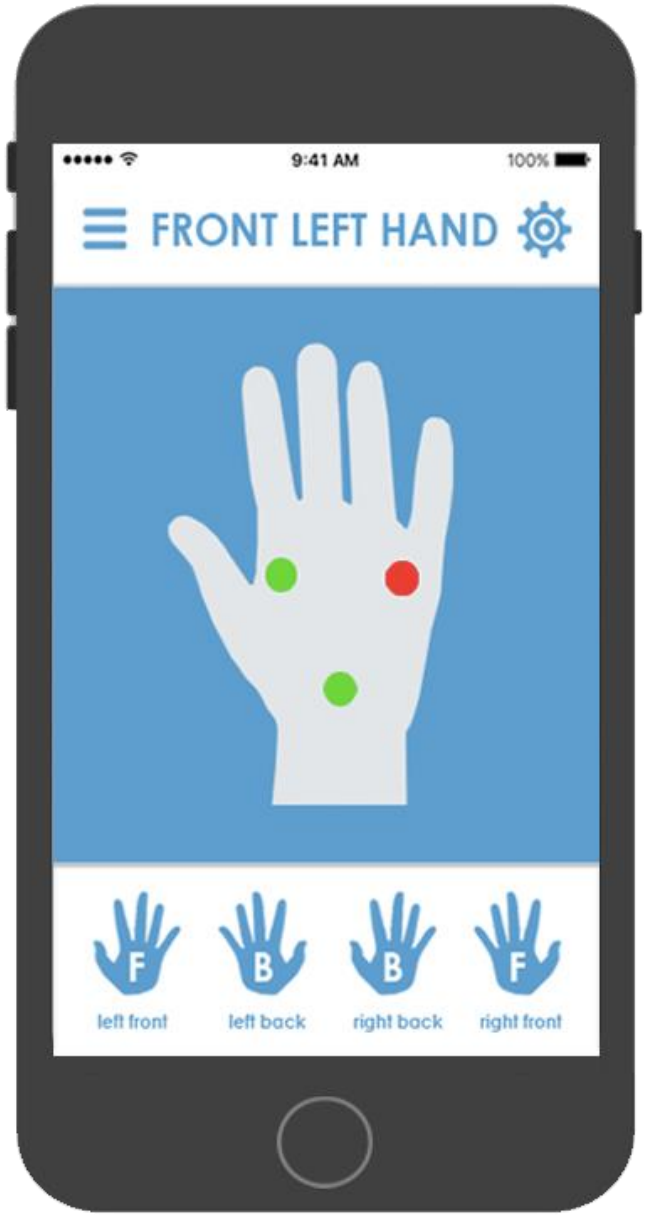

Figure C 4 Concept GUI of the Prototype

Figure C4 is the proposed software app UI design for the prototype. The main view features 4 hand options for the user to select and view the status of the sensors. When the sensors detect excessive pressure, the display of the sensors on the phone will turn red. If the resulting sensor is not on the hand that's displayed, the tab of the hand with the corresponding sensor will be highlighted with a distinctive colour.

4.0 Technical Analysis

ChronoTech Systems believes intuitive designs create the optimal experience when using M-Brace. The design team has followed the seven fundamental principles outlined in Don Norman's "Seven Elements of UI Interaction" [16]. This section summaries the principles and the design as follows.

Discoverability

In an intuitive design, the user knows all of the available options and is able to access them easily. For the PoC, the mobile design of M-Brace is minimalistic. The app only features a single button labelled "graph" and once the user clicks on the button, a simple graph displays all sensor data collected from the brace.

To determine the product's discoverability for the prototype, we analysed the actions in which the user interaction with the device will affect their ability to use M-Brace.
The user needs to:

1. Put on the brace until it fits comfortably.
2. Turn on the device via power switch.
3. Open phone app to see the data collected from the wearable.

For the user to achieve these tasks, we have incorporated the following factors into our prototype design:

1. The wearable product resembles the shape of a brace so the user knows how to wear the device, given that they know how to put on a glove or a brace. The wearable also fits easily like a glove to allow unrestricted movement of the hand.
2. The power switch will be placed on the backside of the brace so the user can see the switch and power on or off the device by themselves.
3. The prototype of the software application features a tab-bar menu to improve the discoverability of the options available on the mobile app. There will be four tabs available; two views (front and back) of each hand (left and right), as the type of sensors and the placement of the sensors will differ depending on the front or back of the hand. Once the user selects the tab of the hand they want to view, the centre of the application will display the hand selected and the sensors on that side of the hand.

