ENSC 405W Grading Rubric for Design Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the design specifications with appropriate justification for the design approach chosen. Includes descriptions of the physics (or chemistry, biology, geology, meteorology, etc.) underlying the choices.	**/20%**
Technical Correctness	Ideas presented represent design specifications that are expected to be met. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text). Equations and graphs are used to back up/illustrate the science/engineering underlying the design.	**/25%**
Process Details	Specification distinguishes between design details for present project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Numbering of design specs matches up with numbering for requirements specs (as necessary and possible).	**/15%**
Test Plan Appendix	Provides a test plan outlining the requirements for the final project version. Project success for ENSC 405W will be measured against this test plan.	**/10%**
User Interface Appendix	Summarizes requirements for the User Interface (based upon the lectures and the concepts outlined in the Donald Norman textbook).	**Graded Separately**
440 Plan Appendix	Analyses progress in 405W and outlines development plans for 440. Includes an updated timeline, budget, market analysis, and changes in scope. Analyses ongoing problems and proposes solutions.	**Graded Separately**
Conclusion/References	Summarizes functionality. Includes references for information sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow logically.	**/05%**
Format/Correctness/Style	Includes letter of transmittal, title page, abstract, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted. Correct spelling, grammar, and punctuation. Style is clear, concise, and coherent. Uses passive voice judiciously.	**/15%**
Comments		

March 31, 2018

Andrew H. Rawicz
School of Engineering Science
Simon Fraser University
V5A 1S6

Re: ENSC 405W Design Specifications for PharmaSort's Axis

Dear Dr. Rawicz,

I am writing to you to review PharmaSort's *Design Specifications* document for the *Axis* platform. Our goal is to create a prescription pill sorting machine that, for personal or professional pharmaceutical use, can accurately identify many different types of prescription pills from their bottles and sort them accordingly for consumption.

Attached, this document will explain the system overview, delving into the separate modular sections of *Axis*, such as the software, mechanical, and hardware designs of the integrated system. In addition, this document will cover the implementation considerations that the team will follow to ensure a refined product that will prove to be both economical and professional.

This document will follow the development life cycle of the product, and classify design specifications according to the delivery stages (such as proof-of-concept, prototype, and final product), while keeping in mind the relative priorities of the system.

PharmaSort features five engineering students: Francis Tran, Hazel Monte de Ramos, Freddy Kooliyath, Mirac Chen, and Ananth Prabhu. With all team members bringing very diverse (yet standardized) skill sets, the team is confident that the requirements of this project can be met.

Please do not hesitate to contact us via our designated contact person, Hazel, for any questions or concerns you may have. You can reach her at hmontede@sfu.ca.

Sincerely,

Francis Tran
CEO

Enclosed: *Design Specification* for PharmaSort Axis

PharmaSort

Design Specification for the **Axis***:* A Prescription Pill Sorter and Dispenser

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Issue date:
March 31, 2018
Version 1.0.0

Abstract

Increasingly so, prescription drug use is a large factor in the health maintenance of many Canadians, serving as the second highest expenditure in healthcare with a cost of $29 billion in 2013 [1]. Among the age demographic of medication users, seniors rank the highest [1], and adversively can also be prone to the highest risks. Drug noncompliance occurs irrespective of age, but seniors - who tend to suffer from vision and memory impairment- often fail in adhering to their medication with greater likelihood. Whether it be misuse, or simply failure to read the fine print on labels, consequences are evident- and they can be severe.

The following requirement specification document addresses the details of a possible solution to this issue: Axis. Our aim is to minimize the drug noncompliance in seniors and other potentially disadvantaged demographics (such as rural or Aboriginal communities [2]) by designing a device that can effectively determine and administer the correct pills and dosage at the appropriate day for a single week. This will be accomplished using a fully integrated system of software, hardware, and mechanical sections working in harmony. From a rudimentary level, the system features a keypad and LCD display which will receive information from the user regarding the pill dosage. The internal mechanical structure will be designed to sort the pills by day, pass any excess medication for that week, and dispense accordingly, while the hardware will provide the brains for joining the software and mechanical functionalities.

The following *Design Specification* document will outline the required design specifications for the designs chosen and will appropriately justify the reasons for doing so. Each design will include a description of the underlying mechanics to work collectively in a systematic manner.

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Glossary

Term	Definition
ISO	International Organization for Standardization
UI	User Interface: the medium through which a human interacts with a machine
LCD	Liquid Crystal Display: Electronic display which utilizes crystals that change molecular alignment in order to change the polarization of light
mangOH	A microcontroller manufactured by Sierra Wireless
PCB	Printed Circuit Board: a board that supports electronic components using conductive tracks
PC	Proof of concept
FD	Final design

1 Introduction

In a society with an aging population, PharmaSort strives to improve the quality of life for the elderly persons through the functionality of it’s pill dispensing device, Axis. This device provides solutions for organising, sorting, and consumption of medication in a timely and concise manner. Combining hardware and software, this device takes user input through an electronic keypad in order to determine the frequency and manner pills should be dispensed. An Arduino will be used in conjunction with a keypad and an LCD display in order to create the interact user interface (UI) for the proof of concept. MangOH will then manage the servo motors according to the input information.

The basic purpose of this project is to be able to dispense a given number of pills in daily compartments based on user input. The most significant aspect of this device is the mechanics, which will work in conjunction with an Arduino in order to reliably dispense one pill at a time. These design specifications will outline how and why each component was chosen, and will provide the appropriate power calculations relating to the overall system. Furthermore future sizing of the system will be determined based on what we have currently deduced from the present prototype.

2 System Overview

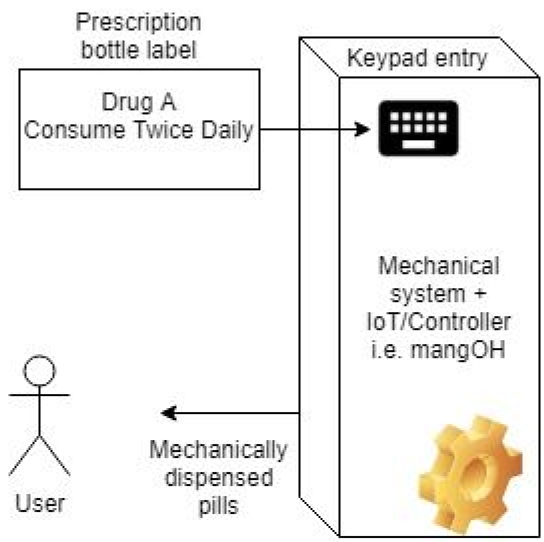

Figure 1: High Level Design of Proof of Concept Model

Two methodologies to determine dosage parameters include a manual entry proposition and a camera sensor alternative (the primary goal of the project). In the proof of concept, a keypad input will be required of the user. This is a mere simplification in order to easily demonstrate the dispensing mechanism. A rough high level diagram of the system can be found in Figure 1. While both can exist harmoniously, the intent of an intelligent system should be to automate as much brute force labour as possible. A rough high level diagram of the final design can be found in Figure 2.

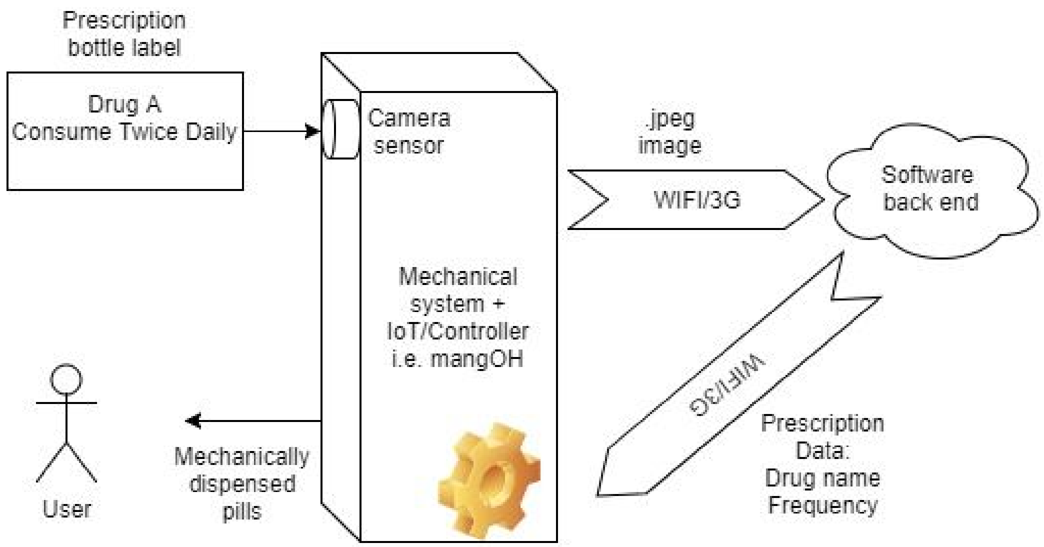

Figure 2: High Level Design of Final Product

Either way, the user prompt system will begin with a simple parameters search modelled after a breadth-first algorithm, eventually expanding to a depth-first model if the pill request increases too much in complexity.

