February 21st, 2021
Capstone Instructional Team
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 405W Requirement Specification for the SWISH Trainer

Dear instructional team,

Attached is the Requirement Specification document for the SWISH Trainer. Our team intends to design and build a versatile basketball passing system which will utilize computer vision and a motor-driven pivoting projectile system in order to return the basketball back to the player wherever they are standing on the court. This will allow the athlete to efficiently receive the basketball at their respective location, thus eliminating the need for the player to fetch the ball after a missed or scored basket.

The purpose of this document is to provide a general overview of the system requirements to design the SWISH Trainer. This will include a detailed system overview, a variety of requirements ranging from electrical to software, and proposed test plan. Our design will be directly correlated to the specified requirements such that we can ensure successful development at the end of our test plan.

Our team consists of five engineering students, specializing mostly in software. Our backgrounds: Jordan Kam — Computer Engineering, Tim Tran — Computer Engineering, Devansh Chopra — Computer Engineering, Ery Polovina — Computer Engineering, and Ray Hoang — Systems Engineering. Together, as a unified team, we hope to strengthen each other's weaknesses and incorporate concepts outside our specialties. Together we are SWISH (Software Integrated Systems and Hardware). If you have any questions or concerns about the Requirement Specifications, please feel free to contact us at rvhoang@sfu.ca.

Sincerely,

Jordan Kam, CEO of SWISH


# Requirements Specification

# SWISH Trainer

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# Abstract

The SWISH Trainer is an intelligent basketball training solution that allows basketball athletes and enthusiasts to practice their free throws with as little training downtime as possible. SWISH Trainer utilizes computer vision and a motor-driven projectile system to be able to return shots made back to the player, wherever they are standing on the court. The problem that athletes face when training is spending significant amounts of time fetching the ball off missed shots. Some NBA players will train their shooting skills for up to 1.5 hours a day up to 500 shots [1]. A gap was identified in the basketball return system market; current products only return balls in one fixed direction or have pre-set settings. Our product seeks to solve both problems to decrease downtime while maximizing training time. It is essential that the SWISH Trainer conforms to safety and engineering standards mandated by local governments. The following document outlines the required specifications for the system to operate successfully in Canada.

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# 1. Introduction

The SWISH Trainer by SWISH is an intelligent basketball training solution that allows basketball athletes and enthusiasts to practice their shot with the most optimized efficiency. Using computer vision and a motor-driven launching mechanism, the SWISH Trainer can return made shots back to the player wherever they are on the court. Athletes train for hours a day and having to rebound your own shot takes away from the time and energy spent on developing their skills.

## 1.1. Background

When practicing your shot for basketball, athletes require to either have a rebounder/passer or must get their own rebounds. Athletes can practice for hours at a time each day [2] honing their skills, so the time spent rebounding is wasted time and energy, also taking up another person's time. The SWISH Trainer seeks to solve this problem by providing an efficient and affordable solution to basketball athletes.

Technology for sports has been around for some time but has not caught on as much with basketball. A typical rebounding system on the market currently goes for upwards of $3000 [3] which is expensive for teams and individuals to own. When practicing, some teams use these systems, and they only allow you to shoot from a fixed point in the court. This is incredibly inefficient as players must stop shooting to move to a different part of the court.

The SWISH Trainer is a system that removes the inefficiencies of current existing platforms by allowing players to spend more time shooting around the court rather than from a fixed position. The SWISH Trainer uses an integrated camera to locate the player and guide the ball to them and the conceptual design is shown in Figure 1 below.

