Final Design Review

Rapid Composter

by

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Sponsor: Girl Scouts of California’s Central Coast

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Statement of Disclaimer

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Abstract

This Final Design Review document outlines and details manufacturing and testing for the Mechanical Engineering Senior Design Project at Californica Polytechnic State University, San Luis Obispo. Our team of five mechanical engineering students is working with the Girl Scouts of California’s Central Coast to design, build, and test an on-site rapid horse manure composter. The goal of this project is to create a solar-powered device that will reduce the amount of horse manure that must be disposed of by recycling it into usable compost. This compost can be used to safely fertilize plants at the camp or sold for profit. Various configurations of the composter were analyzed and reviewed throughout the design process. This document is a detailed overview of the design itself, its implementation, design verification, and any post-project recommendations.
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1 Introduction

Girl Scouts of California’s Central Coast (GSCCC), a regional chapter of Girl Scouts of the USA, have asked us to take on the challenge of creating a rapid composter to reduce the amount of horse waste that must be disposed and to generate a resource for their monarch pollinator gardens in the form of compost. The GSCCC provides their girl scouts with numerous educational opportunities using their ranches as activity and learning centers for the girl scouts. Part of this educational exposure involves interacting with animals, such as horses. At their Camp Arnaz program center in Ventura, CA, the girl scouts have ten horses, each producing roughly 50 lbs. of manure daily. To reduce labor utilized and money spent on the removal of horse manure, our senior project team will deliver a solution to reuse a portion of horse waste. This will involve research on the scientific principles related to our project, existing solutions, and construction of novel ideas. The goal of this project is to produce a full-size, workable composter along with all necessary engineering documentation.

The purpose of this Final Design Review is to relay any design changes since the Critical Design Review (CDR), specify completed procurement, build, and assembly activities, describe our conducted tests and their corresponding results showing whether or not the design specifications were met, and discuss our project results and any recommended next steps if necessary.

2 Design Overview

2.1 Design Description

This design consists of four subsystems: power generation and storage, automatic controls, aeration, and structure. Each subsystem can be manufactured independently, then assembled altogether to form the final design. The power generation and storage subsystem consists of two solar panels and a battery. This battery is connected to the automatic controls that have an Arduino and software written into it. The controls connect to the aeration subsystem that consists of a few shafts, worm and worm gears, drums, and a caster wheel assembly. The main structure supports the aeration subsystem and automatic controls, and consists of pressure-treated wood and a steel skeleton.

![Figure 2.1.1: Overall Design](image)
2.2 Design Changes Since CDR

Since the CDR, a few design changes were made. First, the mounting structure will be steel-reinforced for weathering and structural purposes. The pressure-treated wood alone in the CDR’s design was sufficient, but we made the decision to add some extra protection. We also decided to implement an additional pair of caster wheels on each of the caster subsystems because of drum deformities with two pairs of casters. A more drastic change was made in the maceration subsystem. We decided to take it out altogether for logistics reasons. After some testing with rotating the manure-loaded drums, we saw that the rotation itself was sufficient in breaking apart the larger pieces of manure. If the sponsor wishes, a macerator could be purchased with the remaining project funds.

3 Implementation

3.1 Procurement

The majority of the components for this design were purchased through Amazon, Home Depot, and McMaster-Carr. The battery, stepper motor and planetary gearbox, and drums, which were purchased through DJLBERMPW, Stepper Online, and a small family winery (Glunz Family Winery & Cellars), respectively.

3.2 Manufacturing

For this section of this Final Design Review we will be recap the entire manufacturing process of our verification prototype. Each subsystem (power generation and storage, automatic control system, mounting structure, and aeration system) will be examined separately first, then the entire system’s assembly process will be reviewed.

The power and generation storage consists of the 50-watt solar panels, adapter kit, 10-amp charge controller, copper wire, disconnects, DC solar PV fuse, fuse holder, and 24-volt 100-amp-hour battery. The solar panels, charge controller, and battery should be connected similar to the orientation shown below in Figure 3.2.1. Both 50-watt solar panels are places in series to charge the 24-volt battery. The charge controller is in between the panels and the battery with soldered connections. There is also a 20-amp fuse placed between the positive terminal of the battery and the charge controller.

![Figure 3.2.1: Power Generation and Storage Configuration](image-url)
The automatic control system consists of an Arduino Nano board, a real time clock module, a thermistor, a user interface, a motor controller, a stepper motor with an attached planetary gearbox, and an IP55 container to protect all these components. Along with the hardware included, our team has created a MATLAB and an INO file (Arduino) that has been included in this document.

