Software Requirements Specification for The Nursery Project: The Pot-Pulator

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Revision History

Date	Version	Notes
2022-10-05	Juan Moncada, Aaron Billones, Steven Ramundi, Gillian Ford	Initial release
2023-04-05	Juan Moncada,	Update to better reflect final product

Contents

1   Reference Material

This section records information for easy reference.

1.1   Table of Units

Throughout this document SI (Système International d'Unités) and the Imperial System of Units are employed as the unit systems. For each unit, the symbol is given followed by a description of the unit and the SI or Imperial System name.

symbol	unit	SI/Imperial
m	length	metre
kg	mass	kilogram
s	time	second
rad	angle	radian
"	length	inch
'	length	foot (1' = 12")

1.2   Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The symbols are listed in alphabetical order.

symbol	unit	description
n_{pots}	N/A	number of pots in machine
$n_{potsout}$	N/A	number of pots coming out of machine as detected by verification system
n_{trays}	N/A	number of trays in machine
$n_{traysout}$	N/A	number of trays coming out of machine as detected by verification system
t_{cycle}	s	time per machine cycle

1.3   Abbreviations and Acronyms

symbol	description
CR	Conveyor Functional Requirement
NFR	Non-Functional Requirement
PDR	Pot Dispensing Functional Requirement
PHC	Physical Constraint
SRS	Software Requirements Specification
SWC	Software Constraint
TDR	Tray Dispensing Functional Requirement
VR	Verification Functional Requirement

1.4   Mathematical Notation

$x \; \varepsilon \; A$ - variable x is an element of the number set A

2   Introduction

The current method of preparing pots and trays to be filled with soil and populated with seeds at Sheridan Nurseries is a process with little to no automation, requiring many manual labour hours. Each year, 250,000 pots need to be placed in trays, each one being placed by hand. Recently, the owners of these farms have been finding it increasingly more difficult to fill these roles with enough workers to run the operation smoothly and meet production demands.

We aim to aid in this process by designing and implementing a machine that is able to fill trays with pots and prepare them for populating with soil and seeds. This will alleviate the reliance on manual labour and improve the overall efficiency of the farm.

This introduction will outline the document's purpose, the scope of requirements, characteristics of the intended reader, and the organization of document.

2.1   Purpose of Document

This Software Requirements Specification (SRS) document is to define the purpose of the Pot-Pulator. It will describe how the software will interact with the hardware, and how it is expected to perform, defining the executable requirements leading to the creation of a final product. This document should lay the important groundwork needed for every team member to understand the in-depth technical details of the product to be developed, in preparation for the design stage.

2.2   Scope of Requirements

The branches of the Pot-Pulator include a conveyer belt, tray allocation, pot dropping and verification. These four systems will be implemented to work together to create an efficient product. It will be reliable, easily configurable, affordable, and will greatly reduce the need for hands-on labour in relation to seed population.

The system implemented will be designed exclusively for Sheridan Nurseries, and for the pots and trays at their locations in a three-dimensional workspace. It is limited to usage on their round, 4-inch diameter pots and their respective trays. Considering the conditions of the greenhouses this machine will be used in, material degradation, water resistance, and pressure will all be negligible.

In order to maintain speed of the pots being placed in trays in a timely manor, one of the goals of the machine is to fill each tray with 10 pots every 30 seconds. This is the time it will take for the trays to be populated and move down the conveyer belt. With this goal in place, the machine will only need to be refilled with pots and trays every 7.5 minutes,

greatly reducing the amount of hands-on labour from the workers at Sheridan Nurseries.

After the initial completion of the goal associated with the 4-inch pots, larger pots and trays may be considered as a future goal. There will always be the limitation of the requirement of a rim on the top of the pot, for the machine to easily grasp onto when lifting and dropping.

2.3   Behavioural Overview

The Pot-Pulator will have 4 branches working together to accomplish the task. First, the trays and pots will be manually filled into a section of the machine, ideally 15 trays and 150 pots. The first section of the machine will drop a tray, and the conveyer belt will move it to the pot dropping section.

The conveyer belt will stop once it senses the tray is in the correct position. The machine will drop pots until all 10 spots are filled. The conveyer belt will move the tray according to the needed positions for pot dropping, dispensing 2 pots into the allocated positions, moving forward 4 inches at a time until the process is completed.

