February 12th, 2023

Dr. Michael Hegedus

School of Engineering Science

Simon Fraser University

Subject: Requirement specifications for ENSC 405W.

Dear Dr. Hegedus,

Company 04 is pleased to present to you the requirement specifications for ENSC 405W Capstone A and provides an overview of our proposed HealthBot. In this document, you will find a detailed description of the requirement specifications.

Our mission is to alleviate the burden on healthcare workers in wake of the recent pandemic which has stretched the limits of Canada's and BC's public health. We will automate the collection and transportation of used linens which is intended to both minimize the contact time staff and nurses must spend with contaminated and soiled linens and to increase their productivity in more important aspects of their jobs, such as patient care.

The purpose of this report is to outline the project scope, problem definition, requirement specification, safety and sustainability and engineering standards.

If you have any additional questions or inquiries regarding our project or the requirement specifications, please contact our COO, Steven Borkowski at sborkows@sfu.ca.

Sincerely,

Flynn Dowey

Flynn Dowey

Healthbot: An Autonomous Assistant for a Healthcare Setting

Requirement Specifications

February 12th, 2023

<u>Company 04</u>

Flynn Dowey - CEO

Ngoc Quynh Anh Vo - CFO

Sammy Kaspar - CTO

Steven Borkowski - COO

Bao Nguyen - CMO

Gary Ho – CIO

Abstract

This document details the requirement specifications of Healthbot, a hospital laundry transport robot, to be met by Company 04 in the design and development of this product. First, the scope of the project is introduced, as well as background information on the existing laundry protocol in a healthcare setting. Secondly, an overview of the product follows, along with an enumeration of the criteria the robot must meet, which are based on client needs and studies in the field of hospital hygiene. These specifications are divided into categories highlighting the software, hardware, and sustainability needs that must be met, and are explained. Additionally, it is denoted when each requirement is expected to be met, whether it be in the proof of concept, engineering prototype, or production stage of development. Finally, the document concludes with the engineering standards that Company 04 should adhere to.

1 Table of Contents

List of Figures

List of Tables

2 Glossary of Terms

Term	Definition
ROS	Robot Operating System
RPi	Raspberry Pi
Lidar	Light detection and ranging
ENSC 405W	Engineering capstone course offered at Simon Fraser University
CEAB	The Canadian Engineering Accreditation Board

Table 1 – Glossary of terms

3 Preliminaries

3.1 Introduction

The purpose of this project is to design a laundry transport robot to be used in a hospital or clinical environment. This robot, or "Healthbot", will transport used or soiled linens securely from one location to another, without contaminating its surroundings. It should also be able to navigate through the hospital or clinical environment and be easily controlled by hospital or clinical staff. Ultimately, it will alleviate the need to manually transport contaminated linens and decrease the time that hospital staff is subject to the material. This will then free healthcare workers to focus on other tasks, increasing efficiency and reducing patient waiting times. The initial goal is to have Healthbot operate in low-traffic environments within the hospital, serving as a helpful assistant for facilitating the laundry protocol. It will be equipped with a compartment to securely transport items without the risk of losing them or contaminating the outside environment. Additionally, with a user-friendly interface, Healthbot will allow for efficient usage by hospital and nursing staff, improving the overall healthcare workflow.

3.2 Background

Laundry is a crucial aspect of infection control in a healthcare setting. Soiled clothing may carry pathogens, such as bacteria, viruses, and other infectious agents, which could endanger patients and staff [1]. It is essential to handle used linen properly to stop the spread of illnesses. Additionally giving patients clean linens, gowns, and towels makes the setting more welcoming and comfortable and can improve general wellbeing. As an example of hospital protocol, the flowchart below depicts the process of collecting, washing, and issuing linens:

