Auto-Ball Enterprises

Feb. 21, 2021

Dr. Craig Scratchley
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8888 University Drive
Burnaby, BC V5A 1S6

Re: ENSC 405W Requirements Specification for Auto-Ball Enterprises' Floor General Shooting Machine

Dear Dr. Scratchley and Dr. Jannesar,

Please find attached to this letter the requirements specification document for the Floor General. This reimagined basketball shooting machine aims to provide players with a dynamic, game-like experience. Traditional shooting machines confine players to basic, preset passing patterns, whereas our device will use a combination of motion detection and gesture recognition to adapt to the athlete's custom workout.

The following requirements specification document outlines product deliverables for the proof-of-concept, prototype, and final product phases. Additionally, a detailed test plan was developed to ensure that the function requirements provided in this document are satisfied by the proof of concept.

Auto-Ball Enterprises's team is made up of 6 committed senior engineering students with backgrounds in computer engineering, electronics, and engineering physics. Our diverse multidisciplinary team consists of Rameshwar Kannan, Karan Kakkar, Tal Kazakov, Ramish Khan, Santhosh Nandakumar, and Simone Neufeld.

Thank you for taking the time to review our requirements specification document. If you have any questions or concerns please contact our CCO, Karan Kakkar at kkakkar@sfu.ca, or contact me with any questions through my canvas inbox.

Sincerely,
Rameshwar Kannan
Chief Executive Officer

Requirements Specification
Company 24

CEO Rameshwar Kannan
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Submitted to Dr. Craig Scratchley
Dr. Shervin Jannesar
School of Engineering Science
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Date of Submittal Feb. 21, 2021

Abstract

The Floor General is a state of the art sensor assisted basketball shooting system that is currently under development by Auto-Ball Enterprises. Floor General will bring a revolutionary feature to the basketball world by redefining the concept of an automatic shooting machine. The device will track the user on the court in real-time and use advanced system technology to retract and shoot the basketball to the player. Auto-Ball Enterprises will use motion detection and signal sensors to assist with the coordination of the launching mechanism to replicate a game-like feel to the player. The Floor General will ultimately provide what no other shooting machine can, by allowing for next level training for its users.

The device requirements, listed below, are separated into the following categories: general, software, hardware, electrical, and performance. Furthermore, the safety and sustainability requirements are also defined below. These requirements are to ensure that Auto-Ball Enterprises's Floor General device will perform its features, operate safely, and meet engineering standards, whilst being sustainable. The team at Auto-Ball Enterprises have designated several test case plans to perform acceptance, integration and validation tests on the different components of the system.

Auto-Ball Enterprises is enthusiastic to provide a subversive training feature to the second largest sports community on the planet.

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Glossary

ARD - Arduino

FG - Field Goal

FG % - Field Goal Percentage

FP - Final Product

PCB - Printed Circuit Board

PoC - Proof of Concept

HW - Hardware

Req - Requirement

Rim - Basketball Hoop Rim

RPI - Raspberry PI

SW - Software

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1. Introduction

1.1 Background

Basketball is one of the most popular sports in the world with a following of approximately 825 million worldwide [1]. Shooting the basketball is a fundamental skill requiring countless hours of practice. Current shooting machines can pass the ball to a player but only along a pre-programmed pattern on the court, and at preset passing intervals, which have to be set up by the user in advance. This greatly limits the freedom of a practicing player to move around the court and shoot from their desired shooting location.

Auto-Ball Enterprises plans to develop a state of the art improved basketball shooting machine, featuring real-time tracking of a player's position enabling automatic passing of the ball to the player's desired shooting location. The shooting machine will track the players position on the court using sensor technologies, take shooting cues/gestures from the player and automatically dispense the optimal pass.

The system will be able to target players within the shooting halfcourt and swivel the launcher to their position, allowing for various training routines for competitive basketball players. The product will maximize the training potential of highschool, collegiate, and professional basketball players.