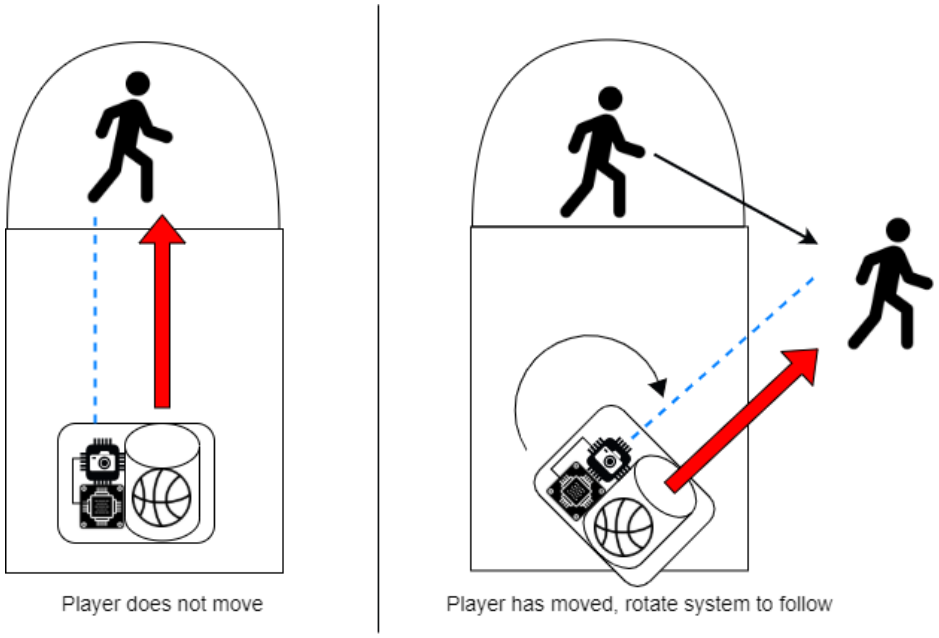


**Figure 1** – Conceptual Overview Diagram

## 1.2. Scope

The scope of this document is to provide a description of the functional requirements of the SWISH Trainer. The specifications will outline the how the system will operate while maintaining the required safety precautions and sustainability of device components as well as engineering standards.

## 1.3. Intended Audience

This document serves as a guideline or provides instruction to engineers. The functional specifications stated in this document will have a detailed description of requirements and design that may be referenced or updated for future revision.

## 1.4. Classification

The following format will represent functional requirements in this document:

**[Req {document section}.{requirement number}-x]**

where the requirement number is the number of a particular functional requirement and **x** indicates the priority of the functional requirement.

Below are the classifications of the priorities:

A This requirement corresponds to our Proof-of-Concept Design – Alpha Phase

B This requirement corresponds to Engineering Prototype – Beta Phase

P This requirement corresponds to Production – Final Prototype

## 1.5. Design Approach

Taking into consideration of all the different components required to build this device, it was determined that working on each sub-component and then assemble it was the best course of action. This is because each sub-component should work independent of each other prior to assembly and then work in tandem as a whole system.

# 2. System Overview

The SWISH Trainer consists of 2 major components: the hardware required to launch the ball and the software required to control the hardware. The hardware consists of 2 motors, each rotating a wheel. The basketball will be loaded to the spinning wheels which will then launch the ball forward. The software system consists of controlling the speed of the motors, detecting where the player is on the court, and a microcontroller which will rotate the system to that player.

The rotating mechanism will take input from the camera module in real-time and relay it to the raspberry pi to communicate to the servo motor to rotate the system. As the tracked player moves, the camera will follow and send a message to the Arduino microcontroller to move the servo motor below which will rotate the entire platform. As the player shoots the ball, the system will rebound it and pass it back to the player using the 2 spinning wheels as mentioned above.