User interface prompting example as shown in Figure 3:

```
Enter pill dosage per day:[N < 10]

Enter dosage frequency: [Every 1/2/3/.../N<7 day(s)]

First day: [Today/Tomorrow/N<7]

Different dosage on recurring day? [No/+1/-1/+N/-N]
```

Figure 3: User Interface Example

For the proof of concept, the system will validate all the user entries by confirming the entry via the pressing of the ‘#’ key. The breadth first search model exits once the user has confirmed the approval of parameters for a simple dispension. For more complex dispensions, there needs to be more algorithmic prompts.

Meanwhile, in the final prototype, the Python engine will make use of algorithmic sorting of parameters received from the bottle label to diagnose the dosage. If the dosage is unreadable or too difficult to prescribe, the system will suggest the user to seek medical professional help to gain safer administration of medications.

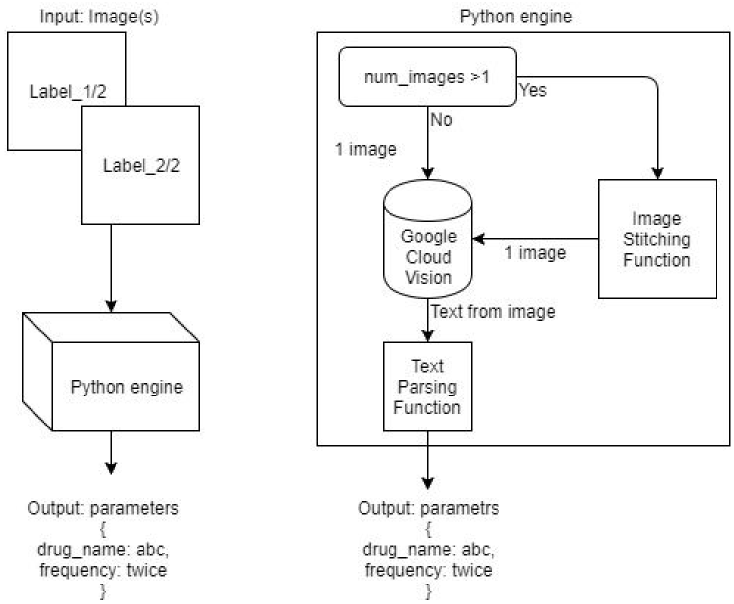

Figure 4: Backend Software System Diagram

Seen above (Figure 4) is a structural diagram of the software backend which will be implemented in the final prototype in order to either completely eliminate, or heavily reduce dependence upon the manual keypad entry. The engine will be running on a back-end server which will be connected to the Google Cloud Vision API and other peripheral libraries such as image uploaders and stitchers.

2.2.1 Mechanical/Hardware Front End Overview

The final proposed design would have the entire system housed inside a spherical combination of pentagons. The structure of the pentagons arranged in a sphere will transfer the impact forces uniformly throughout the structure to minimize shock damage to the system.

The pills will enter the device through a rectangular hopper that narrows down to a square, abstractly depicted in Figure 5. This prevents the pills from being crushed by distributing the forces gradually when being fed into the sorting operation.

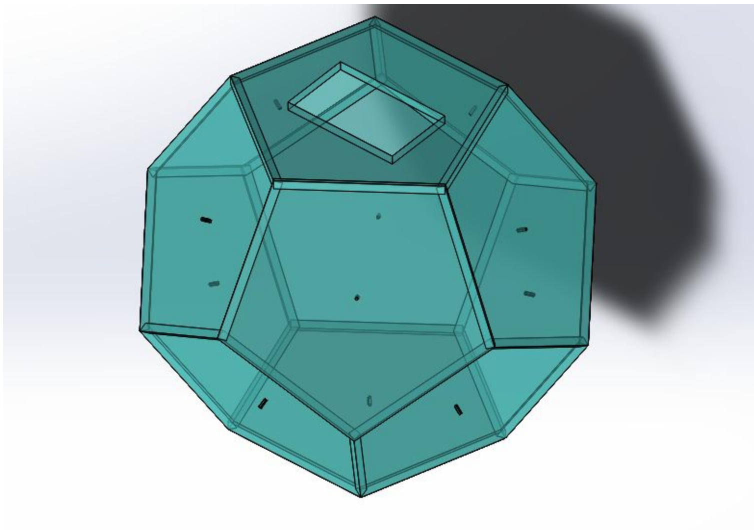

Figure 5: Pentagonal Structure of the Axis Shell Case

The first operation would be to separate the pills one by one to determine what day the patient will have to take the given dosage. The entire bottle of pills is deposited into the rectangular hopper and collected into a square shaped funnel. The narrowing structure will allow the pills to condense and ensure the force of gravity is the predominant factor acting in the depositing of the capsules. There will be mechanisms which will control the side that the pills will go down. If there are an excess amount of pills, then the system will route the pills to their respective destinations. The excess pills tube would lead the pills back to the original bottle which the user will be instructed to place under the dispenser before starting the sorting process.

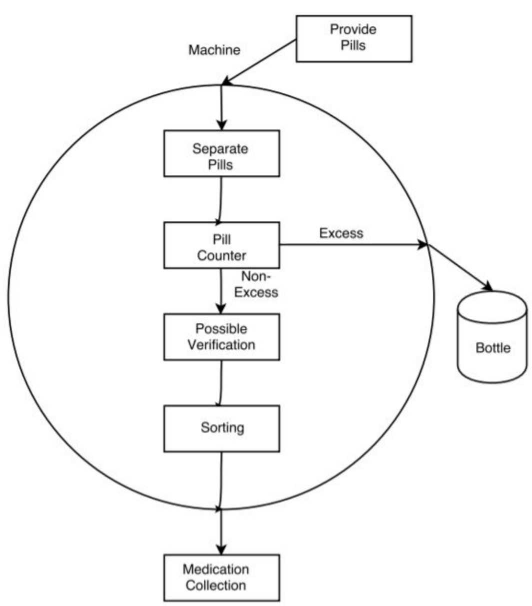

Figure 6: Mechanical System Diagram

As the pills are deposited one by one, they are guided to fall into a circular surface. The pills are sorted by day on this circular surface, which lies at the bottom of the structure. This surface is partitioned into seven sections for each corresponding day of the week, with each section acting as a separate tray. A servo motor will be used to rotate a nozzle in order to align the deposited pill's pathway to the corresponding day on the tray. The tray is expected to be pulled out in a sliding fashion by the user. Figure 6 depicts the mechanical system diagram.

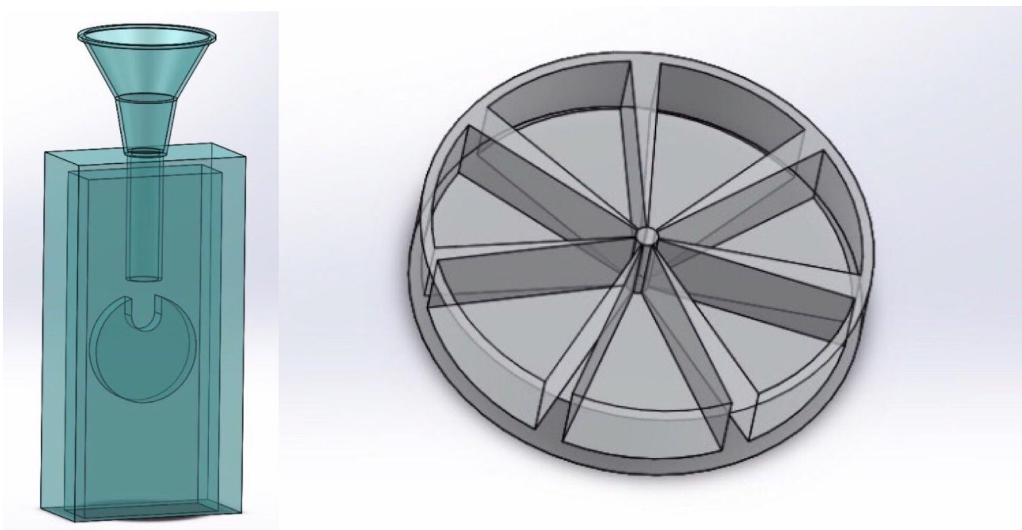

Figure 7: Isometric View of the Pill Dispenser and Pill Tray

Shown in Figure 7 (Left) is the isometric view of our pill dispenser design, and on the right is the pill tray which has slots for each day of the week. This will be fixated to a motor which rotates the base to align the respective day's slot to the pill dropping trajectory from the rotational apparatus.

3 Design Specifications

3.1 General Design

The general design follows the flow chart seen in Figure 8. The main components of the system will be the Arduino, the LCD, the Keypad, the Servo, and the actual mechanical dispensing system. The behaviour of the entire system will be reliant on user input to the keypad. A high level diagram is seen in Figure 8. All these components will be connected through a breadboard for the proof of concept design.