![Figure 3.2.2: Automatic Control System](image)

The mounting structure is a wood structure with steel sheet support. That being said, this subsystem required 2 by 4 and 4 by 6 pressure-treated lumber stock, wood screws, and steel sheet metal. The lumber was cut down to size as shown in the Solidworks file provided. The members are secured by wood screws and sheet metal is bent around the members to reinforce them. Figure 3.2.3 is an image of the mounting structure supporting a portion of the aeration subsystem.

![Figure 3.2.3: Mounting Structure supporting the Aeration Subsystem](image)
The aeration subsystem is the most intricate of the whole design. It consists of 1-inch diameter shaft collars, a keyed stainless steel rotary shaft, a carbon steel rotary shaft, mounted sleeve bearings, stainless steel coupling nuts, two cast iron worm gears, two keyed worms, mounted sleeve bearings with two-bolt flange, stainless steel machine keys, various hex screws and nuts, stainless steel washers, stainless steel split lock washers, silicone washers, flange-mount shaft collars, a chrome-plated carbon steel rotary shaft, four 55-gallon drums, stainless steel bars, clamping shaft collars, and corrosion resistant set screws. Additional manufacturing was done on the carbon steel rotary shaft and worm gears. A key was milled onto the shaft to allow for a more secure interface between the shaft and the worms. The worm gear was also keyed and tapped to allow for a set screw. A coupler was also manufactured for the motor to shaft interface. A CNC mill and lathe were used to do this, shown in Figure 3.2.4. All components were assembled as shown in our Solidworks file. It is important to note that the worm and worm gear interface must be perfectly arranged so that the gears cannot slip. If the gear interface fails, the whole system will fail.

![Figure 3.2.4: Coupler Milling Operation](image)

3.3 Assembly

After all subassemblies are built, they will be put together in the following manner. Figure 3.3.1 shows the final assembly that was presented at the Senior Project Expo. The power generation and storage system will be a separate entity alongside the rest of the system. The solar panels will be mounted on a stand that is positioned with a 34-degree tilt above the horizontal to provide the maximum energy collection. The battery will connect to the automatic control system. The automatic control system will be mounted onto the mounting structure. The stepper motor-planetary gearbox subsystem will be connected to the main rotary shaft via a machined step-down coupler. The whole aeration system will be mounted onto the mounting structure in the same manner shown in our Solidworks file attached.
3.4 Power Supply and Deliver

The power for the entire system is run entirely on two 50 Watt solar panels. Though this may seem small at first, we are running our system at a very slow speed for only a handful of revolutions each day while the solar panels are generating the entire time the sun is up.

The power is stored in a 24V 200AH lithium iron phosphate battery that will allow the system to endure long periods of cloudy days as well withstand extreme temperature changes. This is necessary because the battery, though weatherproofed, will be kept outdoors.

To control the charging, and discharging rate of the battery, a charge controller is hooked up between the panels and the battery. 15A fuses are also implemented in various locations to prevent and potential short circuits.

3.5 Software & Electronics

The electronic controls subsystem is composed of an Arduino Nano, a RTC module, and many I/O devices. All devices determine when the system should operate. Currently, the only user inputs are a main power switch, an operating switch, and an ESTOP button. The main power switch cuts or supplies power to the system. The operating switch allows the code to run to spin the barrel and essential acts as a “code on/off” switch. Finally, the ESTOP switch cuts or supplies power to the motor and also acts as a “code on/off” switch.

For output, the system has many LEDS and one speaker. The LEDS are used for the following: a yellow LED to show when the system’s code is “on”, a set of four yellow LEDS to show the progress towards the next spin, a red LED to act as a warning for an imminent spin, and a green LED to alert the user when the composting process is complete. The speaker acts in tandem with the red LED to provide users with both a visual and audio warning of an imminent spin.

With the user inputs set to allow the system to run, the system will spin for eight minutes once per day, every day until the system is done composting. The code performs this by retrieving the current date and time from the RTC module and calculating the time difference since the last run.
This is non-trivial, as calculating time differences between months is quite complicated. The software then drives the stepper motor for the allotted time, interrupting if the ESTOP switch is pressed. The full code for the software is included in Appendix D of this document.

4 Design Verification

4.1 Specifications

At the beginning of this project, our sponsors, the Girl Scouts of California’s Central Coast (GSCCC) requested certain features for their ideal product. They expressed their basic requirements for the composter, listed in Table 4.1.1 below.

