Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Milestone 1 Report**

Concept of Operations

Project & Subsystem Functional System Requirements

Project & Subsystem Interface Control Documents

Project Schedule

Validation Plan

REVISION 1

3 October 2022

Milestone 1 Report

for

Robotic Sorting System

Team 2

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

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Prof. Kalafatis Date

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T/A Date

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ROBOTIC SORTING SYSTEM

Pace Dominy

Joseph Miller

Lam Tran

**Concept of Operations**

Draft Release

15 September 2022

Concept of Operations

for

Robotic Sorting System

Team 2

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

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Prof. Kalafatis Date

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# Executive Summary

The American agricultural industry is massive, with over 2 million small-scale farms in the U.S. contributing to almost $140 billion in agricultural exports alone. However, farmers and ranchers only receive 8 cents of every dollar spent on food. Much of the additional money goes to overhead costs such as labor and processing [1]. One particularly difficult - and expensive - problem in agriculture is fruit sorting. Fruit that is clearly defective or does not meet a customer’s standards may not be sold and wasted, reducing farmers’ income and contributing to the 40% of food made in America that is never eaten [1]. Our solution to this problem is the Robotic Sorting System, a small, portable, inexpensive fruit sorting system based on robotics and imaging technology.

To use the Robotic Sorting System, the fruit will be placed on a conveyor belt, where it will move to a sensing area. The system will then use a camera to determine the approximate size and color of the fruit. Based on this information, the fruit will then go through a robotic sorting system that will sort the fruit into different “bins” configured by the user. The automation of this process will improve productivity in fruit sorting while reducing or even eliminating the need for human fruit sorting.

Each member of the team will design a certain set of subsystems. Under the proposed schedule, each subsystem will be fully designed by the end of the Fall 2022 semester. In the Spring 2023 semester, each subsystem will be integrated into the overall system, then physically constructed using the team’s $300 budget, the Fischer Engineering Design Center, and outside printed circuit board (PCB) manufacturers. Finally, at the end of the Spring 2023 semester, the group will present a completed, functional prototype of the Robotic Sorting System.

# Introduction

The Robotic Sorting System is a system capable of taking produce that is on its conveyor belt and sorting the fruit by type as well as quality. Quality will be determined by a large presence of scarring or bruising on the fruit as well as whether or not the fruit is overripe. Sorting will be done primarily through the qualitative analysis of the size and color of the fruit. At the end of the sorting process, the weight of the produce that will be sold and the weight of the unwanted fruit will be analyzed separately to get a rough estimate of how much fruit is being discarded and how much possible “shrink” is being prevented. Shrink is the difference between what the store has recorded for inventory and the actual amount of what is in stock. If a product, such as fruit, goes bad and has to be thrown out, that would mean that the store would have shrink from having less fruit in stock then they have recorded for their inventory.

## Background

In order for fruit to be transported to the store to be sold to the consumer, it has to be transported from the field to processing areas, then shipped. While in transport, some of the fruit will end up scarred, bruised or overripe and will be sold by the store where the customer will not buy any fruit that they deem overly scarred, bruised or overripe. This unsold fruit results in shrink for the store.

Our solution to this problem of unsold fruit is the Robotic Sorting System. This system will have a conveyor belt on which fruit will be sorted by type as well as quality. The fruit that does not meet the correct quality standards will be sorted into a receptacle where it will be disposed of later. Sorting out all the low quality fruit after it has been transported will save the store and the farmer from losing money while also not requiring much human interaction with the system.

## Overview



*Figure 1: Diagram of Robotic Sorting System*

Once the fruit is on the Robotic Sorting System’s conveyor belt, a camera will capture a picture of the fruit and determine its type and quality. The conveyor belt will then sort the fruit onto a specific length of the conveyor belt with the Robotic Arms, where the fruit that meets the user’s standards will go on to be sold by the store.

## Referenced Documents and Standards

American Farm Bureau Corporation, “Fast Facts About Agriculture and Food,” *American Farm Bureau Corporation*, 2021. [Online]. Available: <https://www.fb.org/newsroom/fast-facts>. [Accessed: Sep. 15, 2022]

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# Operating Concept

## Scope

The overall goal of the Robotic Sorting System is to reduce food waste and to improve customer satisfaction for both intermediate customers, such as supermarkets, and end customers. To do so, the Robotic Sorting System will use a camera-based system to accurately sort fruits by color and size. This will ensure that customers receive, as closely as possible, the exact quality of fruit ordered. The camera system will also be able to detect some basic fruit defects based on the user’s configuration. After sorting, the weight sensor will provide information on the weight of each sorted “bin” of fruit, which will allow fruit producers to easily see how much fruit is in each sorted category.

The project will be broken down into five fundamental subsystems. The first is power delivery, which will safely deliver the required power to all electrical and electronic components of the sorting system. The second subsystem is the conveyor belt, which will physically move fruit to the sensors, then to the robotic sorting levers and finally to the bin. The third subsystem is the Robotic Arms that will physically sort the fruit based on the information from the sensors. The fourth subsystem, the sensors, will gather the color, size, and weight information then give that data to the robotic control logic. The final subsystem is a mobile application for Android-based devices that will allow the user to easily configure and run the machine.

The actual design and fabrication of the Robotic Sorting System is broken down into the following design goals.

* The only external electrical connection required will be a connection to the standard American power grid (with a voltage of 120 V and a frequency of 60 Hz).
* The data that the sensors collect must be transmissible to the Robotic Arm subsystem’s control logic.
* The conveyor belt must be durable enough to hold fruit without damaging the machine and able to stop and start based on commands from the sensor (so that the sensor data is accurate).
* The robotic arms must use data from the sensors to physically guide the fruit to the correct bin.
* The Android application must be able to control the sorting configuration and the physical operation of the machine via Bluetooth. It should also provide documentation and provide contact information to get help with problems that the user cannot solve by themselves.
* Each system must be integrated into the overall sorting machine.
* Finally, the Robotic Sorting Machine will be physically fabricated.

The resources available for development are the personal time of each member, the shared lab time on Monday afternoons, the $100 given to each member of the team (for a total of $300), and the design and fabrication resources at the Fischer Engineering Design Center.

The design process will take place over the course of two semesters over the following timeline.

* The first revision of the Concept of Operations will be finalized by September 15th, 2022.
* The first revision of the Functional Systems Requirements document, the Interface Control Document, and the Execution Validation Plan will be finalized by October 3rd, 2022.
* The final report for the first semester of work will be finalized by December 4th, 2022.
* The design of each subsystem will be finalized by the end of the Fall 2022 semester.
* The integration of the subsystems and physical fabrication of the machine will be complete by the end of the Spring 2023 semester.

## Operational Description and Constraints

The Robotic Sorting System is intended to be used by workers to automate sorting fruits. Several Robotic Arms and conveyor belts will be installed inside a warehouse that stores fruits. Sensors are used to determine the quality of the fruits. These sensors will include cameras and scales. The cameras will examine each fruit and the microcontroller unit will process the image to check the fruit’s size, shape and color. The microcontroller will verify that the fruit meets the standards set by the user. The Robotic Arms will move the fruit onto a scale to measure its weight. The measured weight value is used to calculate the total weight of fruits that met the standards and the total weight of the fruit that failed. The Robotic Arms will move the fruit onto a specific section of the conveyor belt based on its quality. The conveyor belt will then move the fruit into a receptacle. Once the receptacle is full, it is placed onto a scale to measure the total weight of fruits that met the standards and the total weight of the fruit that failed. Farmers and sorting workers can configure the details of each of these processes via the mobile application connected to the machine via Bluetooth.

The following constraints apply to the design:

* The cameras must capture the entire surface of the fruit.
* The budget is $300, which limits the materials and parts that can be used.
* The Robotic Arm must be able to move the fruit without damaging it.
* The application must work on a commercially available smartphone.

## System Description

Robotic Arms: The Robotic Arm subsystem is a group of levers attached to the conveyor belt that move the fruit on the conveyor belt to the required area. The dimensions of this “required area” will be determined from the data collected from the sensors. Based on the sorting logic, the levers will move the fruit on the belt to the required section of the belt for the fruit to end up in the correct ending state (inside the correct receptacle).

Power: The power subsystem will deliver power to each electrical component of the system at the required voltage. The main power source will have a voltage of 120 V, but it will be necessary to design and implement power converters to avoid damaging components.

Conveyor belt: The conveyor belt will physically move fruit to the area where the sensors will identify each fruit’s color and size. When the robotic control logic has decided where to send each fruit, the conveyor belt will also move the fruit to a sorting bin. The conveyor belt must be able to start and stop on commands from the other subsystems to ensure proper integration. It must also be able to physically support the weight of the fruit.

Sensors: The cameras will capture an image of the fruit at the required area. The microcontroller will process that image to measure the size and color of the fruit with a PI camera algorithm. Then it will determine whether the fruit met a standard for the market or not. The microcontroller will tell the Robotic Arms to move the fruit from the scale to a certain conveyor belt based on the quality of the fruit. The conveyor belt will move the fruit to a conveyor belt. Once the receptacle gets full of fruits, it gets weighed the scale.This data is used to calculate the total weight of fruits that are for the market, or the total weight of “shrink”.

Mobile application: The mobile application is a freely available Android application that serves as the primary interface for the user to configure, run, and troubleshoot the machine. The application will be used to determine the criteria for sorting the fruit and pushing it to the sorting equipment via a Bluetooth connection. The application will also allow the user to start and stop the machine remotely. In the event of a problem with the machine, the application will provide easy access to the user manual and contact information for the manufacturer, allowing users to resolve problems as easily as possible.

## Modes of Operation

The Robotic Sorting System will only have one autonomous mode of operation (except for a human worker turning the system on or off and supervising operation via the app). Once the system is started it will work without any necessary human interaction outside of oversight and configuration.