The tray filled with pots will then move into a verification system, to verify the pots have been placed in the correct positions. The conveyer belt will then move it to an existing conveyer system, which will lead to the collection of completed trays. The only maintenance this machine needs is the refill of pots and trays every 7.5 minutes, and the collection of completed trays at the end of the final conveyer belt.

2.4   Clients and Stakeholders

This system provides a solution for all nursery applications that are not working on the cutting edge. For those nurseries that have an existing assembly line to fulfil their distribution needs, this is a great solution as other solutions replace the assembly line in its entirety and cost significantly more.

Clients include:

- Sheridan Nurseries manager

- Sheridan Nurseries owner

Stakeholders include:

- Dr. Smith (Project Supervisor).

- Juan Moncada, Gillian Ford, Aaron Billones, and Steven Ramundi, (Project Proposers).

- Nicholas Annable (Supervising TA)

2.5   Characteristics of Intended Reader

This SRS document is written for the individuals directly involved with the development of the Pot-Pulator. This includes every member of the team; all being involved with the development of the project. It is useful as reference to the functionality of in-depth details regarding the project, and will be read, reviewed, and maintained as the project progresses by all team members.

In general, any users of this document should have an undergraduate level understanding of software and hardware system functionality, physics, and mathematics.

2.6   Organization of Document

This SRS template is based on **??**. These templates have been modified to reflect rubric requirements, and sections have been reorganized to follow the LazyBots student sample SRS. Sections 3, 4, and 5 describe the project constraints, and show the context and functional decomposition diagrams. Section 6 is dedicated to functional requirements. This section will define functional requirements seperated in terms of the systems which make up the Pot-Pulator. Section 7 describes the non-functional requirements in terms of look and feel, usability, performance, operational, maintainability and portability, security requirements. Section 8 evaluates each functional requirement on its likelihood to change, and specifies how the requirement may change if it is not very unlikely to.

3   Project Constraints

This section identifies the interfaces between the system and its environment, describes the user characteristics, lists the system constraints, and provides assumptions relating to the system/environment.

3.1   System Context

The system will consist of a stack of pots, stack of trays, and the mechanism that will autonomously populate the trays with the pots. The trays will move along a conveyor system that operates at approximately 3 feet and will act as the operating workspace for the device. Once the trays are populated with pots, they are fed into a soil potting machine in preparation for planting.

3.2 User Responsibilities & Characteristics

The user will be responsible for refilling the stacks of trays and pots when the supply is depleted. The user will also be responsible for knowing how the entire system will operate within each state. For example, if a tray fails the validation step, the user must be capable of removing the defect and resume the operation of the machine.

The characteristics of the user will ensure smooth operation and workplace safety. The user should be able to lift a sufficient weight and have a good understanding of basic functionality of the system.

3.3 System Constraints

The system constraints are in place to comply with the physical and technical limits provided to the team.

3.3.1 Physical Constraints

PHC0	Workspace dimensions (including stacks of trays and pots) of height = 12' width = 6' length = 8'
Rationale	the allowable workspace area provided by Sheridan Nurseries

PHC1	Conveyor system must be height = 3' width = 1.5' length = 8' (maximum)
Rationale	the new system will feed trays into an existing soil potting machine via conveyor system so they must operate in a similar manner

PHC2	Operational in winter temperatures (outdoor conditions)
Rationale	operation takes place in a tent outside between January and February

PHC3	Fully operational through a standard 3-prong 120V wall outlet
Rationale	the system's environment requires this as the only source of power

3.3.2 Software Constraints

SWC0	Perform operations and calculations in a timely manner
Rationale	to ensure the system can actually replace a human

3.4   Assumptions

The following assumptions are being made when designing and developing the device:

- The user will fill the machine with stacks of trays and pots as required

- The system will populate 10 pots of 4-inch diameter into its respective tray

- The system can hold stacks sufficient enough for 15-30 minutes of continuous operation

3.5   Constants

Constant Name	Description
Number of Pots	The number of pots that needs to be populated in a single tray
Number of Trays	The number of trays that will be populated at once
Max Pots in Stack	The maximum number of pots that may be stacked in the machine
Max Trays in Stack	The maximum number of trays that may be stacked in the machine
Pot Size/Shape	The size/shape of the pots
Max Rate of Operation	The maximum rate at which the machine operates is determined by the soil potting machine

