February 21, 2021
Dr. William Craig Scratchley
wcs@sfu.ca
School of Engineering Science

Simon Fraser University
8888 University Drive,
Burnaby, British Columbia, V5A 1S6
RE: ENSC 405W/440 Requirements Specification for PuckHoover™

Dear Dr. Scratchley,

The following document prepared by ProjectBot Solutions details the requirement specification for the PuckHoover™, intended for ENSC 405W/440. The goal for our capstone project is to create an autonomous device which can efficiently pick up hockey pucks and stack them in an organized fashion to help save time during hockey games and maximize quality training sessions.

PuckHoover™ uses vision systems and real time machine learning to detect the location of pucks on the ice, and navigates intelligently to collect them. An innovative collection and storage system is used, and informs the user when the storage is full. The PuckHoover™ is designed to be easily transported through ice rink entrances and compact enough to enter hockey nets.

The requirements specification will cover requirements from the proof of concept to the prototype to the final product, which will provide a timeline for the deliverables for our project. This document will review general requirements as well as more specific requirements such as those for our software and electronic components. Lastly, this document will also discuss safety and sustainability requirements, as well as the engineering standards our product will be conforming to.

Our team would like to thank you in advance for taking the time to review our requirements specification. If you have any questions, please feel free to email me at tvt1@sfu.ca .

Sincerely,

Tina Vo Tran
CCO
ProjectBot Solutions

ProjectBot Solutions

PuckHoover™
Requirements Specification

ENSC 405W
Spring 2021
Company 3
February 21, 2021

Partners:
Hanaa Diab
Forbes Ng
Edwin Tam
Jeffrey Wael

Contact:
Tina Tran

Submitted To:
William Craig Scratchley
Shervin Jannesar
Michael Hogedus
Chris Hynes

Abstract

This document outlines the requirements of an autonomous puck collector as part of an 8 month capstone project, the PuckHoover™. The general requirements details the core functionality of the device, before it branches out to technical and safety requirements. In addition to requirements, this document presents the acceptance test plan to take place in the alpha development phase, in addition to the stringent engineering standards that will be followed during the concept, design, and manufacturing of the prototype.

Outline of each requirement:

- General Requirement: including systems and functional requirements
- Technical Requirements: including electrical, structural, and software requirements
- Safety Requirements: including operator & operating environment safety, and sustainability requirements
- Acceptance Test Plan Requirements: additional requirements for normal operations of the device in various parameters

The main design components of the PuckHoover™ involve two phases. The alpha design phase from January to April 2021 will produce a proof of concept of the mechanical systems for the puck collection and stacking. The beta design phase from May to August 2021 will produce the automation system including a fully developed vision system for puck detection, user interface, refinement in hardware systems, and testing.

All requirements and deliverable mentioned in this document will be reached for the final prototype and demonstrated in August of 2021

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1 Introduction

PuckHoover™ aims to automate the process of collecting pucks efficiently. This can help maximize quality time for hockey practices and reduce downtime during hockey game intermissions.

With upcoming improvements and widened applications, vision systems are becoming easily accessible in interdisciplinary fields and industries. Teamed with machine learning, the two technologies can have object recognition abilities, and assist society in various tasks.

The PuckHoover™ from ProjectBot Solutions uses vision systems to seek out the location of the pucks on the ice rink and then uses machine learning to determine the most optimum path to retrieve all the pucks. A parallel pick-up and stacking process is used to decouple the PuckHoover™'s operations so the operations are not dependent on each other.

1.1 Background

As a big number of hockey pucks are used during training sessions, cleaning up the pucks each at a time can be a time consuming task. Hockey teams and players want to be getting the most out of their time with the ice rink as it can cost hundreds of dollars per hour to privately rent. The less time it takes to clean up and prepare the ice rink for the group of people, the more time is spent using the ice rink for training, pre-game warm-ups, etc.