## Users

The target customer for the Robotic Sorting System is relatively small-scale farming operations that may not be able to afford existing large-scale sorting machines, but would still benefit from the improved speed and accuracy that automated sorting offers. Towards this end, the machine will be designed so that it does not require an elaborately prepared space or a highly specialized electrical connection. However, another key beneficiary of the Robotic Sorting System would be workers that sort fruit by hand. With a Robotic Sorting System, the sorting worker can simply oversee the machine, reducing labor while increasing productivity. In some cases, the machine may be able to handle all sorting, freeing up labor for other tasks.

The installation of the Robotic Sorting System will simply require the user to ensure that the machine is assembled correctly, find a space for the machine, and plug the machine into the standard wall outlet. Training to use the machine will also be straightforward, requiring little to no human interaction outside of starting/stopping the sorting process via the application, giving the machine fruit to sort and removing the sorted fruit, and fixing any issues that may arise. The mobile application used to control the machine will be simple and descriptive with the underlying logic handling the more complex parts of the system’s operation. Any error in the system will immediately stop operation and give a clear, descriptive error message to allow troubleshooting.

## Support

The Robotic Sorting System will have support in the form of a User Manual detailing the operation of the system as well as detailing maintenance procedures. The emails of the designers will also be provided in the user manual as a contact if anything needs to be troubleshooted or repaired that falls outside the scope of the provided maintenance procedures. All of this information will be provided in the mobile application for easy reference.

# Scenarios

## Cocktail Tree Sorting

The cocktail tree is a unique variety of tree capable of growing both Meyer lemons and Key limes in the same plant [7]. Naturally, if these trees were used on a large scale, it would be desirable to have a way to automatically sort out the lemons and the limes. Based on the characteristics of lemons versus limes, the user could configure the Robotic Sorting Machine to identify the fruits based on differences in their size and color. Doing so would reduce labor requirements as it would be unnecessary for a worker to manually sort lemons and limes.

## Sorting for Combined Farming

In many cases, a farmer may own enough land to grow multiple different varieties of fruit – for example, they may grow lemons, limes, and grapefruit simultaneously. Much like the cocktail tree scenario described in Section 4.1, the farmer could configure the Robotic Sorting Machine to automatically sort the different kinds of fruits, allowing the farmer to sell only one kind of fruit at a time with little to no additional human labor.

## Citrus Black Spot

As an example of the Robotic Sorting System’s ability to detect visual defects in fruit, the system could be used to detect citrus black spot. Citrus black spot is a disease that affects citrus plants in subtropical climates. In addition to reducing the quantity of fruit produced from the tree, affected citrus fruits have black or brown spots on the rind of the fruit that reduces the quality of the fruit and makes it less desirable to customers [5].



*Figure 2: An image showing citrus black spot on the peel of an orange [6].*

Using the visual sorting capabilities of the Robotic Sorting Machine, a fruit producer could automatically sort out fruits showing symptoms of citrus black spot, ensuring that they are not shipped to customers (who would almost certainly reject the damaged oranges).

1. **Analysis**

## Summary of Proposed Improvements

The Robotic Sorting Machine brings multiple improvements to the fruit sorting process. One improvement is having the system able to be installed easily. The worker will then be able to install the system with minimal effort. Another improvement is the light weight and high mobility of the system. The worker can move the system from one place to another with ease. Another improvement is having the system to be energy efficient. Having the system to be energy efficient will bring the cost of electricity to a minimum without reducing the effectiveness of the system. Another proposed improvement is having the system to be easily maintained, repaired, and modified. The longevity of the system could be sufficient, as long as the farmer regularly keeps up with maintenance. The farmer can modify the system to suit their needs. Like adding solar panels to power the system off grid or installing custom software.

## Disadvantages and Limitations

In addition to the benefits of the Robotic Sorting System, there are also disadvantages and limitations to the system. The system could be a safety hazard to uncareful workers. For example, a worker could get loose clothing tangled from the motor of the conveyor belt. Due to our budget, the robotic arm/lever may not be able to carry a heavy load. So watermelon, eggplant, pumpkin, or any large fruit may not be applicable to the system.

## Alternatives

There are alternatives to the system. One alternative is the traditional, all human and no machine system. The farmer can hire and train workers to check the color, size, weight of the fruits and sort them into receptacles. Another alternative would be to have some machine involvement. The farmer can hire and train workers to check the color, size, weight of the fruits and use the conveyor belts system. Alternatively, the farmer can hire and train workers to use the sensors to check the quality and weight of the fruits and use the conveyor belts system.

## Impact

The system will have many impacts to the market, companies, and fruit “shrink”. Companies will save money with the system, since the training and salaries of workers can have a significant cost. The system will be better at detecting flaws on fruits than workers. This system will lead to the market receiving fruits that are higher in quality, which will in turn lead to better options of fruits for consumers at the store, due to the fruits being more consistent. Fruit “shrink” will decrease and food waste will be reduced from this.

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Functional System Requirements**

Draft Release

3 October 2022

Functional System Requirements

for

Robotic Sorting System

Prepared by:

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Author Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

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# Introduction

## Purpose and Scope

The Robotic Sorting System is an automated system that uses size, color, and weight sensing to automatically sort fruit. The fruit is placed on the conveyor belt, which carries the fruit to the sensing area where a camera-equipped Raspberry Pi determines the size and color information used to sort the fruit. The system then decides what “bin” to sort the fruit into. The conveyor belt then carries the fruit to the robotic sorting arms/guiding rails, which guide the fruit to the correct bin. An overall system diagram is shown in Figure 1 illustrating the primary subsystems and their relationships to each other.

Graphical user interface, application

Description automatically generated

**Figure 1. Conceptual Image for the Robotic Sorting System**

This Functional System Requirements (FSR) document defines the technical requirements for both the Robotic Sorting System and its primary subsystems.

## Responsibility and Change Authority

Each member of the team is responsible for ensuring that their subsystem meets the stated requirements as shown in Figure 2 below. However, the team leader (Pace Dominy) is responsible for ensuring that the project as a whole meets the stated requirements. The requirements stated in this document may only be changed with the approval of the team leader and Dr. John Lusher.

| **Subsystem** | **Responsibility** |
| --- | --- |
| Android Application | Joseph Miller |
| Conveyor Belt | Pace Dominy |
| Power Control | Pace Dominy |
| Robotic Arms | Pace Dominy |
| Sensors | Lam Tran |

# Applicable and Reference Documents

## Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| ANSI/NFPA 70 | 2023 | National Electrical Code |
| Bluetooth SIG 5.0 | 06 December 2016 | Bluetooth Core Specification v5.0 |

## Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
|  | June 2019 | Raspberry Pi 4 Module B Datasheet |

## Order of Precedence

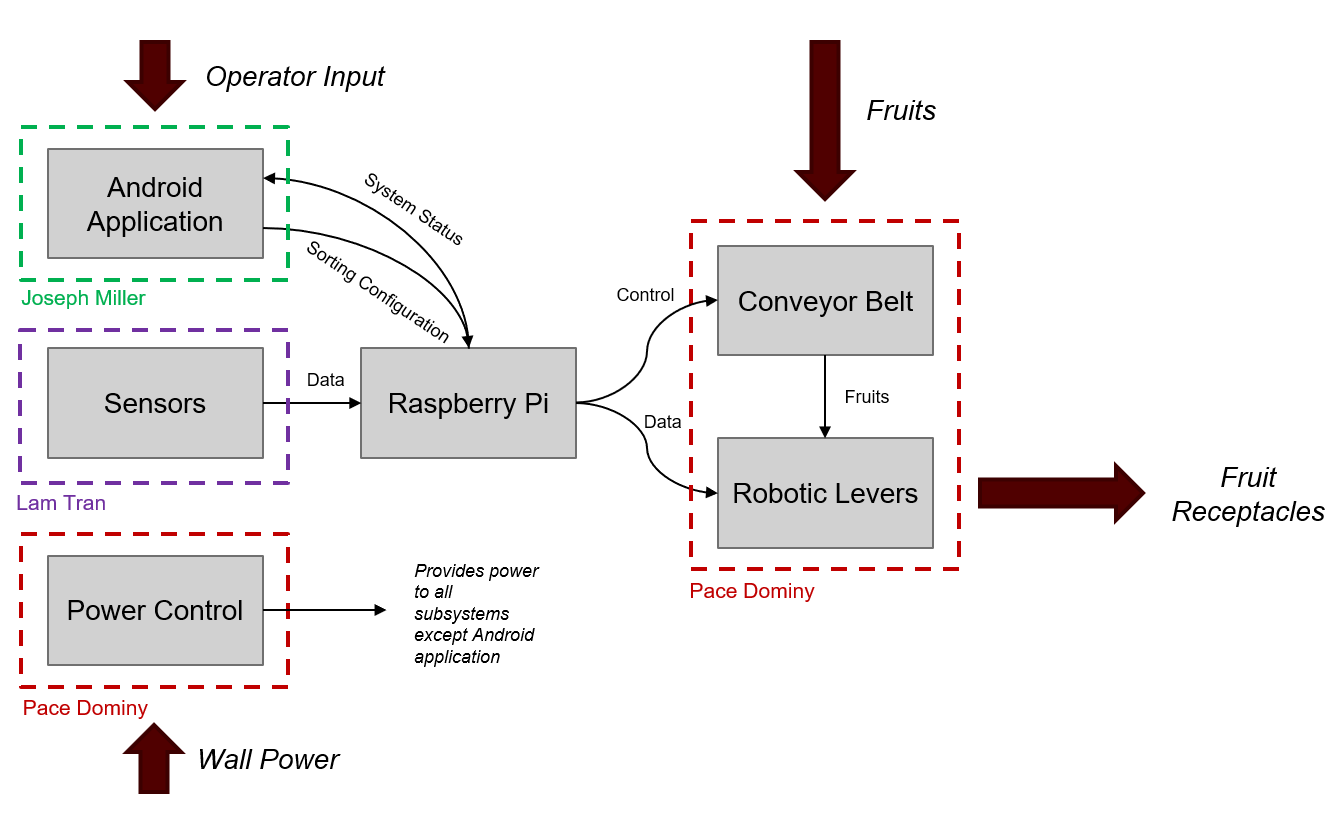
In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

# Requirements

## System Definition

The Robotic Sorting System is an automatic sorting system meant for small farms that can’t afford a large scale and expensive sorting system for sorting their produce. The Robotic Sorting System will allow farmers to allocate very little manpower to sorting and allow them to instead focus on more labor-intensive tasks. Different setups of the system will be allowed such as changing the number of receptacles based on the needs of the farmer.