Feedback

Feedback is used to indicate to the user the device is functional and to alert the user of the state of device after an action is performed.

The PoC of the simulated application displays a blank screen upon start-up. However, a graph is displayed, and data points are plotted when the "graph" button is clicked.

In the prototype, ChronoTech Systems plans to include the following feedback designs for a responsive user experience:

1. When the power switch is powered on, a blue LED on microcontroller unit will turn on.
2. When the power switch is turned off, the LED will turn off to show the device is off.
3. When the user has exerted excess pressure on their hand or when the user has demonstrated a bad posture while wearing the brace, the sensors displayed on the mobile application will change colour, from green to red, to alert the user.

Conceptual Models

A conceptual model allows the user to better understand the functions of the product. M-Brace was designed to resemble a brace, which is universally worn, so the user is expected to have a conceptual idea on how to put on the wearable. As the M-Brace app is designed for smart phones, as long as the user has experience with using mobile applications and know how to connect their phone wirelessly, the user will be able to operate the software app.

Affordance

Affordance refers to the clarity of the design and is the relationship between the look and the intended use of the design. In the PoC, both the software application and the hardware component utilize simple design features. The mobile simulation only features one on-screen button, so the user can easily understand how to start the software application. The hardware application also only has one power button for the user to initialize the device.

Signifiers

M-Brace uses LEDs and colour changes to help convey discoverability and feedback to the user. On the hardware component, the blue LED lights up when the device is powered on and will turn off when the device is powered off. In the prototype stage of the mobile application, colour is also used to indicate pressure detection on the sensors. The change in colour from green to red will alert the user of their hand habits.

Mapping

Mapping is the correlation between the controls the user can use and the effect of the mapping. To achieve good mapping in the prototype design, ChronoTech Systems placed the power switch on the backside of the arm along with the LED of the microcontroller unit. This allows for the power slider to be easily seen and accessed when the brace is worn. By positioning the LED on the same side as the power switch, the user immediately knows when the device is turned on or off.

Constraints

Constraints refer to the limitation of an interface. The software constraints require the user to be familiar with mobile application technology. The screen size of the mobile application limits the number of features that could be displayed. Although the hamburger menu lacks visibility, it does allow for maximization of mobile screen space; thus, the menu is used to hide some of the features the prototype of M-Brace offers. The user must recognize that the stacked lines icon indicates more options are available as not all options can fit in the screen space.

Due to ethical reasons, the wearable cannot be tested on humans yet. To demonstrate the functionality of the sensors, a mannequin hand is used; however, the mannequin hand is unable to fully replicate the same angles of flexion as a hand and only bends ⅕ of what the human hand is capable of. Another restriction in the prototype is the size of the brace. The size of the microcontroller unit that is placed on the backside of brace is restricted by the size of the CY8CKIT-043 PSoC® 4 M-Series Prototyping Kit which contains the microcontroller chip.

5.0 Engineering Standards

M-Brace will be designed to meet various engineering standards published by the IEEE [17], the IEC [18], and the ISO [19] to ensure performance and safety. The following engineering standards will be taken into account for the proposed user interfaces of M-Brace. M-Brace is not intended nor designed to be a medical application; however, some medical standards are also reviewed because ChronoTech Systems plans to expand for medical purposes in the future.

Standard ID	Description of Engineering Standards
IEEE 1074	Standard for developing a software project life cycle process
IEEE 1451	Standard for smart transducer interface for sensors and actuators
IEEE 2700	Standard for sensor performance parameter definitions
IEEE 29148	Standard for systems and software engineering requirements
IEEE P360	Standard for wearable consumer electronic devices
ISO 9001:2015	Standard for customers to receive consistent, excellent quality products
ISO 9241-161	Standards for ergonomics of human-system interaction in software
ISO 14915-1	Standards for visual user-interface elements presented by software
ISO 80002	Standard for validation of medical device software quality systems

Table C 1 A List of Engineering Standards

Standard ID	Description of Safety Standards
IEC 60950-1	Safety standard of battery-powered information technology equipment with a rated voltage not exceeding 600V
IEC 61508	Standard for functional safety of electronic safety-related systems
IEC 62133	Standard for batteries in portable applications/lithium battery safety testing
IEC 60601-2-49	Medical electrical equipment standard – requirements for the basic safety and essential performance of multifunction patient monitoring equipment
ISO 80001	Standard for risk management of safety, effectiveness, and security in the implementation and use of connected medical devices or health software

Table C 2 A List of Safety Standards

6.0 Usability Testing

The usability of a system can be defined by five factors that concern the performance, safety, and user experience: learnability, efficiency, memorability, errors, and satisfaction. There are two types of usability testing, analytical and empirical. Analytical testing is performed without users. While analytical testing is simpler and faster compared to empirical testing, it is also usually less effective. Empirical testing is testing with users. This requires planning and preparation for the end-user testing and could vary from simple informal tests to specific experimental tests.

