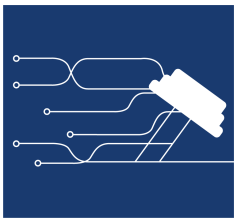
February 21st, 2021



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

RE: ENSC 405w Requirements Specification Document

Dear Dr.Jannesar, Dr.Rawicz and Dr.Scratchley,

The document attached to this letter defines the requirement specifications for our performance tracking barbell attachment, the Levo. Our product will allow weight lifters to record data reflecting their lifting techniques and performance which can then be analyzed personally or by a professional coach to help improve the athlete's performance.

This document outlines the currently foreseeable requirements and features necessary to make the Levo an effective, marketable product. These requirements have been split into three primary sections, being structural, hardware, and software requirements. These requirements reflect the major design elements needed to realize the Levo at all stages of its development. Finally, considerations regarding our test plans, contingency plans, engineering standards as well as product safety and sustainability are outlined.

Levo Technologies is the culmination of the knowledge and experience gained at Simon Fraser University by our team of engineers, consisting of Matthew Chute, Graham Fader, Antonio Kim, Christopher May, and Natalia Page. Our team is looking forward to the successful completion of this project and the experience and knowledge to be gained during Levo's development.

We appreciate the support and guidance of the instructional team during the course ENSC 405w and continuing into ENSC 440. Thank you for your consideration of the Levo requirements specification. Should you have any questions, or require further clarification on the attached documentation, the Levo, or our company Levo Technologies, please contact CCO Graham Fader at gfader@sfu.ca at your convenience.

Sincerely,

Natalia Page

Natalia Page
Chief Executive Officer
Levo Technologies

Company 1

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February 2021

Abstract

The Levo is a performance tracking barbell attachment that will enhance and aid an athlete's ability to understand their performance in the weight room. By tracking the movement of the barbell, several useful performance measurements can be extracted, analyzed and communicated to the athlete in a meaningful way. This document will state all requirements, their explanations, and expectations for the product at the alpha phase proof of concept, and beta phase prototype. Furthermore, it will also include the test plan, sustainability, safety, and engineering standards used to create the Levo.

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1 Introduction

Since the introduction of "Moneyball" by the Oakland Athletics in the early 2000's, sports have entered the "Data Age." The careful use of statistics in-game planning and training has become integral for the successful development of a team's athletes. The Levo aims to effectively collect, analyze and communicate the data associated with an athlete's performance in the weight room. Strength coaches, teams, and athletes use the data collected to better assess areas for improvement, and how to tailor programs to the athlete. Furthermore, metrics that can analyze each rep can help give clues to the technique of the athlete during exercise and can help alter and improve their technique, while maximizing the effectiveness of the rep towards its targeted muscles.

1.1 Background

The Levo is projected to be a barbell attachment to be used for measurement of performance metrics of an athlete during barbell weightlifting. After speaking with athletes and strength and conditioning coaches – including the Simon Fraser University Strength and Conditioning coach, the following metrics were identified:

Peak Force	The goal of strength training is to train muscles to generate force to perform a task, know the maximum capabilities of the athlete can indicate areas for improvement and reflect their improvements since beginning training.
Peak Acceleration	Similar to peak force, however, an athlete will have a maximum acceleration that they are capable of reaching based on their own physiology. Knowing this maximum acceleration may be helpful in planning lifting programs.
Peak Velocity	Closely tied to acceleration, some training philosophies plan their schemes based on the velocity of the weight during the exercise[1].
Percent Drop Off	Indicates the muscular endurance of the athlete between exercises.
Bar Path	Shows if the athlete is wasting motion and by extension energy during an exercise
Time Under Tension	Some training philosophies design weight and rep schemes to reach a certain time threshold of muscle tension. Time under tension schemes have been shown to result in muscle size and strength gains[2] [3]
Asymmetry of the Lift	Indicates if one side is leading or lagging or if the lifter is doing anything which affects the ability to lift the weight in an effective manner.

Table 1: List of Target Metrics to be Measured

The measurements of these metrics are all closely tied to the displacement of the bar over time. Displacement is related to velocity and acceleration through differentiation (velocity is the first derivative of displacement with respect to time and acceleration is the second derivative with respect to time of displacement), a sensor capable of reading acceleration or velocity or displacement will be sufficient for constructing many metrics related to weightlifting performance. Other metrics, such as force, may require the mass of the bar being lifted. This cannot be done by the sensor itself, but will rather be found through user input.