**Figure 2. Block Diagram of System**

Fruit will travel onto the conveyor belt one at a time where they will briefly stop while the camera takes a picture. From here, the Raspberry Pi will determine the type and quality of the fruit via image processing. Next, the raspberry pi will tell the guiding belt to move the Robotic Arms into the correct position to guide the fruit to the correct receptacle. The belt will then start up again and the fruit will be moved down the belt between the Robotic Arms into the corresponding receptacle. Each receptacle will have a load cell (weight sensor) which will be used to determine how much fruit is in the receptacle.

The mobile application will be used to remotely start and stop the sorting system as well as configure the system to look at different criteria while sorting. The user manual and contact information will also be available through the application. Finally, the app will also allow troubleshooting of problems that occur with the system.

## Characteristics

### Functional / Performance Requirements

#### **Processing Speed**

The Robotic Sorting System shall be able to sort at least 3 fruits per minute.

*Rationale: If the sorting speed is too slow, the sorting machine will not be a worthwhile investment (versus simply sorting the fruit by hand). However, if the sorting speed is too fast, it may cause damage to the fruit or even cause the fruit to fall off of the machine. A sort time per fruit of approximately 20 seconds allows the fruit to move quickly through the system without the risk of damage.*

#### **Sorting Accuracy**

The Robotic Sorting System shall be able to sort fruit based on the user-specified criteria with at least 95% accuracy.

*Rationale: Much like processing speed, good accuracy is key to ensuring that the Robotic Sorting System is a worthwhile upgrade over human sorting. An accuracy of 95% allows some room for error while remaining highly accurate.*

#### **Sequential Sorting**

The Robotic Sorting System shall classify and scan only one fruit at a time.

*Rationale: While parallel sorting would greatly increase the throughput of the Robotic Sorting System, maintaining 95% accuracy on parallel tracks would likely require better sensors or more sensors, neither of which are financially viable for this system.*

#### **Number of Sorting Categories**

The Robotic Sorting System shall support at least three sorting categories (or “bins”).

*Rationale: A Robotic Sorting System that supports at least three different bins provides significant added utility compared to a system only capable of sorting into two bins for little additional extra complexity. While there is a possibility to add greater than 3 bins, adding more bins will quickly face diminishing returns compared to the amount of complexity added to the system.*

### Physical Characteristics

#### **Mass**

The mass of the Robotic Sorting System shall be less than 300 lbs.

*Rationale: The Robotic Sorting System must be light enough for it to be portable while having enough mass to be stable and robust. 300 lbs is a good balance for portability and robustness.*

#### **Volume Envelope**

The volume envelope of the Robotic Sorting System shall be less than or equal to 34 inches in height, 28 inches in width, and 64 inches in length.

*Rationale: For height, 34 inches is about half of the average height of an adult male. So having 34 inches for the height should be manageable for the farmer. For the width, 28 inches is a reasonable width for 3 receptacles. For length, 64 inches is a reasonable length for the Robotic Arm to guide fruits to a certain channel.*

#### **Mounting**

Mounting information for the Robotic Sorting System shall be provided in the ICD.

#### **Level Surface**

The level surface for the Robotic Sorting System has a height of 34 inches. The conveyor belt has a rough surface.

*Rationale: The rough surface of the conveyor belt will keep the fruits steady when they are on the conveyor.*

#### **Specified set up for connection to another conveyor belt**

The specified set up for connection to another conveyor belt for the Robotic Sorting System shall be provided in the user manual.

#### **Table**

The table of the Robotic Sorting System is the section between the conveyor belt and receptacles. The robotic arms will guide the fruit into its receptacles.

#### **Food safety of all components**

The material of the conveyor belt, the Robotic Arm, the channels, and the receptacles are food grade. They won’t leach chemicals to the fruits, they can be sanitized, and they are FDA approved.

*Rationale: What components will touch the fruits? The conveyor belt, the Robotic Arm, the channels, and the receptacles.*

* + 1. **Electrical Characteristics**

Diagram

Description automatically generated

**Figure 3. Power System Diagram**

##### Inputs

The inputs for the Robotic Sorting System include power from a wall outlet, images from the Raspberry Pi Camera and resistance measurements from the load cells. An owner of the system can also configure the sorting criteria of the system via a Bluetooth connection on an Android device with the app designed for the system.

*Rationale: Batteries are inconsistent and it is better to use a national standard for power input*

##### Input Voltage Level

The input voltage level for the Robotic Sorting System shall be 120 VAC.

*Rationale: 120 VAC is standard for most outlets (except of course 240 VAC for larger home appliances)*

##### Resistance to Power Surges/Cutoffs From Mains

The Power Subsystem will be resistant to power surges in order to prevent destruction of the circuit.

#### **Outputs**

##### Data Output

Weight data will be outputted to the Android app over Bluetooth.

##### Diagnostic Output

The Robotic Sorting System shall include a page for diagnostics in the Android application for troubleshooting issues. Diagnostic data will be sent over Bluetooth to the Android app.

#### **Connectors**

Connectors will be done in accordance with ANSI/NFPA 70.

*Rationale: All states follow this standard.*

#### **Wiring**

Wiring will be done in accordance with ANSI/NFPA 70.

### Environmental Requirements

The Robotic Sorting System shall be designed to withstand and operate in the environments and laboratory tests specified in the following section.

#### **Heat Resistance**

The Robotic Sorting System shall be designed to withstand and operate the temperature of 36 to 100 degree Fahrenheit.

*Rationale: Some fruits are seasonal. Example: tomatoes are harvested in the summer and tangerines are harvested in the winter.*

#### **Water Resistance**

The Robotic Sorting System shall be designed to withstand and operate in a wet or humid environment.

*Rationale: Ideally, the system would be operated inside a warehouse with fruits that are clean and not covered with water. But for some farms, this might not be the case. Like cranberries for example, since they are submerged in water. So some farmers might want to use the system outside, exposed to the element.*

#### **Dust Resistance**

The Robotic Sorting System shall be designed to withstand and operate in a dusty environment.

*Rationale: Some farms are located in arid deserts. Prickly pears is an example. So dust from the environment should be something to consider for the design of the system.*

### Failure Propagation

In the event of a failure of some sort, the Robotic Sorting System will halt operation and return an error message to the operator via the Android application.

#### **Causes for Failure**

The Robotic Sorting System shall be capable of detecting the following failure conditions. In all of the following cases, all subsystems shall immediately cease operation except the Android app, which will show a popup explaining the system fault.

#### **Belt Blockage**

The Robotic Sorting System shall stop operation if the conveyor belt is blocked.

*Rationale: If the system continues to run while the belt cannot move, the motors that drive the conveyor belt may be damaged.*

#### **Fruit Blockage**

The system shall stop operation if, at any point in the physical flow of fruit, a fruit physically blocks the flow of fruit.

*Rationale: If the system continues to run while a fruit is blocking other fruit, the rest of the fruit will physically spill off of the machine. Additionally, depending on the fruit, the jam may cause the fruit to be crushed and spill juices, potentially causing damage to the system.*

#### **Sensor Fault**

The system shall stop operation if any of the three classes of sensors (weight, color, or size) cannot reliably detect the requisite physical attribute.

*Rationale: Similar to the case of a motor failure, the Robotic Sorting System is not capable of sorting fruit if the sensors aren’t working, i.e. they cannot detect the differences between fruit.*

# Support Requirements

The Robotic Sorting System requires power and an Android device with Bluetooth capabilities that can download the free application that goes with the system. One sorting system consists of (1) conveyor belt, (1) guide belt, (2) robotic arms/guiding rails, (1) raspberry pi 4, (1) raspberry pi camera, (3) receptacles with load cells minimum, (1) printed circuit board and (1) user manual.

# Appendix A: Acronyms and Abbreviations

GUI Graphical User Interface

ICD Interface Control Document

USB Universal Serial Bus

VAC Voltage with AC (alternating current)

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Functional System Requirements**

**Conveyor Belt**

REVISION – Draft Release

3 October 2022

Functional System Requirements

for

Robotic Sorting System (Conveyor Belt)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Pace Dominy 10/03/2022

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

**Change Record**

| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
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| **-** | 10/3/2022 | Pace Dominy |  | Draft Release |

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# Introduction

## Purpose and Scope

This Functional System Requirements (FSR) Document defines the requirements for the conveyor belt which serves as the primary means for moving fruit through the system. The verification requirements for the project are contained in a separate Verification and Validation Plan. Note: Image below will be updated in later revision.

Diagram

Description automatically generated

**Figure 1. Conveyor Belt Conceptual Image**

The following definitions differentiate between requirements and other statements.

Shall: This is the only verb used for the binding requirements.

Should/May: These verbs are used for stating non-mandatory goals.

Will: This verb is used for stating facts or declaration of purpose.

## Responsibility and Change Authority

At the subsystem level, the team member in charge of the Conveyor Belt subsystem (Pace Dominy) is responsible for ensuring that the Conveyor Belt meets all requirements specified in the project-level FSR. The requirements stated in this document may only be changed with the approval of the conveyor belt subsystem leader/project leader (Pace Dominy), and Dr. John Lusher.

# Applicable and Reference Documents

## Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| RSS ICD | 1.0/3 October 2022 | Robotic Sorting System Interface Control Document |
| RSS CBICD | 1.0/3 October 2022 | Conveyor Belt Interface Control Document |

## Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

# Requirements

This section defines the minimum requirements that the Conveyor Belt Subsystem must meet.

## System Definition

The Conveyor Belt subsystem of the Robotic Sorting System is the primary means of movement for any fruit that is processed through the overall sorting system. The Conveyor Belt Subsystem consists of a conveyor belt and two lever arms/guiding rails that move via a guiding belt perpendicular to the main conveyor belt. This guidance system will be attached to the Conveyor Belt subsystem via the frame of the system.