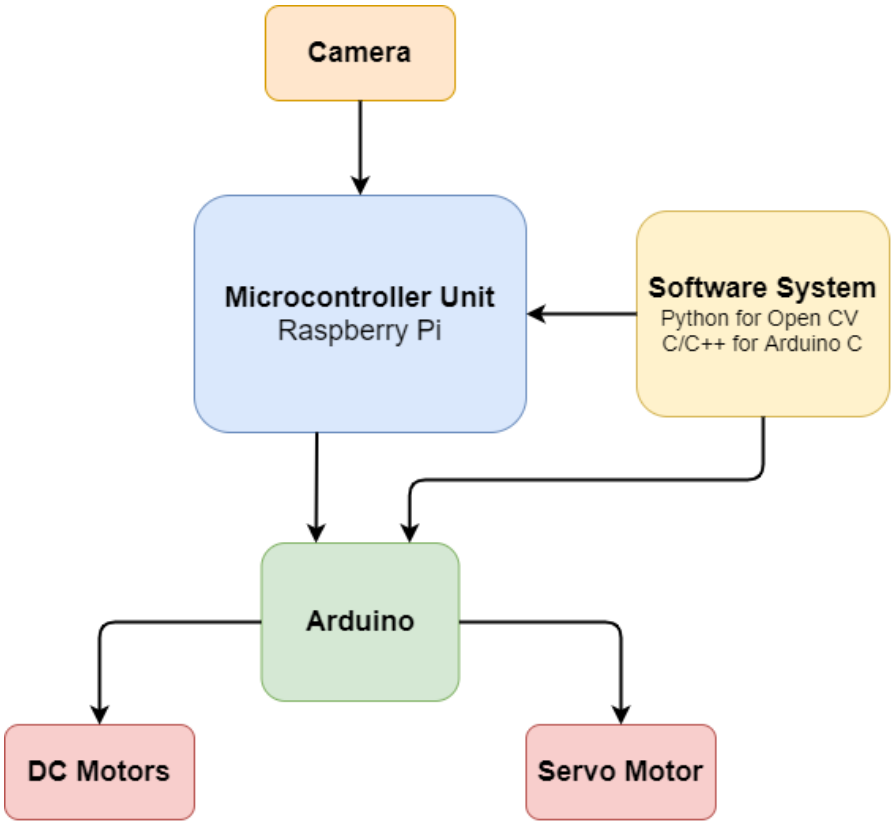


**Figure 2** - System Overview Diagram

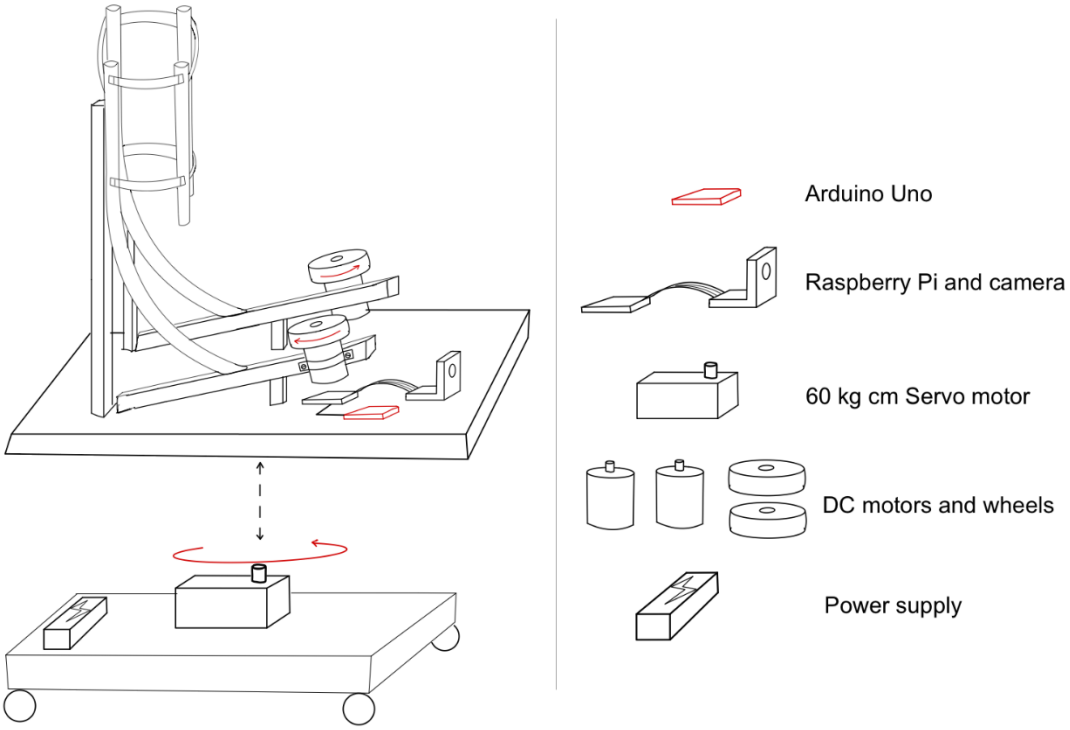


**Figure 3** – Prototype Diagram (Early Prototype Concept)

# 3. System Requirements

The SWISH Trainer retrieves a basketball and passes it back to the player to make shooting practice more efficient. The system will track the player on the court and be ready to pass the back to them when they score. This section describes the requirements for the system. The following sections will detail the various subsystems and their requirements.

## 3.1. General Requirements

| | |
|---|---|
| Req 3.1.1 - B | The SWISH Trainer's user should be able to turn on/off the system. |
| Req 3.1.2 - P | The mechanical and embedded system along with its needed hardware must cost less than $500 to manufacture. |
| Req 3.1.3 - P | Instructional booklet and user manual should be printed and shipped with the SWISH Trainer. |
| Req 3.1.4 - B | The product can be setup and operated by a single person without any prior knowledge of the product. |

**Table 3.1** - General Requirements

## 3.2. Electrical Requirements

| | |
|---|---|
| Req 3.2.1 - A | The SWISH Trainer is powered using a standard 120V AC wall outlet. |
| Req 3.2.2 - A | For outdoor usage, the system will require an extension cord. |
| Req 3.2.3 - A | All components requiring voltage draw should not exceed 24 V. |
| Req 3.2.4 - A | The 24 V power supply should draw about 15 Amps in parallel to each 24 V DC motor for spinning the wheels. |

**Table 3.2** - Electrical Requirements

## 3.3. Physical Requirements

| | |
|---|---|
| Req 3.3.1 - B | The SWISH Trainer should be transportable by a single person to be set up under a basketball hoop. |
| Req 3.3.2 - B | The wheels at the base of the SWISH Trainer must have brakes to stay grounded while in use. |
