Critical Design Review

Smart Pill Box

Oklahoma State University

Senior Design Spring 2023

Overview

Introduction
Project Description
Constraints
Electrical Components
- Parts

Hardware Design
- Components
- Testing

Software Design
- Frontend & Backend

Cost Analysis
Project Plan
Risk Management
Hazard Analysis
Work Distribution
Questions

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3/2/2023

Team Introductions and Roles

Hardware Manager:
- Zarek Rooker
  E.E & C.E.

Assignment:
- Point of Contact
- Hardware
- Electronics

Circuit Designer:
- Zahra Alnahwi
  E.E

Assignment:
- Component Research
- Hardware
- Electronics

Backend Dev:
- Stephen Fransen
  E.E

Assignment:
- Software
- Server Building

UI Designer:
- Daniel Jacobs
  C.E.

Assignment:
- Software
- User Interface

Project Description

Project Vision:

The main vision of this project is to provide an efficient and safe way to manage medication for elderly patients, especially those with cognitive decline, memory loss, and visual impairments. The Smart Pill Box (SPB) can help them to take medication correctly and on time, reduce medication errors, and provide a better way for caregivers to monitor the medication adherence. The SPB can also provide a more convenient, user-friendly, and cost-effective solution compared to other existing solutions.

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Design Constraints

Specifications

1. Store medicine for 7 days and for morning, noon, and evening
2. Lock/Unlock mechanism for medication
3. User interface with a touch screen
4. Speaker to remind the user to take medication
5. Camera to capture images of the user taking medication
6. Send notifications to caregivers upon completion of medication-taking
7. Store medication data in a remote cloud server

Optional:

1. Recognize pill types and quantity through images taken by the camera (optional)
2. Support user authorization through face recognition or fingerprint (optional)

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Consideration and Constraints

Statistics to Consider:

- Average Adult takes 4 prescription medication
- More than four in ten older adults take five or more prescription medications

Target Audience:

- Elderly Patients

Considerations:

- Ease of use: The design should be intuitive and easy to operate, allowing elderly users to quickly and easily access their medication
- Lower risk of medicine contamination
- Lower risk of accidental ingestion of medication
- Accommodating for all

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Consideration and Constraints

Environmental:

- Energy efficient.
- Recyclable/Compostable

Sustainability:

- Long life span
- Refurbish/Reusable

Global:

- Meets regulatory standards
- Meets safety and performance requirements

Health:

- Safe for Use
- Properly Locking
- List Medications

Social:

- Accessible and useable for all

Ethical:

- Ethically produced and sourced

Safety:

- Electrical shock or fire
- Sharp edges & hazards

Cultural:

- Appropriate for target audience

Professional:

- Meets industry standard

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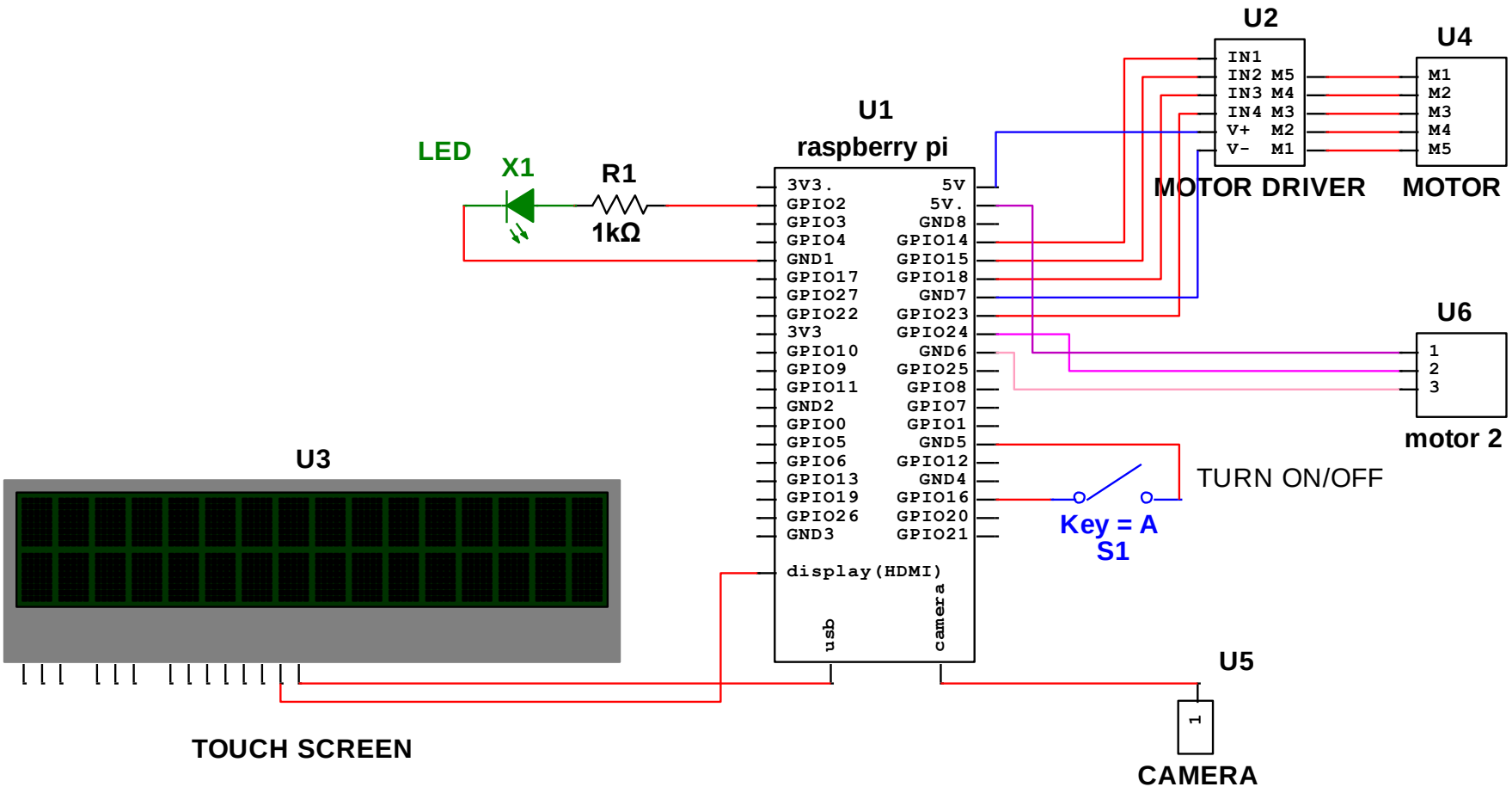
Schematic



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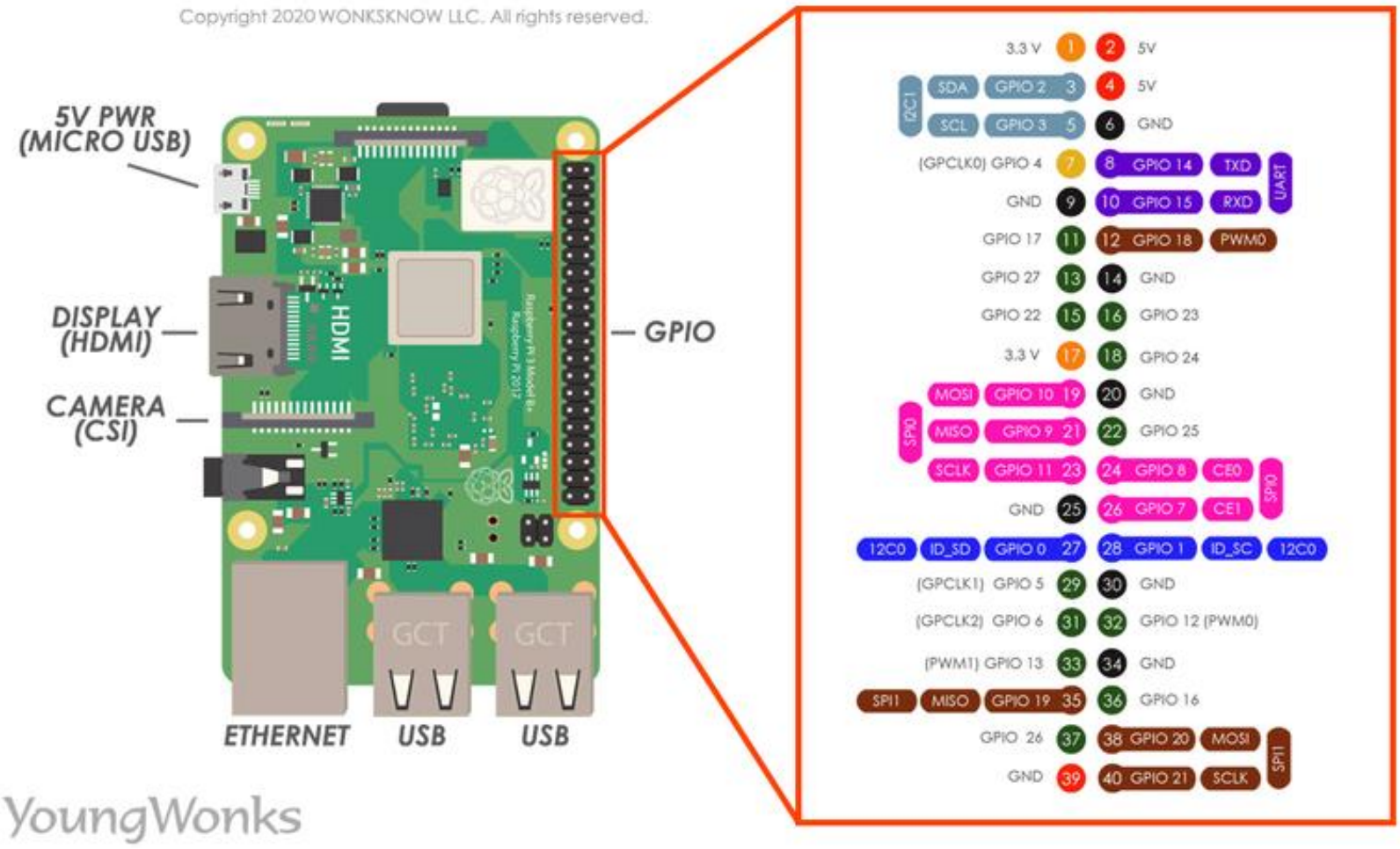
Pins Layout



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POWER CONSUMPTION

Part	Voltage	Voltage Source	Max Drawn Current	Max Power Consumption
1- Raspberry Pi	5.1 V	Official USB-C power supply	0.6A - 1.2 A *See below tables*	3.06W - 6.375 W *See below tables*
2- Camera	3.3 V	Raspberry Pi (Camera Connectors available)	0.12A - 0.42A	0.4W - 1.4 W
3- Touch Screen	5 V	Raspberry Pi (USB)	0.5A	2.5 W
4- Motor (Stepper Motor + Driver)	5 V	Motor Driver *Driver is power by Raspberry Pi (GPIO pins)*	0.24 A	1.2 W
5- Motor (Servo Motor)	5 V	Raspberry Pi	0.01A	0.05W
6- LED + Resistor	3.3 V	Raspberry Pi GPIO pins	0.002A - 0.01A	0.0066W - 0.033W

Total Estimated Max Power Consumption	**11.558W**

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Raspberry pi Power Requirement

Typical Power Requirements

The specific power requirements of each model are shown below.