6.1 Analytical Usability Testing

The analytical usability testing evaluates the user interface design. Each designer will independently review the following conditions. After every designer has tested the application, the results will be compiled and discussed. Due to safety and ethical purposes, the initial stages of testing are not performed on humans. The functionality of the proof of concept will be demonstrated with a silicone gel padding. The silicon is used to replicate a hand and tests the application of pressure on sensors.

Designer's Setup

The designer setup is shows the steps to properly setup the glove and the software phone application for Proof-of-Concept testing. Below are the tasks the designers will carry out to use M-Brace correctly. The following steps are only intended for the proof of concept of M-Brace.

1. Connect circuit via breadboard
2. Connect Arduino on a Mac computer with corresponding Arduino application downloaded in advance
3. Place FSRs on dome-like objected to show pressure data can be sent to the Arduino
4. Remove FSRs from dome. Place on glove with silicone pads and collect pressure data

5. Place Hall Effect Sensor on the wrist of the mannequin with the south pole of a magnet directly above the sensor
6. Bend the wrist towards the sensor and observe the change in voltage across the sensor
7. Remove the Hall Effect Sensor and replace it with the Flex sensor
8. Repeat step 6 and observe the results
9. Run Arduino scripts to enable printing out sensor values onto serial
10. Verify sensor values are read and outputted onto the serial console
11. Check Arduino tab Tools > Port for the corresponding serial port used in the form of "/tty.usbXXXXXX"
12. Open terminal and enter "screen -L /dev/tty.usbXXXXXX 9600" to listen to Arduino serial console and output onto screenlog.0 text file
13. Verify that screenlog.0 is created
14. Run TCPServer.py
15. Simulate M-Brace phone application on XCode
16. Press "Graph" on the application
17. Verify the graph is plotting the values
18. Verify that the graph is updating sensor values in real time within 5 seconds

Heuristic Evaluation

This section inspects the usability problems that users may face during their experience with M-Brace. Designers of ChronoTech Systems will use this to evaluate the product over the course of the designing process of the proof of concept and the prototype.

For the proof of concept:

1. Sensors are detecting change in voltage when pressure is applied to the sensors on the hand and wrist of the mannequin and glove
2. App starts graphing once the "Graph" button is pressed

For the prototype:

1. Glove is comfortable
2. Glove gives minimal mobility restriction
3. Sensors are on the correct placements of the hand when the glove is put on securely
4. After proper device set up with the phone application, data is transmitted to the app
5. App shows that it has correctly received the data within an insignificant amount of time

6.2 Empirical Usability Testing

To create a comfortable and user-friendly product that meets the design goals, empirical usability testing is performed as part of M-Brace's design process.

Personal Testing

ChronoTech Systems will perform testing on a team member to obtain feedback of M-Brace. The size of the proof of concept and the prototype of M-Brace will be designed for one of ChronoTech System's team member's hand. The comfortability and size fitting of the device will be reported. The focus of this test is to determine the proper placement of the sensors and the fit of the glove component. It can also be used to test the sensitivity and functionality of the sensors. For the final product of M-Brace, the device will be tested on various individuals to ensure the designed wearable fits a variety of sizes.

End User Testing

Individuals, selected at random, will be testing the prototype design of M-Brace (the glove and the app ensemble) to provide feedback as potential end users. The user will rate the usability and viability of the product, and record their feedback, suggestions, complaints, and errors. The end users who are surveyed and performing the tests are assumed to have little to no technical background of the product. The user will also be asked if they have any prior knowledge about repetitive motion syndrome.

The end users will be surveyed with the following questions/criteria:

1. What is the user's knowledge about repetitive motion syndrome?
2. First impression of the device?
3. Was the device comfortable to wear while doing the sports activities?
4. Did the wearable device interfere with the activity you were doing?
5. Was the device easy to put on and set up?
6. Was the app easy to use, navigate, and understand?
7. Are you more aware of your gripping habits now? (Did the device notify you of any excessive pressure application?)
8. Would you wear the device on a daily basis? (Please state the max/min time period you would wear this. When would you most likely wear this device?)
9. Would you recommend this product to others? (If yes, please specify who you would suggest this device to and why?)