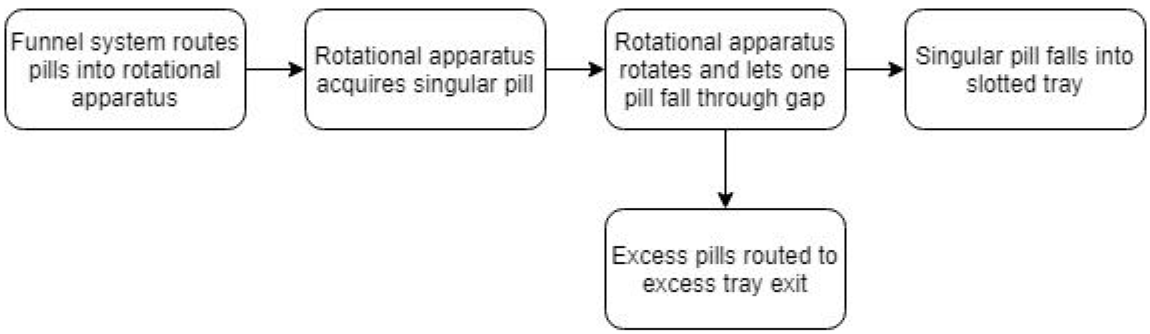

Figure 8: General Design Flow Chart

In the prototype that will be constructed for ENSC 440, the microcontroller and its peripheral units will be elegantly connected and encased to show a professional product with seamless integration. For a manufacturing-grade product, printed circuit board (PCB) methodology would prove to be the most economical, space efficient, and functional solution. Implicitly, this would eliminate the need for breadboards and through hole components, instead favoring surface mounted, compact alternatives.

3.2 Technology Specifications

This design will integrate many different technologies in order to create the dispensing functionality. This section will outline the pre-existing specifications and power requirements in order for each component to operate properly.

3.2.1 mangOH

While the mangOH platform can provide IoT capabilities and various other peripheral advantages, the Arduino development suite boasts the most libraries and ease of use. Since the two platforms can interface seamlessly and the Arduino is very low cost, both will be integrated into the final design as necessary. Ideally, the mangOH can function with reverse compatibility with the Arduino. This is to say that the mangOH can do everything that the Arduino can do, and more. Contingent on the complexity and time, the team will seek to eliminate the Arduino features and migrate it to the mangOH board. As mentioned, it is not detrimental to the project if both boards end up being used in conjunction, simply due to the small space and cost margins.

MangOH platform can provide IoT capabilities and various other peripheral advantages, such as Wi-Fi/Bluetooth/Cellular data connection, built-in sensors etc. We aim to make use of both platforms for our system to function as promised.

An obvious benefit to mangOH's wireless capabilities is the huge market value and functionality that lies behind IoT integration. Functionalities could include reward based systems for users to take pills, or other statistical tracking which can be used by medical professionals to ensure patient compliance and monitor ailment progression.

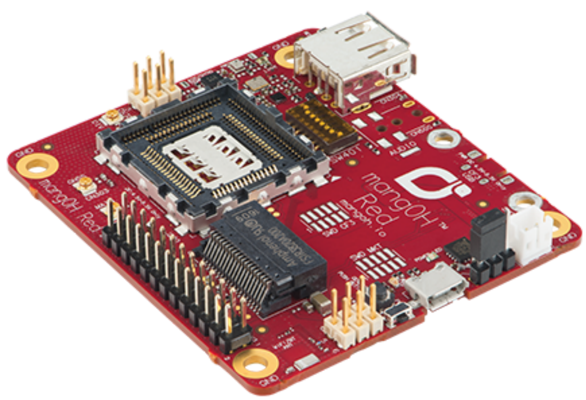

Figure 9: mangOH Red Board [3]

Processor	Cortex M4 RTOS
Cellular connectivity	any 2G, 3G or 4G LTE mobile networks
Wi-Fi	2.4, 5 GHz
Wi-Fi/Bluetooth antenna	1
Audio input	1
µUSB Console connector	1
Pluggable IoT connector	1
Raspberry PI RevB-compatible header	1

micro-SIM slot	1
microSD slot	1
ESIM	1
CF3 module socket	1
Pressure sensor/Temperature sensor	1
Light sensor	1
Width	5.75 cm
Length	6.9 cm

Table 1: mangOH Specifications [4]

3.2.2 Arduino

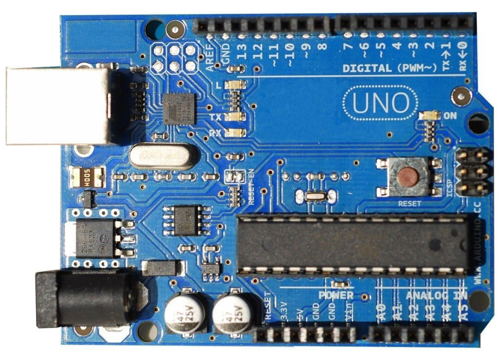

Figure 10: Arduino Uno Rev 3 [5]

The Arduino UNO (Figure 10) is a well known platform featuring the ATmega328P microcontroller. It is used to interface between a user and the mechanics of the system, properly translating desired input into actuation for the servo motor and accompanying peripherals. In the prototype model, pins 0 to 7 are used to connect the keypad. Pins 8 to 11 are used as the data inputs for the 16x2 LCD display. Analog pin A0 is used to control the servo. A B10K solid shaft pot is also connected to the LCD so that the user can control the contrast of the display.

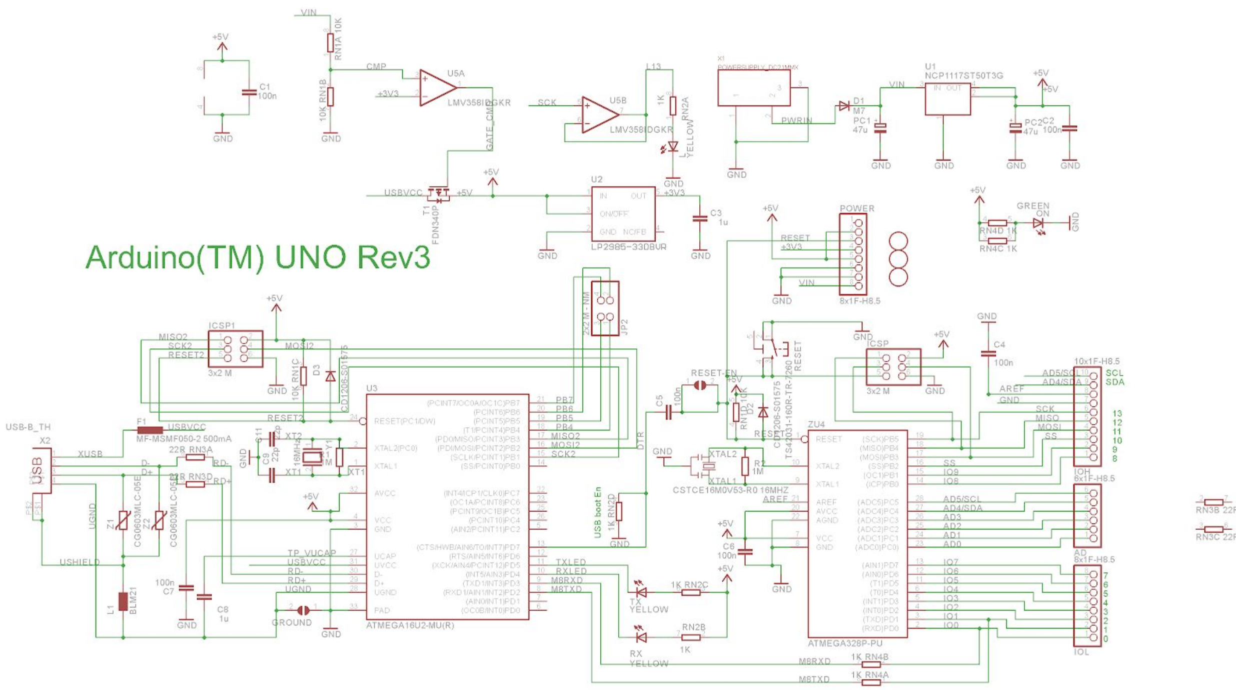

Figure 11: Arduino Schematic Diagram [6]

Seen above in Figure 11 is a schematic which details a reference design for the Arduino UNO Rev3. Although this paradigm features a slightly different microcontroller (ATMEGA8U2-MU), the general functionalities are identical. This schematic shows how the central integration of the microcontroller to the peripherals and accompanying transistors makes Arduino such a favourable platform to test and debug key functionalities on. The components on the board are heavily standardized and understood across a wide user base, resulting in source code also sharing this standardization.

In contrast, for the final product presentation, a mangOH microcontroller will be used instead of an Arduino. The Arduino was chosen for this stage for its simplicity and vast open source libraries. A mangOH microcontroller has similar capabilities of an Arduino, with advanced functionalities. The specifications can be found in Table 2.

Microcontroller	ATmega328P
Operating Voltage	5 V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)

Analog Input Pins	6
DC Current per I/O Pin	20 mA
DV Current per 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P)
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
LEDs (#)	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Table 2: Arduino Specifications [7]

3.2.3 Servo Motor

A SG 90 Servo (fIGURE 12) is used in order to perform the rotational aspects of the system. It's main purposes will be to ensure the proper dispensing of 1 pill at a time, and to ensure that a dispensed pill reaches the correct destination. The specifications of a servo motor can be found in Table 3.

Figure 12: SG90 Servo Motor [8]

Operating Voltage	5 V
Torque	1.80 kg*cm
Speed	500 degrees / sec

Weight	9 g
Dimensions (L x W x H)	23.0 x 12.2 x 29.0 (mm)
Motor Type	3-pole

Table 3: Servo Specifications [8]

In the final design stage of Ensc. 440, servo motors are expected to play a large role in the dispensation of pills. It can be expected that about two will be used in the final design for rotation of the base tray, and dispensing of the pills.