Product	Recommended PSU current capacity	Maximum total USB peripheral current draw	Typical bare-board active current consumption
Raspberry Pi 1 Model A	700mA	500mA	200mA
Raspberry Pi 1 Model B	1.2A	500mA	500mA
Raspberry Pi 1 Model A+	700mA	500mA	180mA
Raspberry Pi 1 Model B+	1.8A	1.2A	330mA
Raspberry Pi 2 Model B	1.8A	1.2A	350mA
Raspberry Pi 3 Model B	2.5A	1.2A	400mA
Raspberry Pi 3 Model A+	2.5A	Limited by PSU, board, and connector ratings only.	350mA
Raspberry Pi 3 Model B+	2.5A	1.2A	500mA
Raspberry Pi 4 Model B	3.0A	1.2A	600mA

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Raspberry pi Power Requirement

This is the typical amount of power (in Ampere) drawn by different Raspberry Pi models during standard processes:

		Raspberry Pi 1B+	Raspberry Pi 2B	Raspberry Pi 3B	Raspberry Pi Zero	Raspberry Pi 4B
Boot	Max	0.26	0.40	0.75	0.20	0.85
	Avg	0.22	0.22	0.35	0.15	0.7
Idle	Avg	0.20	0.22	0.30	0.10	0.6
Video playback (H.264)	Max	0.30	0.36	0.55	0.23	0.85
	Avg	0.22	0.28	0.33	0.16	0.78
Stress	Max	0.35	0.82	1.34	0.35	1.25
	Avg	0.32	0.75	0.85	0.23	1.2
Halt current				0.10	0.055	0.023

Boot State: is the state when the Raspberry Pi is starting up

Idle State: is the state where the Raspberry Pi is on but not doing anything

Stress State: Stress testing is simply running a series of processes on your system which are designed to run the CPU at full power, and monitor the temperature and stability of the system.

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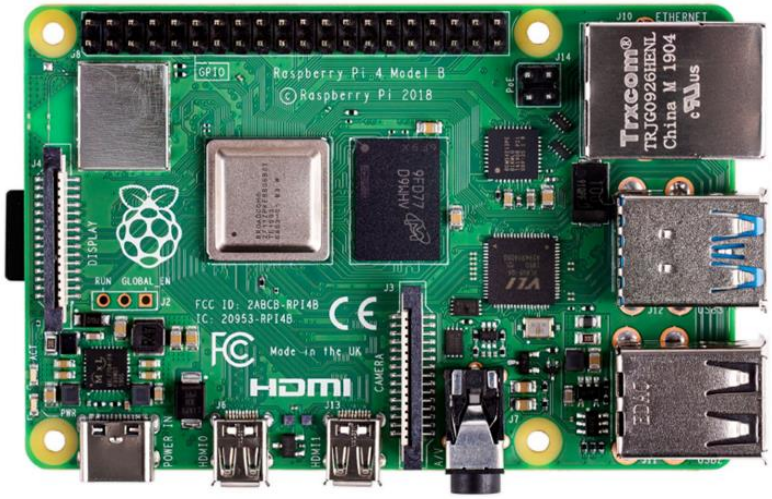
Microcontroller

RASPBERRY PI 4B/4GB

- Can run on 5V/3A DC or 5.1V/ 3A DC
- 40 Digital I/O Pins
- Each GPIO pin could output up to 16mA at 3.3 V
- All GPIO pins together should not exceed 50mA
- Programmed using python



$149

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Touch Screen and Speaker

5” Touch screen

- Touchscreen IPS Display 800x480 USB Powered HDMI Monitor
- Built-in Speaker & Stand for Raspberry Pi Jetson Nano Win PC
- Unite weight : 8.1 ounces

1 x HDMI to Micro HDMI Connector (for RPI 4B)

1 x USB to Micro USB Connector (for RPI 4B)

$61.99

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Camera

Raspberry Pi Camera Module 3

- Power consumption : 0.4 W – 1.4W
- The camera uses power supply from the Raspberry Pi
- Resolution: 11.9 megapixels

$25

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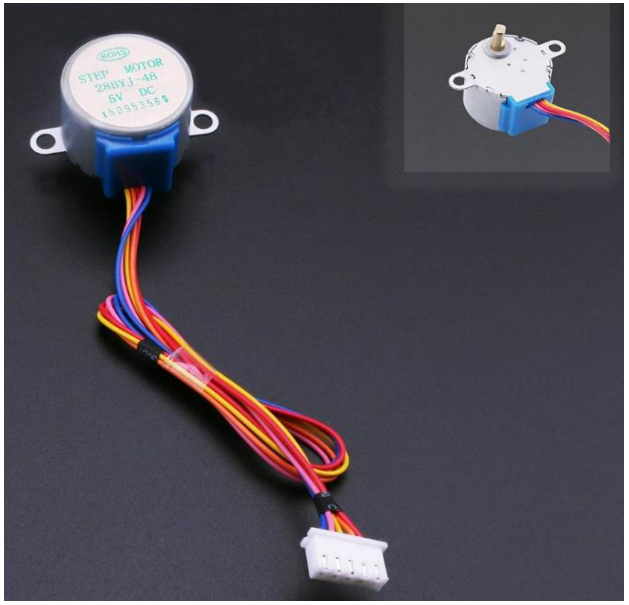
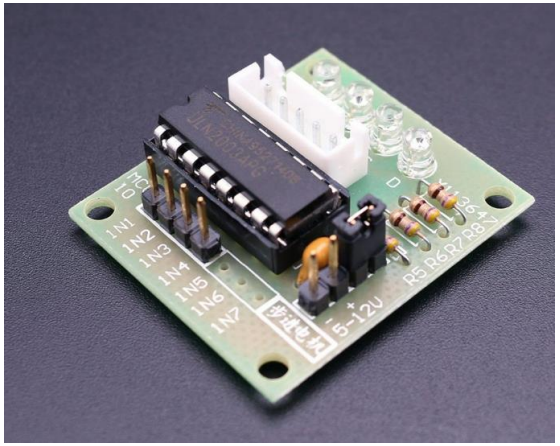
Motor 1

Stepper Motor

- The motor will connect to the driver motor
- The motor and the driver need 5V input
- Both draw 240mA
- Unite weight : 10.4 Ounces





$14.99

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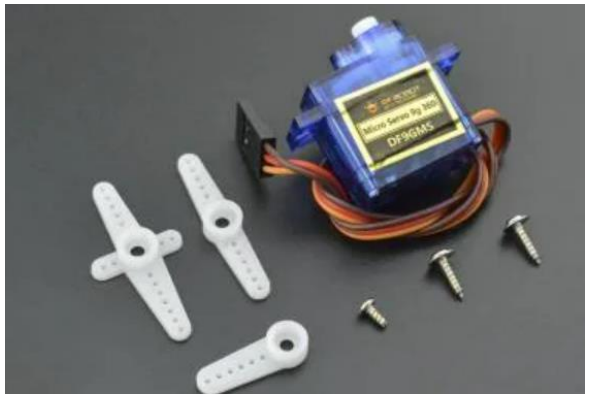
Motor 2

DFRobot Accessories TowerPro SG90C 360 Degree Micro Servo

- the motor need 5V input
- The motor draw 10mA
- Unite weight : 0.352740 oz



$4

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LED

- 1K Ohm resistor
- LED (60mA)

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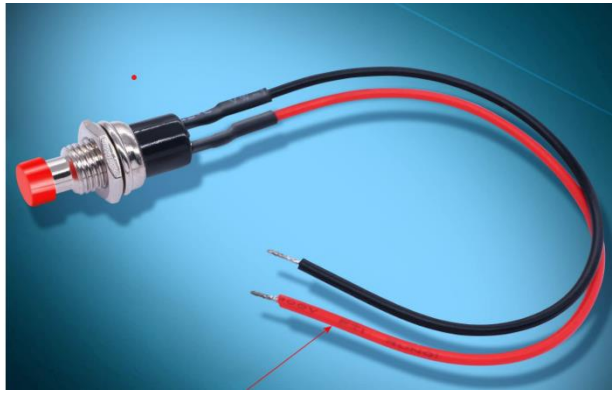
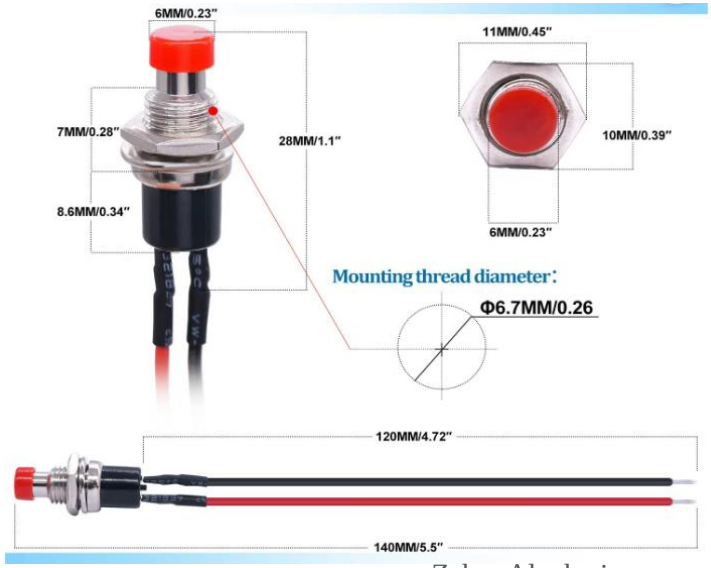
Power Switch