Test Environment	(Ask user to describe what activities they are performing while wearing M-Brace)
Questions for tester/Test Criteria	Test Results: Comments and score out of 10 (10 is great, useful features, comfortable, would recommend to others, would buy and use; 0 is terrible, dislike the features, not comfortable, does not recommend, would not purchase/use)
Is the tester familiar with RMS?	
First Impression (Looks, aesthetics, general idea of functionality and features)	
Rate the comfortability	
Daily general wearability (Were there any interferences?)	
Was the set up of the device simple?	
Rate the user experience of the mobile application.	
Awareness	
Feasibility of daily wearing	
Marketability/recommendation	

7.0 Conclusion

The user interface design is an important parameter in the development process of M-Brace. The UI appendix provides a concise review of the different UI elements that will contribute to the performance, safety, and usability of both the hardware and software components of M-Brace. ChronoTech Systems has analysed the seven fundamental principles of user interface interaction design, as the goal for M-Brace is to be a safe brace with simple features for easy use. The software application is also intended to be intuitive and clear. To ensure both the wearable and the mobile app perform to its full potential and meets the engineering and safety standards, various tests will be conducted for feedback and design improvements. While the PoC of M-Brace focuses on minimalistic design and demonstration of the basic functionalities, the prototype of M-Brace will include additional features for an attractive, safe and user-friendly interface.

ENSC 405W Grading Rubric for User Interface Design
(5-10 Page Appendix in Design Specifications)

Criteria	Details	Marks
Introduction/Background	Appendix introduces the purpose and scope of the User Interface Design.	**/05%**
User Analysis	Outlines the required user knowledge and restrictions with respect to the users' prior experience with similar systems or devices and with their physical abilities to use the proposed system or device.	**/10%**
Technical Analysis	Analysis in the appendix takes into account the "Seven Elements of UI Interaction" (discoverability, feedback, conceptual models, affordances, signifiers, mappings, constraints) outlined in the ENSC 405W lectures and Don Norman's text (*The Design of Everyday Things*). Analysis encompasses both hardware interfaces and software interfaces.	**/20%**
Engineering Standards	Appendix outlines specific engineering standards that apply to the proposed user interfaces for the device or system.	**/10%**
Analytical Usability Testing	Appendix details the analytical usability testing undertaken by the designers.	**/10%**
Empirical Usability Testing	Appendix details completed empirical usability testing with users and/or outlines the methods of testing required for future implementations. Addresses safe and reliable use of the device or system by eliminating or minimizing potential error (slips and mistakes) and enabling error recovery.	**/20%**
Graphical Presentation	Appendix illustrates concepts and proposed designs using graphics.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	**/05%**
Conclusion/References	Appendix conclusion succinctly summarizes the current state of the user interfaces and notes what work remains to be undertaken for the prototype. References are provided with respect to standards and other sources of information.	**/10%**
CEAB Outcomes: Below Standards, Marginal, Meets, Exceeds	1.3 Engineering Science Knowledge: 4.1 Requirement and Constraint Identification: 5.4 Documents and Graphic Generation: 8.2 Responsibilities of an Engineer:	

ENSC 405W Grading Rubric for ENSC 440 Planning Appendix

(5-10 Page Appendix in Design Specifications)

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project. Includes clear project background.	**/05%**
Scope/Risks/Benefits	Clearly outlines 440 project scope. Details both potential risks involved in project and potential benefits flowing from it.	**/10%**
Market/Competition/ Research Rationale	Describes the market for the proposed commercial project and details the current competition. For a research project, the need for the proposed system or device is outlined and current solutions are detailed.	**/10%**
Personnel Management	Details which team members will be assigned to the various tasks in ENSC 440. Also specifically details external resources who will be consulted.	**/15%**
Time Management	Details major processes and milestones of the project. Includes both Gantt and Milestone charts and/or PERT charts as necessary for ENSC 440 (MS Project). Includes contingency planning.	**/15%**
Budgetary Management	Includes a realistic estimate of project costs for ENSC 440. Includes potential funding sources. Allows for contingencies.	**/15%**
Conclusion/References	Summarizes project and motivates readers. Includes references for information from other sources.	**/10%**
Rhetorical Issues	Document is persuasive and demonstrates that the project will be on time and within budget. Clearly considers audience expertise and interests.	**/10%**
Format/Correctness/Style	Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted. Correct spelling, grammar, and punctuation. Style is clear, concise, and coherent.	**/10%**
Comments:		

Appendix D: 440 Planning Design

1.0 Introduction

ChronoTech Systems aims to help people who are at risk of developing Repetitive Motion Syndrome (RMS), which is often diagnosed in people who perform activities that require regular repeated movement of the hand and wrist. Due to the repetition of sudden flexion and hyperextension movements with their hands, many sports players are affected by this disorder that results in pain and loss of strength in the hand. ChronoTech Systems proposes to develop a monitoring device, M-Brace, which will record the behaviour of the user's hands.