1.2 Scope

The following document outlines the design and technical requirements of the product through all phases of development. The development cycle will consist of the following three main phases: proof of concept, prototype and final product.

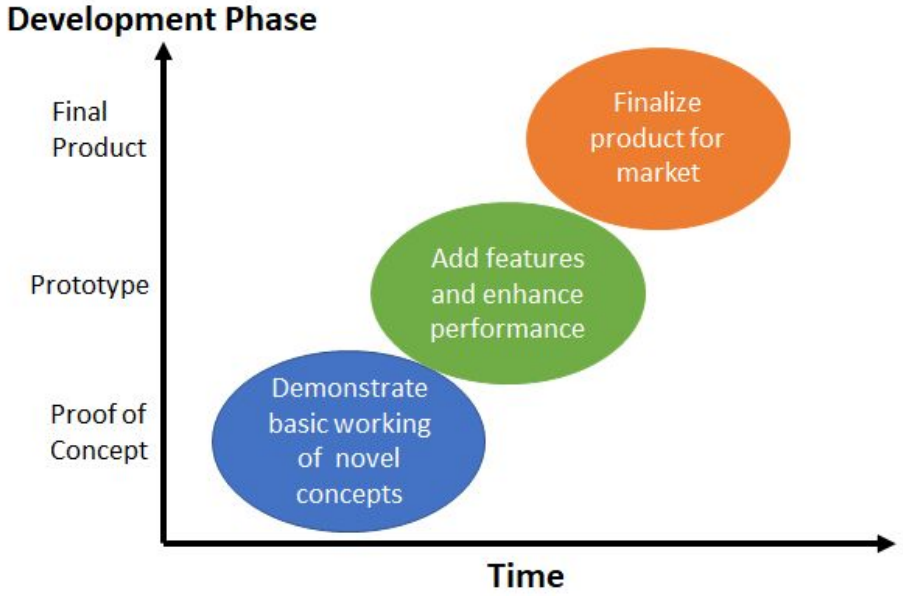

Figure 1.2: Product Development Path

Each stage will have deliverables denoted by the following convention:

Table 1.2.1: Naming Convention for Product Stages

Development Stage	Designation
Proof of Concept	PC
Prototype	PT
Final Product	FP

The requirements outlined in this document will guide the development of the product by setting precise, quantifiable deliverables at each phase of the development cycle. These requirements are broken up into the following categories:

Table 1.2.2: Naming Convention for Requirement Categories

Category	Designation
System Requirements	SY
Software Requirements	SW
Hardware Requirements	HW
Electrical Requirements	EL
Performance Requirements	PE
Safety Requirements	SA
Sustainability Requirements	SU

Furthermore, any relevant standards used to prepare the above requirements will be discussed.

1.3 Intended Audience

This document serves to illustrate the requirements specification for the Floor General. It will showcase the planned capabilities of the product to the supervising team, consisting of the professors and TA's, along with potential customers and collaborative partners. Most importantly, it will guide Company 24's engineering team while developing and testing to realize the product to its full potential.

2. System Overview

2.1 Proof of Concept

The proof of concept will demonstrate the device's ability to locate a single player on the court using distance and azimuthal angle, then take a shooting cue from the player, and process this data to swivel the machine and launch the basketball to the player's location at an appropriate speed. The shooting cue provided by the user will trigger the launching system to pass the basketball to the player.