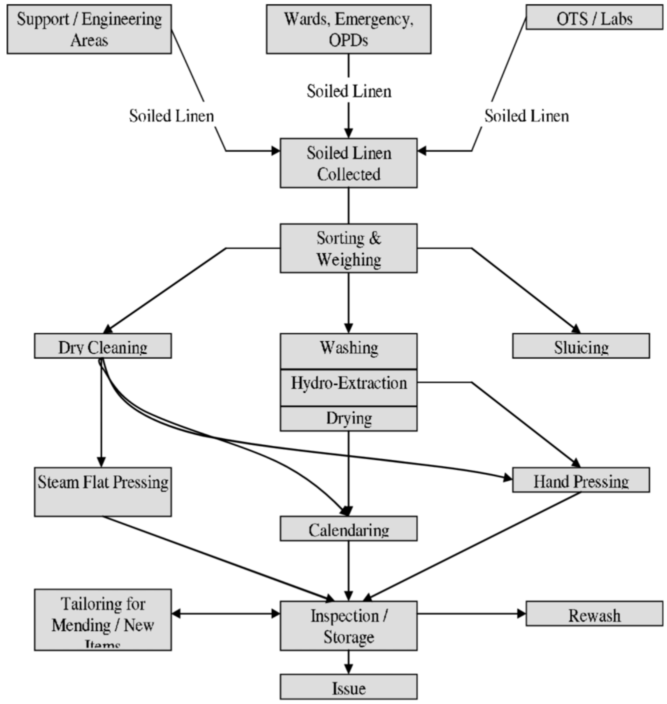

Figure 1 - Flowchart depicting hospital laundry process [2]

As can be seen above, the quantities of laundry produced from different areas in the hospital presents itself as a problem to be addressed.

3.3 Problem Statement

The objective of Company 04 is to create a robot that can safely transport used linens without contaminating the surrounding environment. The manual transportation of laundry from patient rooms to the central laundry facilities in hospitals is a time-consuming and demanding task for hospital staff, leading to higher workloads and decreased patient care which can lead to staff burnout. Consequently, this gives rise to increased staff turnover and lower patient satisfaction. Implementing a more effective solution, such as a laundry transport robot, which can automate the delivery of soiled linens and clothes from patient rooms to the central laundry facilities, is crucial to resolving this issue. This will lessen the burden for hospital personnel and enhance patient care bringing a positive impact on the patients whose wellbeing depends on a tidy and clean hospital setting.

3.4 Current Solutions

The field of autonomous robot assistants is currently an active area of research. Robots have been used by former students of ENSC 405W, including the development of NaviBot, a delivery robot for use in a manufacturing setting [3]. Two more ENSC 405W projects that are similar in kind include Snackbot and the Ez Robot Table [4] [5]. These projects were focused on using navigation for transportation of cargo.

Much research been done on implementing robotics in a hospital environment. For example, HelpMate has been designed for courier tasks, and shows human-like behaviour [6]. Also, Carebot was developed to interact with patients to perform simple healthcare services [7]. Given that these robots have been used in a similar field to that intended for Healthbot, there is knowledge to draw upon for the design of Healthbot. These two robots are shown below as an example:

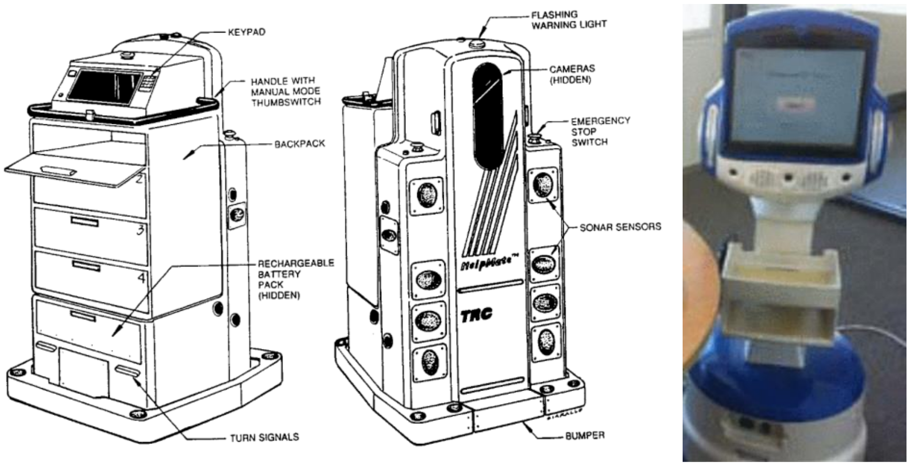

Figure 2 – A front and rear view of HelpMate (left) and a photo of Carebot (right) [6] [7].

3.5 Audience

The intended audience of this report is the prospective clients of this product, especially healthcare facilities, but could also include any fields that require massive laundry service. The requirements that entail have been formulated to address the concerns of end users, that is, staff which are employed in the healthcare sector. This would include nurses and clinicians.

Additionally, the document is directed towards the instructional staff of ENSC 405W, particularly Dr. Michael Hegedus and Usman Ahmed, to inform them of the direction of the development of Healthbot.