Diagram

Description automatically generated

**Figure 2. Block Diagram of System**

The two main components of this subsystem are the belt and the guidance system as mentioned above. The primary function of this subsystem is to move the fruit from its initial position to the end of the belt and finally into the correct receptacle. This function is accomplished with help from the Robotic Arms/Levers which is another subsystem of the Robotic Sorting System.

## Characteristics

### Functional / Performance Requirements

#### **Functional Requirements**

The primary functional requirement of this subsystem is to take inputs from other parts of the Robotic Sorting System in order to move the fruit to the correct receptacle. After the sensors have already received the information and the Raspberry Pi has decided on where the fruit needs to go, the Robotic Arms will then get into the correct position and the Conveyor Belt must simply turn on long enough for the fruit to fall into the correct receptacle. From here, the belt must turn off once the next fruit is in position and await the command to turn on again. Both the Robotic Arms and Conveyor Belt receive their control signals from the Raspberry Pi and their power from the Power Subsystem.

#### **Accuracy Requirements**

The Conveyor Belt must keep the fruit in position under the camera long enough for the camera to get a picture and the Raspberry Pi to determine the type (and possibly quality depending on user preference) of the fruit. The Conveyor Belt must also limit any excess movement not intended by the Raspberry Pi due to latency from the electrical signals, latency in the circuit design or from the motor turning on/off. Excess movement should be limited to no more than half an inch off of target and should keep the fruit mostly in view of the Raspberry Pi camera.

*Rationale: If the fruit is not mostly/fully in view of the camera then that could ruin the results from the image processing. Too little movement of the belt could also prevent a fruit from falling into the receptacle, possibly causing it to fall onto the floor, get stuck, or end up in the wrong receptacle.*

#### **Speed Requirements**

In accordance with the RSS FSR, the Conveyor Belt Subsystem shall be able to sort at least 6 fruits a minute (3.2.1.1). Therefore, the belt speed must be fast enough to meet this requirement.

### Physical Characteristics

#### **Mass**

The weight of the Conveyor Belt Subsystem will be limited to no more than 100 lbs in accordance with the RSS ICD section 3.1.1.

*Rationale: Conveyor Belt should not be too heavy, so that a user can reasonably transport it with their truck or other motor vehicle.*

#### **Volume Envelope**

The volume envelope of the Conveyor Belt shall be approximately 2 ft in height, 2 to 2.5 ft in width, and approximately 6 ft in length max. Specifications are in accordance with RSS ICD section 3.2.3

*Rationale: Conveyor belt must not only reasonably fit in someone vehicle but also not be so large that the conveyor belt becomes too expensive to produce and reasonably sell to a small farmer.*

#### **Mounting**

Conveyor Belt Subsystem must simply be able to be placed flat on a level surface in order to prevent fruit from rolling around on the belt when it is stationary.

*Rationale: Extra complexity would be added if the RSS were able to be placed on a surface not close to or level with the ground.*

### Electrical Characteristics

#### **Inputs**

No power inputs or controller signal inputs to the conveyor belt motor or guiding belt motors should damage or reduce the life expectancy of the RSS.

##### Input Voltage Level

The input voltage level for the Conveyor Belt Subsystem should not exceed the maximums described in the datasheets for the motors for the conveyor belt and guiding belt.

*Rationale: Damage to the motors should be prevented*

#### **Outputs**

##### Movement Output

Only output from the Conveyor Belt Subsystem should be movement via the motor that controls the conveyor belt.

#### **Connectors**

The RSS shall use connectors in accordance with ANSI/NFPA 70.

#### **Wiring**

The RSS shall follow the wiring guidelines outlined in ANSI/NFPA 70.

### Environmental Requirements

Environmental requirements shall match those specified in the RSS FSR section 3.2.4.

### Failure Propagation

In the event of a failure of some sort, the conveyor belt will halt movement. Causes for failure are listed in detail in the RSS FSR section 3.2.5.1.

# Support Requirements

Support for the Conveyor Belt Subsystem will be included as part of the user manual that is included in the Android application. Contact information will also be available in the case that the user manual does not specify a solution to the given problem.

# Appendix A: Acronyms and Abbreviations

GUI Graphical User Interface

ICD Interface Control Document

kHz Kilohertz (1,000 Hz)

kW                        Kilowatt (1,000 Watts)

LCD Liquid Crystal Display

LED Light-emitting Diode

mA Milliamp

mW Milliwatt (1 thousandth of a Watt)

PCB Printed Circuit Board

RSS Robotic Sorting System

USB Universal Serial Bus

VAC                      Voltage with AC (alternating current)

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Functional System Requirements**

**Power**

REVISION – Draft Release

3 October 2022

Functional System Requirements

for

Robotic Sorting System (Power)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Pace Dominy 10/3/2022

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

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| **-** | 10/3/2022 | Pace Dominy |  | Draft Release |

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[**Figure 2. Block Diagram of System 4**](#_heading=h.44sinio)

# Introduction

## Purpose and Scope

This Functional System Requirements (FSR) Document defines the requirements for power delivery to the other subsystems of the Robotic Sorting System (RSS). The verification requirements for the project are contained in a separate Verification and Validation Plan.

The following definitions differentiate between requirements and other statements.

Shall: This is the only verb used for the binding requirements.

Should/May: These verbs are used for stating non-mandatory goals.

Will: This verb is used for stating facts or declaration of purpose.

## Responsibility and Change Authority

At the subsystem level, the team member in charge of the Power subsystem (Pace Dominy) is responsible for ensuring that the Power subsystem meets all requirements specified in the project-level FSR.  The requirements stated in this document may only be changed with the approval of the Power subsystem leader/project leader (Pace Dominy), and Dr. John Lusher.

# Applicable and Reference Documents

## Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| RSS ICD | 1.0/3 October 2022 | Robotic Sorting System Interface Control Document |
| RSS PICD | 1.0/3 October 2022 | Power Interface Control Document |

## Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
|  | June 2019 | Raspberry Pi 4 Module B Datasheet |

## Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

# Requirements

## System Definition

The Power Subsystem is in charge of all power delivery for the RSS.



**Figure 2. Block Diagram of System**

Starting at the top left, the Power Subsystem takes input from a standard US wall outlet of 120 V (AC) with a current of 15 A. The three-phase power input goes to a converter on the Printed Circuit Board (PCB) which will convert the voltage to approximately 24 V (DC) which will then power a multiple output flyback. The windings of the receiving coils will be adjusted to achieve the correct voltage for the connections. The Raspberry Pi 4 will receive power from the top coil of the Flyback at 5V (6V max) with a current of 3A in accordance with the Raspberry Pi 4 Module B datasheet. The load cells will take a DC voltage and appropriate current in accordance with their data sheet. Likewise, the DC motors for the conveyor belt and guiding belt will receive the correct power in accordance with their data sheets.

When it comes to controlling the speed and direction of the motors, the Raspberry Pi 4 will output electrical signals that input into the conveyor belt controller and guiding belt controller. This input will be a PWM (Pulse Width Modulated) signal that controls the speed of the motors as a percentage of the 1 V, the rest of the voltage will be supplied by the Flyback and finally it will have its polarity switched depending on which direction the motor needs to go (H-bridge will allow polarity reversal).

Any parts that do not have a part number are being researched and will be decided no later than 10/5/2022 followed by this document being updated accordingly.

## Characteristics

### Functional Requirements

The only function of the Power Subsystem is to provide the correct amount of power for the other subsystems to operate while also not decreasing the lifetime of the circuit by providing too much power.

### Physical Characteristics

#### **Mass**

The mass of the Power Subsystem will be small enough that it does not add unnecessary weight (no more than 10 lbs) to the RSS.

*Rationale: The Power Subsystem should be small and should not add much weight as wires and PCBs are fairly small and light.*

#### **Volume Envelope**

The Power Subsystem shall fit within the volume envelope specifications of the RSS FSR

#### **Mounting**

The PCB shall be mounted to the RSS in a location where it does not interfere with the operation of the other subsystems but is also accessible in the case that the PCB is required to be swapped out for a new one or repaired.

*Rationale: PCB should not be hidden or in a hard to reach area in case there is a power failure.*

### Electrical Characteristics

#### **Inputs**

Input to the Power Subsystem shall be 1800 Watts in accordance with the standard US wall outlet of 120 V AC with 15 A current.

*Rationale: Power supply is assumed to not deviate from 1800 Watts by any significant margin*

##### Power Consumption

The maximum peak power of the system shall not exceed 2000 watts.

*Rationale: This deviation should account for any fluctuations in input power from the wall outlet.*

##### Input Noise and Ripple

Input Noise is assumed to be negligible from a standard US wall outlet of 120 V and 15 A.

##### External Commands

Signal inputs from the Raspberry Pi 4 shall not damage the PCB.

#### **Outputs**

#### **Connectors**

Connectors will be done in accordance with ANSI/NFPA 70.

#### **Wiring**

Wiring will be done in accordance with ANSI/NFPA 70.

### Environmental Requirements

Environmental requirements shall match those specified in the RSS FSR section 3.2.4

# Support Requirements

Support for the Robotic Arm Subsystem will be included as part of the user manual that is included in the Android application.  Contact information will also be available in the case that the user manual does not specify a solution to the given problem.

# Appendix A: Acronyms and Abbreviations

GUI Graphical User Interface

ICD Interface Control Document

kHz Kilohertz (1,000 Hz)

kW                        Kilowatt (1,000 Watts)

LCD Liquid Crystal Display

LED Light-emitting Diode

mA Milliamp

mW Milliwatt (1 thousandth of a Watt)

PCB Printed Circuit Board

RSS                      Robotic Sorting System

USB Universal Serial Bus

VAC                      Voltage with AC (alternating current)

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Functional System Requirements**

**Robotic Arm Subsystem**

REVISION – Draft Release

3 October 2022

Functional System Requirements

for

Robotic Sorting System (Robotic Arm)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Author Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

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# Introduction

## Purpose and Scope

This Functional System Requirements (FSR) Document defines the requirements for the lever arms that guide the fruit on the conveyor belt to the correct receptacle. The verification requirements for the project are contained in a separate Verification and Validation Plan.