Push Button Switch

- The Raspberry Pi does not have a power button
- Users cannot just unplug the Raspberry from the wall. By doing that, anything that's written to the memory will become corrupted.
- Connect the switch (Normally Open SPST) to 1 GPIO pin and 1 GND pin
- Write a script on the Raspberry Pi to safely shut it down when the button is pressed
- Once the switch is pressed, it will run a script that's on the Raspberry Pi that will safely shut it down





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Power Supply

Official Raspberry Pi Power Supply 5.1V 3A with USB C - 1.5 meter long

$7.98

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Final Design Expectation

Features:

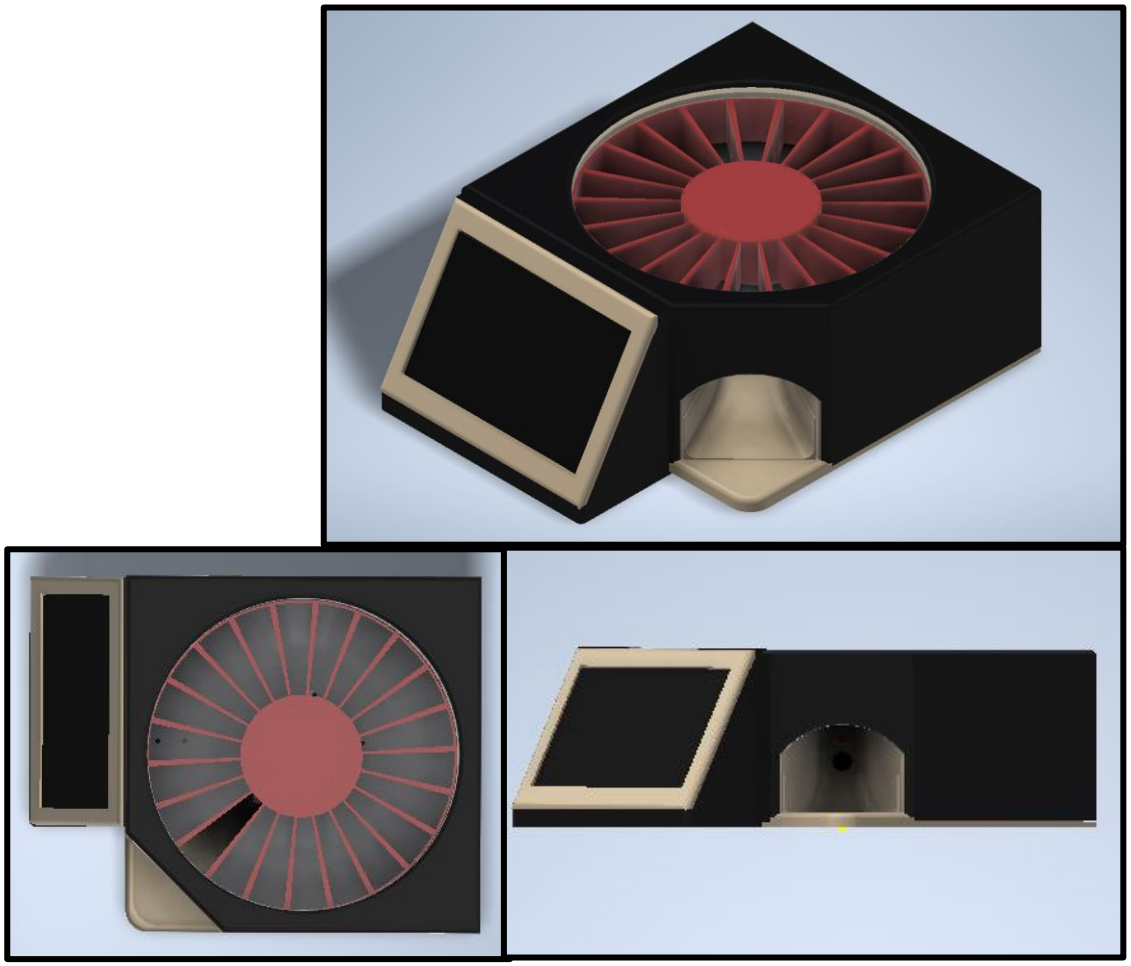
- Rotating Disk Capsules
- Clear Locking Lid
- Mass Loading
- Physical Labels
- 7 Day Supply

Size: 10” x 4” x 8”

Weight: 3.283 lb

Main Components:

- Capsule Piece
- Lid
- Dispenser
- Touchscreen Housing
- Overall Housing



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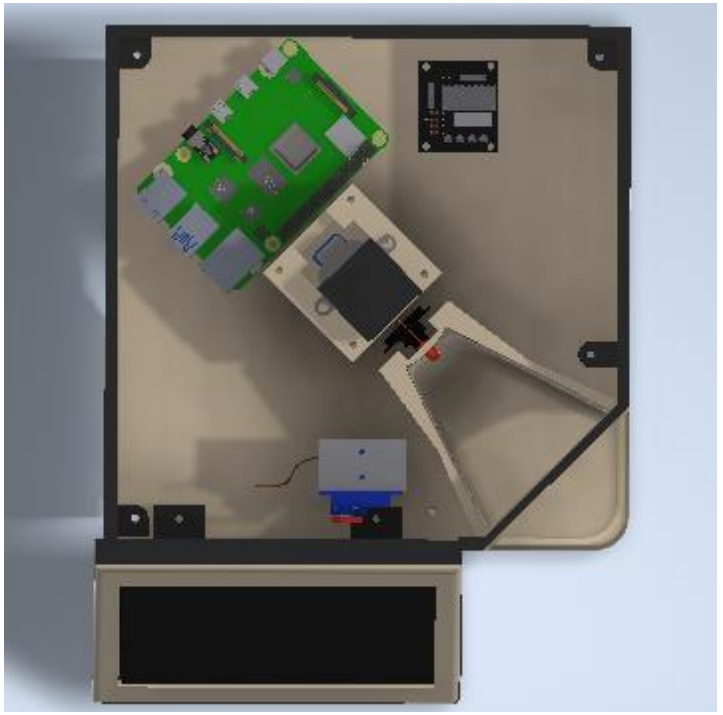
Electronics/Mechanics

Features:

- Camera in Dispenser
- Secured Raspberry Pi
- Stepper Motor & Servo Motor
- LED in Dispenser
- Touch Screen

Parts Not Shown:

- Wires
- Pi Fan
- Power button/Reset Switch
- Power Cord
- Screws (#4-40)



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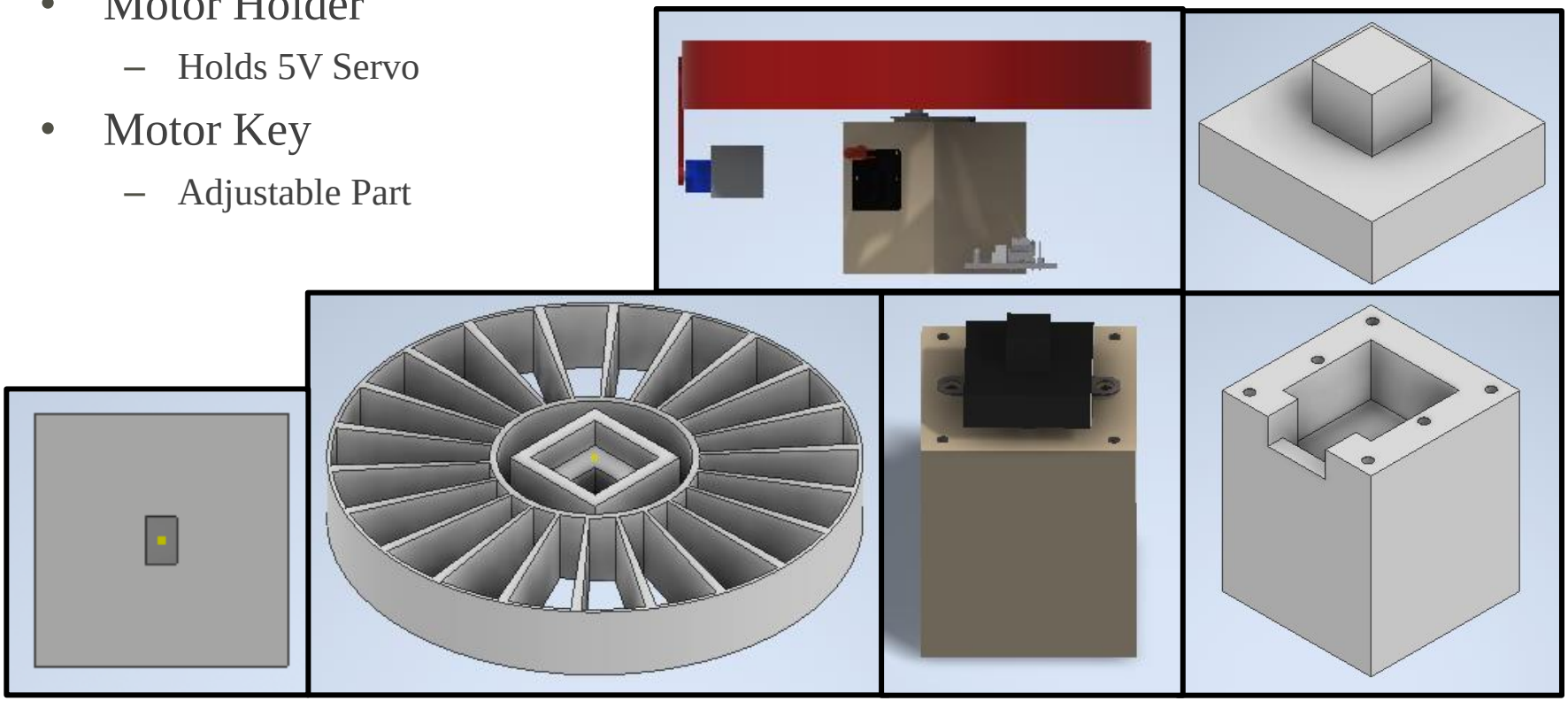
Rotating Capsule