It should be noted that the Levo is not designed to compare or recommend training styles or schemes, but rather is a data collection tool for the user to inform their own training decisions and track progress in the measured metrics.

1.2 Requirement Labelling

To ensure that everything is identified, Levo Technologies used the following labeling system to organize all requirements within this document.

Req U.V.W

U: The category of the requirement, structural as 1, hardware as 2, software as 3, and safety as 4.
V: The requirement number for that section.
W: Denotes whether the requirement is needed for the alpha phase proof of concept, beta phase prototype, or full marketable products. 'A' will be used for alpha phase requirements, 'B' for beta phase requirements, and 'P' for marketable product. All alpha phase requirements will be needed in subsequent phases.

2 Structural Requirements

The following section outlines all structural requirements that Levo needs to meet for all stages of product development. Detailed justification for all these requirements is provided below.

2.1 Table of Structural Requirements

Req 1.1.B	Must be crush resistant and be able to withstand a weight falling onto it from a resting position.
Req 1.2.B	Device must be lighter than 1/2 of a pound or roughly 225 grams (within plate quality control tolerance of elanko/ rogue).
Req 1.3.B	Device must be able to withstand a 10 foot fall without structural damage.
Req 1.4.B	Device must not detach from the bar during use.
Req 1.5.B	Device must be attachable to the barbell in a manner similar to a collar.
Req 1.6.B	Device must be capable of attaching to both 1" and 2" barbell diameters.
Req 1.7.B	Device must not interfere with the user during the the exercise.
Req 1.8.B	Device should be attachable to any spot on the bar or collar.
Req 1.9.B	Device must be near the same width as a typical collar for a 2" barbell.
Req 1.10.B	Device should be able to be placed into a device which can act as a collar.
Req 1.11.B	Device must be easily portable.

Table 2: List of Structural Requirements

2.2 Justification of Structural Requirements

The Levo must be physically attached to the barbell that the user is lifting to collect data. As such it must be easy and intuitive to attach so that it does not become such a burden that the user is disinclined to use it. Additionally, the Levo must be lightweight so that it does not affect the ability of the user to perform the lift or otherwise compromise the safety of the user during the lift. A sufficiently light device would largely ensure that the balance of the bar is not compromised in a way that will affect the user. The plates which a lifter will use during a workout have a quality control tolerance on their weight. If the Levo is within this weight tolerance, any effect on the balance of the bar should be considered tolerable. Because a user may have access to different equipment or have different preferences for where to place the Levo, it should be able to attach anywhere on a barbell or trap bar for their convenience. It, however, is a requirement that the Levo be able to attach to 2" or 1" barbells as those are the two standard diameters for the weight holding part of the barbell. While 2" barbells are more common than the 1" variety, 1" barbells are not uncommon. For the ability of the Levo to "take a hit" a three meter/ten foot/ one story fall seems reasonable for usage at a gym, which from qualitative experience are 1-2 floors. When in the gym, there is always the risk of equipment being stepped on or having another piece of equipment dropped on it. While we expect the user properly protects their device like they would a phone or headphones, mistakes do happen and the Levo should have some forgiveness for things such as a weight plate tipping over on it. 55 pounds/ 25 kilograms is often the heaviest plate in a gym, and as such, the Levo should withstand the impact of a 25 Kg plate tipping over or falling on it from a rest position on the ground. Finally, the Levo must be water-resistant and shield the electronic components from a water bottle spill or a particularly sweaty individual. This water resistance will also allow for the cleaning of the Levo with disinfectant wipes.

3 Hardware Requirements

The following section outlines all hardware requirements that the Levo needs to meet for all stages of product development. Detailed justification for all these requirements is provided below.