**Figure 1. Robotic Arm Conceptual Image**

The Robotic Arms are colored yellow to easily differentiate them from the black supports. The red belt is part of the guide belt (pulley system) that moves the Robotic Arms left and right in order to guide the fruit into the correct receptacle. Note: Colors used in the diagram are just for differentiating parts and do not represent the actual final colors to be used.

The following definitions differentiate between requirements and other statements.

Shall: This is the only verb used for the binding requirements.

Should/May: These verbs are used for stating non-mandatory goals.

Will: This verb is used for stating facts or declaration of purpose.

## Responsibility and Change Authority

At the subsystem level, the team member in charge of the Robotic Arm subsystem (Pace Dominy) is responsible for ensuring that the Robotic Arm meets all requirements specified in the project-level FSR.  The requirements stated in this document may only be changed with the approval of the Robotic Arm subsystem leader/project leader (Pace Dominy), and Dr. John Lusher.

# Applicable and Reference Documents

## Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| RSS ICD | 1.0/3 October 2022 | Robotic Sorting System Interface Control Document |
| RSS RLICD | 1.0/3 October 2022 | Robotic Arm Interface Control Document |

## Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

# Requirements

This section defines the minimum requirements that the Robotic Arm Subsystem must meet.

## System Definition

The Robotic Arms of the Robotic Arm Subsystem are what guides the fruit physically into the correct receptacle. The Robotic Arm Subsystem consists of two Robotic Arms that are guided by a pulley system that moves perpendicularly to the conveyor belt to angle the arms in the correct direction. The supports and the to account for the change in length of the arms that comes with a change in their angle.

Diagram

Description automatically generated

**Figure 2. Block Diagram of System**

## Characteristics

### Functional / Performance Requirements

#### **Functional Requirements**

The primary function of the lever arms is to be at the correct angle specified by the Raspberry Pi in order to guide the fruit into the correct receptacle. The conveyor belt will wait for the robotic arms to be in position and stop before starting up again. The conveyor belt will push the fruit forward while the lever arms simply guide the fruit.

#### **Accuracy Requirements**

The robotic arms’ angle must be accurate within a couple degrees in order to ensure that the fruit makes it into the correct receptacle.

*Rationale: If the angle of the arms is off by too much, then the fruit could either get stuck or go into the wrong receptacle altogether*

#### **Speed Requirements**

On top of being accurate, the robotic arms must also move fast enough to not slow down the overall Robotic Sorting System (RSS)

*Rationale: If the robotic arms are the slowest part, then the entire system will be waiting for the arms to get to the correct angle.*

### Physical Characteristics

#### **Mass**

The mass of the Lever Arm Subsystem shall be no more than 20 lbs.

#### **Volume Envelope**

The volume envelope of the Robotic Arm System shall be approximately 4 inches in height, 2 ft in width, and 1 ft 4 inches in length.

*Rationale: The length of the arms must be long enough that the max change in angle away from the center line does not pull away from the guiding belt too much. Also can’t have too long of arms or else the conveyor belt will have to be longer.*

#### **Mounting**

The mounting information for the Robotic Arm Subsystem shall be captured in the Robotic Arm Subsystem ICD.

### Electrical Characteristics

#### **Inputs**

No power inputs or controller signal inputs to the conveyor belt motor or guiding belt motors should damage or reduce the life expectancy of the RSS.

*Rationale:  By design, should limit the chance of damage or malfunction by user/technician error.*

##### Input Voltage Level

The input voltage level for the Conveyor Belt Subsystem should not exceed the maximums described in the datasheets for the AC motors for the conveyor and guiding belt motors.

*Rationale:  Damage to the motors should be prevented*

#### **Outputs**

##### Movement Output

Only output from the Robotic Arm Subsystem should be movement via the AC motor that controls the belt that guides the lever arms.

#### **Connectors**

*The RSS shall use connectors in accordance with ANSI/NFPA 70.*

#### **Wiring**

The RSS shall follow the wiring guidelines outlined in ANSI/NFPA 70.

### Environmental Requirements

Environmental requirements shall match those specified in the RSS FSR section 3.2.4

### Failure Propagation

In the event of a failure of some sort, the conveyor belt will halt movement.  Causes for failure are listed in detail in the RSS FSR section 3.2.5.1.

# Support Requirements

Support for the Robotic Arm Subsystem will be included as part of the user manual that is included in the Android application.  Contact information will also be available in the case that the user manual does not specify a solution to the given problem.

# Appendix A: Acronyms and Abbreviations

GUI Graphical User Interface

ICD Interface Control Document

kHz Kilohertz (1,000 Hz)

kW                        Kilowatt (1,000 Watts)

LCD Liquid Crystal Display

LED Light-emitting Diode

mA Milliamp

mW Milliwatt (1 thousandth of a Watt)

PCB Printed Circuit Board

RSS                      Robotic Sorting System

USB Universal Serial Bus

VAC                      Voltage with AC (alternating current)

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Functional System Requirements**

**Sensors**

REVISION – Draft

2 October 2022

Functional System Requirements

for

Robotic Sorting System (Sensors)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Lam Tran Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

**Change Record**

| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| --- | --- | --- | --- | --- |
| **-** | [10/2/2022 | [Lam Tran] |  | Draft Release |

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# Introduction

## Purpose and Scope

This document describes the technical requirements for the sensors that will measure data for the Robotic Sorting System. The verification requirements for the project are contained in a separate Verification and Validation Plan.

***1.1.***

***Purpose and Scope***

The following definitions differentiate between requirements and other statements.

Shall: This is the only verb used for the binding requirements.

Should/May: These verbs are used for stating non-mandatory goals.

Will: This verb is used for stating facts or declaration of purpose.

## Responsibility and Change Authority

For the sensor subsystem, the team member(Lam Tran) is responsible for meeting the requirements. The team leader(Pace Dominy) and Dr. John Lusher have the authority to make changes to this subsystem and the requirements .

# Applicable and Reference Documents

## Applicable Documents

| **Document Number** | **Revision/Release Date** | **Document Title** |
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## Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
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## Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

# Requirements

This section defines the minimum requirements that the sensors must meet.

## System Definition

Provide a brief overview of the project, and then describe some of the main sub-systems of your proposed solution.

The sensors for the Robotic Sorting System will consist of a RasPi camera and a load cell. The RasPi camera will take an image of the fruit, then the Raspberry Pi will measure the size and the color of the fruit with the image. This data is used to determine if the fruit meets quality standards. The load cell will weigh a receptacle to find the total amount of “shrink” and the amount of fruits for the market.



**Figure 1. Block Diagram of System**

Describe the block diagram, what are the subsystems, how do they interconnect. Someone reading this section should get a general idea of what you are building, why, and how it will solve the problem you are solving.

For the first row block diagram, a fruit is placed in front of the RasPi Camera. The RasPi Camera will take the image of the fruit, and send it to the RaspBerry Pi. The RaspBerry Pi will use the image to find the height/width of the fruit and its color.

For the second row block diagram, a receptacle that is filled with fruit is placed on to a load cell. When the receptacle is placed on to the load cell, there is a resistive change within the load cell. The voltage of the resistive change is sent to the RaspBerry Pi. The RaspBerry Pi will calculate the weight with this voltage.

## Characteristics

### Functional / Performance Requirements

#### **The operating force of the load cell**

The load cell is able to weigh up to 20 pounds. .

*Rationale: The receptacle will hold 20 pounds of fruits. Workers should be able to carry and move around a 20 pounds receptacle.*

#### **Image Quality**

The camera must create an image that is TBD resolution.

*Rationale: This resolution will have enough quality to find the height and width of the fruit, while still using the minimum amount of memory.*

### Physical Characteristics

#### **Mounting**

The mounting information for the sensors of the Robotic Sorting System shall be captured in the Robotic Sorting System ICD.

### Electrical Characteristics

#### **Inputs**

No signals from the sensors shall damage the Robotic Sorting System, reduce its life expectancy, or cause any malfunction.

##### Input Voltage Level

The input voltage level for the sensors shall be +3.3 VDC to +5 VDC.

*Rationale: Typical voltage for the sensors and Raspberry Pi*

##### Image noise

Image noise can be fixed with digit image processing.

*Rationale: Noise can be reduced by doing some image transformations*

#### ***Outputs***

##### Data Output

The sensors shall include an interface compatible with the data system.

*Rationale: The sensors' information passes directly to the customer’s system.*

##### Diagnostic Output

The sensors’ shall include a diagnostic interface for control and data logging.

*Rationale: Provides the ability to control things for debugging manually and a way to adjust calibration for weight and size measurements.*

##### Raw Image Output

The Search and Rescue System central unit shall include a raw image interface to support external recording.

*Rationale: Too much data to store internally. Would be used for diagnostics.*

### Environmental Requirements

The Robotic Sorting System shall be designed to withstand and operate in the environments and laboratory tests specified in the following section.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Search and Rescue System is integrating.*

#### **Thermal**

#### The Sensors shall be designed to withstand and operate in the temperature of 35 to 100 degree Fahrenheit.

*Rationale: Temperature varies from season to season.*

* + - 1. **Water**

#### The Sensors shall be designed to withstand and operate in a mildly wet environment. .

*Rationale: The environment can be wet depending on the weather conditions.*

* + - 1. **Dust**

#### The Sensors shall be designed to withstand and operate in the dusty environments

*Rationale: If dust covers the camera lens, then there will be a problem with the image quality. Dust may also cause overheating of ICs.*

### Failure Propagation

The sensors shall not allow propagation of faults beyond the system.

# Support Requirements

Support for the sensors is in the user manual.