3.2.4 Liquid Crystal Display (LCD)

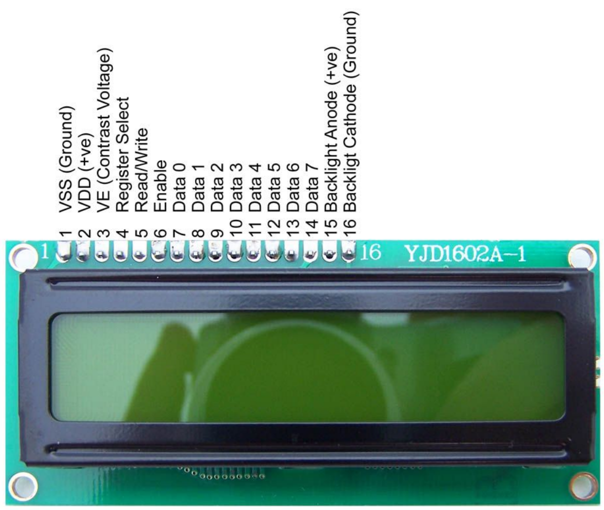

Figure 13: Liquid Crystal Display (LCD) [9]

The LCD display is the primary source of user interaction which is used in the system. The screen displays prompts for the user to enter the respective parameters, and then subsequently displays confirmation messages and other relevant information prior, and during dispensing. The specifications of the LCD display can be found in Table 13.

Supply Voltage	5 V
Dimensions (LxW) cm	8 x 3.58

Table 4: LCD specifications [10]

In the foreseeable future of the final design, it can be anticipated that an LCD may or may not be used for some type of user interface (UI) in order to communicate basic information to the user. This will likely be controlled with a mangOH microcontroller in the final design, but in an emergency situation, it can be easily programmed to work with Arduino.

3.2.5 Keypad

Figure 14: Arduino 4x4 keypad [11]

A 4x4 matrix keypad (Figure 14) will be used to take user input about the number and frequency of pills to be taken. These questions will be specified on the LCD with an appropriate user prompt. Input from the keypad will go into the Arduino, which will determine the manner of dispensation for the servo motor. Refer to Appendix for specific matrix keypad connections and pins. The specifications of the keypad can be found in Table 5.

Maximum Power ratings	24 V, 30 mA
Operating Temperatures	0 - 50 degrees Cels.
Dimensions	6.9 x 7.6 cm

Table 5: Keypad Specifications [11]

In the final design, it would be preferable not to rely on a user input, but the option can always remain open by integration with mangOH. The purpose of the keypad for now is purely for the proof of concept in order for a user to input the number of pills they wish to dispense. The end goal is to have a text recognition replace a keypad input. If it is found that user input via keypad is necessary, its implementation will not be difficult.

3.2.6 Stepper Motor

The stepper motor will act an an actuator that will rotate the base of the pill tray corresponding to the day the pills need to be dispensed. A specs motor is sufficient because the the base and pills are both light. The stepper would need a motor driver in order to reduce the number of pins used by the microcontroller of choice. A stepper motor was chosen as the actuator do to its ability to rotate 360 degrees while also providing precise incremental movements which will be needed to sort the pills accurately.

Operating Voltage	5 V
Steps/Rev	513
Weight	37 g
Holding Torque	150 gram-force*cm
DC impedance/winding	42 ohm
Poles	Unipolar
Max RPM	50
Recommended Operating RPM	25
Dimensions	28mm diameter, 20mm tall nt including 9mm shaft with 5mm diameter

Table 6: Stepper Motor Specifications [12]

3.3 Software Design Specifications

Arduino Code: Arduino Code will be written in the Arduino language which is similar to C. Although C is certainly more versatile, the Arduino language has a lot of documentation online and is very formidable practicality wise due to the extensive user projects and libraries which are generally open source. The Servo, LCD (Liquid Crystal Display), and Keypad libraries will be imported from Arduino. Code will be written to wait for user input from the keypad, which will be translated to the number of rotations for the servo. A rough algorithm flow chart can be found on the next page in Figure 15.

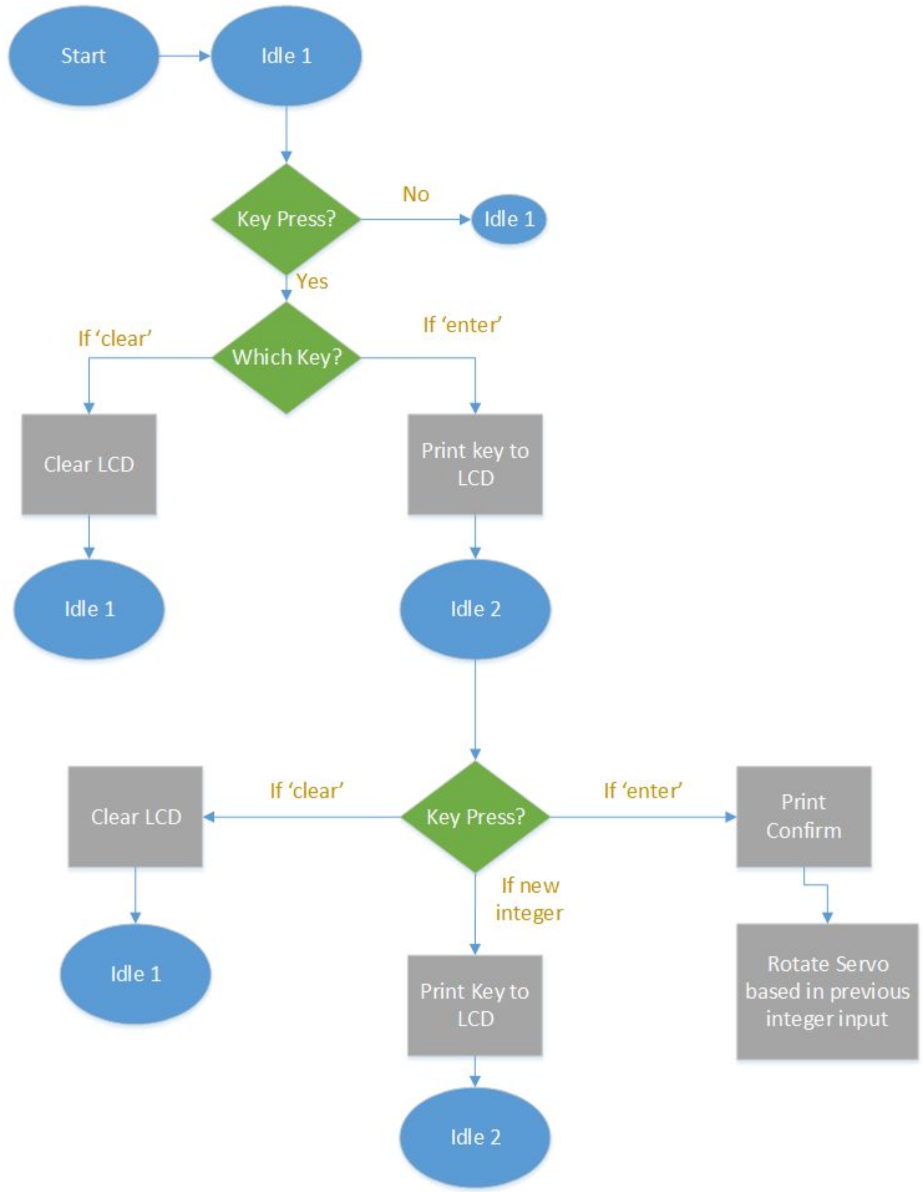

Figure 15: Algorithm Flow Chart

The first idle state is the very initial idle state were the system waits for a user input. If there is no input the system will continue to wait for an input. The second idle state exists for users have a chance to confirm their input. After passing the second idle state, the next confirmation will initiate the dispensation. In the proof of concept model, it will return to an idle type of state, but in the final design, there may be more states added.

3.4 Mechanical Design Specifications

3.4.1 Rotational Base

The length and width of the disc base will be chosen to fit properly into the pentagonal dodecahedron. Each compartment size will be chosen to fit multiple pills. According to the Food Drug Association (FDA), pills are generally not meant to exceed the size of 2.2 cm [13], so a radius of 3 cm would be appropriate to accommodate the general size with an allowance for larger sized pills.

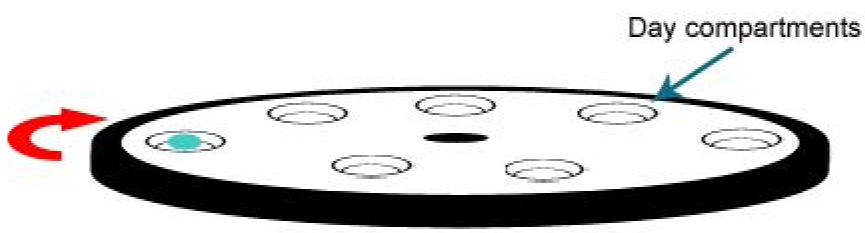

Figure 16: Design Overview of Proof-of-Concept of Rotational Base

Width of rotating base	16 cm
Radius of disc	10 cm
Compartment radius	3 cm

Table 7: Rotating Base Specifications

In the current project design and proof-of-concept, compartments are to be modeled with cups, simplified in Figure 16, however, the final design will feature trays, similar to those seen in Figure 7. The rotating base will be divided into seven sections, corresponding to the days of the week. They will be wide enough and padded in such a way to prevent accidental mixing in between days of the week. The rotational design provides the most efficient way for sorting by day while using the least amount of actuators. The only actuator that will be needed is a motor to rotate the base.