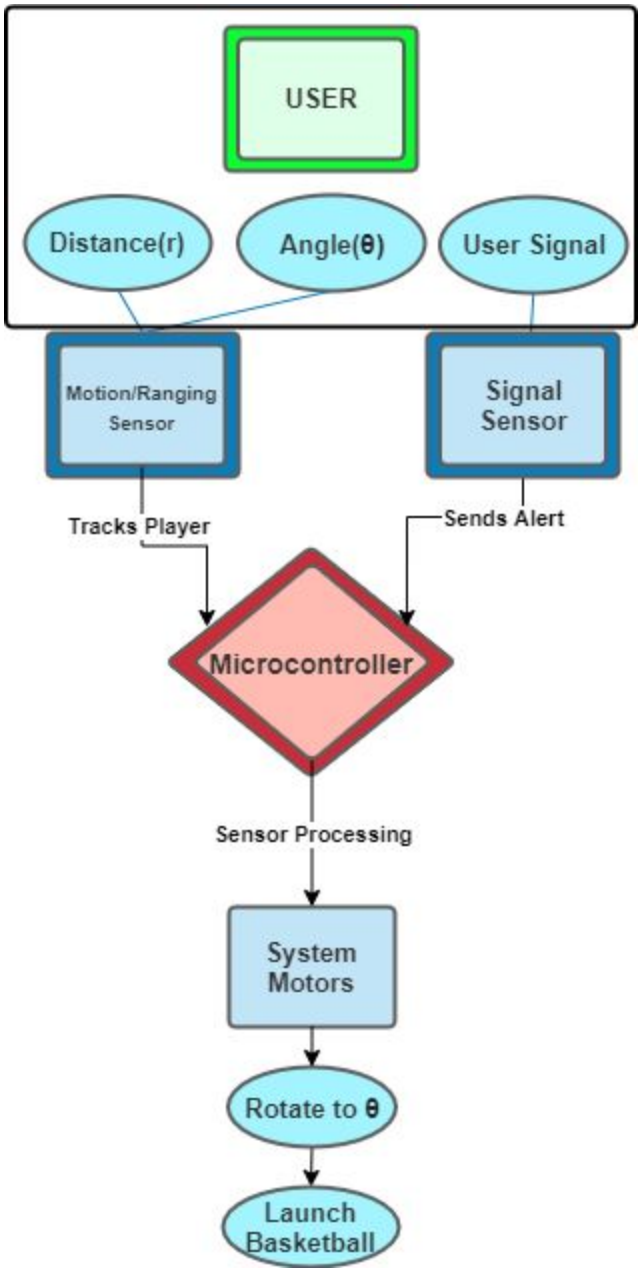

Figure 2.1: Proof of Concept Model

The distance and angle will be calculated by a positioning and ranging sensor, which would scan for a player on the court. Using the device's relative angle to the player, a microcontroller will send out a signal to first position the swiveling mechanism to be in-line with the player. Upon detecting the shooting cue from the player, the microcontroller will use the distance, r to launch the ball as close as possible to the player's location.

Integrating the systems in figure 2.1.1, to launch a full sized basketball to a single player, with reasonable accuracy, will be the main focus of our proof of concept.

2.2 Prototype

The prototype phase will add a number of features which are standard on current basketball shooting machines. This will consist of a funnel system to capture the basketball after a shot is taken. The funnel system will be designed to capture all made shots and the majority of missed shots. Moreover, the prototype should be able to queue up multiple basketballs, allowing for shots to be taken in rapid succession.

A basic image of the proof of concept is highlighted below in figure 2.2.2. The sensors will determine the user's position in real-time, and communicate to the other subsystems coordinating the output of the ball launching system. This will provide an innovative and efficient way to practice jumpshots for players on the basketball court.