3.6   Monitored Variables

Variable	Description	Type	Units
Conveyor Speed	The speed at which the conveyor belt will move	Speed	m/s
Sensor Distances	Measured distances that the sensor identifies	Distance	mm
System State	Determines the state of the system (ie. Ready, Running, Error, Success)	State	N/A
Tray/Pot Weight	Weight of the trays/pots to verify number in the stack	Weight	kg
Tray/Pot Height	Height of the trays/pots to verify number in the stack	Height	m

3.7 Controlled Variables

Variable	Description	Type	Units
Motor Speeds	The speeds at which the motors in the system will turn	Speed	rad/s
Voltage in	Voltage going into the system	Voltage	V
Current in	Current going into the system	Current	A
LEDs	LED status lights	Boolean	N/A

4 Context Diagram

Below is a high level overview of the system. It shows all the inputs and outputs of the overall system.
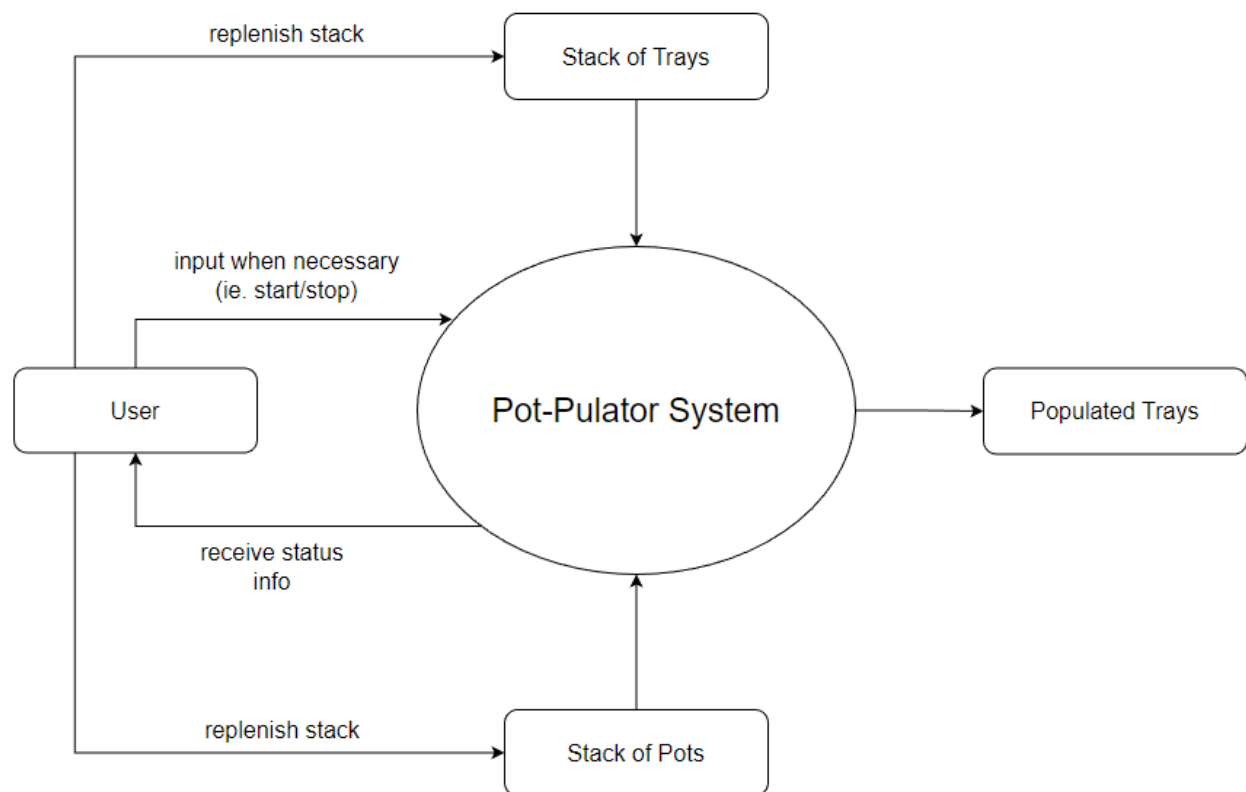