3.4.2 Dispensing Mechanism

The dispensing system will make use of rotational motion to accomplish the output of individual pills; an overview of the system can be seen in Figure 17. The following are the dimensions that the system is proposed to take. The width of the mouth funnel will be large enough so that the pills can be deposited with ease by the user, and should be rounded at the edges to avoid pills from being lodged at the stem. Stem diameter will accommodate the largest diameter of round tablets, which according to the FDA are generally 0.17 cm [13].

Prior to construction for the proof of concept, the following designs were verified to be functional using CAD simulation tools such as Linkage. Their respective designs are displayed below in Figure 17 and Figure 18.

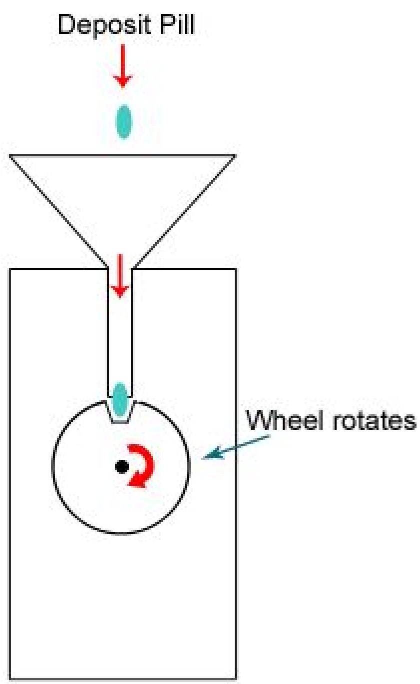

Figure 17: Design Overview of Dispensing System

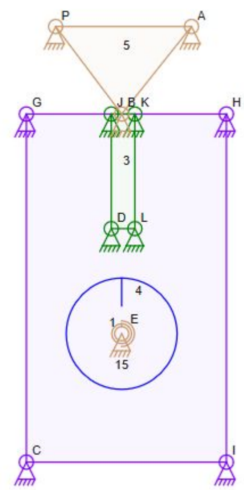

Figure 18: Approximately 30 RPM

Below in Figure 19 is a top view of the rotating base. A nozzle is in place to guide pills into the correct compartment.

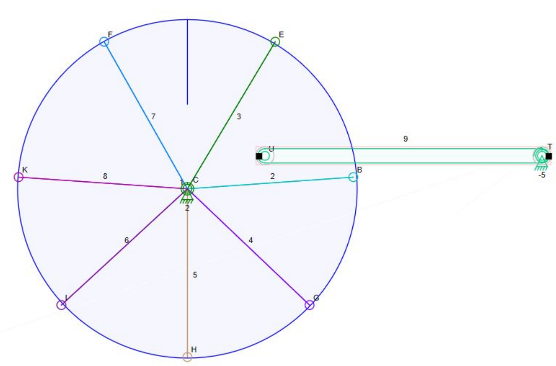

Figure 19: Approximately 2RPM Top View

Height	14.1 cm
Width	10 cm
Thickness	7.8 cm
Radius of rotational wheel	2.35 cm
Thickness of rotational wheel	1 cm
Length of chute of funnel	6 cm
Height of pill dissent from rotating wheel	11 cm

Table 8: Prototype Physical Specifications

In general, all the components mentioned in the technology specifications in section 3.2 will work in conjunction together as follows for a proof of concept model:

Servo Motor: The servo motor we use will be the TowerPro SG90. It generates enough torque to rotate the disk which will serve as the main mechanism for dispensation of 1 pill at a time.

LCD Display: A 16x2 element LCD display is used to display user input prompts from the Arduino.

Breadboard: A standard breadboard is used to electrically connect the parts of the system together. Power comes from the USB cable connecting the Arduino to a computer.

Pills: For testing, tic tacs will be used to simulate the movement of real pills through the system. These were chosen because of their similarity and general homogeneity to the capsule shape.

A diagram of all these functioning together can be found in Figure 20.

3.5 Power Calculations

For the Servo motor, where P is power, I is current, and V is voltage

Operating Power : P = I*V = 220mA*5V = 1.1 W
Max Power : P = I*V = 220mA*5V = 1.4 W
Min Power: P = I*V = 220mA*5V = 0.816 W
Plausible power needed with load: P = 1.2 W

Arduino

Operating Power: P=IV=(500mA)(7V->12V)=3.5W->6W

Plausible power needed with actuators 5.5W

Stepper Motor

Assuming similar to stepper motor,

Plausible Power needed with rotational base load 1.4W

LCD

Operating Power: P=IV=(120mA)(5V)=0.6W

Total Estimated Power= 5.5+1.4+1.2+0.6=8.7 W

(Ignoring any lights or buzzers)

Therefore, a 9V battery will power the microcontroller while a 12V AC/DC adapter will power the actuators. If needed, the power from the adapter will be reduced to operate the actuators sufficiently.

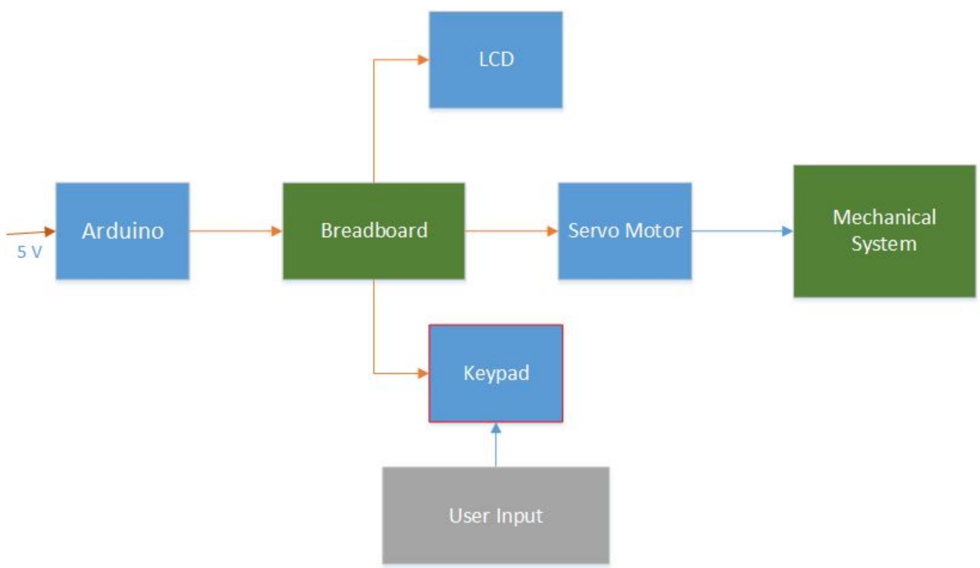

Figure 20: Proof of Concept Technology Interactions (blue arrows: physical change, orange: power)

This design is intended for a proof of concept model. It will feature a user input onto a keypad which will be taken by Arduino and transferred to the servo motor. The servo motor will then dispense that amount of pills one at a time. For this proof of concept however, tic tacs [14] will be used to simulate capsule shaped pills.

It can be expected that a device similar to Figure 20 will be created with some type of 3D printing and used for dispensing of pills. The final design aims to still feature a type of text recognition involving camera scanning and a Python back end. Adjustments will be made to the dispensing mechanism to accommodate for several different sizes of pills. Furthermore, a switch will be made from Arduino to mangOH, a microcontroller by Sierra Wireless.

4 Conclusion

Overall, the *Design Specification* documentation provides a multi-level view and insight into the development methodologies and implementation of the *PharmaSort Axis* platform. In order to ensure seamless development and integration, the team will follow rigorous design procedures to ensure the prototype and subsequent developments of their product will have optimally coupled and functional features. Meanwhile, design procedures have been planned in such ways that milestones will be reached with reasonable time and effort.

Most importantly, the team has approached the design philosophy of this product in such a way that the verification and validation stages of each feature within our test plan will be tested vigorously to ensure a safe and extremely reliable end product. A benefit gained from this includes having detailed schematics, computer models, and mathematical proofs to back up the confidence needed to undertake such a project.

5 Test Plan Appendix

Mechanical Testing

Mechanical tests are to ensure the proper physical interactions between components and elements of the system happen intentionally. Specific test cases can be found in Table 9.

Test	Result	
Dispensing wheel rotates once per second	❒ pass	❒ fail
Pill does not get stuck in transit pipes	❒ pass	❒ fail
One pill is dispensed at a time	❒ pass	❒ fail
Pills fall accordingly to their destination (not a fluke)	❒ pass	❒ fail
Rotational base rotates without hindrance	❒ pass	❒ fail
Trays are able to slide out and slide back in without colliding	❒ pass	❒ fail

Table 9: Mechanical Test Cases

Electrical Testing

Electrical tests are to ensure electrical connections between hardware components are properly and safely powered. Specific test cases can be found in Table 10.