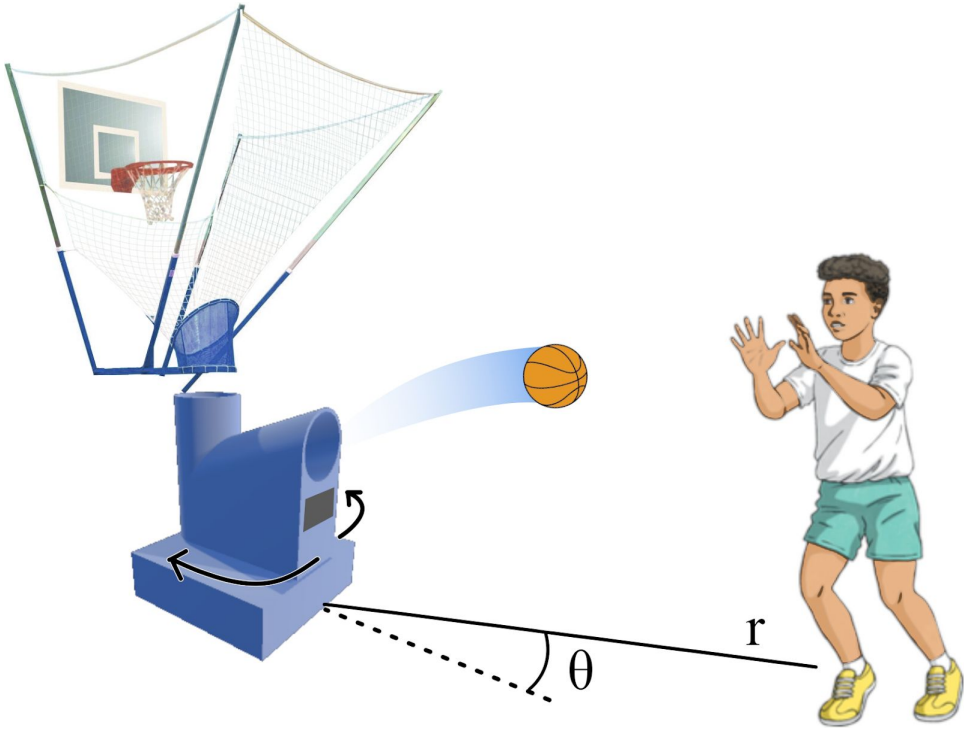

Figure 2.2: 3D Model of the Device. Adapted from [2] and [3]

Furthermore, the prototype should be shock resistant to accidental collisions with basketballs in the event of a missed shot. The prototype model will also include a number of performance enhancements such as speeding up the swivel mechanism to get in line with the player faster, and fine tuning the launching mechanism to allow for greater pass accuracy. These optimizations will be made based on data collected from the proof of concept device.

2.3 Final Product

The final product should include a number of user-friendly features to bring the product to market. The final product should have good ergonomics and a simple, intuitive user interface to easily control the various operating parameters of the device. Some parameters the user should be able to easily alter include passing frequency, speed, height and number of balls to pass upon detection of a user signal.

In addition, the device must be compliant with various safety and sustainability standards. For instance, the device should not launch any loose debris or foreign objects at the user. The device should also have a small physical footprint allowing for easy transport, setup, disassembly and storage.

3. System Requirements

3.1 Motion Detection/Ranging System

The Motion Detection System will consist of sensors to measure the distance (r) and azimuthal angle (θ). These values will then be used to drive the swivelling mechanism and set the parameters of the launching system. Table 3.1 lists the specification requirements for the Motion Detection/Ranging system.

Table 3.1: Motion Detection/Ranging System Requirements

Requirement ID	Requirement Description
Req. 3.1.1-SY-PC	The system must have a field of view of at least 180°
Req. 3.1.2-SY-PC	The system must be able to detect player movement within a semicircle with a minimum radius of 7m
Req. 3.1.3-SY-PC	The system must be able to locate the player relative to the device using the parameters r (distance) and angle (theta)
Req. 3.1.4-SY-PC	The system must be able to perform continuous tracking of the player
Req. 3.1.5-SY-PT	The system must be able to process in real time to minimize the transition delays
Req. 3.1.6-SY-FP	The device can detect multiple users and behave accordingly
Req. 3.1.7-SY-FP	The device should distinguish between the user(s) and other players in its field of view

3.2 "Request Pass" Mechanism

The "Request Pass" Mechanism will be the primary means by which the player cues the shooting machine to pass the ball. Upon a predefined action, a sensor located on the player will send a signal to the microcontroller which will trigger the launching system to pass the basketball. Table 3.2 lists the specification requirements for the "Request Pass" Mechanism.