3.6 Overview

The laundry transport robot is designed with a combination of technology to ensure its functionality and efficiency. It utilizes ROS as the primary communication platform, Raspberry Pi as the control unit, Lidar for obstacle detection, and an Arduino microcontroller for handling low-level mechanics. These components work together to allow the robot to navigate autonomously to the designated laundry drop-off location, detect and avoid obstacles, and perform necessary control functions. The implementation of this technology ensures that the robot can carry out its duties efficiently and effectively, improving the hospital's operations and workflow. An overview of the system is shown in the figure below.

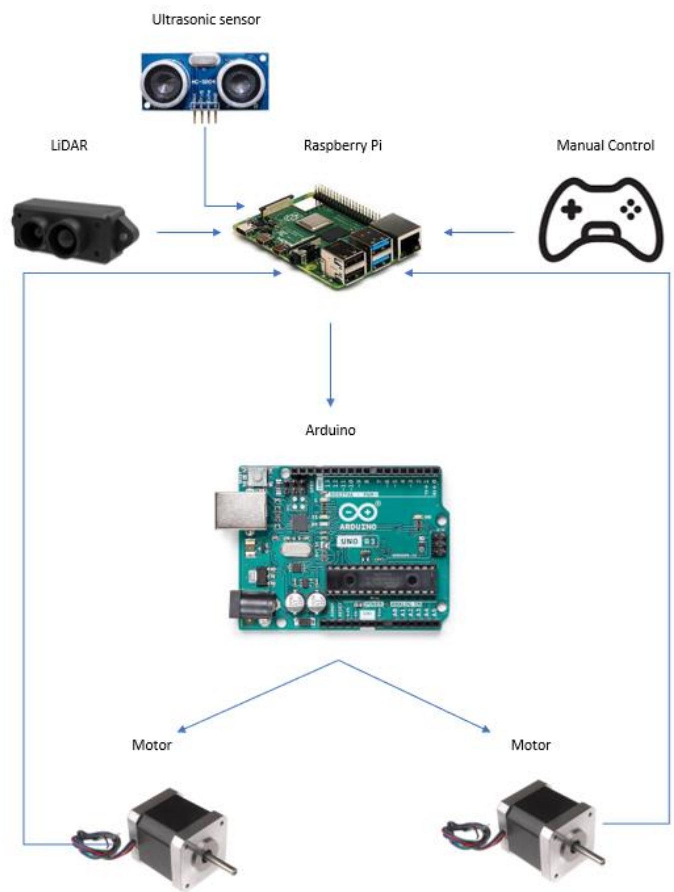

Figure 3 - System diagram of Healthbot

4 Requirements

The requirements in this document will be categorised into three different groups; each group represents a different stage the project's cycle. Refer to the table below for the definitions of each.

Encoding	**Definition**
A	Proof-of-concept
B	Engineering Prototype
C	Production Version

Table 2- Requirement encoding definitions

4.1 System Requirements

The system requirements provide an overview of the main functions Healthbot must perform. The requirements that follow, categorized as software, electrical or mechanical, describe how Healthbot can fit the system requirements.

ID	Encoding	Requirement
Req 1.1	A	The robot should be able to carry loads of laundry without losing or damaging it.
Req 1.2	A	The laundry storage should be sanitary, covered and secured so that pathogens cannot escape [8].
Req 1.3	A	The robot should have a maximum speed of 0.6 m/s [9].
Req 1.4	B	The robot should be able to navigate autonomously between rooms and halls without crashing into staff, patients, or property.

Table 3 - System requirements

Requirements 1.1-1.2 outline the crucial task of Healthbot, that is, collecting laundry in a sanitary way, whereas Requirements 1.3-1.4 detail how it must navigate in the hospital environment. The maximum speed of 0.6 m/s is drawn from the design of HelpMate, which is a hospital mobile robot that serves a similar function to Healthbot and can therefore be used as a model [9].

4.2 Software Requirements

ID	Encoding	Requirement
Req 2.1	A	The robot should be able to be controlled manually.
Req 2.2	B	The robot should be able to function independently.
Req 2.3	B	The robot should be able to detect people and objects to avoid collisions.
Req 2.4	C	The robot should be easily instructed where to go.
Req 2.5	C	The robot should return to a charging station autonomously when not in use or when its battery is low.
Req 2.6	C	When told to leave the charging station, the robot should wait until it has a sufficient battery level.
Req 2.7	C	The robot should inform the user of the battery level and inform the user when it can be used.