| Req 3.3.3 - A | The grounded base and passing mechanism of the prototype should not exceed 1 meter in both length and width. |
| Req 3.3.4 - A | The passing mechanism must be able to house a men's standard sized basketball of 24.2 cm (9.5 inch) diameter. |

**Table 3.3** - Physical Requirements

## 3.4. Environmental Requirements

| | |
|---|---|
| Req 3.4.1 - B | The SWISH Trainer shall operate optimally indoors with good lighting conditions. |
| Req 3.4.2 - A | The SWISH Trainer shall operate optimally in the temperature range of 5°C to 30°C. |
| Req 3.4.3 - A | The SWISH Trainer must operate and be stored in a dry space. |
| Req 3.4.4 - A | The SWISH Trainer must have at least 1 meter of non-obstructive radius in front of the launching mechanism. |

**Table 3.4** - Environmental Requirements

## 3.5. Performance Requirements

| | |
|---|---|
| Req 3.5.1 - A | The SWISH Trainer must be able to pass the basketball to the player. |
| Req 3.5.2 - B | The SWISH Trainer should be able to pass the basketball up to a maximum distance of 6 meters. |
| Req 3.5.3 - A | The tracking system of the SWISH Trainer should be able to rotate and follow the player. |
| Req 3.5.4 - B | The system must have a startup time less than 15 seconds. |
| Req 3.5.5 - P | The system must notify user if they cannot be detected. |
| Req 3.5.6 - P | The netting system should be able to collect most of the player's attempted shots. |

**Table 3.5** - Performance Requirements

# 4. Hardware Requirements

Hardware Requirements will be illustrated with restrictions in in the motor systems, camera, and microcontroller performance in the section below. The hardware requirements encapsulate the core components and electronics used for the development of the SWISH Trainer.