2.0 Project Scope

M-Brace consists of a wearable module and a companion phone application for the user to use while completing their daily tasks. Flexible sensors are embedded in the wearable module at key points on the user's hand. A microcontroller will send those data to a smart device through Wi-Fi. An application will process the information and display the data on a 2D hand outline. The user has the option to receive instant feedback of their hand status and to set reminders, either at regular intervals or specific times, for taking breaks and performing stretches. The primary demographic of M-Brace is athletes because it is easier to analyze their biomechanics. This appendix outlines the development and management of the M-Brace prototype, which ChronoTech Systems promises to produce by August of 2018.

2.1 Potential Benefits

Three primary risk factors for repetitive strain injury are poor posture, poor technique, and overuse. Some of the best ways to prevent this injury is to take breaks and have good posture [20]. However, many people who have hand pain are unaware of their habits and may continue to do the same activities that contribute to the pain and are the cause of RMS. It may be difficult to prevent the patients from performing their daily activities; therefore, the main purpose of M-Brace is to remind the users to take frequent short breaks, to encourage the users to exercise with counter-movements, and to alert the user of the pressure exerted on their median nerve. Similar to training supersets in the gym, the trainee can complete a biceps curl followed by a triceps extension; this allows the trainee to perform with opposing muscle groups. For example, if the M-Brace user constantly flexes their wrist during their daily routine, the UI would recommend the user to extend the wrist after a certain extended period.

This product can be further improved upon for a vast range of potentials, such as a medical device for people who are at risk for Carpal Tunnel Syndrome (CTS). It can allow users to monitor their condition and to prevent further development of the issue.

2.2 Risk Assessment

ChronoTech Systems has evaluated the risks that the team may potentially encounter during the development of M-Brace. A risk severity scale is used to categorize the risks by severity:

- **Critical (C)**
  A risk event could severely impact the desired results for M-Brace. If it occurs, the potential failure could result in having one or more critical objectives not achieved and/or result in requiring rework on the operation.
- **Significant (S)**
  A risk event could significantly impact the desired results for M-Brace. If it occurs, the potential failure could result in having one or more critical objectives achieved with least expectation and/or result in great disruption to subsequent operations.
- **Minimal (M)**
  A risk event could have minor impact on the desired results for M-Brace. If it occurs, the potential failure could result in having one or more critical objectives achieving with slight dissatisfaction; however, it is unlikely to cause issues on subsequent operations.

The team has illustrated the potential risks from the most critical to the least critical as shown in Table D1.

Risk	Severity	Probability	Impact	Mitigation Strategy
Electric Shock	C	Unlikely	Muscle spasms	Prevent current leakage
Overheating	C	Unlikely	Damage to electronics	Allow air ventilation
Inaccurate results	C	Probable	Not meet expectation	Test with other sensors
Incorrect parts	C	Probable	Need to repurchase	Research specifications
Built Limitation	C	Probable	Cannot be fabricated	Test various material
Integrate failures	C	Probable	Fail to transmit data	Test with dummy data
Incomplete testing	S	Unlikely	Delay in process	Allow extra time
Delayed shipment	S	Probable	Delay in built time	Order parts early
Overspending	M	Probable	Cannot buy extra parts	Over budget

Table D 1 Risk Assessment for M-Brace

3.0 Project Market

A study found that over 60% of occupational injuries reported in the United States were classified as an RMS in 1990 [21]. If the condition is caught early, nonsurgical methods such as splinting, non-steroidal anti-inflammatory drugs (NSAIDs), and stretching can be used to reverse the damage. Splinting is the act of securing the wrist in the proper posture to prevent pressure from being applied on the median nerve. This method is most effective when the patient is sleeping because they are not performing activities that require any mobility and dexterity. Unfortunately, splinting is impractical in the workplace. NSAIDs are drugs like Advil and Motrin IB; however, there is not much evidence that suggests the medication can fully treat RMS. Periodically stretching the hands is one of the most effective and the cheapest method to improve RMS. Nevertheless, most people neglect taking breaks from their daily activities to perform stretches that help counter RMS symptoms. Furthermore, those who exhibit the more classic symptoms of RMS may need surgery. Even if the surgery is successful, the patient may still experience residual symptoms [22]. Approximately 75% to 90% of the patients who underwent a surgical intervention will continue to experience pain and paraesthesia [23].