Features:

- Rotating Capsule
  - 22 Compartments
- Motor Holder
  - Holds 5V Servo
- Motor Key
  - Adjustable Part



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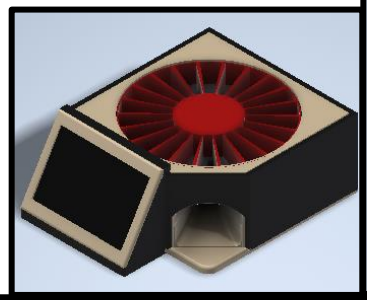
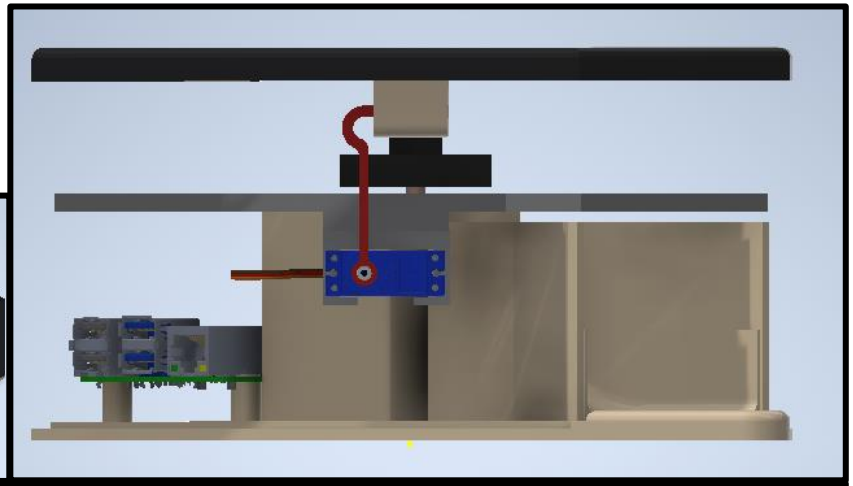
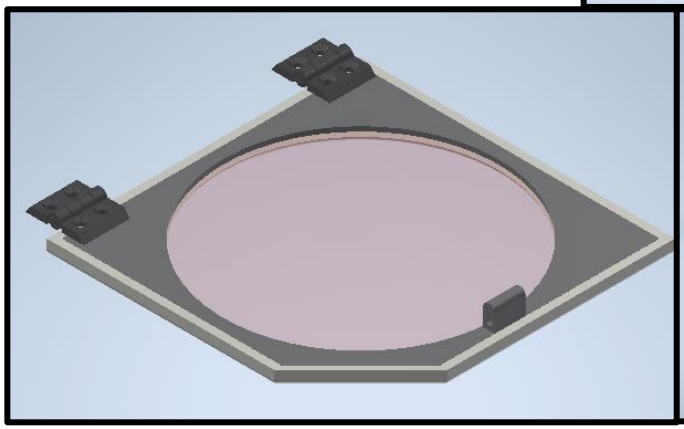
Lid & Locking Mechanism

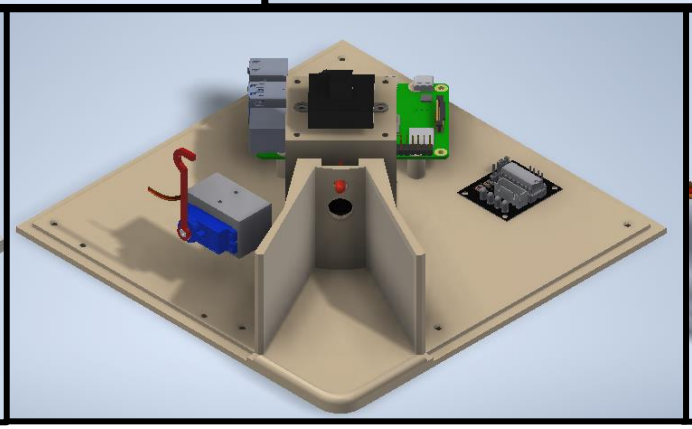
Features:

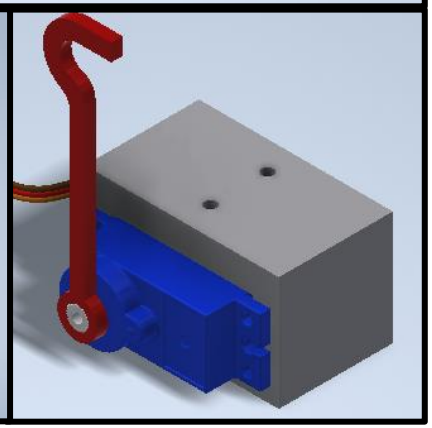
- Locking Mechanism
  - Simple Hook Design
  - Touchscreen Control
- Three Separate Parts
  - Clear Portion
  - Top Lid
  - Lid Support











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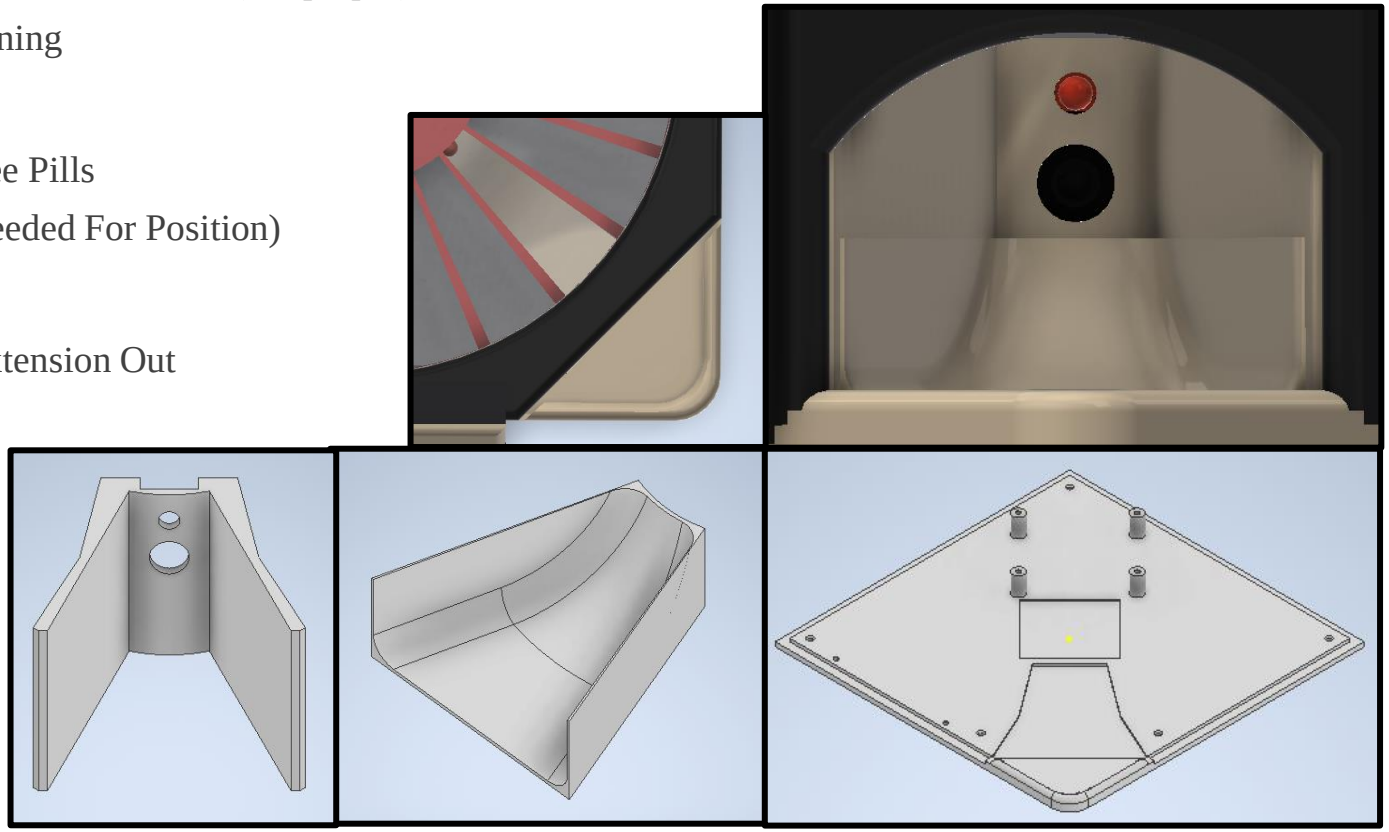
Dispenser/Tray

Features:

- Dispenser
  - Baseplate, Camera Holder (Drop Spot)
  - 3 Inch Opening
- Camera
  - Tilted to See Pills
  - (Testing Needed For Position)
- Slide/Tray
  - 1.5 Inch Extension Out
- LED