<table>
<thead>
<tr>
<th>Table 4.1.1: Composter Requirements</th>
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<tbody>
<tr>
<td>50 pounds per day processing speed</td>
</tr>
<tr>
<td>Withstand ranch environment</td>
</tr>
<tr>
<td>Sanitize bacteria, seeds, and smell in compost output</td>
</tr>
<tr>
<td>Safe to operate</td>
</tr>
<tr>
<td>Easy and intuitive to use</td>
</tr>
<tr>
<td>Easily cleanable</td>
</tr>
<tr>
<td>Semi-automated</td>
</tr>
<tr>
<td>Solar powered</td>
</tr>
<tr>
<td>Transportable</td>
</tr>
</tbody>
</table>

Our whole project was designed around these list of needs. That being said, we also curated a list of tests to perform to ensure these requirements were being met.

4.2 Testing and Results

The test procedures are included in Appendix F of this document. There are five procedures testing the following criteria: drum integrity, power requirements, electrical power delivery, mechanical power delivery, and temperature control.

We performed was a basic torque test as a prequel for the mechanical power delivery test. This test was developed to ensure that the rated torque of the motor is sufficient to turn 1000 pounds of manure at a time. The setup for this test is shown in Figure 4.2.1. The test result showed that the torque output of the motor would be adequate to turn the loaded drums.
The first official test we performed was the drum integrity test. The drum walls were thin, so we were concerned that it would not be strong enough to hold 250 pounds of manure while on the casters. The drums were set up and was spun everyday and allowed to sit for three weeks. There was slight deflection on the drums after this cycle but nothing of concern. The casters left a shallow indent in the drum surface, shown in Figure 4.2.2.

The power requirements test was done to ensure the power usage of the motor is less than the amount of power generated and stored by the solar panels and the battery. The test set-up is shown in Figure 3.2.1 in the Implementation chapter of this document. On a sunny day, the solar
panels were able to charge the battery much more than the motor’s power withdraw. Ventura’s climate should be sunny enough for this.

The electrical power delivery test confirms the power generation and storage and automatic controls subsystems are durable and weatherproof enough to withstand the environment. We secured the battery and controls box into their own weatherproof boxes. The wires are sufficiently protected and unexposed. The weatherproofing box is shown in Figure 4.2.3.

The mechanical power delivery confirms the secure interfaces between the worm and worm gears, the shafts and the drums, and the drums and the flanges. All of these interfaces were fixed, so the test was successful. The worm to worm gear interface is shown in Figure 4.2.4 below.
The last test we did concerned temperature control. We monitored and recorded the internal temperature of the loaded drum for three weeks. Figure 4.2.5 is a screen capture of the temperature data of the manure inside the drums. It appeared that the temperature drastically decreased when the drum rotated. This is an important note for temperature regulation. It is also important to note that the temperature must reach about 150 degrees Fahrenheit for three days straight for a proper compost cycle. In the three weeks we recorded temperature, it never reached 150 degrees. It should be noted that the climate in San Luis Obispo (testing location) was unseasonably cold at this time of year, which contributed to the low internal temperatures. This can be fixed with insulation. Luckily, Ventura’s year-round climate is warmer than San Luis Obispo, so this may not be an issue in its respective place.

![Temperature Data](image)

Figure 4.2.5: Temperature Data

Given that (mostly) all the tests have passed, we can conclude that the design is sound. There are definitely improvements that can be made, which will be discussed in the next section of this document.

5 Discussion & Recommendations

5.1 Discussion

This project had many limitations. The sponsors wanted us to be able to include a device that could monitor and control temperature and moisture of the contents in the drums, but these requests are simply beyond our capabilities. This project would have greatly benefited from a computer engineering/science team to take care of these features. That being said, there is no way this machine is able to monitor and control temperature and moisture. We had tested and monitored the drum’s internal temperature for three weeks as one of our design verification tests. The results showed that the temperature had never reached the temperature required to properly compost the manure.

Manure samples from Camp Arnaz were taken to test for composting properties. The results showed that the carbon to nitrogen ratio was too low, and the moisture too high for composting. If these issues are not resolved and corrected, the manure will never compost.
5.2 Recommendations and Next Steps

For this project to continue, there are a few optimizations that could be made. The barrel attachment system can have adjustments to make the assembly easier to mount and dismount. For example, the plate and flange can be affixed to the shaft. The current plate within the barrel could remain with the bolts acting as standoffs for the flange/plate to mount to. From there a sliding or hinge mechanism can be used to fit over the standoffs/plate. This would allow simpler operation.