# Appendix A: Acronyms and Abbreviations

BIT Built-In Test

CCA Circuit Card Assembly

EMC Electromagnetic Compatibility

EMI Electromagnetic Interference

EO/IR Electro-optical Infrared

FOR Field of Regard

FOV Field of View

GPS Global Positioning System

GUI Graphical User Interface

Hz Hertz

ICD Interface Control Document

kHz Kilohertz (1,000 Hz)

LCD Liquid Crystal Display

LED Light-emitting Diode

mA Milliamp

MHz Megahertz (1,000,000 Hz)

MTBF Mean Time Between Failure

MTTR Mean Time To Repair

mW Milliwatt

PCB Printed Circuit Board

RMS Root Mean Square

TBD To Be Determined

TTL Transistor-Transistor Logic

USB Universal Serial Bus

VME VERSA-Module Europe

# Appendix B: Definition of Terms

TBD

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Functional System Requirements**

**Android Application**

REVISION 1

3 October 2022

Functional System Requirements

for

Robotic Sorting System (Android Application)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Joseph Miller Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

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| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| --- | --- | --- | --- | --- |
| **1** | 10/3/2022 | Joseph Miller |  | Draft Release |

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# Introduction

## Purpose and Scope

This Functional Requirements Document (FSR) defines the technical requirements for the Android application that serves as the primary user interface for the Robotic Sorting System. The verification requirements for the project are contained in a separate Verification and Validation Plan.

The following definitions differentiate between requirements and other statements.

Shall: This is the only verb used for the binding requirements.

Should/May: These verbs are used for stating non-mandatory goals.

Will: This verb is used for stating facts or declaration of purpose.

## Responsibility and Change Authority

At the subsystem level, the team member in charge of the Android application subsystem (Joseph Miller) is responsible for ensuring that the Android application meets all requirements specified in the project-level FSR. The requirements stated in this document may only be changed with the approval of the application subsystem leader (Joseph Miller), the project leader (Pace Dominy), and Dr. John Lusher.

# Applicable and Reference Documents

## Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| Bluetooth SIG 5.0 | 06 December 2016 | Bluetooth Core Specification v5.0 |
| RSS ICD | 1.0/3 October 2022 | Robotic Sorting System Interface Control Document |
| RSS AAICD | 1.0/3 October 2022 | Android Application Interface Control Document |

## Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

# Requirements

This section defines the requirements of the Android application to ensure proper functionality and integration with the larger Robotic Sorting System project.

## System Definition

The Android application for the Robotic Sorting System (RSS) is the primary user interface that the operator uses to interact with the System, consisting of an application that runs on a separate Android device (the user’s personal device or one provided by the purchasing organization).

Diagram

Description automatically generated

**Figure 1. Block Diagram of System**

The user interface consists of three primary components: support information, sorting system configuration, and weight sensor readouts. The first component, support information, provides a full copy of the user manual and the manufacturer’s contact information for quick reference. The application also shows diagnostic information and error messages returned from the Robotic Sorting System for easy, human-readable troubleshooting.

The second function of the application is to allow easy configuration of the Robotic Sorting System. Using a Material Design-based Android graphical user interface (GUI) makes changing the sorting configuration simple and similar (in terms of GUI) to many popular Android apps.

The Android application also serves as the user’s primary interface with the weight sensors. The data that the sensors collect is transmitted via Bluetooth to the application, where the user can easily find it.

## Characteristics

### Functional / Performance Requirements

#### **Android Version Compatibility**

The Android application shall target and be primarily designed for Android API level 31, which corresponds to Android 12. It shall be compatible with devices running Android versions 9.0 and higher. The primary Android device used for testing will be a 2020 Galaxy Tab S6 Lite running Android 12.0.

*Rationale: Google requires that new Android applications uploaded to the Google Play store target Android API level 31 as of August 1st, 2022. Because Google does not officially support Android versions older than 9.0 as of October 3rd, 2022, Android 9.0 will be the cutoff for application support. Using an Android 12-based device ensures that the application will work well with the targeted version of Android.*

#### **Device Form Factor Compatibility**

The Android application shall run on smartphones and tablets running Android.

*Rationale: Android smartphones and tablets are widely available and provide the best screen space and utility for the kind of data that the application will handle. Other Android-based devices (smartwatches, car navigation systems, smart TVs, etc.) do not have enough screen space to make the application useful or are not relevant to a farming operation.*

#### **Programming Language and Development Environment**

The Android application shall be developed using the Android Studio development environment in the Kotlin programming language.

*Rationale: Android Studio and Kotlin are Google’s current preferred environment and language for building Android applications. This means that Google has significant resources available for learning these tools, making the development process as straightforward as possible.*

### Physical Characteristics

#### **Application Size**

The Robotic Sorting System Android application shall take up no more than 30 MB of space.

*Rationale: The most popular Android applications on the Google Play store were approximately 55-73 MB in size* [*as of February 2022*](https://www.statista.com/statistics/1296527/size-top-android-apps/)*. Because this application will be significantly less complex than those apps, it should be no greater than half of the size of the most popular apps.*

### Electrical Characteristics

#### **Inputs**

No sequence of commands to the Android application shall damage or reduce the life expectancy of the Robotic Sorting System.

*Rationale: By design, should limit the chance of damage or malfunction by user/technician error.*

### Environmental Characteristics

The Bluetooth functionality of the Android device will be tested at 15°C, 22°C, and 35°C.

*Rationale: The Bluetooth Core Specification v5.0 requires that Bluetooth connections be tested for operation between 15°C and 35°C. Room temperature (~22°C) will also be used as a middle-ground testing point.*

#### **Outputs**

##### System Configuration Output

The Android application shall provide configuration data to the Robotic Sorting System that will then be used to configure the logic of the robotic arm.

*Rationale: The Android application acts as the primary configuration interface for the Robotic Sorting System.*

##### Diagnostic Output

The Android application shall include a diagnostic readout system to help identify and resolve problems with the system.

*Rationale: A diagnostic readout system makes it significantly easier to identify problems with the Robotic Sorting System so that it can be easily resolved.*

#### **Connection**

The Android application shall establish and use a Bluetooth connection in accordance with the Bluetooth Core Specification version 5.0 to transmit and receive data.

*Rationale: The use of Bluetooth ensures compatibility with a wide range of Android devices. Version 5.0 of the Core Specification will be used because the Raspberry Pi that the Android device will connect to has a Bluetooth 5.0-capable processor.*

### Failure Prevention

The Android application shall not allow faulty configurations to be transmitted to the Robotic Sorting System.

#### **Failures from Incorrect Inputs**

##### Incompatible Configuration Detection

The Android application shall detect when the user attempts to pass a sorting configuration that the System cannot accomplish.

*Rationale: This will ensure that a user’s sorting configuration does not damage the equipment or provide a greatly inaccurate sorting result.*

##### Failure Recovery

Upon an attempt to apply an incompatible configuration, the Android application will push a notification to the user. It will not apply an incompatible configuration.

*Rationale: This prevents incompatible configurations from being applied to the machine, ensuring that the machine functions as intended and does not damage itself in the process.*

# Support Requirements

To run the Robotic Sorting System Android application, the user must have an Android smartphone or tablet with Bluetooth compatibility and running Android 9.0 or higher. Support for the application will be included as part of the user manual available in the application. For issues that the user manual does not resolve, the contact information for the manufacturer of the Robotic Sorting System and the developers of the Android application will be provided in the manual and in the application. Depending on the nature of the issue, a technician may be dispatched to the customer for repair, or the customer may be able to start a return/replacement process.

# Appendix A: Acronyms and Abbreviations

API Application Programming Interface

App Short for “application”

FSR Functional System Requirements

GUI Graphical User Interface

ICD Interface Control Document

MB Megabyte(s)

RSS Robotic Sorting System

SIG Special Interest Group

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Interface Control Document**

REVISION 1

3 October 2022

Interface Control Document

for

Robotic Sorting System

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Author Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher II, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

**Change Record**

| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| --- | --- | --- | --- | --- |
| **1** | 10/3/2022 | Robotic Sorting System |  | Draft Release |

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# 

# Overview

This document will provide details on the interfaces of the Robotic Sorting System. There are 4 types of interfaces: physical, thermal, electrical, and communications/devices. Each interface is explained in great detail. The Robotic Sorting System is for the small farmers to quickly validate and sort their fruits by quality standards. This system includes a conveyor belt, two Robotic Arms/guiding rails, sensors, and an Android application. A Raspberry Pi receives data from the sensors which it uses to control the conveyor belt, control the Robotic Arms, and provide updates of the system status to the Android application.

# References and Definitions

Provide any references (i.e., standards documents) and definitions. Examples are shown below.

## References

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| ANSI/NFPA 70 | 2023 | National Electrical Code |
| Bluetooth SIG 5.0 | 06 December 2016 | Bluetooth Core Specification v5.0 |
|  | June 2019 | Raspberry Pi 4 Module B Datasheet |

## Definitions

CCA Circuit Card Assembly

mA Milliamp

mW Milliwatt

MHz Megahertz (1,000,000 Hz)

TBD To Be Determined

# Physical Interface

## Weight

* + 1. **Weight of Conveyor Belt System**

The conveyor belt system will weigh no more than 100 lbs in order for the system to be moved without any large machinery.

* + 1. **Weight of Robotic Arm System**

The Robotic Arm system will weigh no more than 20 lbs and will be attached to the frame of the conveyor belt system so as to not interfere with the conveyor belt. The Robotic Arm arms will be light enough to be supported by the guiding belt as well as to not add unnecessary weight to the overall system. Likewise, the supports will be just light enough to support the guiding arms and guiding belt.

| **Part** | **Weight** |
| --- | --- |
| Lever Arms/Guiding Rails | >8 lbs |
| Guiding Belt | >1 lb |
| Guiding Belt Motor | >1 lb |
| Supports | >10 lbs |

* + 1. **Weight of Printed Circuit Board**

The printed circuit board will weigh less than one pound.

## Dimensions

### Dimensions of Phone Application

The phone application shall take up no more than 30 MB of space. This will ensure that the system requirements are relaxed, enabling as many Android devices as possible to run the application.