Test	Result	
Arduino is powered with 5V	❒ pass	❒ fail
Servo has 5V	❒ pass	❒ fail
All components are powered and functioning properly	❒ pass	❒ fail

Table 10: Electrical Testing

Hardware Testing

Hardware tests are in place to ensure the electrically dependant components perform their function to satisfaction. Specific test cases can be found in Table 11.

Test	Result	
Servo rotates appropriate angle per rotation	❒ pass	❒ fail
LCD displays correct user prompt	❒ pass	❒ fail
Motor rotates appropriate angle per rotation	❒ pass	❒ fail
Keypad input is accurately reflected on LCD	❒ pass	❒ fail
Camera sensor correctly takes required images	❒ pass	❒ fail

Table 11: Table of Hardware Tests

Software Testing

Software tests are in place to ensure proper translation from computer code to physical functionality in a manner that appropriately suits the needs for this system. The specific test cases can be found in Table 12 below.

Test	Result	
Source code compiles without error	❒ pass	❒ fail
Servo rotates according to user input	❒ pass	❒ fail
Servo rotates at the angle corresponding to the source code	❒ pass	❒ fail

Table 12: Table of Software Tests

User Testing

User tests are in place to ensure that the user is able to utilize the device with success and maximize the full benefit for which its purpose serves.

Test	Result	
User is able to operate the device with no supervision	❒ pass	❒ fail
User feels encouraged to use the device	❒ pass	❒ fail
User is alerted when pills haven't been taken	❒ pass	❒ fail
User is able to understand instructions administered by the device	❒ pass	❒ fail
Disabled user group is able to use the device	❒ pass	❒ fail
User feels safe using the device	❒ pass	❒ fail

Table 13: Table of User Tests

ENSC 405W Grading Rubric for User Interface Design
(5-10 Page Appendix in Design Specifications)

Criteria	Details	Marks
Introduction/Background	Appendix introduces the purpose and scope of the User Interface Design.	**/05%**
User Analysis	Outlines the required user knowledge and restrictions with respect to the users' prior experience with similar systems or devices and with their physical abilities to use the proposed system or device.	**/10%**
Technical Analysis	Analysis in the appendix takes into account the "Seven Elements of UI Interaction" (discoverability, feedback, conceptual models, affordances, signifiers, mappings, constraints) outlined in the ENSC 405W lectures and Don Norman's text (*The Design of Everyday Things*). Analysis encompasses both hardware interfaces and software interfaces.	**/20%**
Engineering Standards	Appendix outlines specific engineering standards that apply to the proposed user interfaces for the device or system.	**/10%**
Analytical Usability Testing	Appendix details the analytical usability testing undertaken by the designers.	**/10%**
Empirical Usability Testing	Appendix details completed empirical usability testing with users and/or outlines the methods of testing required for future implementations. Addresses safe and reliable use of the device or system by eliminating or minimizing potential error (slips and mistakes) and enabling error recovery.	**/20%**
Graphical Presentation	Appendix illustrates concepts and proposed designs using graphics.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	**/05%**
Conclusion/References	Appendix conclusion succinctly summarizes the current state of the user interfaces and notes what work remains to be undertaken for the prototype. References are provided with respect to standards and other sources of information.	**/10%**
CEAB Outcomes: Below Standards, Marginal, Meets, Exceeds	1.3 Engineering Science Knowledge: 4.1 Requirement and Constraint Identification: 5.4 Documents and Graphic Generation: 8.2 Responsibilities of an Engineer:	

6 User Interface Appendix

6.1 Introduction

The following User Interface Appendix documents all requirements necessary to ensure the intended audience clearly and effectively communicates with the device and utilizes its primary function. Sections will outline all required experience the user is expected to have, and the proposed user interface design will be analyzed in depth with "The Seven Elements of UI Interaction" [16] along with all necessary engineering standards. Lastly, analytical and empirical user testing will be included to further assure a positive outcome with our intended design. Considering there are currently two possible designs being optioned for the final design- the confirmed proof-of-concept (PC) involving manual user input and the targeted final design (FD) with the camera sensor- the analysis will take both into account.

6.2 User Analysis

To ensure the viability of our device with respect to the user interface, a user analysis was conducted to allocate the varying degrees of knowledge and experience the user is expected to have. These requirements stem from the underlying functionalities of the Axis, and will ensure success at the user end. The following is a list of necessary requirements:

- User should display enough independence to handle and maintain their own medication
- User should be capable of fine motor skills such as being able to pour the pills into the device and place the bottle in the excess section
- User should be able to read letters and numbers on a LCD of size 6.5 x1.5 cm with or without visual correction
- User should posses basic cognitive skills to understand instructions on LCD (PC)
- User should not have tremors to ensure bottle can be scanned accordingly (FD)
- User should have hearing capabilities to hear a buzzer of roughly 65 dB [15]
- User should have enough dexterity to open the pill bottle

A user will generally be expected to have most of these capabilities. Any user lacking in two or more should contact a person who can perform these tasks in their stead.

6.2 Technical Analysis

The following analysis takes into consideration "The Seven Elements of UI Interaction" from the Don Norman text [16]. These design elements help to create a more user friendly environment in any system, and provide guidance to use the device without explicit words. The team will conform to these principles where possible in order that the device's purpose and function be as clear as possible, maximizing a positive user experience.

6.2.1 Discoverability

In designing the user interface, it is critical that the user be able to discern all possible courses of action of the device and the current state for which it is in- or as specified by Don Norman: "discovering what it does, how it works, and what operations are possible [16]". We intend to structure the device in such a manner that will make it adhere to this principle, beginning primarily by the layout.

A wide opening at the top of the device aims to direct the user to where the pills need to be dispensed. An LCD display will be positioned in the center of the device to ensure that the user clearly identifies where the central point of interaction will be, and a keypad will be placed directly beneath in order that the user understands where the texts prompts displayed on the LCD will be inputted. For the FD, the user will be able to immediately correlate the keypad with the LCD in case corrections need to be made to an incorrect image scan. Furthermore, the strings that the LCD outputs will effectively communicate the current state the device is in- such as when the device is in idle mode, or ready to process the next steps for pill sorting.

6.2.2 Feedback

Critical to the functioning of the device will be the appropriate feedback it returns to the user, in order that they properly understand the system is working as they expect [16]. Taking this into consideration with our own device, the main source of feedback will be the LCD display. Here, the software will be designed as such that the appropriate strings will display either success or errors depending on how the user provides their input. For the PC, when the user inputs the pills, the LCD will display the beginning string prompts, informing the user what information will be needed, providing the user with appropriate feedback as to what stage they are in. In the FD, after the camera has scanned the bottle, the LCD will display all information parsed from the label to let the user know what information was obtained.

6.2.3 Conceptual Models

In order that the device aspects clearly communicate to the user its purpose, conceptual models will be utilized where possible. In order to implement this concept, a better idea is needed of the system, and the current prototype model is simply not enough. Extensive user testing is needed in order to identify user problems, and create work-arounds that can act as intuitive solutions.

6.2.4 Affordances

Designing the user interface will be done in such a way as to consider the affordance of each aspect of the device, in order that the user understands how each part should be used. The wide opening at the top of the device affords as the entryway for the pills, its size and shape appropriately designed to help emphasize this. The opening at the bottom affords as the holder for the pill bottle, for when the excess pills are deposited. The keypad affords as the central means of the user communicating with the device, and the LCD affords as the way for the user to determine its current state. For the FD, the camera sensor will afford to scan the pill bottle for the required information. Internally, a buzzer will be programmed so that it will afford to communicate to the user when their pills are ready for consumption.

6.2.6 Signifiers

Considering the signifiers principle, it is important that the user be able to determine the correct actions that occur for each aspect of the device. The buzzer sound will be implemented to signify to the user that their pills are ready to be consumed. A red LED will flash simultaneous with the buzzer, should there still be pills remaining in the tray by the end of a day. On the exterior, we intend to include small symbols to greater emphasize where pills should be deposited, and where the empty bottle should be placed. Ridges on the edge of the rotational base will signify where the user is to grab and pull the tray so that they may obtain their pills.

6.2.7 Mappings

Something that must be considered in the UI design is known as mapping. The purpose of a good mapping is create an intuitive layout where a user can easily deduce how to control each element of the device. This is a quality that the device should have, particularly since it's catered toward the elderly. In this regard, the design is simple enough to have minimal user interaction. There will not be many functions and controls necessary for the dispensing function.

6.2.8 Constraints

Constraints are elements that help guide the user in a manner that feels natural [16]. Not enough constraints provide too many possibilities which can easily overwhelm a user. This system has a limited possibility to what it can do, namely it aims to read in information from a bottle label, and dispense pills. There are a limited number of simple actions required from a user to make this operation happen. In this manner, the final design confidently meets the constraint criteria described in Don Norman's "Seven Elements of UI Interaction" [16].

6.3 Engineering Standards

Given the nature of the computerized interfacing system, the team will heavily focus on standards pertaining to the interactions which lead to the retrieval of parameters from the user. Due to the fact that these parameters will be trusted on an honor based system for the proof of concept (and in circumstances where the manual keypad entry is allowed in the final prototype), the team will ensure that rigorous validation and structural planning of user interaction takes place.