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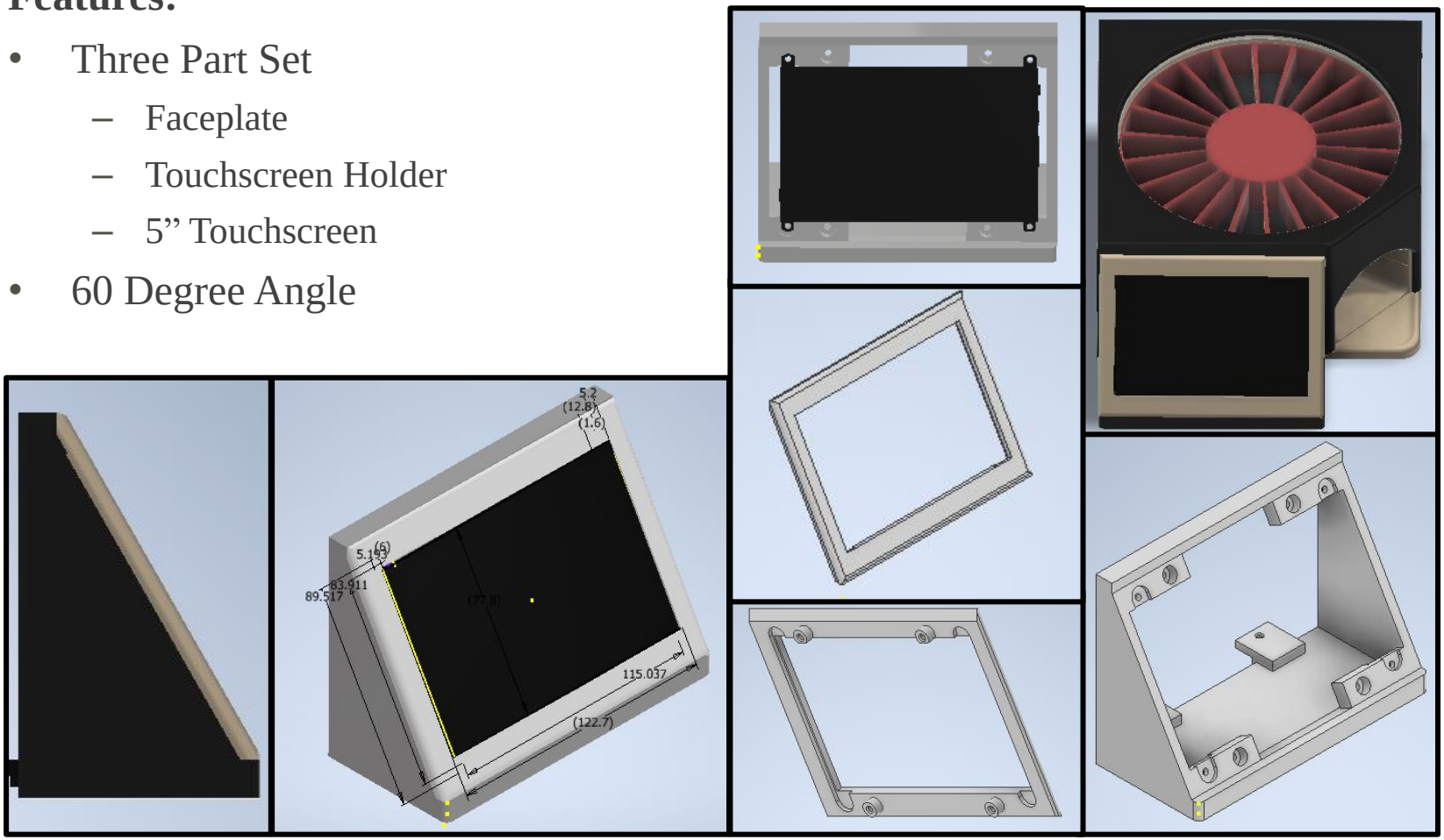
Touchscreen Housing

Features:

- Three Part Set
  - Faceplate
  - Touchscreen Holder
  - 5” Touchscreen
- 60 Degree Angle



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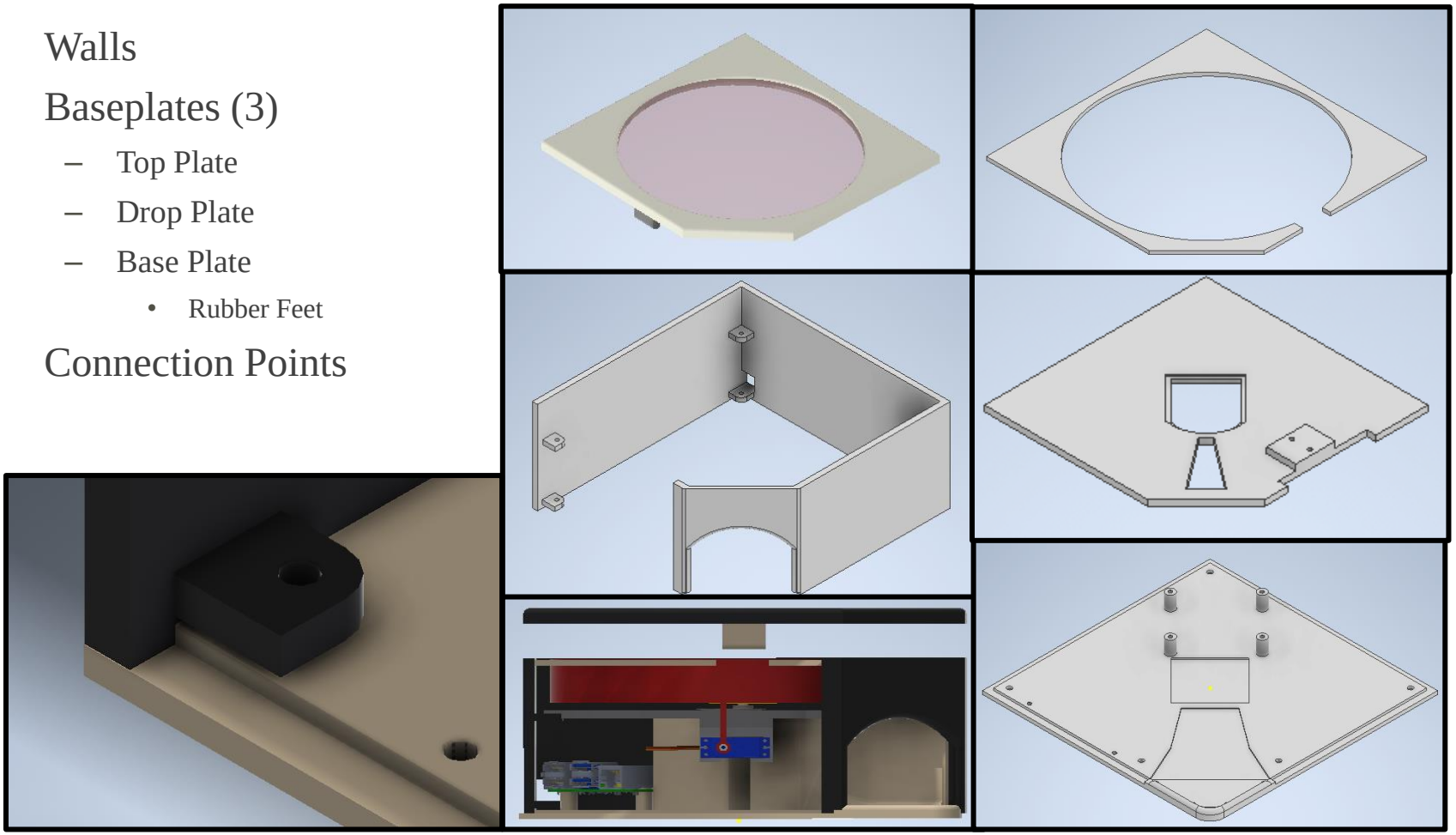
Overall Housing

Features:

- Walls
- Baseplates (3)
  - Top Plate
  - Drop Plate
  - Base Plate
    - Rubber Feet
- Connection Points



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Hardware Overview

Components:

- Total Parts ~16

Hardware Testing Done:

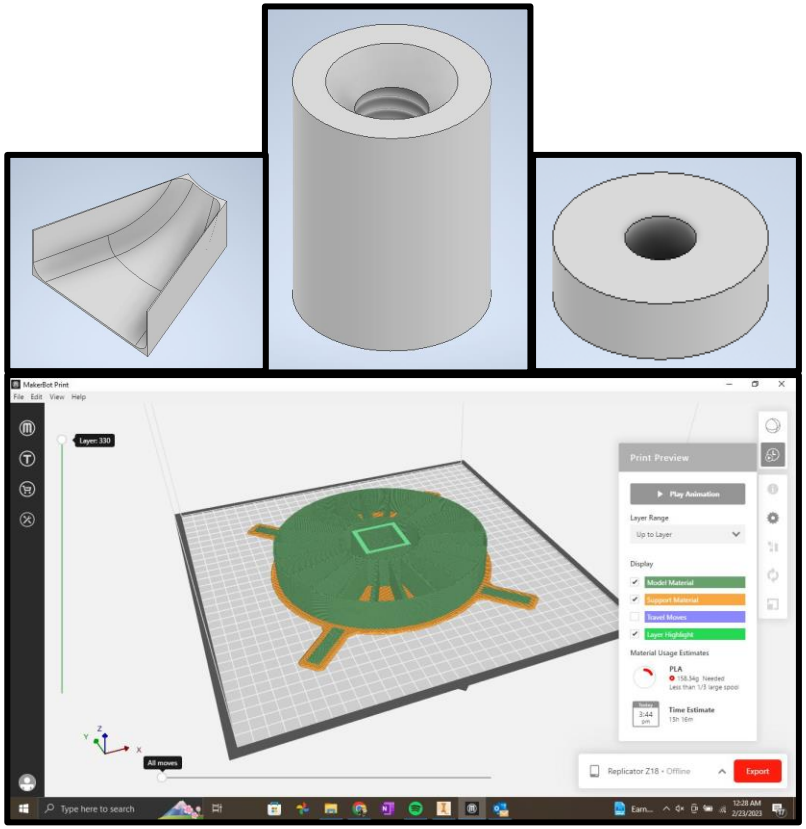
- Tested Motor Torque
- Motor Key Fitting, Screw Fitting, Bolt Fitting
- Parts Tested:
  - Rotating Capsule
  - Motor Holder

In Progress:

- Fabrication
- Alignment For Models
- Fixing Small Model Errors
- Finish Parts (2)

To Do:

- Camera Position, Tray Piece Testing



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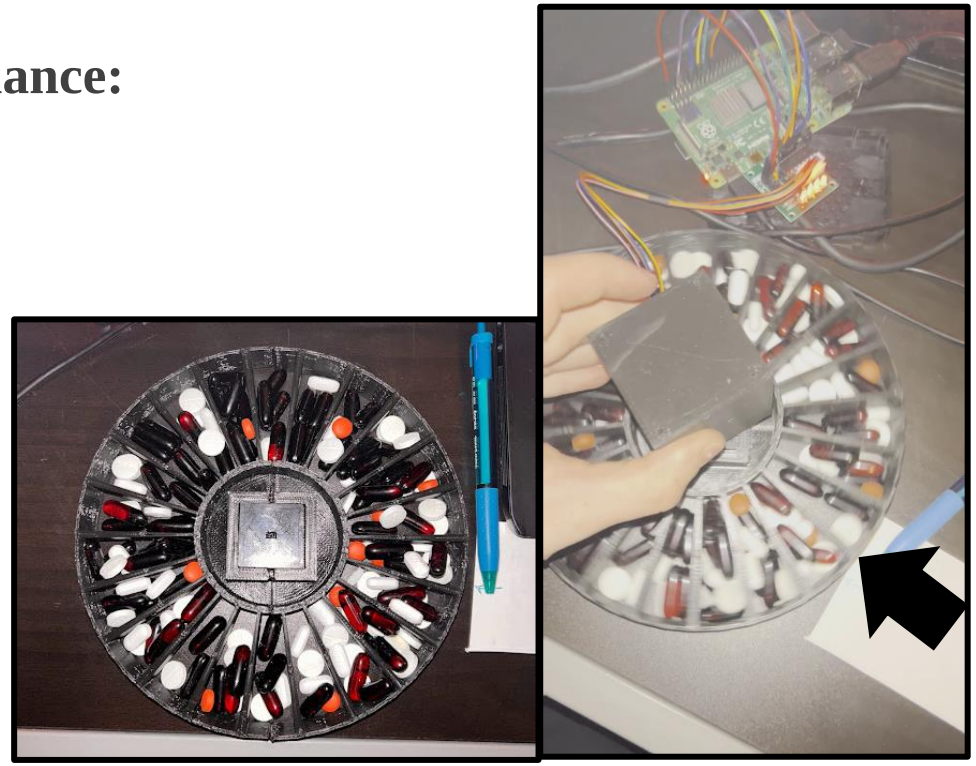
Torque Testing

Torque:

- Holding Torque: 150 gram-force*cm, 15 N*mm/ 2 oz-force*in
  - (Measure that keeps the motor from moving)

Solutions To Increase Performance:

- Reduce Friction Coefficient
  - Lighter Model
  - Ball Bearings & Ball Rollers
  - Different Material

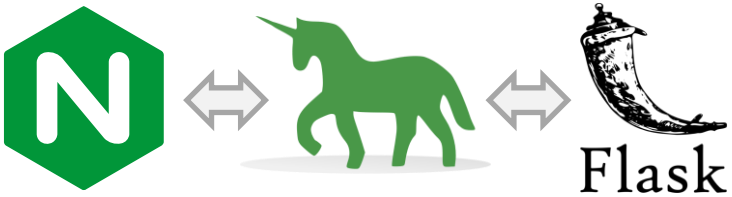


Software Design

Remote Server

Caregiver

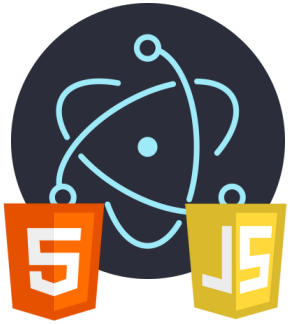
Webapp Server



Database

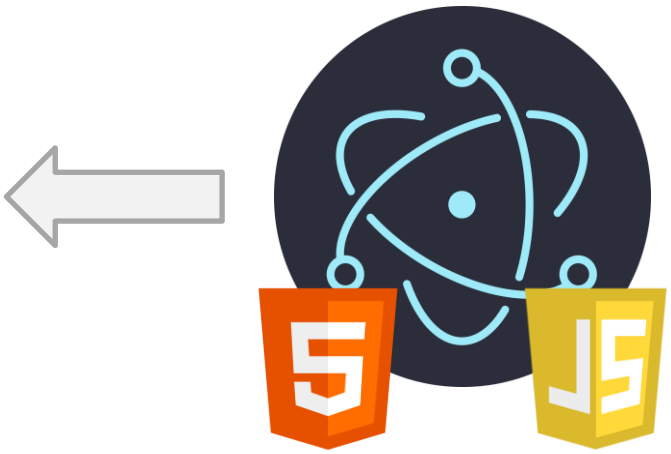
SPB

Motor Control



Software Design - SPB

Motor Control



We will be using Electron to create the UI for the Smart Pillbox

- Uses HTML 5 and JavaScript
- Ease of Use
- Open-Source
- Access to DB

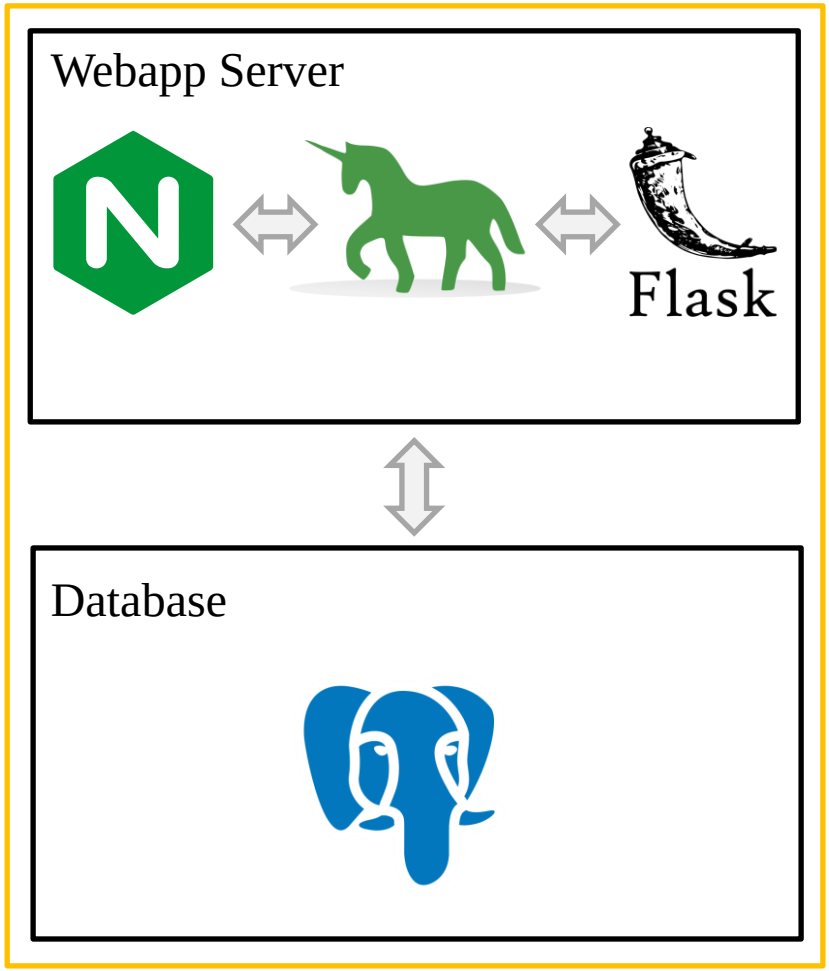
Advantages:

- Experience using HTML, CSS, and JavaScript
- Use same languages for local UI and website

Disadvantages:

- May be some design quirks

Software Design – Remote Server



We have decided to move to a Remote Server

- Secure
- Unified Log-in

We are using Flask as the framework for our webapp and serving it through a combination of Gunicorn and NGINX

- Flask is a native WSGI application framework
- Gunicorn will serve the webapp
- NGINX will act as a reverse proxy and receive HTTP calls more securely and effectively

PostgreSQL will serve as our DB

- Secure
- Multi-Access

User Interface Design

Desired Outcome:

- Simplicity
- Easy to Use

Required Features:

- Touch screen
  - Use it to unlock and access pills
- Take photos before and after
  - Saved in database (remote cloud server)
- Notification sent to caregiver after completion

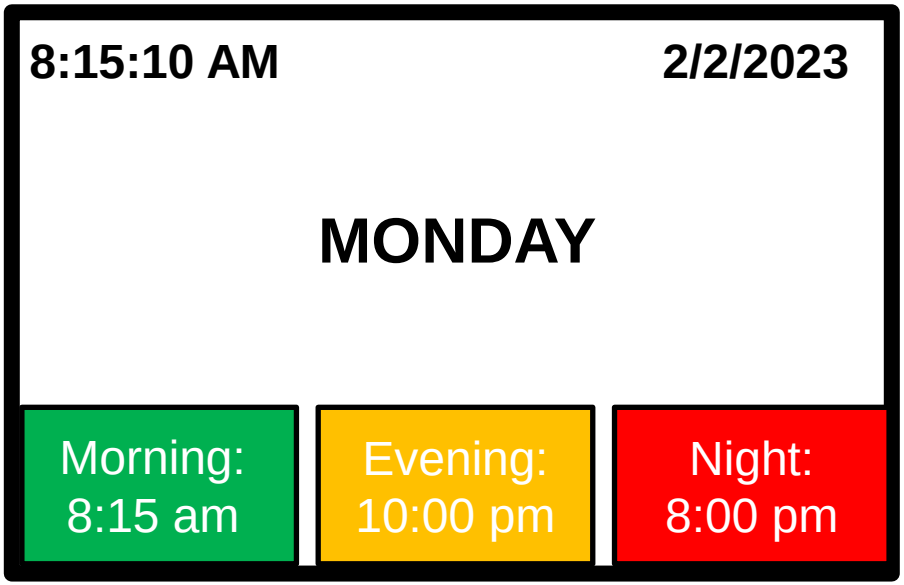
Concerns:

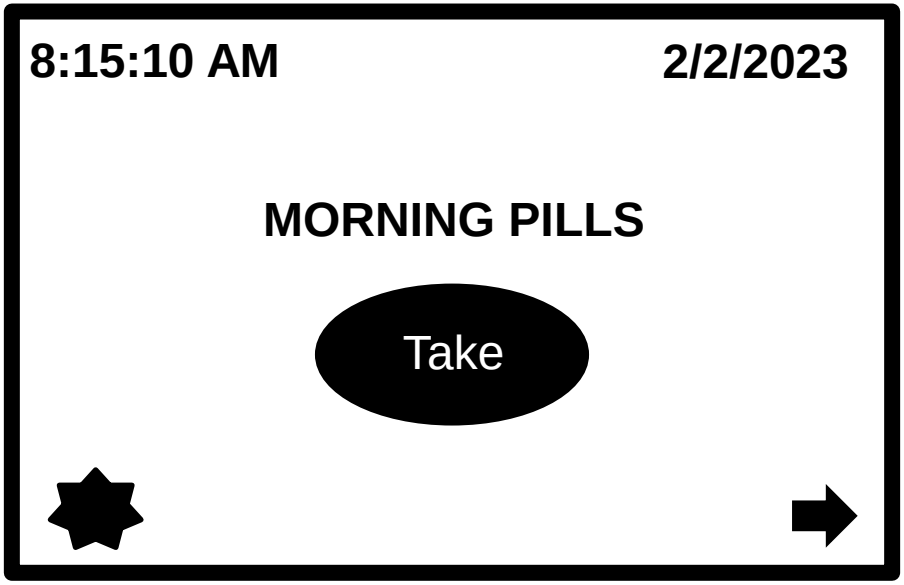
- Missed Medication
  - Beep for 20 Minutes
  - Notify Caregiver

User Interface Design

Always on Display:

- Date
- Time
- Schedule Time





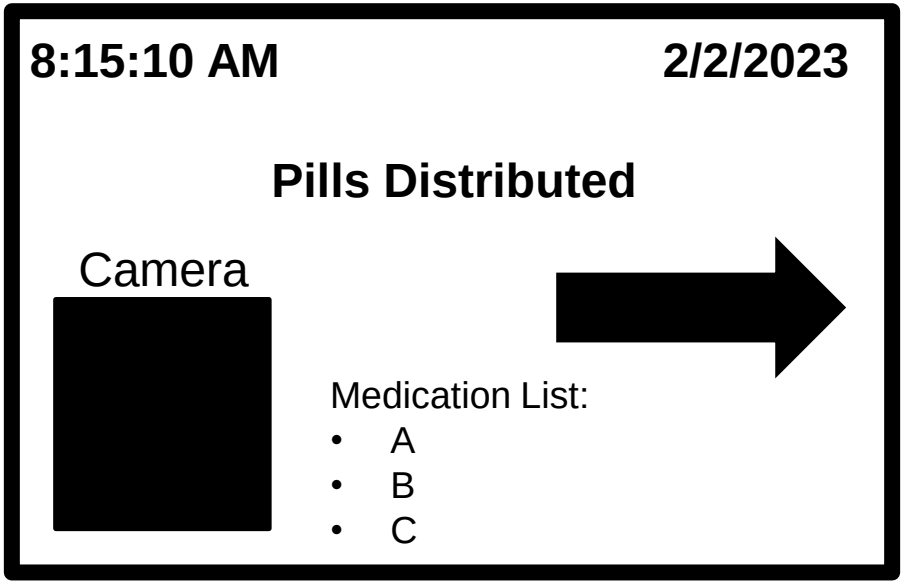
Alert Display:

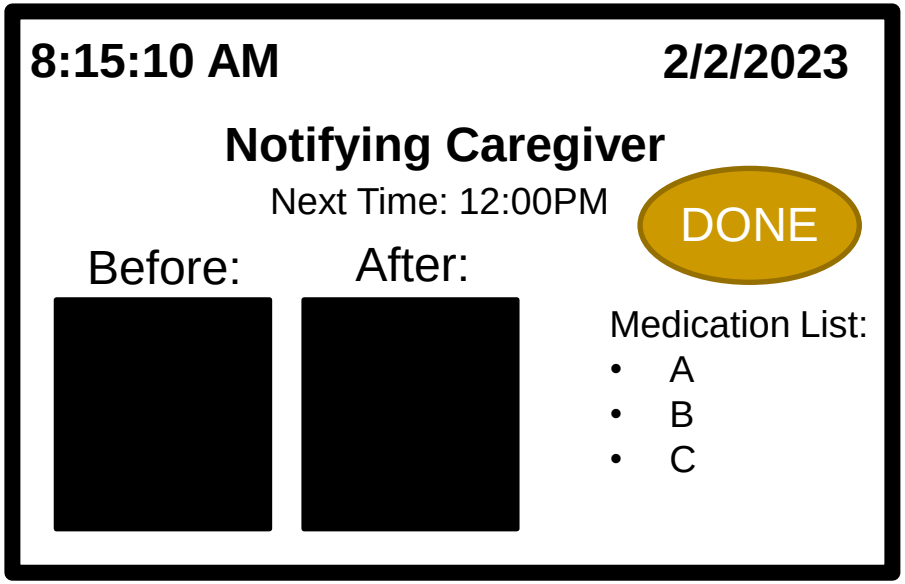
- Unlocks on Interaction
- Settings
- Snooze Alarm
- Time
- Schedule Time

User Interface Design

Distribution Display:

- Medication List
- Live Camera View
- Unlocks on Interaction





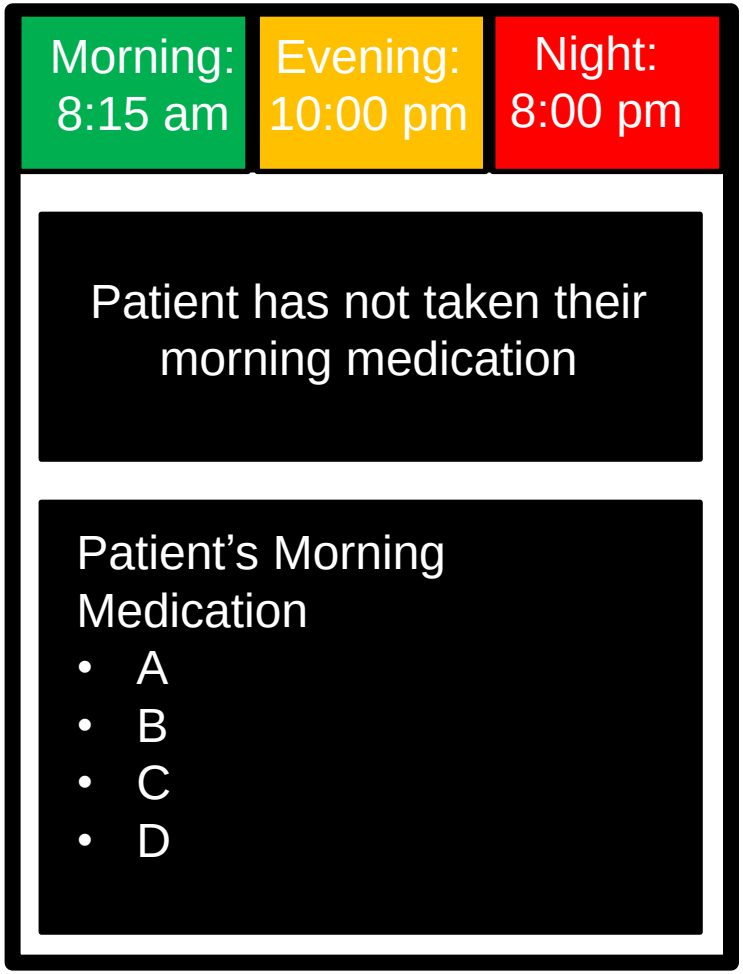
Acknowledgement Display:

- Confirmation Message
- Next Medication Time
- Medication List
- Before & After Picture

Web Application Features

Web/Phone Application

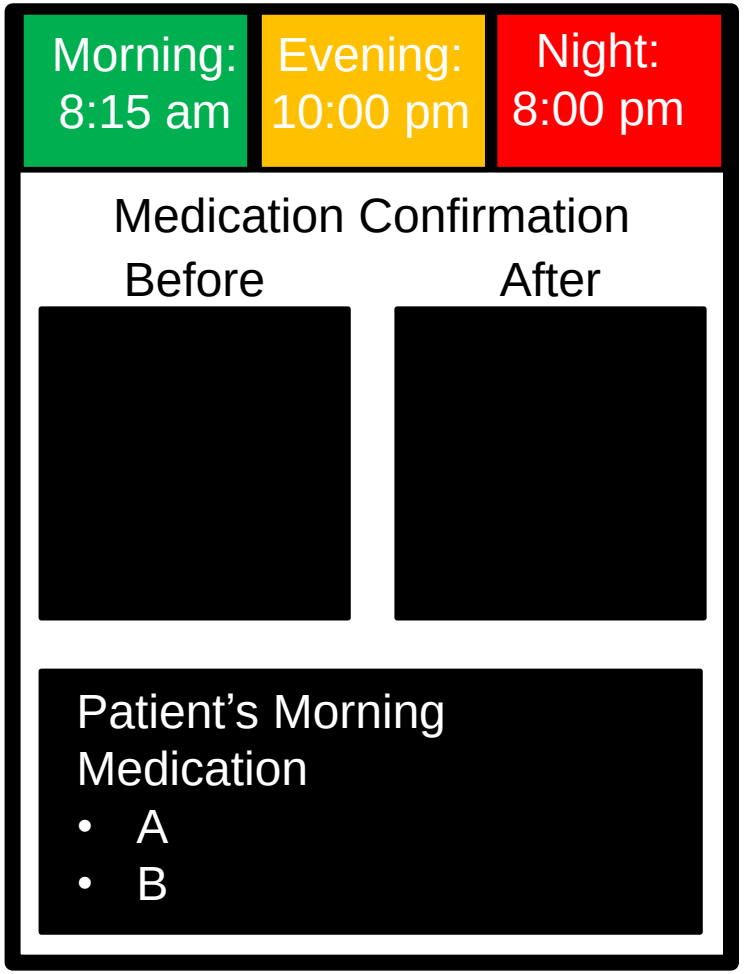
- Medication Notifications
  - Notified if patient has/has not taken their medication yet
  - List patient's medication for upcoming period