Table 3.2: "Request Pass" Mechanism Requirements

Requirement ID	Requirement Description
Req. 3.2.1-SY-PT	The mechanism must be able to initiate the launching system to pass the basketball
Req. 3.2.2-SY-PT	Any components attached to the user must be wearable
Req. 3.2.3-SY-FP	The mechanism must correct itself if request to launching system to pass the basketball is lost

3.3 Swivelling System

The Swivelling System will rotate based on the distance (r) and angle (θ) data obtained from the motion/ranging system. This system will also be responsible for aligning the ball launching system to the player. Table 3.3 lists the specification requirements for the Swivelling System.

Table 3.3: Swivelling System Requirements

Requirement ID	Requirement Description
Req. 3.3.1-SY-PC	The swivelling system must be able to rotate to any angular position between 0 - 180° in the horizontal plane
Req. 3.3.2-SY-PC	The swivelling system must be able to hold its position after rotating to its final position
Req. 3.3.3-SY-PC	The swivelling system must be able to support the weight of the launching system
Req. 3.3.4-SY-PT	The angular position of the swivelling system must be at 90° upon device startup
Req. 3.3.5-SY-PT	The base of swivelling system should be easy to transport

3.4 Ball Launching System

The Ball Launching System will be composed of a variety of motors that are responsible for launching the basketball to the player. Launching parameters determining how far the ball will need to travel will be set according to distance data gathered by the Motion Detection/Ranging System. Table 3.4 lists the specification requirements for the Ball Launching System.

Table 3.4: Ball Launching System Requirements

Requirement ID	Requirement Description
Req. 3.4.1-SY-PC	The system must be able to launch a full size 7 (22 oz) basketball to any point within a 7m radius
Req. 3.4.2-SY-PC	The system must be securely mounted to the swivelling system
Req. 3.4.3-SY-PT	The system should identify whether there is a basketball ready to be launched or no basketball is present
Req. 3.4.4-SY-PT	This system should be able to hold the ball until the player requests a pass
Req. 3.4.5-SY-PT	The system should be able pass the ball on target to the player's shooting pocket
Req. 3.4.6-SY-PT	The system should be able to hold up to 4 basketballs and pass them upon player request
Req. 3.4.7-SY-FP	The system should have adjustable settings to control passing speed

3.5 Funnel System

The Funnel System will be responsible for collecting both made and missed shots. Ideally, the ball should always land in the funnel after a missed shot. This extension of the machine beyond the height of the rim forces players to develop the appropriate arc, a key component in any good jumpshot. Table 3.5 lists the specification requirements for the Funnel System. A standard Funnel System is displayed in figure 3.5 below.

Table 3.5: Funnel System Requirements

Requirement ID	Requirement Description
Req. 3.5.1-SY-PT	The height of the missed shot funnel should extend 1-2 feet above the rim
Req. 3.5.2-SY-PT	The netting in the missed shot funnel should extend 5 feet past the rim in each direction
Req. 3.5.3-SY-PT	All parts of the funnel should withstand impact forces caused by a basketball shot
Req. 3.5.4-SY-FP	The lower part of the funnel should have a maximum diameter of 35” such that only one basketball can get through at a time
Req. 3.5.5-SY-FP	The height of the missed shot funnel should be adjustable by the user

Figure 3.5: Funnel System Demonstration. Adapted from [2]

3.6 General Requirements

The following general requirements are for the device operating as a complete system.