1.2 Scope

This document will go through the requirements specifications for our PuckHoover™ product. It includes the system outline, the general and specific requirements, the requirements to reach the highest possible sustainability and safety. As well as the test plan for our proof of concept demo and the standards we will follow to produce our product.

1.3 Intended Audience

The target market for the PuckHoover™ includes hockey teams of any level, sports arenas, kids camps, training facilities, ice rinks, hobbyists, and amateurs.

1.4 Requirement Classification

Below is the classification used for our requirements:

`Req {Section}.{Subsection}.{Sub-subsection}.{Requirement number}.{Stage of Development}`

Development stages for each requirement are:

- A - Alpha phase
- B - Beta phase
- F - Final phase

2 System Overview

The PuckHoover™ is a robotic system designed to autonomously search for pucks on the ice with a mounted camera, travel to the pucks, and pick them up into the internal storage of the device. This is designed for hockey teams, hobbyists, or solo practices such that they can spend more time training rather than spending that time picking up pucks themselves.

The mechanism for picking up the puck would be a spinning wheel that spins towards itself. This way the puck is "sucked" into the bot into storage. From then on the puck would neatly stack in another mechanism inside the bot.

The device is fairly large considering it will be able to carry a relatively substantial number of pucks (about 25 to 50 pucks). The device would use modified spiked tires to traverse the ice. As for micro-controllers, we would be using a Raspberry Pi to program the device. It will use imaging processing from OpenCV to detect the pucks. This will require machine learning to train the bot to identify pucks. For power, we plan for a rechargeable battery for the unit. The following figure depicts how this system is implemented.