3.1 Table of Hardware Requirements

Req 2.1.A	Device must be capable of reading its own acceleration OR velocity OR displacement.
Req 2.2.A	Device must be capable of telling its own roll/ pitch/ yaw.
Req 2.3.B	Signals from device must be in in chronological order.
Req 2.4.A	Hardware must be powered by power source.
Req 2.5.B	Device must function for at least 3 hours.
Req 2.6.B	Device should function for at least 5 hours.
Req 2.7.B	Device must easily replace depleted power source.
Req 2.8.B	Hardware should have a standby state and a working state that's controlled by the software.
Req 2.9.A	Hardware must be capable of wireless communication to the software running device.
Req 2.10.A	Hardware must convert analog data to digital data before transmission to software device.
Req 2.11.B	Hardware should indicate to the user the state of the device (off/standby/active).
Req 2.12.A	Hardware must be able to be put into the on state with a user input.
Req 2.13.A	Hardware must have some on board computing power i.e a microcontroller.
Req 2.14.B	Hardware should be able to perform operations to the data to take load off of the software when possible.
Req 2.15.B	Hardware should be able to work in tandem with a second Levo attached to the same bar.

Table 3: List of Hardware Requirements

3.2 Justification for Hardware Requirements

TThe hardware of the Levo needs to be easy to use and should communicate with the software on the user's device in a seamless way that does not require the user to do anything but turn it on. After being powered on, the device should have two states, standby and active, which will be controlled by the software. The standby state should allow the Levo to conserve energy and not be actively sending data to the app since it will not be being used. In the active state, the inertial measurement unit **IMU** should begin tracking the x,y, and z positions of the device as well as the roll, pitch and yaw. These six data points should then be transmitted from the IMU to the microcontroller's wireless transmitter for relay to the user's device. The data should be received by the user's device in chronological order such that the data (for example) at t=1s can be processed and communicated before the data at t=2s. The data that the software running device must be in digital form for processing as such, the IMU must output a digital signal to the microcontroller.

Since the Levo should be easy to use in a dynamic environment such as a gym, the Levo must be battery-powered and easily moveable from equipment piece to equipment piece and not constrained to a wall outlet. A workout can vary greatly in the time to completion. As such the Levo must have at least 3 hours of use from a full charge but ideally should have closer to 5 hours of use. This will accommodate longer workouts or several training blocks for usage by a trainer or coach without concern for the battery dying.

4 Software Requirements

The following section outlines all software requirements that the Levo needs to meet for all stages of product development. Detailed justification for all these requirements is provided below.

4.1 Table of Software Requirements

Req 3.1.A	Application must be able to receive data from the hardware over a wireless connection.
Req 3.2.B	Application must present data to the user in a meaningful way.
Req 3.3.B	Application must be able to display user's performance progress over time.
Req 3.4.A	Application must be operable on both iOS and Android devices.
Req 3.5.B	Application must be able to run on the most recent and previous version of iOS and Android.
Req 3.6.B	Application must not exceed the specified application size of it's respective app store.
Req 3.7.A	Application must store the users data.
Req 3.8.A	The user must create an account to access the application.
Req 3.9.A	Application must store user data to a database upon internet connection.
Req 3.10.A	Application must work with no internet connection (have an offline state).
Req 3.11.B	Application must be able to identify barbell weight.
Req 3.12.B	Application must be able to run in the background.
Req 3.13.B	Application must not share personal data with any other third-party without user's consent.
Req 3.14.B	Application must give user the option on how to store data, and its duration on the device.
Req 3.15.B	Application should identify when the user has stopped using the Levo without user's input.
Req 3.16.P	Application should continuously update requiring an additional update from the app store.
Req 3.17.B	Application should you user preference setting such as choice of units.
Req 3.18.P	Application should not interfere with accessibility features on the device.

Table 4: List of Software Requirements

4.2 Justification for Software Requirements

The purpose of our mobile application is to communicate the data obtained from the Levo hardware in a meaningful way to the user. The user must be able to view their immediate results, as well as track their performance over time. A mobile application has been chosen for the following reasons. The first reason being the ability to download and use the application without requiring any additional hardware besides the Levo and the mobile device. Second, the gym has many hazards which could result in a computer becoming damaged, broken, or stolen. The application must be developed to run natively on both iOS and Android, with consideration to the two most recent versions of each OS. Additionally, the application must not exceed the specified application size of its respective app store. Furthermore, the application will have additional features including the ability to operate without a wireless connection (offline mode), and a barbell weight identifier.