Table 3.6: General System Requirements

Requirement ID	Requirement Description
Req. 3.6.1-SY-PT	The device must be portable
Req. 3.6.2-SY-PT	The device should have on/off capability and must clearly be indicated by the device
Req. 3.6.3-SY-FP	The device must be shock and vibration resistant
Req. 3.6.4-SY-FP	The device should collapse into a smaller footprint for easy storage
Req. 3.6.5-SY-FP	The device sound levels must not be distracting to players practicing
Req. 3.6.6-SY-FP	The device must be powered by a standard AC wall outlet
Req. 3.6.7-SY-FP	The device must not damage the hardwood and paint on the court
Req. 3.6.7-SY-FP	The device setup and take down can be performed by one person
Req. 3.6.8-SY-FP	The device has an on board display to show statistics like: shots attempted, shots made and field goal percentage
Req. 3.6.9-SY-FP	The device production cost should not exceed $1200

4. Software Requirements

The software will receive and process data from all motion/ranging sensors. It will ensure all subsystems are synchronized with one another. The software will run on a microprocessor and utilize sensor readings to control the various system components. To reduce latency between the player's cue and the pass being received, the player's location will be continuously tracked. Table 4.1 details the Software requirements for the Floor General.

Table 4.1: Software Requirements

Requirement ID	Requirement Description
Req. 3.2.1-SW-PC	The sensor data should be processed continuously
Req. 3.2.2-SW-PC	The software must compute the player's location from the collected data
Req. 3.2.3-SW-PC	The software should set the rotating angle of the swivel mechanism
Req. 3.2.4-SW-PC	The software must wait for the user signal before launching the ball
Req. 3.2.5-SW-PC	The software must execute the detect, swivel and launch routines within an acceptable time frame
Req. 3.2.6-SW-PT	The software must have a startup and calibrate time of no more than 20s
Req. 3.2.7-SW-PT	The software must determine the swivel mechanism's position upon startup
Req. 3.2.8-SW-PT	The software must be able recover from errors and glitches
Req. 3.2.9-SW-PT	The software must be able to do a system reboot if it encounters an irrecoverable error
Req. 3.2.10-SW-FP	The software should be able to accept inputs to configure the launching speed and rate of rotation of the swivel mechanism
Req. 3.2.11-SW-FP	The software must notify the user if garbled data is collected from a sensor

5. Hardware Requirements

The hardware of the device will consist of various motors, motion/ranging sensors and a microcontroller [4],[5]. Apart from these major components, smaller mechanical components will be required to develop a smoothly functioning device. Moreover, each hardware-subsystem will be implemented using a modular approach, which will enable the user to replace any damaged parts. Table 5.1 details the Hardware requirements for the Floor General.

Table 5.1: Hardware Requirements

Requirement ID	Requirement Description
Req. 3.3.1-HW-PC	The launching mechanism must be able to pass a full size 7 (22 oz) basketball to any point within a 7m radius
Req. 3.3.2-HW-PC	The swivelling mechanism which holds the launching mechanism must be able to rotate 180° in the horizontal plane
Req. 3.3.3-HW-PC	The swivelling mechanism should be able to swivel at an appropriate speed while supporting the weight of the launching mechanism
Req. 3.3.4-HW-PC	The motion detection system must detect user movement within a semicircle with a 7 meter radius
Req. 3.3.5-HW-PT	Net system used to funnel missed shots must be compatible with standard 72” backboards
Req. 3.3.6-HW-PT	The total weight of the hardware components should not exceed more than one person can reasonably transport
Req. 3.3.7-HW-PT	All the hardware components should return to startup state after a reboot.
Req. 3.3.8-HW-PT	All hardware attached to the user must be wearable
Req. 3.3.9-HW-FP	The wearable hardware must not obstruct or hinder the player’s ability to shoot the basketball
Req. 3.3.10-HW-FP	All components susceptible to damage should be covered by some protective housing

6. Electrical Requirements

The several components of the Floor General will be powered using electricity. Furthermore, the various electrical requirements are extremely vital to ensure the system will function properly. Team Auto-Ball will ensure that all electrical components are supplied with the correct power to guarantee safety and mitigate any risks [6], [7]. Table 6.1 details the Electrical requirements for the Floor General.