Figure 1: Context Diagram

5   Functional Decomposition Diagram

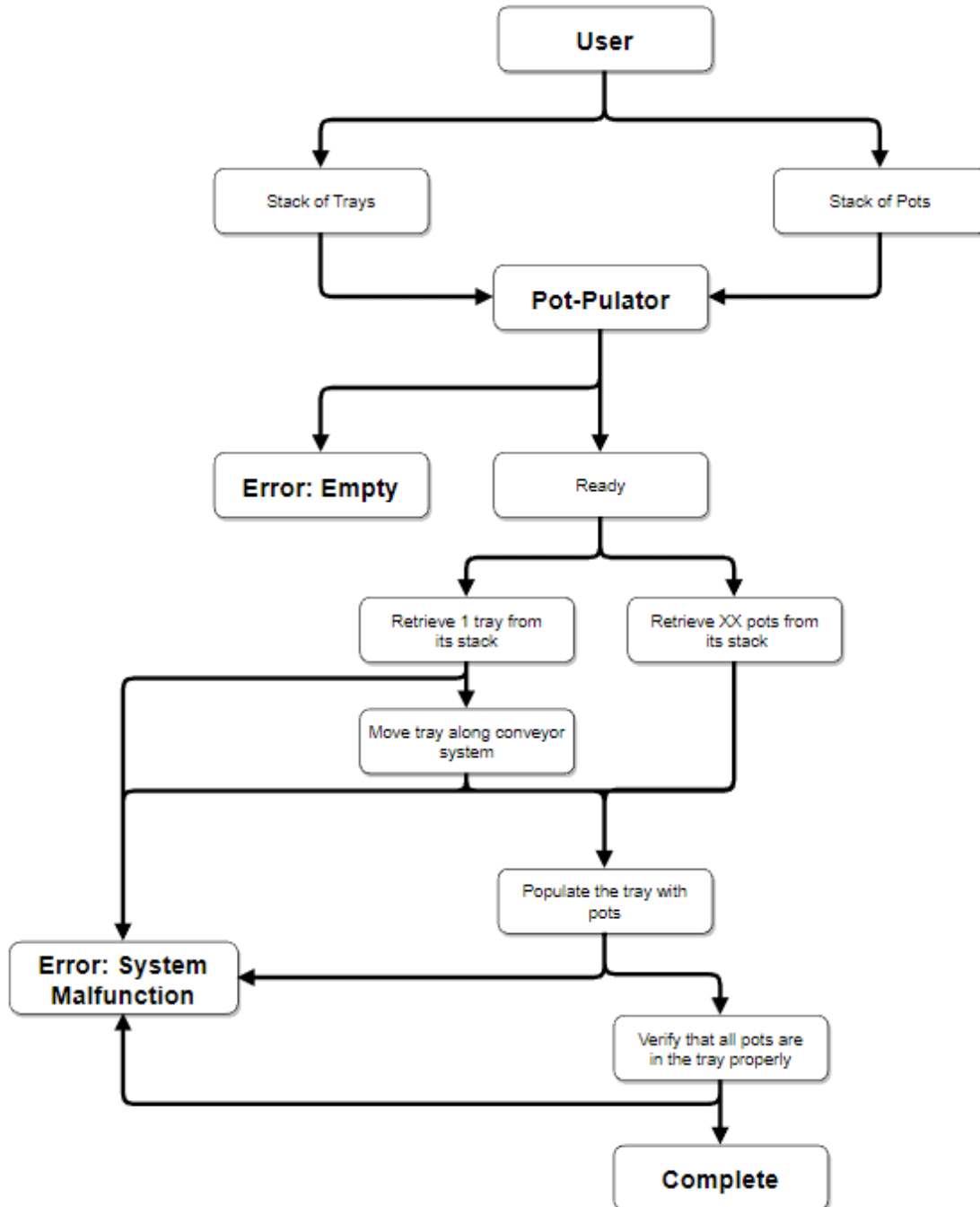Below is a decomposition of the system. It shows the states and processes that occur within the system.

Figure 2: Functional Decomposition

6   Functional Requirements

This section provides the functional requirements of the Pot-Pulator, seperated into tray dispensing, pot dispensing, conveyor, and verification requierements.