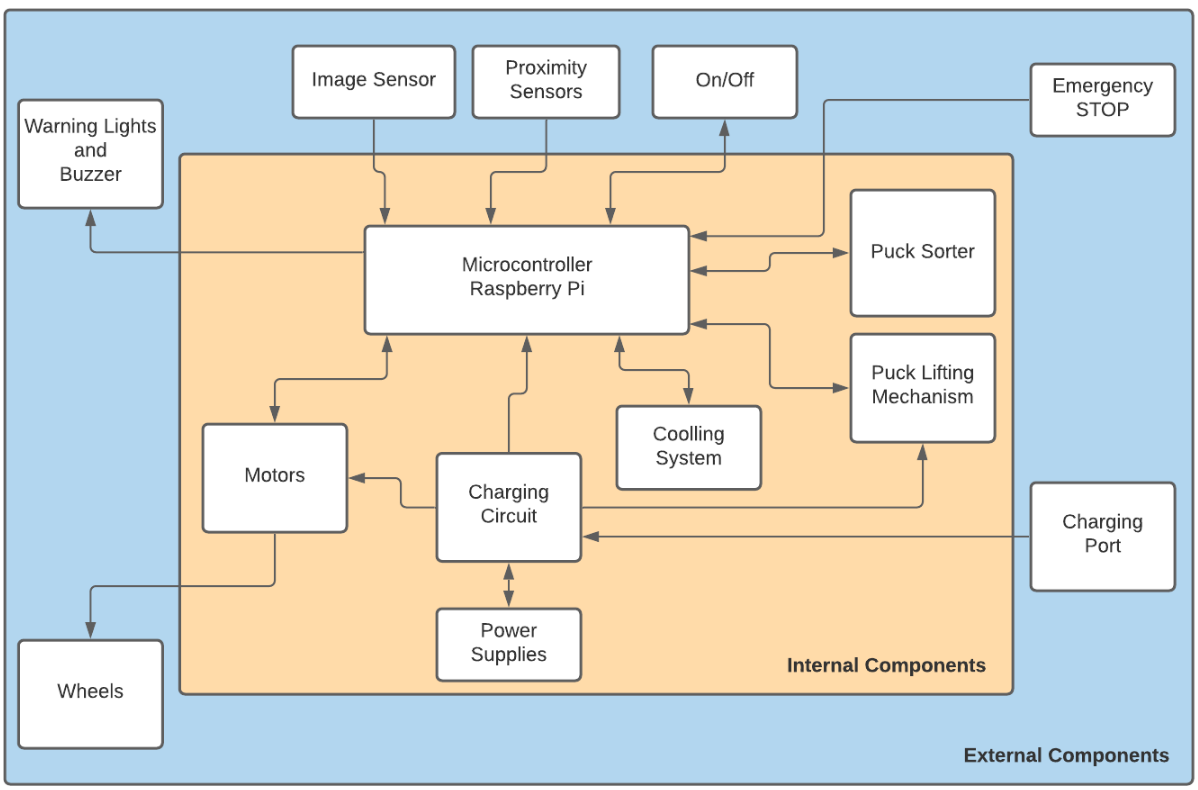

Figure 2.1: Block Diagram of Hardware Components

3 General Requirements

In this section, the general requirements for the user control abilities and the features of the device are outlined. The focus of both system and functional requirements are to ensure that the device is usable on a regular basis.

3.1 System Requirement

Requirement ID	**Requirement Description**
Req 3.1.1 A	Battery life must last for 20 to 30 minutes to last the ending parts of a training or practice session [1]
Req 3.1.2 A	Device should have a start/pause/stop switch to interrupt normal operation as needed
Req 3.1.3 B	Device must have a on/off switch for power saving, transportation, and storage purposes
Req 3.1.4 F	Device should be switchable between autonomous mode and manual mode for storage and deployment purposes

Table 3.1: System Requirements

3.2 Functional Requirements

3.2.1 Puck Storage Requirements

Requirement ID	Requirement Description
Req 3.2.1.1 B	Device should be able to carry 25 to 50 (approx. 4.25 - 8.5kg) pucks as the maximum goal is to collect the maximum number of pucks used during a training session (100 pucks) and knowing that the puck weight is about 170 g [2][3]
Req 3.2.1.2 B	User must be able to access to the pucks container from the device when required by the user
Req 3.2.1.3 B	Device must be able to identify the puck and retrieve it
Req 3.2.1.4 F	Device should be able to stack the pucks in an organized matter for space efficiency within the device

Table 3.2: Functional Requirements

3.2.2 Mobility Requirements

Requirement ID	Requirement Description
Req 3.2.2.1 B	Device must maintain traction while moving on ice
Req 3.2.2.2 B	Device must be able to stop within 0.3m (1.27ft) from max speed at max load (8.5kg) for safety purposes
Req 3.2.2.3 B	Device must not severely damage the ice surface to allow a playable surface for the players
Req 3.2.2.4 F	Device must operate at a maximum 1.3 m/s (2.91 mi/hr) in order to have a fast speed but low enough to prevent damage to it or others around it. This value was taken from a device used indoors [4]

Table 3.3: Mobility Requirements Requirements

3.2.3 Protection Requirements

Requirement ID	Requirement Description
Req 3.2.3.1 B	Device must be waterproof and shockproof for durability purposes (e.g. lifting the device out of the rink and collecting pucks with a lot of ice)

Table 3.4: Protection Requirements

4 Technical Requirements

4.1 Hardware Requirements

The hardware requirements are based on the mechanical and physical of the device. As the operating environment is in an ice rink, the surface temperature can be as low as -3 to -5.5 degree Celsius (22 to 25 Fahrenheit) [5]. The device should survive in such low temperatures while keeping the internal components dry. Hence, the device should be equipped with cold tolerable components and the device should be sealed in order to prevent ice entering into electrical components Unlike a typical ice resurfacer, the device will be powered by electricity rather than gas-powered [6]. This would require having a battery and electric motors installed, and the battery will be rechargeable so that the device creates less environmental damage as well as increases user convenience.