## 4.1. DC Motor

There are 2 DC motors used in the projectile system which will rotate two wheels at a fast speed to launch the basketball to a target distance. These motors are chosen such that there is enough stall torque to rotate the weight of the wheels, also enough RPM to launch the ball.

| | |
|---|---|
| Req 4.1.1 - A | The 24 V DC motor should spin within the range of 1000 - 2000 RPM under load. |
| Req 4.1.2 - A | The DC motor must be able to spin both clockwise and counterclockwise. |
| Req 4.1.3 - P | The DC motor should be able to continuously operate for extended periods of time (1-2 hours). |
| Req 4.1.4 - A | The DC motor must have enough stall torque to rotate 2lbs. |
| Req 4.1.5 - A | The DC motor should not draw more than 15 Amps under normal operating conditions. |

**Table 4.1** - DC Motor Requirements

## 4.2. Servo Motor

| | |
|---|---|
| Req 4.2.1 - A | The servo motor must be able to rotate the passing mechanism with a range of roughly 180 degrees. |
| Req 4.2.2 - A | The servo motor must be able to receive digital signal inputs from the Arduino. |

**Table 4.2** - Servo Motor Requirements

## 4.3. Camera

| | |
|---|---|
| Req 4.3.1 - A | The camera must be able to capture a wide-angle picture with at least 720p/60 fps. |
| Req 4.3.2 - A | The camera must be connected to the Raspberry Pi using a short ribbon cable. |
| Req 4.3.3 - A | The camera must not operate in overly bright environments or dark environments. |

**Table 4.3** - Camera Requirements

# 5. Software Requirements

The software used by the SWISH Trainer will include the firmware on Arduino and Python for OpenCV used by the Raspberry Pi. Together, these systems will allow the hardware to operate.

## 5.1. Arduino Requirements

The Arduino will be used controlling the DC motors and the Servo motor. The DC motors will be used to spin the wheels for the launching mechanism and the Servo motor will be used for rotating the entire device to point in the direction of the user. The Arduino will be serialized with the Raspberry-Pi.

| | |
|---|---|
| Req 5.1.1 - A | The Arduino should be able to control the DC motors and the Servo motor. |
| Req 5.1.2 - A | The Arduino code should be written in Arduino/C++. |
| Req 5.1.3 - A | The model/version of the Arduino should be at least an Arduino Uno. |
| Req 5.1.4 - A | The Arduino should be able to receive input stimuli from the Raspberry-Pi and based on that rotate the Servo motor. |
| Req 5.1.5 - P | The software written for the Arduino should be modular and easy to understand. |
| Req 5.1.6 - A | The Arduino should be connected to Raspberry Pi using UART/USB. |

**Table 5.1** - Arduino Requirements

## 5.2. Object Detection Requirements

Object detection is part of the SWISH trainer where the device performs decision making to determine where the user is. This will be done using a Raspberry-pi camera connected to a Raspberry-pi which will process the object detection and send the signal to the Arduino for rotating/launching the basketball.

| | |
|---|---|
| Req 5.2.1 - B | The object detection software should correctly identify users. |
| Req 5.2.2 - A | The object detection software shall be written in Python using OpenCV. |
| Req 5.2.3 - P | The software should differentiate between basketball players and other entities in the environment. |
| Req 5.2.4 - P | The software must not activate due to non-human stimulus. |
| Req 5.2.5 - B | The Raspberry-Pi should find the user using the camera and send a signal to the Arduino in less than 15 seconds. |
| Req 5.2.6 - P | The software for the object detection should be modular and easy to understand. |

**Table 5.2** - Object Detection Requirements

# 6. Safety and Sustainability Requirements

The SWISH Trainer improves a basketball athlete's practice session optimizing time and effort spent on shooting rather than rebounding. Thus, the proper safety precautions must be considered to allow for a durable and efficient system.