While the proof of concept relies heavily on the prompting algorithm described in the *Design Specification*, the final prototype will rely on parsing and not as heavily on the user's help to retrieve relevant machine parameters. Special care will be given to the demographic of our user base, and efforts will be taken to make sure that a senior population can easily understand and manipulate the user interface with reasonable dexterity.

Clearly, common sense practices shall be followed to ensure a safe product such as:

- No sharp protruding edges or wires
- No exposed circuitry or internal architecture
- Non-hazardous materials used (especially to avoid pill contamination)
- Simple *user interface prompts* and documentation to encourage fool-proof usage

A widely used industry standard for human-computer interactions is the ISO 9241 from the International Organization for Standardization. Additionally, the International Electrotechnical Commission (IEC) has laid out several guidelines which are recognized as excellent implementation philosophies in user interface design. Especially pertinent subcodes within these standard include:

AWS Cloud	Guidelines for safeguarding user info sent to cloud (received through UI) [17]
IEC TR 61997	Guidelines for the user interface and accompanying ***word choices*** *[18]*
ISO 20282	Ease of operation for everyday products [19]
ISO 9241-210	Guidelines for human-centric user interface design [20]
ISO 9241-303	Requirements for electronic displays [20]
RoHS	Guidelines from European Union on hazardous materials used [21]

Table 14: Engineering Standards

6.4 Analytical Usability Testing

This product should be designed with user experience and quality of life in mind. With this in mind, the user interface and general functions of PharmaSort's Axis will be quite minimal. User prompts and updates shall be implemented in a user-friendly, minimalistic, easy-to-understand manner. The system will not require much cognitive ability from the user, but mainly a small amount of physical dexterity. Furthermore, the alert systems for dispensed pills will be easy to understand and respond to.

In order to obtain quantitative results from our testing, several test cases are proposed with expected results, and a 1-5 rating scale where 1 stands for Strongly Disagree, and 5 is Strongly Agree

1. The device is easily powered on/off
2. The instructions on the interface are easy to understand
3. The layout of the machine is intuitive
4. The device does not pose any structural hazard (not prone to tip over/fall)
5. The user is easily alerted in case of an error
6. The tray can be easily taken out and inserted back in
7. The buttons (keypad) are responsive
8. The machine allows for ergonomic pouring of pills from bottle

There is one safety concern which needs to be addressed. The system must ensure that in the case falling or tipping over, all pills must remain intact, and in the same compartments they had been sorted in to. Otherwise, there are not too many other cases; all microcontrollers and servo motors will be securely fixed against the inside wall.

6.5 Empirical Usability Testing

It is extremely important that Axis undergoes extensive user testing in order to ensure that it provides quality performance. During the proof of concept stage, functionality and user interface testing will be extremely limited. This is because the interface will be very minimal. Although this is the case, we plan still plan to have several user test cases, but they will likely be other engineers found at SFU. This is to ensure that it is in fact possible to use the device. We are fully aware that an engineer has a very technical background which does not reflect the general market that is being targeted with this.

In development, we have several resources which can be used to give feedback and research help to our project. These include, but are not limited to:

- Family members and friends (especially elders/grandparents)
- SFU Department of Gerontology
    - A department devoted to the scientific study of old age, the process of aging, and the particular problems of old people
- Senior societies
- Medical professionals (especially pharmacists)

In the future when the final product is complete, the test audience will be expanded to include elderly, as well as middle aged people. This is to observer the non-technical user experience which overall will likely prove as the most valuable test audience. During this time, a user experience analysis will be taken with similar criteria to the Don Norman's "Seven elements for UI Design" [16]. Further criteria will be added to this analysis, such as recoverability, and physical safety. These tests help to identify potential hazards or risk causing factors in the device that were overlooked during the design period. Testers will be asked to rate the usability of the system based on the previously described criteria. If there is time before the deadline, changes will be made to accommodate feedback, and the testing process will repeat.

6.6 Conclusion

Currently the prototype consists of a cardboard structure holding together servo motors and an Arduino. A breadboard is used to electrically connect all components with jumper cables. The servo motor is connected to a disk with a slot in which a tic tac will fall. The size of the slot is such that only one tic tac will fit in per cycle. The the servo rotates, the tic tac will fall into a tray. Tic tacs are fed into the slot through a straw. An overview of the current prototype can be seen in Figure 21.

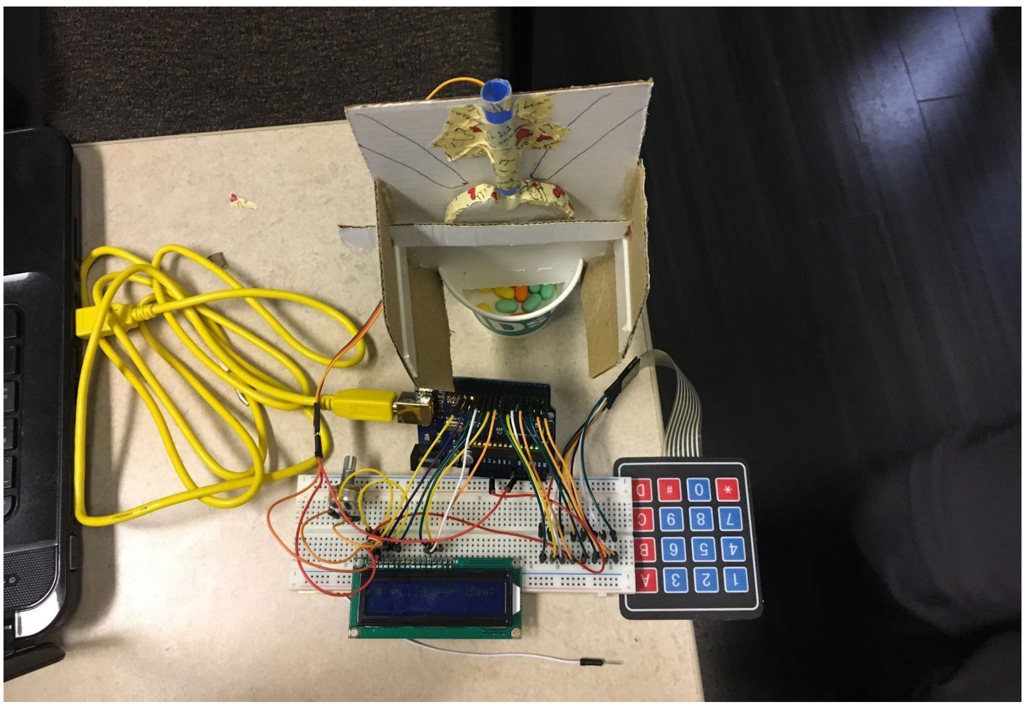

Figure 21: Proof of Concept Model as of March 25, 2018

Future work includes 3D printing of the actual shell and exterior walls. The cardboard will be replaced with 3D print material and the Arduino will be replaced with mangOH microcontroller. Furthermore, designs are in the making to dispense different sized pills rather than one size of tic tac. As well, text recognition software and the Python backend will be added to the system in order to parse information on the label. A camera will also be added for this purpose. This is the current foreseen future work, however, other features may be added if the timeline allows.

ENSC 405W Grading Rubric for ENSC 440 Planning Appendix

(5-10 Page Appendix in Design Specifications)

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project. Includes clear project background.	**/05%**
Scope/Risks/Benefits	Clearly outlines 440 project scope. Details both potential risks involved in project and potential benefits flowing from it.	**/10%**
Market/Competition/ Research Rationale	Describes the market for the proposed commercial project and details the current competition. For a research project, the need for the proposed system or device is outlined and current solutions are detailed.	**/10%**
Personnel Management	Details which team members will be assigned to the various tasks in ENSC 440. Also specifically details external resources who will be consulted.	**/15%**
Time Management	Details major processes and milestones of the project. Includes both Gantt and Milestone charts and/or PERT charts as necessary for ENSC 440 (MS Project). Includes contingency planning.	**/15%**
Budgetary Management	Includes a realistic estimate of project costs for ENSC 440. Includes potential funding sources. Allows for contingencies.	**/15%**
Conclusion/References	Summarizes project and motivates readers. Includes references for information from other sources.	**/10%**
Rhetorical Issues	Document is persuasive and demonstrates that the project will be on time and within budget. Clearly considers audience expertise and interests.	**/10%**
Format/Correctness/Style	Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted. Correct spelling, grammar, and punctuation. Style is clear, concise, and coherent.	**/10%**
Comments:		

7 440 Planning Appendix

7.1 Introduction

In order to keep the project objectives clear and to ensure that key requirements are not delayed or completely sidetracked, the team has embraced a strategy to review and solidify requirements. This may entail micromanaging certain features or making sure that certain features are developed concurrently.

To aid with this strategy, the following sections will detail scope analyses, market research, and time/team management along with the budgetary aspects of the project. These factors have been planned in such a way that the risk of slippage is heavily reduced, and any deviance from plan can be quickly corrected as so to lose as little time as possible.

7.2 Scope, Risks, and Benefits

In the pursuit of a final product, the team will make use of 3D printing services to create a compact design. The team will also explore the use of a hand soldered circuit board to reduce the bulk of the breadboard used in the proof of concept. Furthermore, extensive research will be done in the field of image stitching and scanning cameras. This is in order to implement the original design which included text recognition and label parsing.