6.1   Tray Dispensing Functional Requirements

TDR1: The tray dispenser must start when the Pot-Pulator start is pressed.

TDR2: The tray dispenser must be able to place a standard tray from the loaded stack onto the conveyor belt.

TDR3: The tray dispenser must be able to store multiple trays at a time.

TDR4: The tray dispenser must stop operating once it has run out of trays.

TDR5: The tray dispenser must be able to recognize when trays need to be reloaded and notify an operator.

TDR6: The tray dispenser must stop when an error arises (verification failed, pot dispenser malfunction/empty, conveyor malfunction).

TDR7: The tray dispenser must be able to reset after it has been stopped due to error or needs to reload.

6.2   Pot Dispensing Functional Requirements

PDR1: The pot dispenser must start when the Pot-Pulator start is pressed.

PDR2: The pot dispenser must be able to place a pot into an empty place in a tray.

PDR3: The pot dispenser must be able to dispense a 4" diameter pot.

PDR4: The pot dispenser must be able to store multiple pots at a time.

PDR5: The pot dispenser must stop operating once it has run out of pots.

PDR6: The pot dispenser must be able to recognize when pots need to be reloaded and notify an operator.

PDR7: The pot dispenser must stop when an error arises (verification failed, tray dispenser malfunction/empty, conveyor malfunction).

PDR8: The pot dispenser must be able to reset after it has been stopped due to an error or needs to reload.

6.3   Conveyor Requirements

CR1: The conveyor must start when the Pot-Pulator start is pressed.

CR2: The conveyor must be able to move a tray from the tray dispensing station to the verification station.

CR3: The conveyor must be able to stop when a tray is being placed on the conveyor, or when a pot is being placed in a tray.

CR4: The conveyor material must have a high enough friction such that the trays do not slide while in contact with the belt.

CR5: The conveyor must stop when an error arises (verification failed, pot dispenser malfunction/empty, tray dispenser malfunction/empty).

CR6: The conveyor must be able to reset after it has been stopped due to an error or pots/trays need to be reloaded.

6.4   Verification Requirements

VR1: The verification must check that only one tray is being output by the conveyer belt, and the tray is filled with exactly 10 pots, such that $n_{traysout} = 1$ & $n_{potsout} = 10$

VR2: The verification must notify all other systems if verification fails, such that $n_{traysout} \neq 1$ or $n_{potsout} \neq 10$

7   Nonfunctional Requirements

This section provides the non-functional requirements of the Pot-Pulator.

7.1   Appearance Requirements

NFR1: All electrical equipment and electronics must be well covered and protected. The user must not have access to equipment.

NFR2: All wiring must be tucked away and not accessible to avoid potential electrical failure.

NFR3: All moving parts must be covered and protected. Moving parts should be covered to protect both the mechanism and the safety of the operator.

7.2 Usability Requirements

NFR4: System must have tray and pot refill locations visible and accessible in order to provide visual verification of capacity status.

NFR5: System output (end of conveyor) must be clear and visible in order to provide visual verification and access to failed outputs.

7.3 Learning Requirments

NFR6: System must be simple to operate, requiring minimal training to operate effectively ($< 1\ hour$).

7.4 Accessibility Requirements

NFR7: System must have both audible and visible signal outputs for each system status.

7.5 Speed Requirements

NFR8: Conveyor system must not accelerate in a manner that would shift the position of the tray on the conveyor belt. A shift in the position of the tray could result in a misalignement and potential error.

NFR9: The pot dispenser must dispense pots at a rate of 10 pots every 30 seconds, such that $t_{cycle} = 30\ seconds$ & $n_{pots}(t) = 300 - t/3;\ t\ \varepsilon\ \{30, 60, 90, ..., 900\}$. This will allow the machine to meet the output goal required.

NFR10: The tray dispenser must dispense trays at a rate of 1 tray every 30 seconds, such that $t_{cycle} = 30\ seconds$ & $n_{trays}(t) = 30 - t/30;\ t\ \varepsilon\ \{30, 60, 90, ..., 900\}$. This will allow the machine to meet the output goal required.

7.6 Safety Critical Requirements

NFR11: System must have emergency cut off. In case of any emergency, this will trip off all power to the Pot-Pulator.