Table 4 - Software requirements

Requirements 2.1-2.2 give options for controlling Healthbot, although in the engineering prototype and final design, it should be able to navigate autonomously. Requirement 2.3 informs what kind of sensors to use in designing Healthbot so that it can navigate through a room or hallway while also checking if there are people in its path. Finally, Requirements 2.4-2.7 consider the ease of use of Healthbot. Also, it should keep its battery level into account and act accordingly. As an example of this, below is the route Healthbot would take daily:

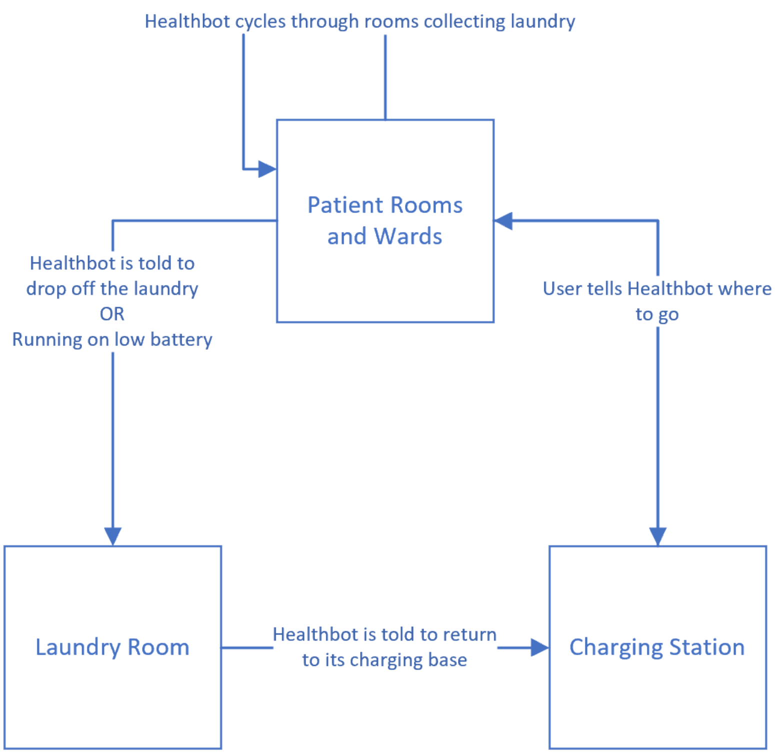

Figure 4 - Diagram of Healthbot's route.

Note that in the scenario when Healthbot is experiencing a low power level, it should warn its user prior to completing a task for safety precautions. In the ideal case, Healthbot would complete its programmed task first, and then take the necessary actions to recharge.

4.3 Mechanical Requirements

The following requirements concern the mechanical components of the robot, namely the laundry storage unit, the frame housing of the wheels and electronics, and the overall construction of the robot.

ID	Encoding	Requirement
Req 3.1	A	The laundry storage should be able to carry 17lbs of linens [10].
Req 3.2	B	The laundry storage should be enclosed so that items cannot fall out.
Req 3.3	C	The laundry storage should be easy to clean.

Req 3.4	B	The robot should not tip over when pushed.
Req 3.5	B	The robot should not tip over when being loaded with linens.
Req 3.6	C	The edges of the robot should be rounded to prevent injury.
Req 3.7	C	The robot should be able to function after a collision.
Req 3.8	C	The robot should have a pleasant appearance to avoid causing distress in staff and patients.

Table 5 - Mechanical requirements

The weight described in Requirement 3.1 comes from a study by the NIH concerning the ergonomics of transporting laundry in a hospital. It was found that the recommended weight lift limit when lifting a bag with one's arms slightly removed from the body, is 17lbs [10]. Requirements 3.2-3.3 detail how the robot should be designed to be sanitary for the healthcare environment. The design of the laundry bin must keep into account cleanliness as well as convenience of the user when loading and cleaning the bin. Requirements 3.4-3.7 concern the safety of hospital patients and staffs around the robot. As it will be used around people and equipment, the structure of the robot must be designed so that in a potential collision, neither the user nor the robot is damaged. Finally, Requirement 3.8 considers the mental health of hospital patients and staff. In recent years, care has been taken to give robots a friendly appearance when they will be interacting with people [7].

4.4 Electrical Requirements

The following requirements concern the electrical components of the robot, namely the power system and electrical connections.

ID	Encoding	Requirement
Req 4.1	A	The robot's electronics should be powered by a sustainable and efficient power source – battery powered.
Req 4.2	B	The robot's power system should be rechargeable.
Req 4.3	C	The robots power system should have a recharging time less than 6 hours
Req 4.4	C	The electronics should be covered so that collisions will not cause loss of power.
Req 4.5	C	The power system should be easy to maintain.