Table 6.1: Electrical Requirements

Requirement ID	Requirement Description
Req. 3.3.1-EL-PC	System is powered by a power supply
Req. 3.3.2-EL-PT	All electronic components must be electrically stable during typical operation
Req. 3.3.3-EL-PT	Device must be powered via a standard wall outlet
Req. 3.3.4-EL-PT	All electrical connections must be safely insulated
Req. 3.3.5-EL-FP	Overcurrent/short-circuit protection
Req. 3.3.6-EL-FP	A master switch must be installed to turn on/off the device

7. Engineering Standards and Responsibilities

To ensure the safe operation, the Floor General must conform to various electrical, software, hardware and safety standards. The Floor General will be designed to meet standards from various organizations such as: CSA, IEEE, and ISO.

The following table describes the relevant standards for the Floor General. The components for the Floor General are yet to be finalized. As such, the requirements below serve as a general guideline for the various components of the Floor General.

Table 7.1: Relevant Engineering Standards

Standard	Description
CAN/CSA-C22.2 NO. 61508-1:17	Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 1: General Requirements [9]
CAN/CSA-C22.2 NO. 0-10	General Requirements - Canadian Electrical Code, Part II [10]
IEEE 12207-2017	IEEE International Standard - Systems and software engineering — Software life cycle processes [11]
IEEE 829-2008	IEEE Standard for Software and System Test Documentation [12]
IEEE 2700-2014	IEEE Standard for Sensor Performance Parameter Definitions [13]
ISO 12100:2010	Safety of machinery — General principles for design — Risk assessment and risk reduction [14]

8. Safety

The Floor General is a system composed of various software, hardware, and electronic components functioning together to create a state of the art basketball shooting machine. The device design must therefore be robust, reliable, and ensure the safety of the user during all times of operations.

Electronic motors and components will be powered within a safe range, and will include protective shielding from the user to prevent misuse[6]. The device and all its accessories such as the net, power supply, and cabling must also be positioned in a safe manner away from the users position on the court.

Table 8.1: Safety Requirements

Requirement ID	Requirement Description
Req. 8.1.1-SA-PT	The device should not overheat
Req. 8.1.2-SA-PT	The device housing should be made of non toxic materials
Req. 8.1.3-SA-PT	The enclosure should not have sharp edges which can cause injury
Req. 8.1.4-SA-PT	There must be no exposed wires poking out of the housing
Req. 8.1.5-SA-FP	The funneling system must be sturdy and secured
Req. 8.1.6-SA-FP	The device must only launch full sized basketballs and not foreign objects

9. Sustainability

Auto-Ball Enterprises strives to deliver the highest quality product while complying with the highest level eco-conscious sustainability standards. One of these standards is the Cradle-to-Cradle (C2C) standard and will be followed by the team to gauge the environmental impact of each component. The C2C is based on nature's own recycling method and shown below in figure 9.1. Once the product's life cycle is complete, the materials can be used in new products thus limiting the overall waste created and reducing the environmental waste.

The Floor General will use recyclable components to follow the technical cycle of the C2C cycle. Non-toxic and biodegradable materials will be used where possible to allow the components to be reused in as many applications as possible and follow the biological cycle. The team will make an effort to research all chemicals used to create the components are not on the C2C list of banned chemicals.

Due to the limited availability of affordable components, it may be difficult for the team to create a product that is entirely environmentally sustainable. An effort will be made to reuse hardware components throughout the development phases.

Figure 9.1: Cradle to Cradle Cycle

Table 9.1: Sustainability Requirements

Requirement ID	Requirement Description
Req. 9.1.1-SU-PT	The device must be power efficient
Req. 9.1.2-SU-FP	The devices body and protective housing must be manufactured with environmentally safe material
Req. 9.1.3-SU-FP	Components prone to breaking must be easily replaceable and recyclable
Req. 9.1.4-SU-FP	The electrical components should be reusable for upgraded device version

10. Conclusion

Auto-Ball Enterprises will deliver a brand new technology that has never been realized for training players in the global sport of basketball. Auto-Ball Enterprises is driven to provide its users a game-immersive training routine that allows for free movement and the configuration for game-like shots. Whether the player is on one side of the court or the other, the Floor General system will provide an innovative solution to send the basketball to its user at ease. With a brand new variety of motors and advanced sensor technology Auto-Ball Enterprises aims to redefine the concept of a basketball shooting machine in 2021.