As of right now, ChronoTech Systems is solely focused on helping professional athletes and sports enthusiasts; however, there is a much wider demographic that would benefit with M-Brace. It may potentially include people who are recovering or had recovered from RMS. Those people with daily routines that require any amount of pressure to the wrist can use M-Brace to monitor their habits since there is the possibility for the symptoms to return if the habits are not improved. Artists, musicians, and textile workers are prime examples of professionals who require grip strength and dexterity but are at a high risk of developing RMS by the very nature of their jobs.

Eventually, ChronoTech Systems would like to work with more medical experts to help improve the accuracy of the device to aid in research on other medical conditions like arthritis and gout. ChronoTech Systems would like to help patients suffering from chronic pains and monitor the development of their conditions with later iterations of M-Brace.

3.1 Possible Competition

Other products that treat RMS symptoms or monitors hand behaviours are listed in Table D2 and Table D3. Refer to the M-Brace Proposal document for more detailed explanation and for competitor product images.

StringyBall [24]	Wrist Splinting [25]
StringyBall is a stress ball on a string. It is a cheap option at $13 CAD for performing hand exercises while wearing the product. Furthermore, a ball tied to one’s wrist at all times would be inconvenient and impractical.	Wrist splints are used to secure the user’s wrist and to limit the pressure applied, selling at around $26 CAD. Unfortunately, the wrist splints main feature is also a major drawback as they severely reduce mobility; therefore, they are recommended to use while sleeping.

Table D 2 Other Preliminary Treatment Solution

SensoGlove [26]	Grip™ System [27]
SensoGlove aims to teach its user how to properly hold a golf club by measuring the grip pressure. The product resembles of regular golf glove, as shown in Figure D1, so there is not much to grow accustomed to if the already uses golf gloves when playing. However, SensoGlove has no other uses off the golf course and its commercial price is $120CAD.	Grip™ System measures static and dynamic pressures from grasping objects to assess comfort, design, and ergonomics. The usage of this product is similar to M-Brace; however; Grip™ system is relatively bulky, as shown in Figure D2. It is mainly used for research and development purposes, and it is not meant for the average user. Thus, there is no commercial price available online.
 *Figure D 1 SensoGlove*	 *Figure D 2 Grip™ System*

Table D 3 Other Technological Monitoring Solutions

4.0 Project Timeline

The proof of concept of M-Brace will be completed by April 9, 2018. The timeline for further progress is specified in the Grant Chat, as shown in Figure D3. The prototype development has been divided into four major phases. The hardware and software tasks to be completed during each phase are as listed. The project timelines are estimated durations for each corresponding task. Thus, a contingency of at least a week is added to each phase.