## 6.1. Safety

Safety concerns of the SWISH Trainer development and usage are involved in two aspects – mechanical and electrical. Mechanical risks are to be mitigated by the elimination of contact with moving parts striking the operator. Any electrical risks require mitigating potential shock hazards.

Any data collected by the SWISH Trainer is to be used solely for the purpose of research and development. Data will not be stored anywhere remotely, and thus in-between uses of the SWISH Trainer any data processed via camera capture will be erased.

| | |
|---|---|
| Req 6.1.1 - P | The system shall not have any exposed moving parts that present itself as a hazard to the user. |
| Req 6.1.2 - A | The motor's connected power supply must have automatic overload cut-off, over-voltage cut-off, thermal cut-off, and short circuit protection. |
| Req 6.1.3 - A | High voltage wiring shall be fully insulated to ensure working safety for operators. |
| Req 6.1.4 - P | Wiring of the system shall be encased and unexposed to the end user. |
| Req 6.1.5 - A | The power and circuitry must not be a fire or explosion hazard. |
| Req 6.1.6 - A | The device shall not have materials that are toxic to humans. |
| Req 6.1.7 - B | The device must have a way to safely shut off in event of system failure. |
| Req 6.1.8 - B | The system shall be load balanced such that it can be safely moved across the floor on 4 castor wheels without falling over. |
| Req 6.1.9 - A | The prototyping and testing must adhere to the standards outlined in the Electrical BC Safety Standards Act [4] |

**Table 6.1** - Safety Requirements

## 6.2. Sustainability

The development of the project will adhere to Cradle to Cradle (C2C) design [5], which is the principle that all components can be reused for the next iteration of the project. To become as sustainable as possible, SWISH Trainer will adhere to the C2C model by choosing ecofriendly products that can either be recycled or reused.

Materials used for SWISH Trainer will be durable, yet sustainable. The frame will be made from wooden planks and PVC piping which uses recycled plastic. Any wires and electronic components can be easily reused in the alpha, beta, and production phase.

| | |
|---|---|
| Req 6.2.1 - A | Microcontrollers and electronics shall be reused in future iterations of the product. |
| Req 6.2.2 - B | Any composite wood and wiring shall be reused in during the development stage. |
| Req 6.2.3 - A | Materials used in the prototyping shall consist of sustainable materials that can be reused or recycled. |

**Table 6.2** - Sustainability Requirements

# 7. Engineering Standards

SWISH Trainer is a sports utility device, so it is important to consider proper engineering standards when creating a durable and maintainable product. The Canadian Standards Association and International Organization for Standardization both contain guidelines that SWISH Trainer must adhere to.

The guidelines outlined by CSA and ISO are widely used and recognizable, therefore we have chosen to adhere to their standards. Our goal during development is to meet most of their standards. At the end of our PoC we plan to meet most of their standards, and by the end of our final production prototype we plan to meet all the standards outlined. The selected engineering standards are listed in the table below.

| **Standards** | **Description of standard** |
|---|---|
| CSA-C22.2 NO. 61508-1:17 | The functional safety of electrical/electronic/programmable electronic safety related-systems – Part 1: General Requirements [6] |
| ISO/IEC/IEEE 29148:2018 | Systems and software engineering -- Software life cycle processes [7] |
| CSA-C22.2 NO. 0-10 | General requirements - Canadian electrical code - Part 2 [8] |
| ISO/IEC TR 25060:2010 | Systems and software engineering — Systems and software product Quality Requirements and Evaluation [9] |
| C22.2 NO. 100-14 (R2019) | Electric motor and generators installation and usage guidelines [10] |
| CAN/CSA-ISO/TR 14062-03 (R2013) | Environmental Management - Integrating Environmental Aspects into Product Design and Development (Adopted ISO/TR 14062:2002, first edition, 2002-11- 01) [11] |
| CAN/CSA-ISO 14040- 06 (R2016) | Environmental Management - Life Cycle Assessment - Principles and Framework (Adopted ISO 14040:2006, second edition, 2006-07-01) [12] |
| CAN/CSA-C22.2 No. 94.2-07 (R2012) | Enclosures for Electrical Equipment, Environmental Considerations [13] |