4.1.1 Electrical Requirements

Requirement ID	**Requirement Description**
Req 4.1.1.1 A	Device must use battery to make device portable
Req 4.1.1.2 A	Device must use motors to move around the hockey ice rink
Req 4.1.1.3 A	Device must be operational in low temperatures to handle the coldness of the rink
Req 4.1.1.4 B	Device must use an image sensor for puck detection
Req 4.1.1.5 B	Device must use proximity sensors for collision prevention

Table 4.1: Electrical Requirements

4.1.2 Structural Requirements

Requirement ID	Requirement Description
Req 4.1.2.1 A	Device should be made from recycled and new plastics for robustness and sustainability
Req 4.1.2.2 A	Device must be under 60 cm (2 feet) in width to fit through doorways and player entrance gate [7][8]
Req 4.1.2.3 A	Device must be under 120 cm (4 feet) in width to fit through goal post [9]
Req 4.1.2.4 B	Device must have a stopping distance of less than 30 cm regardless of payload
Req 4.1.2.5 B	Device must incorporate gaskets, drainage, and sealing measures for shut lines that are susceptible to moisture

Table 4.2: Structural Requirements

4.2 Software Requirements

For the software requirements, it is based on the autonomous features of the device. As the device is able to detect pucks in ice rinks, the images from the camera require a certain amount of time to process in order to track any pucks in the rink, and we limit to response time to one to five frames per second such that the autonomous operation will not be delayed by the image processing. Additionally, machineries on ice are easy to skid when it accelerates and slows down. To ensure the device is safe to the people or objects nearby, sensors and software will have to detect when the wheels skid.

Requirement ID	Requirement Description
Req 4.2.1 B	Software must be able to find a puck on the ice in an image, 1 to 2 m (3 to 6 ft) in front of the robot
Req 4.2.2 B	Image processing must be fast enough to process updated images of the robot as it moves
Req 4.2.3 B	Software must detect when the device skid and impose safety stop in such cases for its own safety and safety of others
Req 4.2.4 F	Software must be able to detect when the device is full of pucks

Table 4.3: Software Requirements

5 Safety Requirements and Sustainability

At ProjectBot Solutions we try to make sure we follow all the safety and sustainability requirements for our product. We are planning to build the device in a way it can get recycled by the end of its lifetime by using recyclable materials to build it. As our product will be moving on ice and have circuitry, we plan to fully cover the circuit to prevent the user from electrocution, and have a heat sink away from the ice to prevent any possible ice melt.

Requirement ID	**Requirement Description**
Req 5.1 A	Device must be waterproof, as all circuitry need to be covered to prevent electrocution
Req 5.1.1 A	Device must equip handles to ease the carrying of the robot and prevent any possible electrical shock
Req 5.2 A	Device must be able to stop in emergency situations
Req 5.3 A	Device must incorporate visual and audio cues to alert bystanders that the robot is in operation
Req 5.4 B	Device external body must not include sharp edges in order not to harm the handler
Req 5.5 B	Heating sinks must be present and away from the ice, and safely power off if it overheats to not damage the ice
Req 5.6 B	Battery should be rechargeable and therefore reduce battery waste
Req 5.6.1 F	Charging portal must be cover-able so as not to have foreign objects go into the portal unintentionally
Req 5.7 F	Device must be easily cleaned and stored
Req 5.8 F	Device must not impose hazardous or environmental threats
Req 5.9 F	Device must be rustproof to prevent it from degenerating from its exposure to moisture and oxygen

Table 5.1: Safety Requirements and Sustainability

6 Engineering Standards

Standards allow a clear understanding between engineers, business and the market [10]. For our product to be safe, efficient and marketable we need to obey the Canadian standards [10]. To ensure that, all electrical components purchased must be Canadian Standards Association (CSA) approved, and properly grounded. To ensure our safety and mental health we would follow COVID-19 standards.