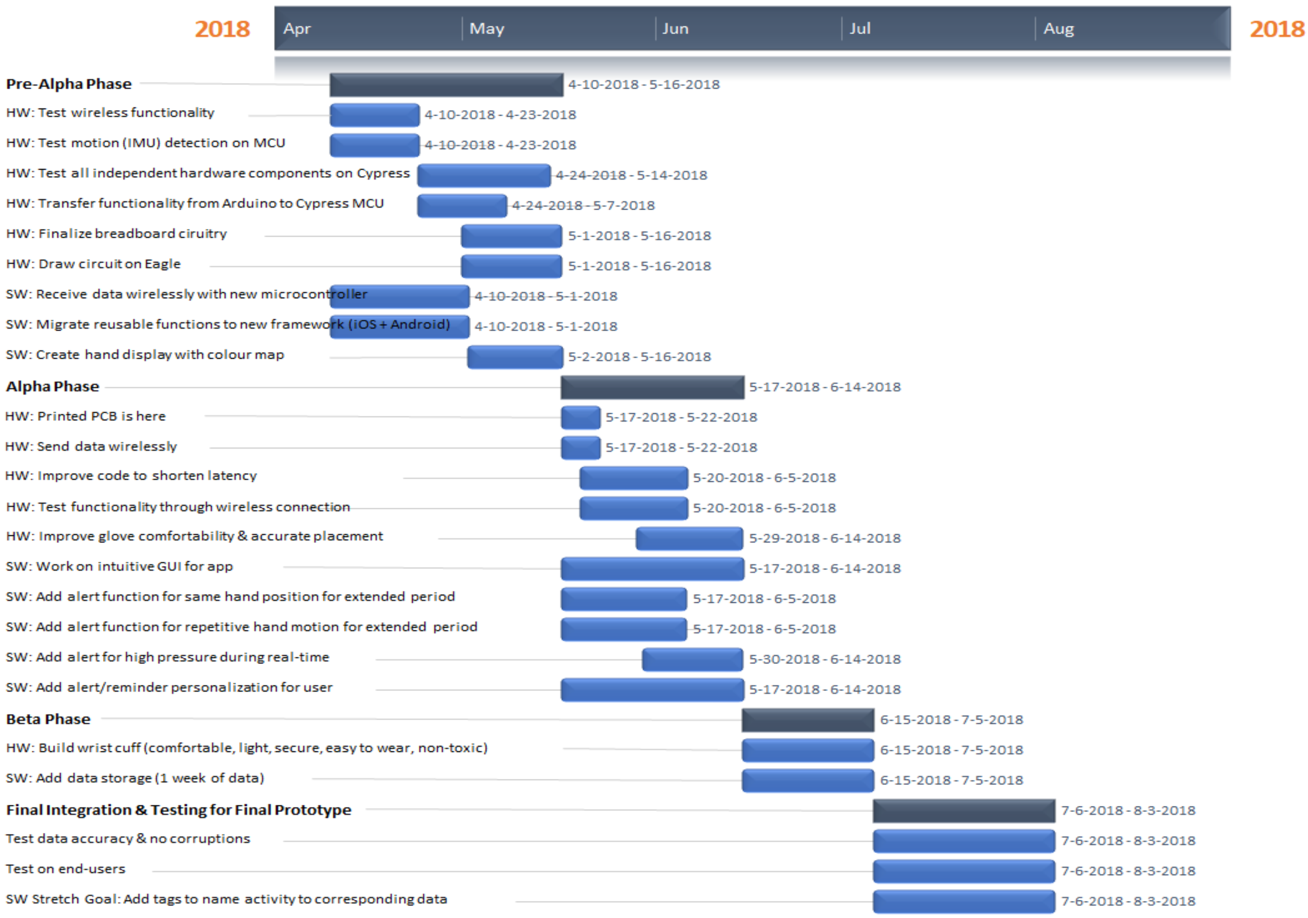

Figure D 3 Grant Chart

To summarize, the milestone timeline for M-Brace is shown in Figure D4. It indicates the due dates of all the major documentation and the key tasks to the development of the project.

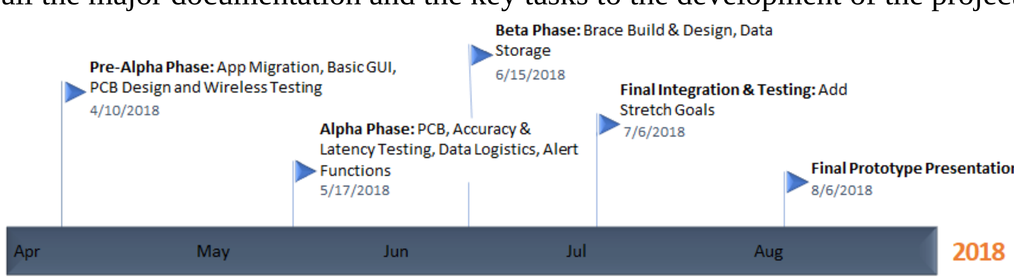

Figure D 4 Milestone Timeline of M-Brace

5.0 Budget Estimation

To date, ChronoTech Systems has spent a total of $122.96 CAD on an Adruino Uno R3, several force sensing resistors, a conductive cord, two Hall effect sensors, and other miscellaneous parts to test the feasibility of M-Brace proof of concept.

During the prototyping phase, the team will be purchasing a compact microcontroller, additional sensors, and miscellaneous parts. Miscellaneous parts include, but are not limited to, PCB adaptor, batteries, breathable fabric, Velcro, conductive thread, surface mount resistors, slide switches, linear voltage regulators, prototyping headers, 3D printing materials cost and etc. To reduce the shipping cost, ChronoTech Systems will be combining the shipments with other companies, such as Geat and Telaio Technologies. A contingency of 20% of the subtotal is included to account for any other additional cost or additional components. ChronoTech Systems is expected to spend up to $480 during the prototyping phrase. Table D4 includes a list of approximate prices in Canadian dollars for the corresponding component. The values are rounded to the nearest integer and do not reflect the actual bill of materials.