**Table 7.1** - Engineering Standards

# 8. Conclusion

This requirement specification outlines various aspects of the SWISH Trainer which work together to return the basketball to the user. The requirements outlined in this document provide a clear description of the design and product development with specific labels for their respective classification for the stage at which they are appropriate for.

The following is the summary of the key requirements:

1. **Software:**
    - Motion tracking will be a core functionality used to track the position of the player; thus, the SWISH Trainer must be able to correctly identify the player.
    - The Raspberry Pi and Arduino must be a system that can respond to real-time events and work in tandem to track the player and launch the ball.

2. **Hardware:**
    - A netting apparatus shall be used to collect the basketball(s) and feed it into the projectile system.
    - The microcontroller must be able to effectively send signals to control the motors of the SWISH Trainer.
    - DC motors of the SWISH Trainer must be capable to launch a basketball.

3. **Electrical:**
    - The SWISH Trainer shall be powered efficiently with a power supply which will allow the system to run for 1-2 hours.

4. **Safety and Sustainability:**
    - Cradle to cradle model shall be used to reduce the cost and remain sustainable during the development process.
    - Proper safety guidelines will be followed during development and safety features will be integrated during development.

5. **Engineering Standards:**
    - The engineering standards are taken into consideration by observing ISO and CSA standards and guidelines.

Extensive testing of each subsystem will be performed to proceed and complete the development of the final prototype. Though the proof-of-concept is still under heavy development, the first prototype of the SWISH Trainer is expected to be completed by April 23rd, 2021.

# 9. Glossary

| | |
|---|---|
| **AC** | Alternating Current |
| **C++** | Language typically used to interface software with hardware. |
| **C2C** | Cradle to Cradle |
| **Computer Vision** | A term used to describe how computers can interpret images/video. |
| **CSA** | Canadian Standards Association |
| **DC** | Direct Current |
| **ISO** | International Standards Organization |
| **OpenCV** | A library of programming functions aimed at computer vision. |
| **PoC** | Proof of Concept |
| **Python** | Programming language |
| **RPi** | Raspberry Pi |
| **SWISH Trainer** | Product Name |
| **UART** | Universal Asynchronous Receiver/Transmitter |
| **USB** | Universal Serial Bus |

# 10. References


[1] “3 NBA Players Share Their Offseason Schedule”. [Online]. Available: https://www.usab.com/youth/news/2011/04/3nba-players-share-their-offseason-schedule.aspx. [Accessed: 20-Feb-2021]

[2] “How Often We Practice”. [Online]. Available: https://skydmagazine.com/2014/10/often-practice/ [Accessed: 20-Feb-2021]

[3] “Best of Basketball rebounding machines”. [Online]. Available: https://www.momotion.com/rebounding-machines/ [Accessed: 20-Feb-2021]

[4] “BC safety standards act”. [Online]. Available: https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/18_105_2004#part4 [Accessed: 20-Feb-2021]

[5] C. A. Bakker, R. Wever, C. Teoh, and S. De Clercq, “Designing cradle-to-cradle products: a reality check,” International Journal of Sustainable Engineering, vol. 3, no. 1. pp. 2–8, 2010, doi: 10.1080/19397030903395166.