Table 6 - Electrical requirements

Requirement 4.1 describes that the robot must be battery operated, as opposed to it being plugged into a wall outlet, allowing for better mobility. Requirement 4.2 considers that a rechargeable battery should be used to allow for better sustainability. Finally, Requirements 4.3-4.5 are concerned that the battery can operate in a hospital environment efficiently and safely.

4.5 Sustainability Requirements

The following requirements concern the design elements of the robot that make it a more sustainable solution.

ID	Encoding	Requirement
Req 5.1	B	When planning its route, the robot should use an efficient path.
Req 5.2	C	The design of the robot should be lightweight to use less power when driving.
Req 5.3	C	The robot should be designed to be repairable so that individual parts can be replaced.
Req 5.4	C	The robot should be made of sustainable or recycled materials.
Req 5.5	C	The robot should be made of high quality materials that will last without needing to be replaced often.
Req 5.6	C	The packaging of the robot should be recyclable or biodegradable

Table 7 – Reliability and Sustainability requirements

Requirements 5.1-5.2 describe how the robot should be designed to use less power, allowing for longer battery life and extend its usage overall. Requirements 5.3-5.6 are concerned with reducing the carbon footprint of the robot and its packaging thereby making it more eco-friendly.

4.6 Constraints

There are several things that constrain the development of Healtbot. One of which is the fact that developing a robot can be a costly endeavor that requires significant investment in hardware and software. The financial constraint implies that Company 04 needs to keep costs at a reasonable level while maintaining its goals.

Time restriction is an additional constraint that needs to be considered, since the deadline for the Engineering Prototype is in August 2023. However, developing a robot is a complex and time-consuming process that requires specialized technical expertise in various areas including software, electrical and mechanical, which can be challenging to acquire since learning ROS has a steep learning curve.

Furthermore, the safety of patients, staff members, and hospital equipment is of utmost importance in the design and operation of the robot. Therefore, its design is required to minimize the risk of harm in the event of a collision. This requires careful consideration of factors such as the shape and materials used in the robot's construction. The robot should be designed with rounded edges and surfaces that will not injure bystanders in the event of a collision. Additional, sensors would need to be equipped with algorithms that allows obstacle detection, and the robot would need to maintain a safe distance to avoid collisions.

The project's requirement and constraint identification phase are essential for ensuring the finished product adheres to industry standards and practices. This phase involves data collection on technical and operational requirements, along with evaluating any potential constraints that might impact the robot's design and execution. It also assists in ensuring the reliability, sustainability, and safety of the product, leading to improved operational efficiency and patient satisfaction. The result of this phase will help layout a well-defined that will guide the team in making design decisions and guarantee that the finished product meets the needs and expectations.

5 Standards

5.1 Responsibilities of an Engineer

The engineer would be responsible for ensuring that the project is finished on schedule, within budget and meet the level of the desired quality. The engineer would also oversee risk management, quality assurance, and product testing. The robot will be operating in a hospital setting, which is subject to strict health and safety regulations. Hence, the engineer is also held accountable for making sure that the robot complies with all relevant safety and regulatory standards. The robot will need to integrate with existing hospital system to function effectively, such as the hospital's information technology network. This requires significant planning and coordination to ensure compatibility and avoid disruptions to hospital operations. What follow is a series of standards that Company 04 should abide by in the design of Healthbot:

5.2 Electrical Standards

Standard	Description
CAN/CSA-C22.2 NO. 61508-1:17	Functional safety of electrical/electronic/programmable electronic safety related systems [11].
CSA Z32:21	Electrical safety and essential electrical systems in health care facilities [12].

Table 8 - Description of Electrical Standards

5.3 Mechanical Standards

Standard	Description
CSA Z1002.3-13	Establish principles for the safe use of robots in learning and research environments while reducing the risk of injury to users, bystanders, and property [13].

Table 9 - Description of Mechanical Standards

5.4 CEAB Standards

Standard	Description
CEAB 3.1 #10 Ethics and equity	An ability to apply professional ethics, accountability, and equity [14].
CEAB 3.1 #6 Individual and teamwork	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting [14].
CEAB 3.1 #9 Impact of engineering on society and the environment	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions, and the concepts of sustainable design and development and environmental stewardship [14].