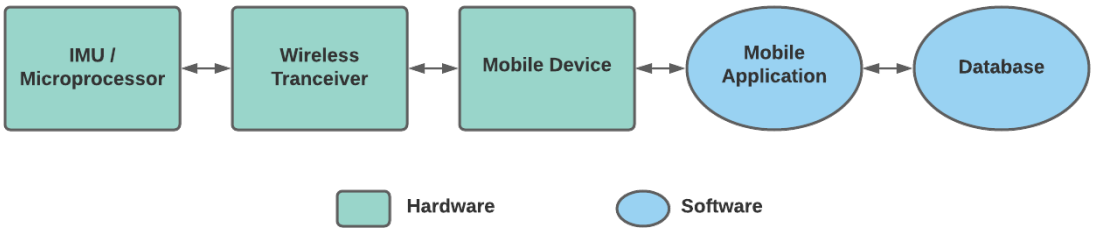

Figure 1: Data Acquisition and Processing Flow Chart

5 Test Plan

Alpha state proof of concept - This section outlines the alpha test plan for proving the conceptual viability of the Levo. All alpha phase requirements have been stated and a detailed explanation of the tests that will be conducted to ensure that all requirements have been met.

5.1 Alpha Phase Requirements

Requirement	Description of Test
Req 2.1.A	The hardware generates a signal in response to movement of the device.
Req 2.2.A	The hardware generates a signal in response to the rotation of the device
Req 2.9.A	The hardware can send a signal which is received by the software running device
Req 2.10.A	The hardware generates a digital waveform at the port connecting to the transmitter
Req 2.13.A	The on board computing must demonstrate some level of usage in the circuit
Req 3.1.A	Application receives data over the wireless transmitter
Req 3.4.A	The application can be launched on an iPhone as well as an Android device.
Req 3.7.A	The application stores data received over the wireless transmission locally.
Req 3.8.A	The user launches the application, and then creates an account to gain further access.
Req 3.9.A	Once an internet connection is established, the app uploads the locally stored data to the database.
Req 3.19.A	The application continues to store data locally, when no internet connection is available.

Table 5: Alpha Phase Test Plan

5.2 Procedure of Alpha Phase Test Plan

Req 3.4.A will be demonstrated by launching the application prototype on the mobile devices of interest. 3.8.A will be done using a sample email created for the demonstration and show the creation of a user account. Following account creation, the mobile device will be disconnected from the internet. Electronics testing will use an oscilloscope connected to the ports of interest for a particular test with the resulting output reflecting the behaviour of the device. The board housing the electronic components will be moved in a manner to create an output from the sensors it contains– This will satisfy the testing of Req 2.1.A. Similarly for 2.2.A, the board will next be rotated to produce an output indicating the ability of the prototype to measure yaw/ roll/ pitch. for 2.10.A, the device will be moved to generate some signal, one measurement probe will be connected to the output port of the sensor with a second probe measuring the output port of the analog to digital converter– the waves will be compared to see if the analog to digital converter successfully digitizes the output of the sensor (if the is sensor chosen has a built-in analog to digital converter only one measurement probe will be necessary for ensuring the signal is digital). A similar procedure will be used to test Req 2.9.A and 3.1.A, however, in addition to the electronic measuring equipment, the software running device will output the data it receives from the wireless transmitter. This

data should match the electronic measurement tools. Req 2.13.A The microcontroller on the circuit will have to demonstrate that it is performing some operation on the signals. This will be done by measuring with an oscilloscope the microcontroller's input(s) and seeing some operation on the outputs. 3.7.A and 3.19.A will be shown in the saved data from the testing of Req 2.9.A and 3.1.A. The mobile device will now be reconnected to the internet. Following this connection, the database will be check to see if the locally stored data has been successfully uploaded to the desired database.

Note: To prevent a bottleneck of one requirement failure from preventing the testing the device, a sample signal can be injected anywhere along the hardware data patch to ensure other requirements are met. This test plan is subject to change.

6 Sustainability and Safety

The following section outlines how Levo Technologies will follow sustainability protocols and list all safety requirements that the Levo must meet. All examples of electronics and plastics to recycle are commonly used in many devices, and are stated to show how these materials follow the "Cradle to Cradle" sustainability.

6.1 Sustainability

With any new product or technology, sustainability must be considered to ensure resources are not being over consumed and can be reused in a beneficial way. The idea of "Cradle to Cradle" sustainability is a cyclical system of resources for both materials that can biodegrade and be reabsorbed within the ecosystem, or technological items that can be broken down into their raw elements and be reused in other products [4]. Considering that the Levo is a small electronic device we will mainly be analysing the technological cycle for our product once it has reached the end of its life.