NFR12: System must be able to locate and identify failures within each independent subsystem.

7.7 Precision Requirements

NFR13: Tray dispenser must centre trays on conveyor within 1 cm

NFR14: Pot dispenser should dispense pots within a 0.5 cm radius of centered position.

7.8 Capacity Requirements

NFR15: The pot dispenser must be able to hold a maximum of 300 pots at all times, such that $n_{pots}(t) \leq 300$ This will allow the machine to meet the output goal required.

NFR16: The tray dispenser must be able to hold a maximum of 30 trays at all times, such that $n_{trays}(t) \leq 30$ This will allow the machine to meet the output goal required.

7.9 Reliability Requirements

NFR17: System must be able to operate under constant low and high frequency vibration (small amplitude).

7.10 Robustness and Fault Tolerance Requirements

NFR18: Components must withstand 250,000 cycles. System should call for replacement parts after a full season of operation.

7.11 Scalability or Extensibility Requirements

NFR19: System must fit into the existing assembly line and should take minimal effort to implement ($< 1 \; day$).

7.12 Expected Physical Environement Requirements

NFR20: System must withstand operating in a room with high arial polution including dust, dirt, and small amounts of water.

7.13 Maintenance Requirements

NFR21: System must be built for ease of maintenance. High wear parts should be easily accessible.

7.14 Requirements for Interacting with Adjacent Systems

NFR22: System must operate at same speed as adjacent systems.

NFR23: System must operate at the same conveyor height as the current system to maintain continuity between systems.

7.15 Supportability Requirements

NFR24: System documentation must be available to troubleshoot, diagnose and fix common issues and replace high-wear parts.

7.16 Compliance Requirements

NFR25: System must follow electronics system safety requirements.

8 Functional Requirements Likelihood of Change

8.1 Tray Dispensing Functional Requirements

TDR1: Very unlikely to change, key implementation of system.

TDR2: Very unlikely to change, key implementation of system.

TDR3: Very unlikely to change, key implementation of system.

TDR4: Very unlikely to change, ensures safety of operator reloading trays.

TDR5: Very unlikely to change, key implementation of system.

TDR6: Very unlikely to change, ensures safety of operator and prevents machine from dispensing trays while conveyor and/or pot dispenser are not operational.

TDR7: Unlikely to change, ensures safety of operator and robustness of Pot-Pulator. May change to be integrated with start command or resume command.

8.2 Pot Dispensing Functional Requirements

PDR1: Very unlikely to change, key implementation of system.

PDR2: Very unlikely to change, key implementation of system.

PDR3: Unlikely to change, pot size is standard across the nursery. New pots may be introduced at a future time.

PDR4: Very unlikely to change, key implementation of system.

PDR5: Very unlikely to change, ensures safety of operator reloading pots.

PDR6: Very unlikely to change, key implementation of system.

PDR7: Very unlikely to change, ensures safety of operator and prevents machine from dispensing pots while conveyor and/or tray dispenser are not operational.

PDR8: Unlikely to change, ensures safety of operator and robustness of Pot-Pulator. May change to be integrated with start command or resume command.

8.3   Conveyor Functional Requirements

CR1: Very unlikely to change, key implementation of system.

CR2: Unlikely to change, ensures accuracy of placement of trays and pots. May change to place trays on conveyor as conveyor is moving.

CR3: Very unlikely to change, key implementation of system.

CR4: Very unlikely to change, ensures safety of operator and prevents machine from dispensing pots while conveyor and/or tray dispenser are not operational.

CR5: Unlikely to change, ensures safety of operator and robustness of Pot-Pulator. May change to be integrated with start command or resume command.

8.4   Verification Requirements

VR1: Very unlikely to change, key implementation of system.

VR2: Very unlikely to change, key implementation of system.

Appendix — Reflection

The information in this section will be used to evaluate the team members on the graduate attribute of Lifelong Learning. Please answer the following questions:

1. What knowledge and skills will the team collectively need to acquire to successfully complete this capstone project? Examples of possible knowledge to acquire include domain specific knowledge from the domain of your application, or software engineering knowledge, mechatronics knowledge or computer science knowledge. Skills may be related to technology, or writing, or presentation, or team management, etc. You should look to identify at least one item for each team member.

   (a) Steven:
   I will acquire skills related to programming microcontrollers and interfacing hardware and software.