The wheel base system for the barrels should also be affixed to the internal metal spine. This would ensure that the barrels and the main shaft would remain aligned for easy coupling.

The barrel can be reinforced along the walls to decrease the effects of continued hoop stress of the cylindrical containers. Due to the fluctuating heat, pressure from the wheels, and potential impacts during use, barrel reinforcement would add to the longevity of the system.

More robust sensors for humidity and temperature could also be added. This would allow for more precise control over the composting process.

The housing can be made waterproof and sealed along the edges. Adding additional sealant to the composite housing would prevent the protective cover itself from deteriorating due to weather.

In the Discussion section of this document, Camp Arnaz manure samples were taken but the criteria levels were insufficient for composting. That being said, the user must ensure these levels are sufficient before loading the contents into the drums. There must be more plant waste included to resolve the carbon the nitrogen ratio, and the manure must be dried for a short period of time to fix the moisture content.

6 Conclusion

This Final Design Review is an overview of our design, implementation, and design verification. This document was written with the intention of revealing the full details of the manufacturing and testing of our design so the build may be replicated and improvements may be made.

All things considered, this project was very successful. The mechanical system was perfectly aligned, allowing for a smooth operation. As mentioned previously, a computer programming team would have greatly benefitted this project, as there could have been better condition regulation.

The system passed all tests but one, ensuring that the design is sound. Minor adjustments can be made to further improve the design.

References

Appendices

Appendix A – User Manual

Post-Transportation Final Product Assembly

Because of the sheer size of our product, the rapid composter must first be disassembled to be transportable. The drums and the casters must be removed to allow for the rest of the assembly (power generation and storage, automatic controls, and mounting structure) may fit into an 8-foot truck bed. When the subassemblies have been moved to its final location, the mounting structure and power generation subsystems must be placed on a flat area. The solar panels must be placed at a 34-degree angle (or an angle matching the local latitude) above the horizontal and be south-facing in order to collect the maximum amount of solar energy. Once the previous steps have been done, the caster subassembly should be placed in the configuration shown in Figure A.1 below.

Figure A.1: Caster Orientations

After the casters are placed, the drums can be situated on top of the casters and bolted in to secure the drum-to-shaft engagement.

General Use

As a general disclaimer, all loading and unloading operations are manual and are physically demanding. Personal protection should be considered and any aid should be taken advantage of (ie. carrying and shoveling partner, dolly, back brace). To load the drums, a shovel will be required. Gloves and eye protection are recommended when handling organic waste, but not required.

Loading

From the completed assembly, the drums must be removed to be loaded or loaded while being mounted on the casters and the shaft. For the latter, the lids must be taken off so the manure can be loaded. The manure can then be shoveled into the drums to half capacity.

To remove the drums for loading, the set screw on the flange attached to the shaft must be removed so the drum-flange subassembly can be easily removed from the rest of the system. The set screw is shown in Figure A.2 below. The drums may then be propped
up to be loaded with manure. The lids should be placed back onto the drums before reloading them onto the structure. The set screw must be screwed back on before the system can be powered on again.

![Set Screw on the Drum-Flange Assembly](image)

**Figure A.2: Set Screw on the Drum-Flange Assembly**

**System Controls**

Once the drums have been loaded with the appropriate amount of manure and attached back onto the system, the controls may be powered on. The motor should immediately begin drawing power from the battery to turn the shaft that drives the whole system. The drums should begin to rotate very slowly. There are light indicators on the controls box that will show whether or not this is happening, as the rotations may be too slow to see. The internal temperature of the system must be maintained at 120 degrees for three days straight for the pathogens to be eradicated properly. The entire process should have a three-week duration. The controls will indicate when that time is up and the compost may be unloaded.

**Unloading**

Similar to the loading portion of this manual, the drums may be removed completely to be unloaded or unloaded while still being attached to the system. For the latter, the lids must be removed so the compost can be shoveled out and collected.

To remove the drums for unloading, the coupler set screw must be undone so the drums can be easily removed from the rest of the system. The drums can then be transported to be unloaded in their designated places.