When an electronic device has reached the end of its life it must be disposed of and recycled by hazardous waste service providers due to the presence of toxic heavy metals such as lead, mercury,and cadmium [5], [6]. Several locations across Canada have special drop-off zones for electronics, and ultimately our device, that has reached the end of their life spans to ensure that no hazardous material is leaked into the environment and parts can be recycled. Depending on the device, most plastics, glass and several metals such as gold, silver, copper, palladium, platinum, lithium and cobalt can be recycled without losing their chemical properties and reused for other parts [6]. The table below shows the basic electronics that our device will need to operate, the type of cradle to cradle cycle it goes through, and the main material that can be extracted from the part. In terms of the casing, there are two types of plastics that we can use both with different properties and therefore will show both in the table. However, once a prototype is made only one type of plastic will be used in printing the case.

Parts	Cycle	Main Recycled Material
Case	Biological Technological	Polylactic Acid (**PLA**) Acrylonitrile Butadiene Styrene (**ABS**)
PCB	Technological	Copper
Microprocessor	Technological	Gold
IMU	Technological	Copper
Battery	Technological	Zinc or Lithium

Table 6: List of Recyclable Materials

PLA is a type of bioplastic that can naturally degrade when thrown into the environment over a period of 6-24 months [7]. PLA cannot hold hot liquids and is usually used for disposable medical devices or items that have short life spans such as water bottles and containers for fruits and vegetables [7]. However, it is still very robust and commonly used for casing electronics. ABS is a common, durable, thermoplastic that can be shredded, recycled, and reused to create more ABS at low-cost [8]. Often used in products that require a protective casing or need to withstand external forces. For example, many children's toys are made out of ABS because they need to be impact/crush resistant and safe for human interaction. It is non-toxic and 99 percent of recycled ABS can be recovered from ABS products [8].

6.2 Safety

Safety is of paramount importance and must be analyzed to ensure our consumers can fully enjoy the benefits of the Levo without any concerns about being harmed. The following table are the safety requirements that the Levo needs to meet.

Req 4.1.B	Device must be sealed to prevent water damage to the device electronics.
Req 4.2.B	Device must not have exposed wiring.
Req 4.3.B	Device must not react to common cleaning products.
Req 4.4.B	Device must not have sharp edges.
Req 4.5.B	Device must not interfere with the user.

Table 7: Safety Requirements

7 Engineering Standards

Since the product requires both hardware module and software. The main standards that it will have to meet are the electronics and the software standards described in the following:

C22.2 No. 205-17 Signal Equipment. [9]
S.C. 2010, c. 21 Canada Consumer Product Safety Act [10]
ISO/IEC/IEEE 29119-3:2013(E) Software and systems engineer – Software Testing Part 3: Test documentation [11]
ISO/IEC/IEEE 29119-4:2015(E) Software and systems engineer – Software Testing Part 4: Test

techniques [12]
Apple Developer App Store Review Guidelines [13]
Health Canada Technical Guide for Safety Code 6: Health Canada's Radiofrequency Exposure Guidelines [14]
Health Canada Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz [15]

Because the data is being collected and displayed through the device, the information saved on the device will also adhere to Personal Information

S.C. 2000, c. 5 Personal Information Protection and Electronic Documents Act [16]
SBC 2003 - CHAPTER 63 Personal Information Act [17]

8 Conclusion

Levo Technologies is committed to creating a product that gives coaches and athletes the edge for making improvements on their performance. The Levo device will be attached to the lifting equipment and record the raw data of the user's lift. This data will be transferred from the hardware to the software over a wireless transmitter. Then, the mobile application will take this raw data, analyze it, and display it to the user in a meaningful way such that they can interpret it, track their performance over time, and assess areas for improvement.

The requirements stated above, outline the milestones that Levo Technologies must meet for creating our proof of concept and a working prototype. This includes the structural requirements, hardware requirements, and software requirements of our product. Additionally, we address the safety standards, sustainability requirements, as well as further engineering standards to guarantee our product is in accordance with all of the above.

9 Glossary

ABS - Acrylonitrile Butadiene Styrene
CCO - Chief Communications Officer
IMU - Inertial Measurement Unit
Levo - Product Name
Levo Technologies - Company Name
OS - Operating System
PLA - Polylactic Acid

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