Web Application Features

Web/Phone Application

- Medication Notifications
  - Notified if patient has/has not taken their medication yet
  - List patient's medication for upcoming period
- Medication Confirmation
  - Confirm patient has taken medication
  - Confirm correct medication has been dispensed



Software Testing Methods

Planned testing:

- Proper hardware control
- Interface responsiveness
- Server connection
  - Raspberry Pi sending information
  - Caregiver receiving information
- Website functionality
- Login security

Design Cost Analysis

Parts:	**Cost:**	**Parts:**	**Cost:**
Raspberry Pi 4B	$200	Screws/Bolts/Nuts	$7.8
Pi Cord	$8	Cable USB	$6.12
Touchscreen	$100	Cable HDMI	$3.00
Camera	$25	Hinge(2)	$4.53
Stepper Motors	$22	SD Card	$10.81
Servo Motor	$4		
Ball Bearings (4)	$1	**Total Cost:**	$399.26

Future Contingency Costs: >$50

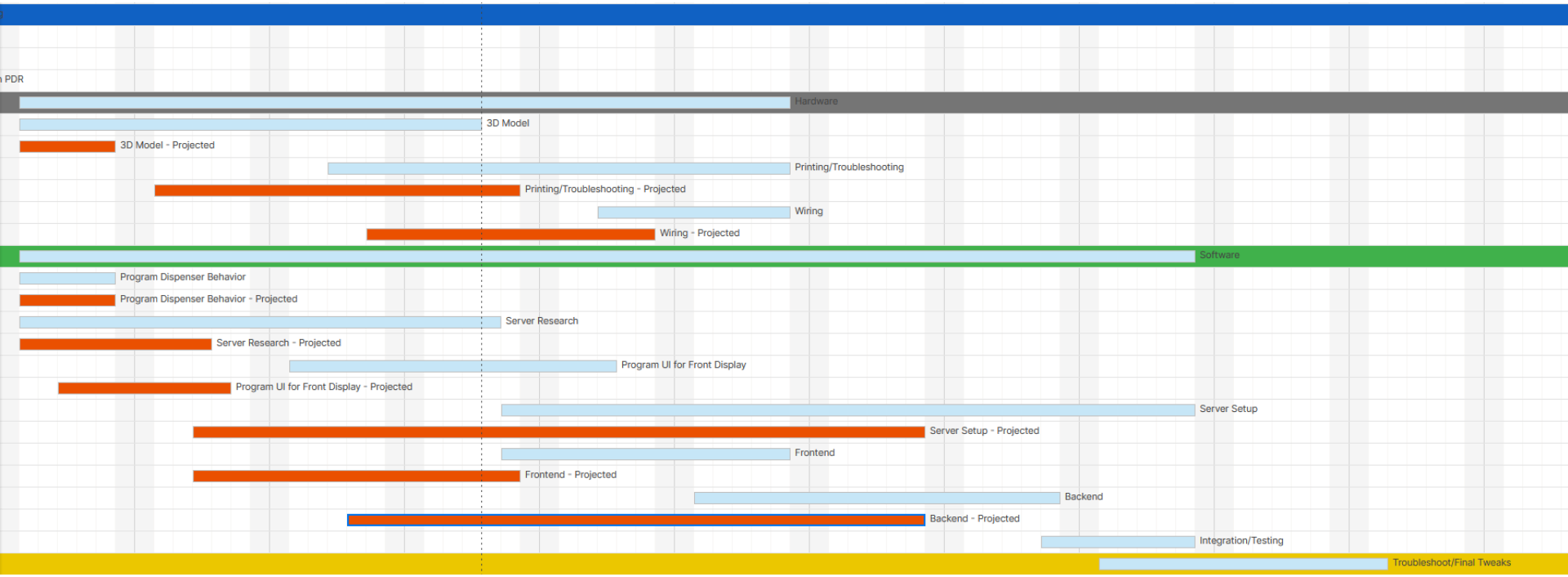
Touchscreen and Pi make up 75% of cost
Production cost given purchases in bulk and utilizing any vendor. ~$250

Zarek Rooker
3/2/2023

Project Plan

Planning	01/17/23	02/02/23
Initial Brainstorm	01/17/23	01/20/23
Finalize Design	01/23/23	01/27/23
Work on PDR	01/30/23	02/02/23
Hardware	**02/06/23**	**03/17/23**
3D Model	02/06/23	03/01/23
3D Model - Projected	02/06/23	02/10/23
Printing/Troubleshooting	02/22/23	03/17/23
Printing/Troubleshooting - Projected	02/13/23	03/03/23
Wiring	03/08/23	03/17/23
Wiring - Projected	02/24/23	03/10/23
Software	**02/06/23**	**04/07/23**
Program Dispenser Behavior	02/06/23	02/10/23
Program Dispenser Behavior - Projected	02/06/23	02/10/23
Server Research	02/06/23	03/02/23
Server Research - Projected	02/06/23	02/15/23
Program UI for Front Display	02/20/23	03/08/23
Program UI for Front Display - Projected	02/08/23	02/16/23
Server Setup	03/03/23	04/07/23
Server Setup - Projected	02/15/23	03/24/23
Frontend	03/03/23	03/17/23
Frontend - Projected	02/15/23	03/03/23
Backend	03/13/23	03/31/23
Backend - Projected	02/23/23	03/24/23
Integration/Testing	03/31/23	04/07/23
Troubleshoot/Final Tweaks	**04/03/23**	**04/17/23**

Project Plan



Stephen Fransen
3/2/2023

Risk Management

Impact

Likelihood

	Negligible	Minor	Moderate	Significant	Severe
Very Likely			3D Printer Failure		
Likely				Server/Networking Issues	
Possible	Motor Failure	Selected Parts are Unavailable	Broken Parts/Screens		
Unlikely				Design Does Not Meet Specification	
Very Unlikely					

Hazard Analysis

Wrong Drug Dosage: Smart pill boxes may have inaccurate dosages if users forget to double-check their input or if the machine malfunctions

Mitigation Strategy:

Keep and display a record of all medications taken and dosages.

Malfunctioning: The smart pill box may malfunction due to programming errors, hardware issues, or power outages, leading to incorrect prescriptions being dispensed.

Mitigation Strategy:

Regularly check and maintain the device to ensure it is functioning properly. Implement a redundancy system that can detect any errors and alert the user.

Zarek Rooker
3/2/2023

Hazard Analysis

Accidental Overdose: Overdose of medication due to incorrect dosage settings or incorrect usage of the device.

Mitigation Strategy: Educate users on how to use the device correctly, including instructions on how to set the dosage, and provide an emergency contact number in case of accidental overdose. The smart pill box should be programmed to alert the user if too many doses are taken in a day.

Security and privacy risks: Data stored on the device may be accessed by unauthorized users.

Mitigation Strategy: Utilize encryption technology to protect user data from being accessed by unauthorized users and to prevent data tampering. Additionally, provide a secure login system with password protection.

Presentation Work Disbursement

Zarek- Description**,** Design Constraints, Considerations, Hardware Design, Torque Calculations, Hazard Analysis

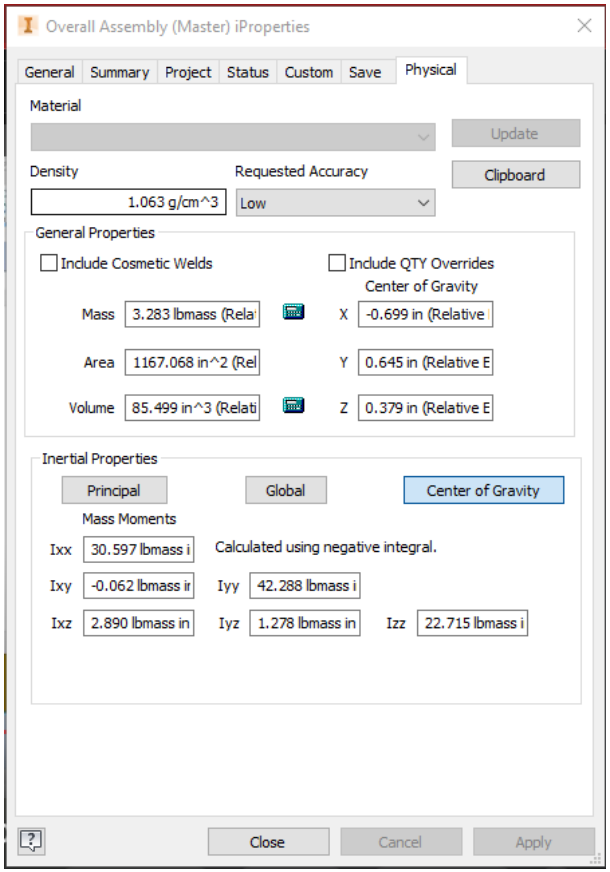
Zahra- Parts Research, Price Research , Power consummption, and Schematic

Stephen- Risk Management, Software Design, Project Plan, Web Application Features

Daniel – Testing, Decision Matrix, and Experimentation

Questions?

Reference Material



Weight from Inventor and Center of Gravity

Name	Quantity	Price
Raspberry Pi	1	$55.00
Display	1	$100.00
Camera	1	$35.94
Speaker	1	$13.00
Motor	7	$14.00
Adafruit DC & Stepper Motor	1	$22.50
Power	1	$12.50
	Total Price	$323.94
	Proposed Cost	$400.00

Initial Cost Estimate

References:

Prescription drug statistics 2022 (singlecare.com)

Medication overload and older Americans - Lown Institute