The process can then be started again, from loading to operating the system to unloading.
<table>
<thead>
<tr>
<th>System / Function</th>
<th>Potential Failure Mode</th>
<th>Potential Effects of the Failure Mode</th>
<th>Stringency</th>
<th>Potential Causes of the Failure Mode</th>
<th>Control Preventative Activities</th>
<th>Description</th>
<th>Control Preventative Activities</th>
<th>RN</th>
<th>Recommended Activity</th>
<th>Responsibility &amp; Target Completion Date</th>
<th>Actions Taken</th>
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<tr>
<td>Drier / compactor access</td>
<td>Door stuck</td>
<td>g. compactor cannot be unloaded/baled</td>
<td>3</td>
<td>g. blockage</td>
<td>a. Air flow sensor</td>
<td>3</td>
<td>Code testing of door operation</td>
<td>12</td>
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<tr>
<td>Valve / process control</td>
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<td>a. Compactor cannot be pressurized</td>
<td>4</td>
<td>a. interlock contacts</td>
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<td></td>
<td>Ensure proper venting and control of compactor</td>
<td>14</td>
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<tr>
<td>Bolt / mixture support</td>
<td>Bolt slip break</td>
<td>a. Shall not spin</td>
<td>5</td>
<td>a. Improper gasket</td>
<td></td>
<td></td>
<td>Check size of shunt port</td>
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<tr>
<td>Supports / support whole frame weight &amp; vibration</td>
<td>Deteriorates</td>
<td>a. Their role off</td>
<td>6</td>
<td>a. Improper gasket</td>
<td></td>
<td></td>
<td>Check connections points of support system</td>
<td>63</td>
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<tr>
<td>Temperature Failure / system temperature</td>
<td>Point/Wear/Temperature</td>
<td>a. Shutter does not close</td>
<td>7</td>
<td>a. Improper gasket</td>
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<td></td>
<td>Test proper gasket</td>
<td>[20]</td>
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<tr>
<td>Motor / sensor detected no mechanical power</td>
<td>Failure breaks</td>
<td>a. Gently close compactor</td>
<td>8</td>
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<td></td>
<td></td>
<td>Test proper gasket</td>
<td>[20]</td>
<td></td>
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<tr>
<td>Gear Box / drive motor</td>
<td>Gear box breaks</td>
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<td>a. Improper gasket</td>
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<td>Test proper gasket</td>
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<td>Solder joints / provide power to system</td>
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<td>a. Compartments can be closed</td>
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<td>Motorized Pulley / maximum moisture</td>
<td>Motorized malfunction</td>
<td>a. Shutter does not close</td>
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<td>a. Improper gasket</td>
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<td></td>
<td>Test proper gasket</td>
<td>[20]</td>
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<td>System Insulation / maximum temperature</td>
<td>Temperature gets too high</td>
<td>a. Compartment pressure too high</td>
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<td>Test proper gasket</td>
<td>[20]</td>
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<tr>
<td>Control System/Venting / stack vent</td>
<td>Vents malfunction</td>
<td>a. Can drive or completely stop compactor</td>
<td>13</td>
<td>a. Improper gasket</td>
<td></td>
<td></td>
<td>Test proper gasket</td>
<td>[20]</td>
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F104 Rapid Composter
# Appendix C – Final Project Budget

## Materials Budget for Senior Project

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<th>Vendor</th>
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<td>01/12/23</td>
<td>Amazon</td>
<td>4 Pack Breadboards</td>
<td>$13.99</td>
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<tr>
<td>01/12/23</td>
<td>Amazon</td>
<td>3 Pack LAHV8 Nano Boards</td>
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<td>01/20/23</td>
<td>Home Depot</td>
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<td>Eye Bolt Latch</td>
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<td>Home Depot</td>
<td>6-32x1/2” Bolts</td>
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Materials budget given for this project: $7,750.00
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Total expenses: $ 4,884.18

Budget: $ 7,310.00
actual expenses: $ 4,884.18
remaining balance: $ 2,365.82
Appendix D – Software

//Including necessary libraries
#include "Arduino.h"       //Base
#include "uRTCLib.h"       //For RTC module (keeping track of time)
#include <EEPROM.h>        //For EEPROM (keeping track of vars even when power is lost)

// uRTCLib rtc specifying RTC Module
uRTCLib rtc(0x68);

//Setup Weekday Array for Serial Output

//Setup minutes in each month
//THIS DOES NOT ACCOUNT FOR THE NON-LEAP YEAR in 2100
//If you are still using this in 2100, god help you
long monthMins[] = {44640, 40320, 44640, 43200, 44640, 44640, 43200, 44640, 44640, 43200, 44640, 43200, 44640};
long monthMinsLeap[] = {44640, 41760, 44640, 43200, 44640, 43200, 44640, 44640, 43200, 44640, 43200, 44640};