6.1 Robotic Standards

Standard	**Description**
1872-2015	IEEE Standard Ontologies for Robotics and Automation [11]
1012-2016	IEEE Standard for System, Software, and Hardware Verification and Validation [12]

Table 6.1: Robotic Standards

6.2 Electrical Standard

Standard	**Description**
CSA C22.1:21	Canadian Electrical Code, Part I (25th Edition), Safety Standard for Electrical Installations [13]

Table 6.2: Electrical Standard

6.3 Software Standards

Standard	**Description**
P2755.2/D2, Sept 2020	IEEE Approved Draft Recommended Practice for Implementation and Management Methodology for Software Based Intelligent Process Automation (SBIPA) [14]
1633-2016	IEEE Recommended Practice on Software Reliability [15]

Table 6.3: Software Standards

6.4 Safety Standard

Standard	Description
CAN/CSA-IEC 31010:20	Risk management - Risk assessment techniques (Adopted IEC 31010:2019, second edition, 2019-06) [16]

Table 6.4: Safety Standard

6.5 Testing Standard

Standard	Description
829-2008	IEEE Standard for Software and System Test Documentation [17]

Table 6.5: Testing Standard

6.6 COVID-19 Standards

Standard	Description
CAN/CSA-Z1003-13/BNQ 9700-803/2013	Psychological health and safety in the workplace — Prevention, promotion, and guidance to staged implementation [18]
Z1003.1-18	Psychological health and safety in the paramedic service organization [19]

Table 6.6: COVID-19 Standards

7 Acceptance Test Plan - Alpha Phase

The alpha phase prototype will have the following fundamental components of the robot function for demonstration at the end of ENSC 405W. Listed with each proof of concept prototype component are the test plan details for their demonstration, each ordered in terms of priority.

What is being tested	How it will be tested	How it will be evaluated
The mechanism that will lift the puck from the ice	A puck will be pushed into the collecting mechanism of the robot to simulate the robot itself moving towards a puck and picking it up. A standard NHL size puck will be used and the test will be performed on ice.	The puck should be lifted from the ice with enough speed to enter the mechanism of the robot that will store/stack the pucks. The lifting mechanism should be able to collect the puck in a timely manner, as it will handle multiple pucks in future iterations.
The robots basic maneuverability on the ice surface	The path that the robot will traverse will be hard coded into the robot for the test. The robot will move forward 10 meters rotate, 360 degrees, and forward 10 meters back to its starting position. Then test the manual controls for the movement. The test will be performed with no payload and then with a full payload (50 pucks = 8.5Kg).	The robot traverses the desired distance and rotates 360 degrees. During the test, the robot does not travel faster than 1.3 meters per second. The robot does not lose control and move efficiently toward the input direction.
The robot's ability to withstand the colder temperature of the ice rink and its battery range	The robot will repeat the maneuverability test for 20 to 30 minutes	The robot does not decrease in moving speed during the duration of the test and it runs for the full test duration
The durability of the robot	Aggressively rolling the robot from the rink bench area to the ice, with and without payload (8.5 Kg).	Make sure all functions are operational after dropping it from 0.3 m (2x Safety Factor) repeatedly

What is being tested	How it will be tested	How it will be evaluated
The image sensor's ability to detect a puck in front of the robot	Pucks will be placed in various positions in front of the sensor for it to detect	The image processor should be able to detect all the pucks in its field of view and identify them in the order of their distance from the sensor.

Table 7.1: Acceptance Test Plan

Relevant Requirements for the test plans:

- Req 3.1.1 A
- Req 3.1.2 A
- Req 4.1.1.1 A
- Req 4.1.1.2 A
- Req 4.1.1.3 A
- Req 4.1.2.1 A
- Req 4.1.2.2 A
- Req 4.1.2.3 A
- Req 5.1 A
- Req 5.1.1 A
- Req 5.2 A
- Req 5.3 A