Although several new features are being considered, the risks of a device generally remain the same. That is, risk of mixing up medication, or missing a dose on a given day. On the other hand, benefits of such a device with these features will increase. There will be less of a dependence on user input. This is an attempt to minimize risk associated with users. However introducing this means that the system has to function perfectly 100 percent of the time.

7.3 Market Research

According to an article in the National Center for Biotechnology, it is estimated that a range of 40% to 75% of drug noncompliance exists within the elderly community [22], with age related health issues being one of those reasons.

Age-related Macular Degeneration (AMD) associated with age, currently stands as the number one reason for vision loss in Canada [23], and since prescription labels can often have small print, it can be significantly challenging for an older individual to correctly decipher the instructions or identify the medication itself. In terms of memory related issues, about 40% of those above the age of 65 demonstrate some form of memory loss [24], and about 7.6% among the age 75 and above sustain memory disabilities [25]. Challenges in being able to recall if a pill was taken, can lead to overuse or underuse of medication, and with most seniors taking multiple pills in a single day, this can become increasingly problematic.

Moreover, a study involving participants aged 70 and older showed that among the 95% that experienced problems taking their medication, a few of those problems included reading and understanding instructions and simply taking the medication [26].

Additionally, since the end design boasts a 3G/4G SIM slot, a data connection is feasible for rural Aboriginal, or otherwise remote areas. This could help administer medications to populations which do not have a readily available pharmacist to assist in dispensing. In these cases, the label of the medicine can even be updated via reprint and sticking on the bottle. The pharmaceutical resources available to rural and Aboriginal communities is definitely lacking, according to studies [27].

Analyzing this background information, and assessing the problems of medication adherence, our primary market focus will be the elderly, particularly those who live alone and require prescription medicine frequently (though we do perceive that there is a potential market among other demographics). As well, we expect that the senior population in Canada will continue to grow, seeing as their numbers have substantially increased in the past years [2]. Table 15 shows how the demographic has seen an incline from 2000 to 2010, which is sure evidence to us that the Axis will be marketable.

Although drug noncompliance is not exclusive the elderly, as personal opinions and decisions of the individual play a large role, a device such as Axis is a sure shot solution to those who simply need an inexpensive yet effective solution to help take their medication.

	2000		2010	
	Males	Females	Males	Females
65 to 69	549,849	592,079	712,574	756,351
70 to 74	458,800	546,223	519,504	585,046
75 to 79	334,483	470,538	412,120	500,247
80 to 84	184,298	311,022	283,842	404,310
90 and older	32,319	96,045	59,374	158,762
Total Number	**1,648,478**	**2,203,481**	**2,138,036**	**2,681,565**

Table 15: The Numbers of Senior Citizens in Canada [28]

7.4 Personnel Management

The team intends to continue keeping their duties divided as per the planned ENSC 405 protocol.

Briefly, this entails:

Ananth Prabhu: Software frontend (mangOH support and debugging) and backend (Python engines and API). Responsible for software functionality, integration, and high level system diagrams.
Ananth's experience includes software development co-ops and general background working with API's and documentation.

Francis Tran: Software support, electrical design, image processing, microcontroller support. Responsible for image stitching algorithms, implementation, and algorithm flowchart design.
Francis' experience includes image processing, MATLAB development co-ops and background working with hardware and biomedical applications.

Freddy Kooliyath: Electrical and mechanical design, 3D design and printing. Responsible for mechanical design and CAD diagrams.
Freddy's experience includes machine/robotics development co-ops and excellent understanding of lab equipment, power tools, and 3D printing and design.

Hazel Monte de Ramos: Electrical and mechanical design. Responsible for electrical design and overall documentation aesthetic.
Hazel's experience includes software development and testing co-ops and general background working with computer aided design and documentation.

Mirac Chen: Software frontend (mangOH), microcontroller support. Responsible for internet connectivity, and specializing in mangOH.
Mirac's experience includes software development co-ops, app and web development, and working with IoT/firmware integration at Sierra Wireless (mangOH division)

Although the above roles are reasonably solidified, the team was constructed with a desire for both individuals with diverse skill sets **and** individuals with flexible, overlapping skills. As the team proved in the construction of the proof of concept, there have been no issues when team members needed to switch responsibilities to deal with sidetracked/late features.

7.5 Time Management

The team intends to keep following the prescribed Gantt chart once the project has been streamlined back into the intended path seen in Figure 22. It combines both ENSC 405W and ENSC 440 to compare for schedule slippages and differences going into ENSC 440.

ID	Task Name	Duration	Start	Finish
1	**Project Idea**	**29 days**	**Fri 17-12-22**	**Wed 18-01-3**
2	Brainstorming	17 days	Fri 17-12-22	Mon 18-01-1
3	Research/Planning	29 days	Fri 17-12-22	Wed 18-01-3
4	Finalized Idea	0 days	Wed 18-01-3	Wed 18-01-3
5	**Documentation**	**61 days**	**Mon 18-01-1**	**Mon 18-04-0**
6	Proposal	13 days	Mon 18-01-1	Wed 18-01-3
7	Requirements Specification	15 days	Thu 18-02-01	Wed 18-02-21
8	Design Specifications	25 days	Thu 18-02-22	Wed 18-03-2
9	UI Design Appendix	25 days	Thu 18-02-22	Wed 18-03-2
10	Poster	8 days	Thu 18-03-29	Mon 18-04-0
11	ENSC 405W Completion	0 days	Mon 18-04-0	Mon 18-04-0
12	**Software Design**	**48 days**	**Thu 18-02-01**	**Mon 18-04-0**
13	Panoramic Image Stitching	7 days	Thu 18-02-01	Fri 18-02-09
14	Character Parsing	14 days	Sat 18-02-10	Wed 18-02-2
15	SIM Card Implementation	5 days	Thu 18-03-01	Wed 18-03-07
16	Testing	23 days	Thu 18-03-08	Mon 18-04-0
17	Software Design Completion	0 days	Mon 18-04-0	Mon 18-04-0
18	**Hardware Design**	**62 days**	**Thu 18-03-01**	**Fri 18-05-25**
19	Pill Feeding Mechanism	17 days	Thu 18-03-01	Fri 18-03-23
20	Pill Seperating	16 days	Sat 18-03-24	Fri 18-04-13
21	Daily Compartments	12 days	Sat 18-04-14	Sat 18-04-28
22	Shell	9 days	Sun 18-04-29	Wed 18-05-0
23	Testing	12 days	Thu 18-05-10	Fri 18-05-25
24	Hardware Design Completio	0 days	Fri 18-05-25	Fri 18-05-25
25	**Electronic/Firmware Design**	**51 days**	**Fri 18-04-20**	**Sat 18-06-30**
26	Pill Counting Mechanism	16 days	Fri 18-04-20	Fri 18-05-11
27	Excess Pill Removal	7 days	Sat 18-05-12	Mon 18-05-2
28	Dispensing	9 days	Tue 18-05-22	Fri 18-06-01
29	Pill Bottle Label Scanner	11 days	Sat 18-06-02	Fri 18-06-15
30	Testing	12 days	Sat 18-06-16	Sat 18-06-30
31	E/F Design Completion	0 days	Sat 18-06-30	Sat 18-06-30

Figure 22: Project Schedule Gantt Chart

Any slippage in the schedule will be compensated for through extra working hours during the next week. This is in place to avoid a snowball effect of falling behind.

7.6 Budgetary Management

Overall, the cost of the final project has not changed very much since the project proposal. Several servo motors will be needed as well as 3D printing services from SFU. Integration with mangOH would have proven costly, but Sierra Wireless will be sponsoring the project so long as the mangOH microcontroller is being used.

	Estimated cost per unit	Total Cost
Servo motors (~4)	$15	$60
3D Printing (SFU)	$0.03/gram and $1/hour	$50
Stepper Motor (5V)	$20	$60
Sensors (Including a camera)	$150~200	$200
SIM card subscription (data)	$10-20/month (free if you have Wi-Fi)	$20
Power Supply	$50	$50
Overall + Contingency cost (20%)		$528

Table 16: Budget Breakdown

Allowing for a 20% overshoot in contingency costs, the estimated project cost (if all components are newly purchased) comes in at $528. Insofar as our personal project has gone, our team has currently not spent any money, and has been using personal resources. The team will continue to use their own resources but also tap into the existing Sierra Wireless funding if necessary.

7.7 Conclusion

The development of the project was embarked to create a device that would ensure the benefit of seniors in relation to drug non-compliance. Researching the issues that seniors faced, such as vision impairment and memory loss, gave us a better understanding on the issue we were determined to solve, and allowed us to consider these aspects as we designed our requirements. Presently, we have grasped a better understanding on the software and mechanics for which we will be utilizing by being able to complete a proof-of-concept model of the single pill dispensing mechanism. Considering the continuation of our project in 440 we intend to develop the exterior of our prototype using 3D printing, and expect to continue more research into image stitching in order to realize our initial design of scanning the pill bottle. In terms of time management, our Gantt chart will aim to keep us on track, although we are prepared to pour in extra hours should we find ourselves falling behind this plan. Furthermore, our target budget gives us a good grasp on what parts we expect to obtain and keeps us aware of how we will manage funding.

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