//Setup Time Interval of Rotation
const double intervalHour = 24; //hours
//Calculating minutes that it translates to DO NOT TOUCH
int intervalMin = intervalHour*60;
int intervalMinShort = intervalHour*30;

//Setup warning time
const int motorWarningTime = 2; //minutes

//Setup times
const int loopTime = 500; //ms, MAXIMUM IS 1 MINUTE OR 60,000 MS
const int buzzerTime = 5000; //ms
const int motorRunTime = 8; //minute

//Setup minute counters
long diffMonth = 0;
long diffDay = 0;
int diffHour = 0;
int diffMin = 0;

//Setup Run Count'
int runCount = 0;
int toggleState = LOW;

//Setup input/output pins
const int redLedPin = 10;
const int yellowLedPin = 11;
const int greenLedPin = 12;
const int buzzerPin = 5;
const int toggleSwitch = 13;
const int led[] = {6, 7, 8, 9};  // Progress indication lights
const int driverPUL = 4;  // Stepper PUL- pin
const int driverDIR = 3;  // Stepper DIR- pin
const int ESTOP = 2;  // Estop Pin

//Setup for flashing light
bool blink = false;

void setup() {
  //Setting up connection to RTC Module
  Serial.begin(9600);
  delay(3000);  // wait for console opening
  URTCLIB_WIRE.begin();  //Begin Connection to RTC Module
  /*
  //setting Date and Time, Comment out after initial use
  //rtc.set(second, minute, hour, dayOfWeek, dayOfMonth, month, year)
  //set day of week (1=Sunday, 7=Saturday)
  rtc.set(0, 1, 2, 5, 10, 2, 23);
  
  //Storing last rotation in EEPROM
  //MAKE SURE TO COMMENT OUT AFTER INIT
  //EEPROM HAS LIMITED WRITE LIFE (RO)
  EEPROM.write(0, 1);  //Minute
  EEPROM.write(1, 2);  //Hour
  EEPROM.write(2, 10);  //Day
  EEPROM.write(3, 2);  //Month
  EEPROM.write(4, 23);  //Year
  */

  //Setup all IO pins
  pinMode(driverPUL, OUTPUT);
  pinMode(driverDIR, OUTPUT);
  pinMode(ESTOP, INPUT);
  pinMode(redLedPin, OUTPUT);
  pinMode(yellowLedPin, OUTPUT);
  pinMode(buzzerPin, OUTPUT);
  pinMode(toggleSwitch, INPUT);
pinMode(iLed[0], OUTPUT);
pinMode(iLed[1], OUTPUT);
pinMode(iLed[2], OUTPUT);
pinMode(iLed[3], OUTPUT);
//toggleState = 0;

digitalWrite(driverDIR,HIGH); // Stepper motor never needs to change direction
}

void loop() {
  // Load RTC DATA
  rtc.refresh();
  // Check for E-stop pressed, if so, keep updating last recorded time and set intervalmin to the half length
  if(ESTOP == HIGH){
    EEPROM.update(0, rtc.minute());
    EEPROM.update(1, rtc.hour());
    EEPROM.update(2, rtc.day());
    EEPROM.update(3, rtc.month());
    EEPROM.update(4, rtc.year());
    intervalMin = intervalMinShort;
  }
  // Print "Current Date & Time: Month/Day/Year (Weekday) Hour:Minute:Second"
  Serial.print(rtc.month());
  Serial.print('/');
  Serial.print(rtc.day());
  Serial.print('/');
  Serial.print(rtc.year());
  Serial.print(" ");
  Serial.print(daysOfTheWeek[rtc.dayOfWeek()-1]);
  Serial.print(" ");
  Serial.print(rtc.hour());
  Serial.print(':');
  Serial.print(rtc.minute());
  Serial.print(':');
  Serial.println(rtc.second());