Table 10 - Description of CEAB Standards

6 Conclusion

The requirement specifications for the proposed Healthbot outlines the key functional requirements and constraints that must be met to create a successful solution. Through careful research and analysis, the key challenges and opportunities associated with this project were identified. A clear understanding of what is required to meet the needs of hospital staffs was then developed. Using technologies such as ROS, Lidar, Arduino, and Raspberry Pi, Healthbot will prove to be a solution that is reliable, sustainable, and cost-effective. By following the specifications laid out in this document, Company 04 is confident in delivering a high-quality transportation robot that meets the demands needed to successfully operate in a hospital environment.

7 References

[1] L. Sehulster and R. Chinn, "Guidelines for Environmental Infection Control in Health-Care Facilities," *Infection Control,* 2003.

[2] D. Singh and S. Tabish, "Quality Control in Linen and Laundry Service at A Tertiary Teaching Hospital in India," *IJHS,* vol. 3, pp. 33-44, 2009.

[3] D. Hogg, A. Srdic, M. Lavin, M. Kim and M. Yang, "NaviBot: The Autonomous Delivery Robot," Simon Fraser University, Burnaby, BC, 2022.

[4] F. Amah-Nnachi, S. Dhillon, V. Lund, E. Zheng, E. Komolafe and R. Scyczynski, "Snack Bot," Simon Fraser University, Burnaby, BC, 2022.

[5] D. Song, F. Borghei, S. Momuli, T. Yang and T. Lee, "EZ Table: Household Courier Robot," Simon Fraser University, Burnaby, BC, 2022.

[6] B. Krishnamurthy and J. Evans, "HelpMate: A robotic courier for hospital use," in *1992 IEEE International Conference on Systems, Man, and Cybernetics*, Chicaog, IL, 1992.

[7] H. Ahn, M. Lee and B. MacDonald, "Healthcare robot systems for a hospital environment: CareBot and ReceptionBot," in *2015 24th IEEE International Symposium on Robot and Human Interactive Communication*, Kobe, Japan, 2015.

[8] Occupational Safety and Health Administration, "Bloodborne Pathogens," *Occupational Safety and Health Standards, 1910-1030.*

[9] J. Evans, B. Krishnamurthy, B. Barrows, T. Skewis and V. Lumelsky, "Handling real-world motion planning: a hospital transport robot," *IEEE Control Systems Magazine,* vol. 12, no. 1, pp. 15-19, 1992.

[10] E. Teeple, J. Dennerlein, D. Hashimoto, L. Soto, E. Losina and J. Katz, "An Ergonomic Assessment of Hospital Linen Bag Handling," *PubMed Central,* 2018.

[11] "Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 1: General requirements," CSA Group, 2017.

[12] "Electrical safety and essential electrical systems in health care facilities," CSA Group, 2021.

[13] "Occupational health and safety - Hazard identification and elimination and risk assessment and control," CSA Group, 2012.

[14] Engineering Instruction and Accreditation, "Consultation on Advances in Accreditation," Engineers Canada, 2016.

8 Appendix A: Proof of Concept

The purpose of this appendix is to provide a compressive list of the functionalities that will be presented in the proof-of-concept poster presentation for ENSC 405W. This appendix will act as a source of reference for Company 04 during the development of the proof-of-concept and defines the scope of the poster presentation.

Functionality	Description	Explanation
Basic functionality	Core features Healthbot should be able to accomplish.	Easy to control and maneuver. Adjustments should be minimal.
Performance	Response time and error handling.	Low latency and fast response time is suggested.
Interface	Look and feel of the proof-of-concept.	Aesthetic appearance should correlate to the intended environment.

Table 11 - PoC functionalities

Table 11 above lists the core functionalities that will be thoroughly tested to ensure proper function and validity of the proof-of-concept. The results from the proof-of-concept will be used for future enhancements and modifications to meet the stage B requirement specifications.

Below is a sample acceptance test plan for Healthbot in the proof-of-concept stage.

Company 04 Test Sheet	
	Date: ________________
Mechanical Parts	
1. Driving system Robot drives at 0.6 m/s ☐ Yes ☐ No	Comments:
2. Laundry bin Bin can hold 17lb of laundry ☐ Yes ☐ No	Comments:
Electrical Parts	
1. Battery Battery outputs 12V and 5V ☐ Yes ☐ No	Comments:
2. Motor Drivers Outputs required voltage for motors ☐ Yes ☐ No	Comments:
Software Parts	
1. Joystick Joystick controls robot ☐ Yes ☐ No	Comments:

Table 12 - Sample acceptance test plan