* + 1. **Dimensions of Robotic Arm Arms**

The Lever Arms/Guiding Rails will be approximately 1 ft long in order to reach either end of the belt as well as to prevent from having to make the conveyor belt too long to compensate for longer guiding arms.

* + 1. **Dimensions of Conveyor Belt System**

The conveyor belt will be approximately 2 ft in width while the overall conveyor belt system will be max 2 ft 6 in in width. The conveyor belt will be around 2 ft tall and the length of the conveyor belt will be 6 ft long max.

* + 1. **Dimensions of Power System**

The PCB will be no bigger than 40 . The wiring to and from the PCB will take up as little space as possible and be neatly routed.

* + 1. **Dimensions of Sensors**

## Mounting Locations

* + 1. **Raspberry Pi**

The Raspberry Pi is mounted on the side of the conveyor belt within a protective container.

* + 1. **Lever Arms/Guiding Rails**

The lever arm is mounted on the side of the conveyor belt. One end of the Lever Arm is fixed to the side of the conveyor belt, while the other end is connected to a linear actuator.

* + 1. **Motors**

The motors are mounted at the end of the conveyor belt and the end of the guiding belt.

* + 1. **Camera**

The camera is mounted on the side of the conveyor belt. The camera is also adjusted to point at the conveyor belt.

* + 1. **Weight Sensor**

The weight sensor is mounted on the ends of the conveyor belt and under the receptacles.

# Thermal Interface

* 1. **Raspberry Pi**

The Raspberry Pi will have an attached heatsink. It does not require a cold wall.

# Electrical Interface

## Primary Input Power

Primary input power will be 120 VAC with a current of 15 A. This input is standard in the US and equates to 1800 Watts.

## Bluetooth Interface

The Android app will connect to the Robotic Sorting System via the Bluetooth 5.0 interface on the Raspberry Pi’s Broadcom BCM2711 processor.

## Picture Interface

* + 1. **Raspberry Pi Camera**

Raspberry Pi camera will be connected to the Raspberry Pi camera port via a ribbon cable.

## User Control Interface

The user will interact with all system functions, including belt control, sorting configuration, and weight readouts, through the provided Android application on an Android smartphone or tablet. The system will also push error messages to the Android app based on the presence of a failure condition as described in paragraph 3.2.5 of the project Functional System Requirements document.

# Communications / Device Interface Protocols

## Wireless Communications (Bluetooth)

The Bluetooth connection between the Android device and the Raspberry Pi used in the Robotic Sorting Machine shall be established and used under the Bluetooth Core Protocol, version 5.0.

## Raspberry Pi Input/Output

Raspberry Pi will take input power from the PCB and output controller signals from the GPIO pins back to the PCB, specifically to the motor controllers. Raspberry Pi will also take input from the Raspberry Pi camera.

## Image Interface

Reference Robotic Sorting System ICD Section 5.4.1

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Interface Control Document**

**Conveyor Belt**

REVISION – Draft

3 October 2022

Interface Control Document

for

Robotic Sorting System (Conveyor Belt)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Pace Dominy 10/3/2022

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher II, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

**Change Record**

| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| --- | --- | --- | --- | --- |
| **-** | 10/3/2022 | Pace Dominy |  | Draft Release |

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# Overview

The Interface Control Document for the Conveyor Belt Subsystem will detail the physical, electrical and communication interfaces of this subsystem in detail. The Conveyor Belt Subsystem consists of the frame, the conveyor belt and the motor that turns the belt. Control signals will come from the Raspberry Pi and power will come from the Power Subsystem.

# References and Definitions

Provide any references (i.e., standards documents) and definitions. Examples are shown below.

## References

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| ANSI/NFPA 70 | 2023 | National Electric Code |
| RSS FSR | 1.0/3 October 2022 | Robotic Sorting System Functional System Requirements |
| RSS Conveyor Belt FSR | 1.0/3 October 2022 | Conveyor Belt Functional System Requirements |

## Definitions

CCA Circuit Card Assembly

mA Milliamp

mW Milliwatt

MHz Megahertz (1,000,000 Hz)

TBD To Be Determined

# Physical Interface

## Weight

Conveyor Belt Subsystem will weigh no more than 100 lbs in accordance with RSS ICD section 3.1.1.

## Dimensions

The Conveyor Belt Subsystem shall be no wider than 2.5 ft, no taller than 3 ft and no longer than 6 ft.

## Mounting Locations

### Motor

The conveyor belt motor will be connected to one of the rollers and will be mounted to the side of the frame.

### Robotic Arm Subsystem

The Robotic Arm/Guidance Subsystem will be mounted to the frame of the Conveyor Belt and will be just above the conveyor belt but not touching the belt so as to not interfere with its movement.

# Thermal Interface

The Conveyor Belt Subsystem does not require any sort of thermal interface.

# Electrical Interface

## Primary Input Power

Power delivery will come from the Power Subsystem as specified in the Power Subsystem ICD.

# Communications

## Device Peripheral Interface

Controller signal inputs will come from the Raspberry Pi and go through the PCB. Protocol will be specified as necessary in the Power Subsystem ICD.

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Interface Control Document**

**Power**

REVISION – Draft Release

3 October 2022

Interface Control Document

for

Robotic Sorting System (Power)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Pace Dominy 10/3/2022

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher II, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

**Change Record**

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| **-** | 10/3/2022 | Pace Dominy |  | Draft Release |

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# Overview

The Interface Control Document for the Robotic Sorting System (RSS) Power Subsystem will detail the physical, electrical, thermal and communication interfaces of this subsystem in detail. The Power subsystem will consist of the Printed Circuit Board (PCB) and any wires/connections between subsystems that deliver power to and from the PCB.

# References and Definitions

## 2.1 References

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| ANSI/NFPA 70 | 2023 | National Electric Code |
| RSS FSR | 1.0/3 October 2022 | Robotic Sorting System Functional System Requirements |
| RSS Conveyor Belt FSR | 1.0/3 October 2022 | Conveyor Belt Functional System Requirements |
|  | June 2019 | Raspberry Pi 4 Module B Datasheet |

## 2.2 Definitions

CCA Circuit Card Assembly

mA Milliamp

mW Milliwatt

MHz Megahertz (1,000,000 Hz)

TBD To Be Determined

# Physical Interface

## 3.1 Weight

The Power Subsystem will weigh no more than 5 lbs with the PCB weighing less than 1 lb.

## 3.2 Dimensions

The PCB will be no bigger than 40 and the wiring to and from the PCB shall take up as little space as possible. The wiring will also be color coded as much as possible and be neatly routed.

## 3.3 Mounting Locations

Mounting will be done in accordance with the RSS Power FSR (section 3.2.2.3.).

# Electrical Interface

## Primary Input Power

Primary input power will be 1800 Watts (120 V AC with 15 A) as part of the US National Standard for power outlets.

## Polarity Reversal

Polarity reversal will be allowed for the motor controllers, specifically as an input from the Raspberry Pi 4 to the H-bridges in order to allow control of the rotation direction of the motors.

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Interface Control Document**

**Robotic Arm**

REVISION – Draft

3 October 2022

Interface Control Document

for

Robotic Sorting System (Robotic Arm)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Author Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher II, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

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# Overview

The Interface Control Document for the Robotic Arm Subsystem will detail the physical, electrical and communication interfaces of this subsystem in detail. The Robotic Arm Subsystem consists of the two robotic arms, a pulley system that guides the arms and the supports for the robotic arms.

# References and Definitions

## References

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| ANSI/NFPA 70 | 2023 | National Electric Code |
| RSS FSR | 1.0/3 October 2022 | Robotic Sorting System Functional System Requirements |
| RSS Conveyor Belt FSR | 1.0/3 October 2022 | Conveyor Belt Functional System Requirements |

## Definitions

CCA Circuit Card Assembly

mA Milliamp

mW Milliwatt

MHz Megahertz (1,000,000 Hz)

TBD To Be Determined

# Physical Interface

## Weight

Robotic Arm Subsystem will weigh no more than 20 lbs in accordance with RSS ICD section 3.1.2.

## Dimensions

The Robotic Arm Subsystem shall be no wider than 2 ft, no taller than 5 inches and no longer than 1 ft 4 inches.

## Mounting Locations

### Motor

The motor for the guiding belt will be mounted to the frame of the conveyor belt subsystem.

### Robotic Arms

The Robotic Arms will be connected to two supports that are attached to the conveyor belt subsystem frame and that sit above the conveyor belt. The end of the levers will slant upward so that they can attach to the guiding belt which sits above the conveyor belt.

### Guiding Belt

The guiding belt will sit high enough that fruit can pass under the belt/pulley system. The guiding belt also functions as a support for the Robotic Arms. The ends of the guiding belt will have two rods connected to the conveyor belt frame that the pulleys rotate around in the x-y plane.

# Thermal Interface

The Robotic Arm Subsystem does not require a thermal interface.

# Electrical Interface

## Primary Input Power

Power delivery will come from the Power Subsystem as specified in the Power Subsystem ICD.

# Communications / Device Interface Protocols

## Device Peripheral Interface

Controller signal inputs will come from the Raspberry Pi and go through the PCB. Protocol will be specified as necessary in the Power Subsystem ICD.

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Interface Control Document**

**Sensors**

REVISION – Draft

2 October 2022

Interface Control Document

for

Robotic Sorting System (Sensors)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Lam Tran Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher II, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

**Change Record**

| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| --- | --- | --- | --- | --- |
| **-** | [10/2/2022] | [Lam Tran] |  | Draft Release |

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# Overview

This document will cover details about the physical, thermal, electrical and communications interface of the sensor subsystem for the RSS. The sensor subsystem consists of a RasPi camera, a load cell, and Raspberry Pi. The camera will capture an image of the fruit, and the load cell will weigh the receptacle. These datas will be sent to the Raspberry Pi.

# References and Definitions

Provide any references (i.e., standards documents) and definitions. Examples are shown below.