M-Brace Prototype Development Budget Estimation	Cost (CAD)
Cypress Microcontroller Kit CY8CKIT-043 [28] x2	$30.00
Expressif Systems WiFi Module ESP8266 [29] x2	$20.00
BreakOut Motion Sensors SEN-13762 [30] x2	$45.00
Conductive Fabric LTT-SLPA-20K [31] and NW170-SLPA-2K [32]	$50.00
Miscellaneous Parts [33] [34] [35] [36] [37]	$175.00
Shipping and Handling	$80.00
Subtotal	**$400.00**
Contingency (20%)	$80.00
Grand Total	**$480.00**

Table D 4 Budget Estimation for M-Brace Prototype Development

5.1 Funding and Resources

To cover the funding required to build the prototype, the team will apply for the Engineering Science Student Endowment Fund (ESSEF), the IEEE Canadian Foundation Special Grants, and the Wighton Fund during the second term of the project's progression. Since the expenses are not expected to be fully covered by these funds, the remaining cost will be shared evenly by the team to ensure the development of M-Brace.

6.0 Internal Personnel Management

Randel Argel Rivera - Chief Executive Officer

Randel is a fifth-year Systems Engineering student at Simon Fraser University. As the Chief Executive Officer of ChronoTecth Systems, he has access to a network of experts who act as consultants to the development of M-Brace. As the co-head of the hardware development department, he is in charge of circuit design as well as the sensor specialist of the team. Lastly, Argel is overseeing the development of the physical module to be presented in August.

Ying Hsin Lan - Chief Technology Officer

Cindy is a fifth-year Systems Engineering student at Simon Fraser University. As the Chief Technology Officer of ChronoTech Systems, she oversees the progress of the project M-Brace. As the co-head of the hardware development department, she is in charge of the microcontroller programming and the PCB circuit design. She will also take part in the final built of the physical module of M-Brace and integrate the prototype with the entire team.

Princess Krizia Macanlalay - Chief Financial Officer

Princess is a fifth-year student with Computer Engineering Major with Computer Science Minor at Simon Fraser University. As the Chief Financial Officer, she manages the budget planning. As the co-head of the software team, she is the back-end developer in charge of server/client architecture. She also works on the data analysis and interpretation from sensor data. In addition to her expertise in crafting, she would be directing the sewing of the M-Brace prototype.

Michelle Ho - Chief Operating Officer

Michelle is a fifth-year Systems Engineering student at Simon Fraser University. As the Chief Operating Office, she oversees the daily operations and product design in ChronoTech Systems. As the co-head of the software team, Michelle is responsible for the front-end development of M-Brace's mobile application. She also works on the sensor data analysis and integration of the hardware and software components with the ChronoTech Systems team.

6.1 External Resources

For the research and development of M-Brace between January to March of 2018, ChronoTech Systems has obtained valuable information from the library database of medical research paper and the Internet. Furthermore, the team has reached out to some Simon Fraser University (SFU) kinesiology and engineering faculty members, patients diagnosed with RMS, as well as a team member's colleagues from the medical research field. ChronoTech would like to thank the following people for their constructive criticism and feedback.

For overall medical inquires, the team has approached Dr. Andy Hoffer, a SFU kinesiology professor. He has given valuable insights on the basics of RMS and has directed the team to more in-depth research on similar commercial products, such as SensoGlove. For technical inquiries, the team has consulted some graduate students in Engineering Science who are knowledgeable about biomedical engineering. The teaching assistants of ENSC 410, Neha Chhatre and Shaun Fickling, also have lab experience with medical devices. Furthermore, the team has spoken with Dr. Shahram Payandeh to choose the ideal motion sensors.

Other important sources of information include the medical experts and patients in the team's network. One team member is able to contact Mr. John Colin Anthony Cruz Rey, a kinesiology graduate student at Trinity Western University, and Dr. Andre Rodriguez, the head of rheumatology at Makati Medical Center, for information regarding the human body and user ergonomics. As the project was inspired by personal connections, the team will also consult friends and family members, who are suffering from CTS, for their opinions on the user design and desired features.

ChronoTech Systems will be arranging an online meeting with Dr. Bonnie Gray to gain insight in the current design, in wearable technology and in polymer microfabrication.

7.0 Conclusion

After in-depth research, ChronoTech Systems has found no direct competitor for commercial products to monitor patients with Repetitive Motion Syndrome (RMS). Thus, there is a massive untapped potential market for the product M-Brace. Based on the results found in the proof-of-concept for M-Brace, the initial design seems promising. ChronoTech Systems has analyzed the potential risks and benefits associated with the development of M-Brace and have proposed further project milestones, timelines, and budgets with which the team is committed to achieving until August 2018. With the combination of the expertise of the engineering students in the team, the feedback from patients suffering from RMS, and the guidance from medical professionals in our network, M-Brace has the potential to improve the quality of life for people suffering from RMS.

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