[6] CSA, “CAN/CSA-C22.2 NO. 61508-1:17. - Functional safety of electrical/electronic/programmable electronic safety related systems — Part 1: General requirements” [Online] Available: https://www.scc.ca/en/standardsdb/standards/28870 [Accessed: 20-Feb-2021]

[7] IEEE/ISO/IEC 29148-2018 - ISO/IEC/IEEE International Standard - Systems and software engineering -- Life cycle processes -- Requirements engineering. [Online]. Available: https://standards.ieee.org/standard/29148-2018.html. [Accessed: 20-Feb-2021].

[8] “General requirements - Canadian Electrical Code, Part II,” Standards Council of Canada - Conseil canadien des normes, 25-Apr-2019. [Online]. Available: https://www.scc.ca/en/standards/notices-of-intent/csa/general-requirements-canadian-electrical-code-part ii#:~:text=1.3%20Objective%20of%20the%20Canadian,and%20high%20quality%20of%20work. [Accessed: 21-Feb-2021].

[9] “ISO/IEC TR 25060:2010 Systems and software engineering — Systems and software product Quality Requirements and Evaluation (SQuaRE) — Common Industry Format (CIF) for usability: General framework for usability-related information”. [Online] Available: https://www.iso.org/standard/35786.html [Accessed: 20-Feb-2021]

[10] “C22.2 NO. 100-14 (R2019) Motors and generators,” CSA Group, 21-Nov-2020. [Online]. Available: https://www.csagroup.org/store/product/2423226/. [Accessed: 20-Feb-2021].

[11] “CSA Group, "CAN/CSA-ISO/TR 14062-03 (R2013) - Environmental Management - Integrating Environmental Aspects into Product Design and Development (Adopted ISO/TR 14062:2002, first edition, 2002-11-01)," CSA, Mississauga, 2013”. [Online]. Available: https://www.scc.ca/en/standardsdb/standards/19019 [Accessed: 20-Feb-2021]

[12] “CSA Group, "CAN/CSA-ISO 14040-06 (R2016) - Environmental Management - Life Cycle Assessment - Principles and Framework (Adopted ISO 14040:2006, second edition, 2006-07-01)," CSA, Mississauga, 2016. [Online]. Available: https://www.scc.ca/en/standardsdb/standards/23295” [Accessed: 20-Feb-2021]

[13] “Enclosures for Electrical Equipment, Environmental Considerations”. [Online]. Available: https://www.scc.ca/en/standardsdb/standards/23524 [Accessed: 20-Feb-2021]

# Appendix A: Acceptance Test Plan (for PoC)

**Test Purpose:** The following is a test plan provided to ensure certain components of the SWISH Trainer should function as intended and meets the requirements for the ENSC 405 demo.

## Hardware Test Plan

| Testing Number | Description | Pass/Fail (P/F) | Comments |
|---|---|---|---|
| 1 | The wheels of the passing system should be able to be mounted on the DC motors and rotate in both clockwise and counterclockwise directions. | | |
| 2 | The Servo Motor should be able to rotate with a range of 180° with a relatively quick response time. | | |
| 3 | The DC motors and wheels should be able to shoot/pass the basketball. | | |
| 4 | The Ball should be able to be fed through the passing mechanism and reach the spinning wheels. | | |
| 5 | Camera should be able to capture most of the playing field. | | |
| 6 | The power supply can power 2 DC Motors simultaneously. | | |

## Software Test Plan

| Testing Number | Description | Pass/Fail | Comments |
|---|---|---|---|
| 1 | The RPi can correctly detect the person. | | |
| 2 | The Arduino can control the DC and Servo motor. | | |
| 3 | The Arduino can receive input stimuli from RPi. | | |

## System Integrated Test Plan

| Testing Number | Description | Pass/Fail | Comments |
|---|---|---|---|
| 1 | All components of the system can be powered by one single power supply. | | |
| 2 | A ball can be fed into the SWISH Trainer manually, and the system should be able to fire the ball. | | |
| 3 | A user should be able to shoot a basketball into a basketball hoop and it will land into the SWISH Trainer, where it should rotate to the player and shoot back the ball in their direction. | | |