   (b) Juan:
   This project presents a unique challenge when it comes to group management and teamwork, this being one of few interdisciplinary capstones it is the only capstone project(from my knowledge) that includes groups from vastly different engineering streams. While ECE and CAS Share many common teachings, engineering physics lacks that familiarity. this, however, in my opinion, is a great representation of the future. When working in the industry there are very few instances that you will be surrounded by those with similar knowledge sets and backgrounds, most of the time the team you will work with will be of diverce experience and backgrounds. Understanding how to work as a team is detrimental to good productivity. I believe throughout this project I will further develop my project management skills, they will be put to the test as each member of the team will have their expertise and we will be fusing knowledge to create a solution. Team management and general coding.

   Throughout this project I also wish to enhance my general coding skill. Which I have always had an interest in coding and have made attempts to use it whenever possible throughout my university career. I am excited to take on a project with a defined goal and no clear solution to improve my coding ability.

   (c) Aaron:
   Communication, team management, and time management are crucial to the success of the project. Working towards improving these skills will greatly benefit me and my team members in the future. I also expect to further my knowledge in both hardware and software while working on this capstone project so it can propel me into the future of becoming an engineer.

(d) Gillian:
Throughout this project, I am looking forward to learning skills from the other members of the team. As an Engineering physics student, the areas I would like to improve the most about are software and writing. I would like to be prepared for the industry and potentially working in a job that requires coding because it's something I enjoy, but I don't think it's something I am experienced enough in yet. In terms of writing and communication, it isn't often where I am required to write long reports anymore, and I like the challenge provided by creating this extent of documentation. I look forward to my writing skills to improve over the course of this capstone project.

2. For each of the knowledge areas and skills identified in the previous question, what are at least two approaches to acquiring the knowledge or mastering the skill? Of the identified approaches, which will each team member pursue, and why did they make this choice?

(a) Steven:
An approach to acquiring programming skills is researching and practicing specific programming exercises that are specific to the environment I will be working in. An alternative approach is familiarizing myself with microcontroller documentation and creating solutions from the knowledge I obtain. I will pursue the former approach, as I find myself able to learn more effectively and efficiently with a hands on approach, rather than reading through documentation. Approaches to learning how to interface hardware and software include reviewing previous coursework, and immitating examples I find as practice. I will chose the latter option for the same reason stated above.

(b) Juan:
Project management skills can be developed throughout this project in many different ways. The first will be in taking a heavy role in the logistical and administrative side of the team, another is to run the project management through an issue tracking system like the one provided by git hub. This might be tedious as it adds an extra step to all tasks as they will have to be updated and status regularly, but the pros outways the cons as this will help with the overall management of the team. Of the two solutions, both will be attempted however more emphasis will be put on the task tracking software as it adds the added benefit of simulating how large corporations are running their business.
To improve general coding two approaches can be taken on. the first being that I can take on a software dominant portion and be responsible for its fruition, or I can volunteer to take one of these software challenges on with another member in my group who is better versed in coding so that we may work hand in hand. This way if there will be support and guidance throughout and could offer a solution faster. The second option, in this case, seems more reasonable as

there are hard deadlines for this project and the system itself is already ambitious.

(c) Aaron:
Working towards improving my team communication is something that I strive to do while participating in this capstone. This can be achived in several ways. One approach that I will take is to strengthen my bond with the team members. In doing so, I will feel more comfortable in sharing ideas and being constructive when necessary. Another approach is to document what each team member is working on and some of the problems they have run into. This will increase my team awareness and ultimately lead to the success of the project. I chose to pursue this skill because I know sometimes I want to do a lot of work on my own without developing trust towards my team members. This skill will help me when I become an engineer and work with large teams where communication and collaboration is crucial.

(d) Gillian:
I know I can improve my coding skills effectively by working on something closely to another member of the team who is more skilled in that area. I think this will be very helpful because I can work on a portion of software on my own, and if I have questions or get stuck, I will have someone working on something similar who will understand the problem and can help me troubleshoot. I can improve writing and communication skills by reviewing and editing not only my own work, but the writing of my peers as well. After each deliverable is finished, I think it is very useful when we go over all the writing as a team and come up with ideas on how each section of the documentation can possibly be improved.