  // Calculating how long it has been since last rotation
  // This is long and complicated because it accounts for changes in months, years, leap years, etc
  if(rtc.month() == EEPROM.read(3)){
    diffMonth = 0;
  }
  else if(rtc.year() % 4 != 0){

if(rtc.month()-EEPROM.read(3) == 1){
    diffMonth = monthMins[rtc.month()];
}
else if(EEPROM.read(4) % 4 != 0){
    diffMonth = monthMins[1];
}
else{
    diffMonth = monthMins[1] - 1440;
}
else{
    if(rtc.month()-EEPROM.read(3) == 1){
        diffMonth = monthMinsLeap[rtc.month()];
    }
    else if(rtc.month() < EEPROM.read(3)){
        diffMonth = monthMins[1];
    }
    else{
        diffMonth = 50000;
    }
}

diffDay = (rtc.day()-EEPROM.read(2))*1440;
diffHour = (rtc.hour()-EEPROM.read(1))*60;
diffMin = rtc.minute()-EEPROM.read(0);

long currentRotMin = diffMonth + diffDay + diffHour + diffMin;

//Print current difference to serial monitor for debugging
Serial.print(" dm:");
Serial.print(diffMonth);
Serial.print(" dd:");
Serial.print(diffDay);
Serial.print(" dh:");
Serial.print(diffHour);
Serial.print(" dm:");
Serial.println(diffMin);
Serial.println(intervalMin - currentRotMin);
/*
if(toggleSwitch == HIGH){
    if(toggleState = 0){
        toggleState = 1;
    }
    else {
        toggleState = 0;
    }
*/
// Check state of toggleSwitch
toggleState = digitalRead(toggleSwitch);
// If it has been six weeks, stop spinning and turn on green light
if (runCount > 42){
    digitalWrite(greenLedPin, HIGH);
    // If the toggle switch is flipped to off, turn off the green light and reset the timer
    if (digitalRead(toggleSwitch) == LOW){
        digitalWrite(greenLedPin, LOW);
        runCount = 0;
    }
    // Else, do not spin the barrel
    else{
        toggleState = LOW;
    }
}

if (toggleState == HIGH){   // Check if the toggle switch is on
    Serial.println("on");
    // If it has been a long time since the last rotation, reset the timer to 1/2 the time
    if (intervalMin - currentRotMin < 0 || currentRotMin < 0){
        EEPROM.update(0, rtc.minute());
        EEPROM.update(1, rtc.hour());
        EEPROM.update(2, rtc.day());
        EEPROM.update(3, rtc.month());
        EEPROM.update(4, rtc.year());
        intervalMin = intervalMinShort;
        currentRotMin = 1;
    }
    digitalWrite(yellowLedPin, HIGH);  // Light the yellow LED to indicate that the system is running
    // For each of the progress LEDs, check to see if should be on
    for (int i=0; i<4; i++) {
        if (currentRotMin > (1+i)*(intervalMin/5)){  // Progress LEDs turn on at 1/5, 2/5, etc progress
            digitalWrite(iLed[i], HIGH);
        } else {
            digitalWrite(iLed[i], LOW);
        }
    }
//motorWarningTime Minutes before the motor runs, flash red LED
if (currentRotMin + motorWarningTime >= intervalMin && blink == false){
    digitalWrite(redLedPin, HIGH);
    blink = true;
}
else if (currentRotMin + motorWarningTime >= intervalMin && blink == true){
    digitalWrite(redLedPin, LOW);
    blink = false;
}

//When it is time to spin, do the following
if (currentRotMin >= intervalMin){
    //Set this time as the last time the motor ran
    EEPROM.update(0, rtc.minute());
    EEPROM.update(1, rtc.hour());
    EEPROM.update(2, rtc.day());
    EEPROM.update(3, rtc.month());
    EEPROM.update(4, rtc.year());
    //Run Buzzer before motor runs
    analogWrite(buzzerPin, 125);
    delay(buzzerTime);
    analogWrite(buzzerPin, 0);
    //Run Motor and turn RED LED solid
    digitalWrite(redLedPin, HIGH);
    int initTime = EEPROM.read(0);
    int finalTime = initTime;
    while((finalTime - initTime) < motorRunTime){
        digitalWrite(driverPUL, HIGH);
        delayMicroseconds(500);
        digitalWrite(driverPUL, LOW);
        delayMicroseconds(500);
        if(millis()%1000 == 0){
            rtc.refresh();
            finalTime = rtc.minute();
            if((finalTime - initTime) < 0){
                finalTime = finalTime + 60;
            }
        }
        if(digitalRead(ESTOP) == HIGH || digitalRead(toggleSwitch) == LOW){
            finalTime = initTime + motorRunTime + 10;
        }
    }
    runCount++;
    digitalWrite(redLedPin, LOW);  //Turn Red LED off
}
intervalMin = intervalHour*60;  //Reset the interval to the standard length
} else{
  //turn off LEDs
  digitalWrite(yellowLedPin, LOW);
  for (int i=0; i<4; i++) {
    digitalWrite(iled[i], LOW);
  }
  digitalWrite(redLedPin, LOW);
  //If the motor is getting close to running, delay the run by a half cycle
  if(intervalMin-(currentRotMin+motorWarningTime) <= 0){
    EEPROM.update(0,rtc.minute());
    EEPROM.update(1,rtc.hour());
    EEPROM.update(2,rtc.day());
    EEPROM.update(3,rtc.month());
    EEPROM.update(4,rtc.year());
    intervalMin = intervalMinShort;
  }
} Serial.println();
delay(loopTime);
## Appendix E – Design Verification Plan & Report (DVPR)