## References

## 

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| RSS FSR | 1.0/3 October 2022 | Robotic Sorting System Functional System Requirements |
| RSS Sensors FSR | 1.0/3 October 2022 | Robotic Sorting System Sensors Functional System Requirements |
|  |  |  |

## Definitions

mm miltermeter

TBD To Be Determined

# Physical Interface

## Weight

| Component | Weight | Number of Items | Total Weight |
| --- | --- | --- | --- |
| RasPi Camera | 0.106 ounces | TBD | TBD |
| Load Cell | TBD | TBD | TBD |
| Raspberry Pi | TBD | 1 | TBD |

## Dimensions

| Component | Height | Width | Length |
| --- | --- | --- | --- |
| RasPi Camera | 25mm | 23mm | 9mm |
| Load Cell | TBD | TBD | TBD |
| Raspberry Pi | TBD | TBD | TBD |

## 3.3. Mounting Locations

The Raspberry Pi and the RasPi Camera are mounted on the side of the conveyor belt. The load cell is mounted on the end of the conveyor belt, under the receptacle.

# Thermal Interface

The RasPi Camera and the load cell may not need a thermal interface. They are connected to the Raspberry Pi, and it will have a heatsink.

# Electrical Interface

Provide details on the electrical interface. Examples are:

## Primary Input Power

The Robotic Sorting System is powered by a plug in wall outlet. There is an AC to DC converter installed within the system.

## Voltage and Current Levels

| Component | Voltage (V) | Current (mA) | Power (mW) |
| --- | --- | --- | --- |
| RasPi Camera | TBD | TBD | TBD |
| Load Cell | 5 V | TBD | TBD |
| Raspberry Pi | 5V | TBD | TBD |

## User Control Interface

There is an Android Application that connects to the Raspberry Pi via bluetooth. The user has the ability to check if the sensors are working properly.

# Communications / Device Interface Protocols

## Android Application

There is an Android Application that connects to the Raspberry Pi via bluetooth 5.0.

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Interface Control Document**

**Android Application**

REVISION 1

3 October 2022

Interface Control Document

for

Robotic Sorting System (Android Application)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Joseph Miller Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher II, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

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| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| --- | --- | --- | --- | --- |
| **-** | 10/3/2022 | Joseph Miller |  | Draft Release |

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[2.2.](#_heading=h.111kx3o) Definitions 1

[**3.**](#_heading=h.3l18frh) **Physical Interface 2**

[3.1.](#_heading=h.206ipza) Device Range 2

[**4.**](#_heading=h.4k668n3) **Thermal Interface 2**

[**5.**](#_heading=h.2zbgiuw) **Electrical Interface 2**

[5.1.](#_heading=h.1egqt2p) Device-Side Electrical Interfaces 2

[5.2.](#_heading=h.3ygebqi) User Control Interface 2

[**6.**](#_heading=h.2dlolyb) **Communications / Device Interface Protocols 2**

[6.1.](#_heading=h.sqyw64) Bluetooth 2

[6.2.](#_heading=h.3cqmetx) Device Peripheral Interface 2

# Overview

This Interface Control Document (ICD) for the Android application for the Robotic Sorting System (RSS) details the interfaces of the Android application with the outside world and with other project subsystems. This document focuses in detail on the communication between the Raspberry Pi built into the Robotic Sorting System and the Android application.

Because the physical aspects of the Android device itself (except for those components used in the Bluetooth connection) may vary greatly depending on the user’s choice of Android device, most physical aspects are outside of the scope of this ICD. Because the Android device is not physically attached to the RSS, its physical characteristics are dependent far more on user chose than the technical constraints of the RSS (provided that the device meets the hardware requirements specified in Paragraph 4 of the Android Application Functional System Requirements (AAFSR) document.

# References and Definitions

## 2.1 References

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| Bluetooth SIG 5.0 | 5.0/6 December 2016 | Bluetooth Core Specification v5.0 |
| RSS FSR | 1.0/3 October 2022 | Robotic Sorting System Functional System Requirements |
| RSS AAFSR | 1.0/3 October 2022 | Android Application Functional System Requirements |

## 2.2 Definitions

AAFSR Android Application Functional System Requirements

FSR Functional System Requirements

ICD Interface Control Document

RSS Robotic Sorting System

SIG Special Interest Group

# Physical Interface

As mentioned in Paragraph 1, the Android device is not physically attached to the RSS and is provided separately by the operator. For this reason, the weight and size of Android devices may vary greatly but does not affect the operation of the RSS.

## 3.1 Device Range

The range of a Bluetooth connection depends on several factors based on the specifications of both Bluetooth systems. Because the specification of the Android device’s Bluetooth system will vary, a blanket connection range for all configurations cannot be determined. However, to ensure basic usability, the Bluetooth connection will be tested to ensure that it is stable at 2 meters from the Raspberry Pi using a Samsung Galaxy Tab S6 Lite.

# Thermal Interface

The thermal interface for the Android device itself will vary depending on the construction of the device that the user provides. The Raspberry Pi on the RSS has a heatsink integrated as detailed in paragraph 4.1 of the project-level ICD.

# Electrical Interface

## Device-Side Electrical Interfaces

The electrical interfaces on the device side, to include the power source and Bluetooth controller, will vary based on the device provided by the user.

## User Control Interface

The Android application serves as the primary user interface for the Robotic Sorting System. It will present, using a GUI based on Google’s Material Design, relevant diagnostic information and a configuration program that pushes different sorting configurations to the RSS. The user will also start and stop sorting from the Android application. For more information, see paragraph 3.1 of the AAFSR.

# Communications / Device Interface Protocols

## Bluetooth

All communication between the Android device and the Raspberry Pi will use Bluetooth 5.0 as outlined in the Bluetooth Core Specification v5.0. The communication will go both ways: configuration information will be pushed to the RSS and diagnostic and weight information will be pushed to the Android device.

## Device Peripheral Interface

The Raspberry Pi will hand the configuration data imported from the Android device off to the Robotic Arm subsystem, which will then configure the controlling logic to match.

Robotic Sorting System

Pace Dominy

Joseph Miller

Lam Tran

**Interface Control Document**

**Android Application**

REVISION 1

3 October 2022

Interface Control Document

for

Robotic Sorting System (Android Application)

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Joseph Miller Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher II, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

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| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| --- | --- | --- | --- | --- |
| **-** | 10/3/2022 | Joseph Miller |  | Draft Release |

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[2.2.](#_heading=h.111kx3o) Definitions 1

[**3.**](#_heading=h.3l18frh) **Physical Interface 2**

[3.1.](#_heading=h.206ipza) Device Range 2

[**4.**](#_heading=h.4k668n3) **Thermal Interface 2**

[**5.**](#_heading=h.2zbgiuw) **Electrical Interface 2**

[5.1.](#_heading=h.1egqt2p) Device-Side Electrical Interfaces 2

[5.2.](#_heading=h.3ygebqi) User Control Interface 2

[**6.**](#_heading=h.2dlolyb) **Communications / Device Interface Protocols 2**

[6.1.](#_heading=h.sqyw64) Bluetooth 2

[6.2.](#_heading=h.3cqmetx) Device Peripheral Interface 2

# Overview

This Interface Control Document (ICD) for the Android application for the Robotic Sorting System (RSS) details the interfaces of the Android application with the outside world and with other project subsystems. This document focuses in detail on the communication between the Raspberry Pi built into the Robotic Sorting System and the Android application.

Because the physical aspects of the Android device itself (except for those components used in the Bluetooth connection) may vary greatly depending on the user’s choice of Android device, most physical aspects are outside of the scope of this ICD. Because the Android device is not physically attached to the RSS, its physical characteristics are dependent far more on user chose than the technical constraints of the RSS (provided that the device meets the hardware requirements specified in Paragraph 4 of the Android Application Functional System Requirements (AAFSR) document.

# References and Definitions

## 2.1 References

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| Bluetooth SIG 5.0 | 5.0/6 December 2016 | Bluetooth Core Specification v5.0 |
| RSS FSR | 1.0/3 October 2022 | Robotic Sorting System Functional System Requirements |
| RSS AAFSR | 1.0/3 October 2022 | Android Application Functional System Requirements |

## 2.2 Definitions

AAFSR Android Application Functional System Requirements

FSR Functional System Requirements

ICD Interface Control Document

RSS Robotic Sorting System

SIG Special Interest Group

# Physical Interface

As mentioned in Paragraph 1, the Android device is not physically attached to the RSS and is provided separately by the operator. For this reason, the weight and size of Android devices may vary greatly but does not affect the operation of the RSS.

## 3.1 Device Range

The range of a Bluetooth connection depends on several factors based on the specifications of both Bluetooth systems. Because the specification of the Android device’s Bluetooth system will vary, a blanket connection range for all configurations cannot be determined. However, to ensure basic usability, the Bluetooth connection will be tested to ensure that it is stable at 2 meters from the Raspberry Pi using a Samsung Galaxy Tab S6 Lite.

# Thermal Interface

The thermal interface for the Android device itself will vary depending on the construction of the device that the user provides. The Raspberry Pi on the RSS has a heatsink integrated as detailed in paragraph 4.1 of the project-level ICD.

# Electrical Interface

## 5.1 Device-Side Electrical Interfaces

The electrical interfaces on the device side, to include the power source and Bluetooth controller, will vary based on the device provided by the user.

## 5.2 User Control Interface

The Android application serves as the primary user interface for the Robotic Sorting System. It will present, using a GUI based on Google’s Material Design, relevant diagnostic information and a configuration program that pushes different sorting configurations to the RSS. The user will also start and stop sorting from the Android application. For more information, see paragraph 3.1 of the AAFSR.

# Communications / Device Interface Protocols

## 6.1 Bluetooth

All communication between the Android device and the Raspberry Pi will use Bluetooth 5.0 as outlined in the Bluetooth Core Specification v5.0. The communication will go both ways: configuration information will be pushed to the RSS and diagnostic and weight information will be pushed to the Android device.

## 6.2 Device Peripheral Interface

The Raspberry Pi will hand the configuration data imported from the Android device off to the Robotic Arm subsystem, which will then configure the controlling logic to match.

Robotic Sorting System

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**Schedule and Validation Plan**

REVISION 1

3 October 2022



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