The Floor General system is composed of various subsystems with a handful of requirements that are selected to ensure customer safety, satisfaction, engineering standards and sustainability efforts. By fulfilling these requirements Auto-Ball Enterprises will be able provide a new product to the market. It is paramount importance that all acceptance tests plans are passed for each respective subsystem of Floor General. By accomplishing the mentioned requirements, standards, and testing, Auto-Ball Enterprises will guarantee a cohesive, functional product.

The final goal of Auto-Ball Enterprises will include the various requirements and standards, but also will aim to cut down on non-recyclable materials to ensure sustainability across subsystems. The proof of concept and prototype will be developed over the next several months.

Our engineering team at Auto-Ball Enterprises will deliver a proof of concept, prototype, and final product, whilst ensuring all requirement outlines are met. The team will consider functional and non-functional requirements for each piece of technology within the subsystems. The various subsystems will be constantly validated during each addition or integration to the overall device; these acceptance test plans are listed below in Appendix A.

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12. Appendix A: Acceptance Test Plans

To ensure the quality and safety of the product, the following test procedures must be carried out on the proof of concept device. The test plan will evaluate the functionality of each sub-system and will outline general tests that will be performed on the device. All tests primarily focus on the motion detection system, swivelling mechanism and launching mechanism.

Table 12.1: Acceptance Test Plans

Inspection and Test Plan		
Test No.	**12.1 General Tests**	Pass/Fail
12.1.1	The device can work as a single unit by tracking the user, focusing the ball launcher toward the user, and launching the ball	❑ Pass ❑ Fail
12.1.2	Force the device into an error state and confirm that it can recover	❑ Pass ❑ Fail
12.1.3	Perform a field of view test by varying the player's location and verify that the machine can set the swivelling and launching parameters accordingly	❑ Pass ❑ Fail
12.1.4	Turn on the master switch to confirm that the device automatically calibrates within 10 seconds and moves to ready state	❑ Pass ❑ Fail
12.2 Hardware Tests		
12.2.1	The machine can rotate 180°	❑ Pass ❑ Fail
12.2.2	Launch the basketball towards the user when the user is standing 7 meters away. Confirm the ball is at a height between 3 feet and 5 feet when it reaches the user. Repeat this test with the user standing 6 meters away, then again at 5 meters away.	❑ Pass ❑ Fail
12.2.3	Have the user shoot the ball towards the basketball hoop 10 times and confirm that at least 9 of these 10 shots is properly captured by the collection mechanism and that every captured ball is then set up for launching.	❑ Pass ❑ Fail
12.2.4	The wearable hardware can collect and send the data to the microprocessor.	❑ Pass ❑ Fail
12.2.5	The microprocessor is in a ready state to receive user data at device startup	❑ Pass ❑ Fail
12.2.6	The distance from the machine to the user can be measured	❑ Pass ❑ Fail
12.2.7	The motion sensor provides coverage of the entire shooting area	❑ Pass ❑ Fail

12.3 Electrical Tests		
12.3.1	Ensure all electric motors are within the specified resistance range	❑ Pass ❑ Fail
12.3.2	Ensure all hardware operates with the specified voltage and current input	❑ Pass ❑ Fail
12.3.3	Perform a short circuit check on each sub-system of the device	❑ Pass ❑ Fail
12.4 Software Tests		
12.4.1	The software runs an initial sequence check after device startup	❑ Pass ❑ Fail
12.4.2	The software can correctly process the user's signal to pass the ball	❑ Pass ❑ Fail
12.4.3	The software can trigger the launching mechanism	❑ Pass ❑ Fail
12.4.4	The software can accurately process the motion sensor data	❑ Pass ❑ Fail