8 Conclusion

PuckHoover™ is a device that eliminates the task of having to manually pick up each and every puck off of the ice by autonomously roaming the ice rink, scanning the ice surface pucks, and diverting to pick them up. This document outlines the requirements that will be satisfied at each of the development phases, which are the alpha phase, beta phase, and final phase. The alpha phase is set to be completed by the end of April 2021 and the beta phase is set to be completed by the end of Summer 2021. The requirements are broken up into general, technical, safety, and sustainability requirements for the development process of the device. Lastly, the acceptance test plan states the tests that the alpha phase prototype will perform at the end of the alpha phase. Each test plan clearly states what component of the prototype is being tested, how it is being tested, and how the test will be evaluated. Going forward, the requirements specification will guide the design process of the device and ensure that design decisions being made satisfy the requirements at each of the respective development phases.

9 References

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10 Appendix

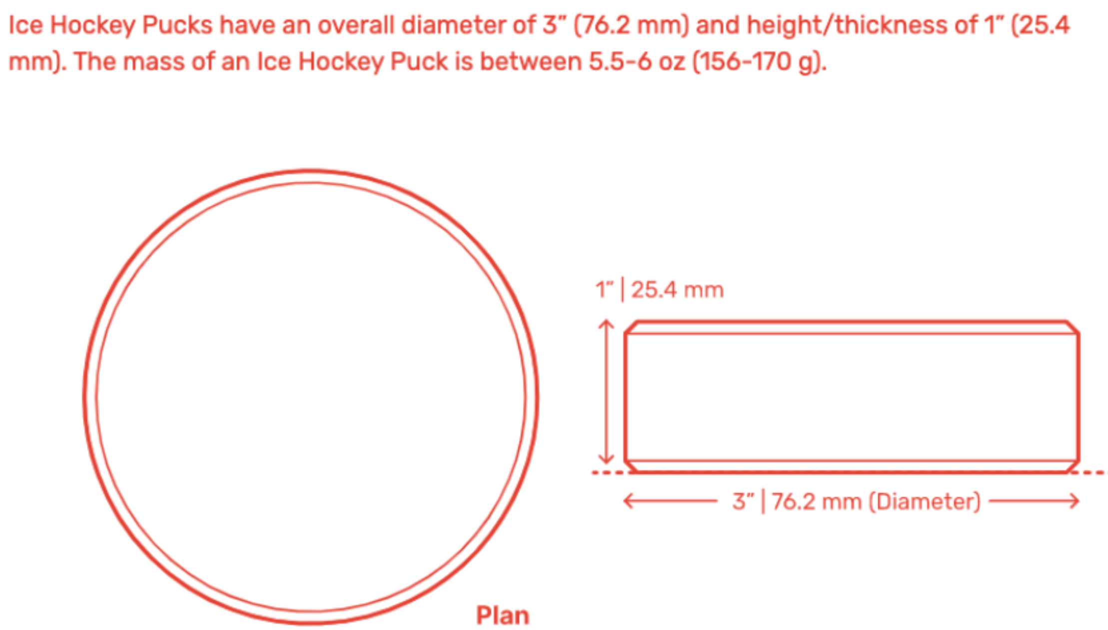

Figure 10.1: Dimensions and Mass of a Hockey Puck [3]