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<td>2</td>
<td>Power Requirements</td>
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<td>3</td>
<td>Electrical Power Delivery</td>
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<td>Mechanical Power Delivery</td>
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<td>Temperature Regulation</td>
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Appendix F – Test Procedures

Drum Integrity

Purpose: Ensure the drums can withstand the client-specified load.
Location: Cal Poly Composting
Equipment: Drum, Shovel, Weight Scale, 6 Raisers/Casters, Level, Measuring tape/ruler
Safety Equipment: Gloves, Eye protection

Planned Data Collection & Documentation:

Finite element analysis (FEA) using SolidWorks or Abaqus will be performed on the drum to test for yield strength of the material and how much it will deflect under the required load with a factor of safety of 1.5. As for the physical testing of the drum, we will load the drum with 300 pounds of compost and measure the deflection over the course of three weeks. The deflection will be recorded twice a week.

Test Procedure:

1. Ensure your own safety by properly suiting up with personal protective equipment.
2. Shovel 300 pounds worth of compost into the stainless steel drum.
3. Set up the raisers/casters spaced out as they would be in the overall system to simulate the realistic point loads.
4. With a partner (or two), set the drum on its side onto the raisers/casters.
5. Record the initial deflection of the drum using the level and the measuring tape.
6. Let the system sit over the course of three weeks, measuring deflection twice a week.

Power Requirements

Purpose: Ensure the daily motor power usage is less than the solar panel’s power generation.
Location: Cal Poly Composting
Equipment: Power Supply, Completed System with Loaded Drums
Safety Equipment: N/A

Planned Data Collection & Documentation:

This will be tested based on a pass/fail criteria. The system will be powered on, then run so that our theoretical assumptions were correct.

Test Procedure:

1. After the system is built and complete, the system will be allowed to sit outside in the sun to collect solar power for about 10 minutes.
2. The system will be powered on to turn the manure.
3. The system will be given a pass if the aeration system is turned with ease. If not enough power is supplied to the system and the drums do not turn, the system will be given a fail.

Electrical Power Delivery

Purpose: Ensure the wiring system is well connected, durable, and weatherproof and can deliver power to the system.
Location: Cal Poly Composting  
Equipment: Completed System with Loaded Drums  
Safety Equipment: N/A  
Planned Data Collection & Documentation:  
This test will be performed on an observational basis. The criteria will be pass/fail.  
Test Procedure:  
1. After the whole system is set up, multiple people will observe the criteria:  
   Durable, Weather-proof, Power is Delivered  
2. Each criterion will be pass/fail.  
3. If the system is sound, all will pass.

Mechanical Power Delivery  
Purpose: Ensure the worm is engaged with the worm gear and the worm gear is secure to the drum.  
Location: Cal Poly Composting  
Equipment: Completed System with Loaded Drums  
Safety Equipment: N/A  
Planned Data Collection & Documentation:  
The test will be performed on an observational basis with a pass/fail criteria. If the system is well engaged, the aeration system will work properly.  
Test Procedure:  
1. After the system is set up, the composter will be powered on.  
2. If the worm gear-worm and worm gear-drum interfaces are engaged properly, the drums will turn.  
3. If the system works as specified, the system will pass. If not, it will fail.

Temperature Control  
Purpose: Determine the effectiveness of the aeration system in the form of monitoring temperature and temperature regulation.  
Location: Russell’s Residence  
Equipment: Completed System with Loaded Drums  
Safety Equipment: N/A  
Planned Data Collection & Documentation:  
Temperature will be automatically read and recorded with the controls system. The data will be analyzed and an uncertainty analysis will be performed.  
Test Procedure:  
1. After the system is set up, the thermistor will begin recording the drum’s internal temperature.  
2. The temperature data will be recorded for three weeks.  
3. Uncertainty analysis will be performed on the data.