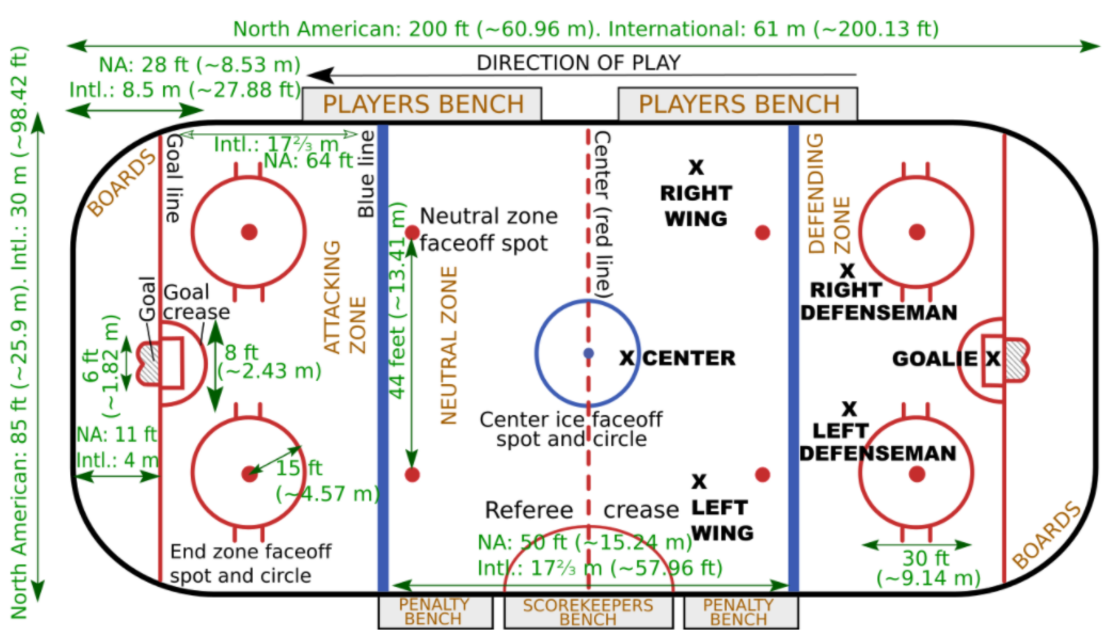

Figure 10.2: Dimensions of an Ice Hockey Rink [7]

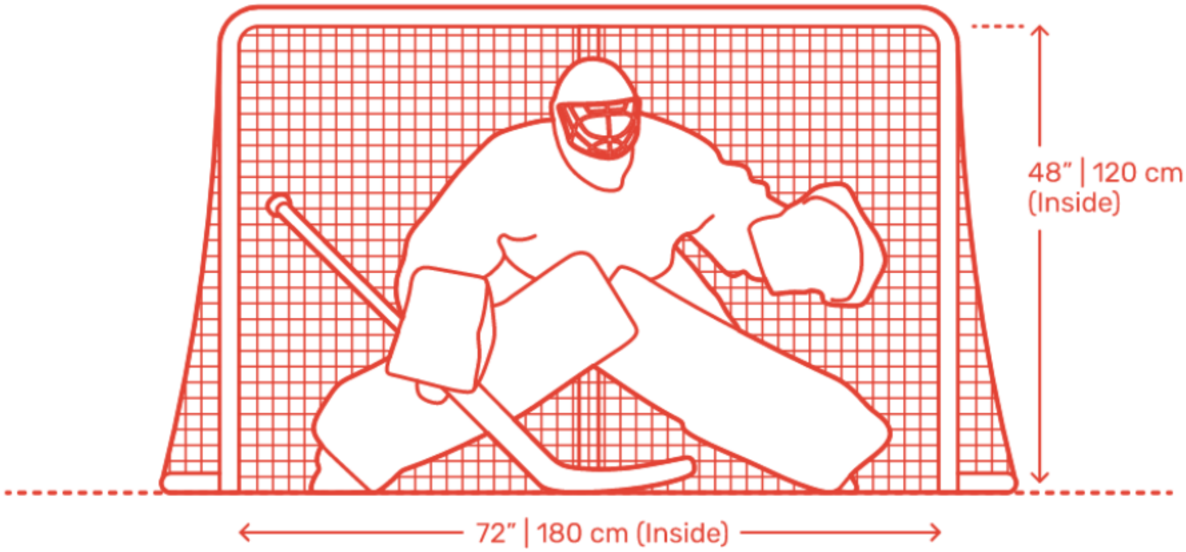

Figure 10.3: Dimensions of a Hockey Goal [9]