Autonomous Surface Disinfection Robot to Combat SARS-CoV-2

Monthly Report - April

IEEE REGION 3
ORLANDO SECTION

Overview

The IEEE Orlando Section's Disinfection Robot project aims to design and implement an autonomous robot capable of mapping and navigating a room, identifying all of the surfaces in the room, and then using germicidal UVC radiation to sanitize all of those surfaces. In the previous months, we researched the radiation levels necessary to inactivate SARS-CoV-2, determined the requirements for automating sufficiently powerful UVC lamps, and planned the steps that the robot should take when operating.

The following is a summary of the progress made in the month of March:

- We implemented a 12-volt lead-acid battery and a 300-watt power inverter into our testing to simulate the power system that will exist in the final product.
- After analyzing the performance of our 2D LIDAR sensor, we determined that a more robust 3D sensor will be required to meet our design specifications.
- Development began on a web application that will allow a user to access the robot from outside the room where the robot is operating.
- We began the process of 3D modeling the robot for simulation and manufacturing.

The next benchmarks are set for the end of this month. In order to stay on pace for completion in November 2021, the next month should be spent preparing PCB designs, finalizing plans for charging the robot's battery, assembling a full 3D model of the final robot, and implementing the proposed algorithms in software.

OVERALL PROJECT TIMELINE

2020

November - December
- Research UVC technology
- Divide subcomponent teams

January
- Select UVC lamps
- Begin electrical designs
- Research necessary sensors

February
- Prototype with sensors and lamps
- Continue circuit design
- Begin mechanical design

March - April
- Prototype with sensors and lamps
- Design complete circuit
- Design complete mechanical system

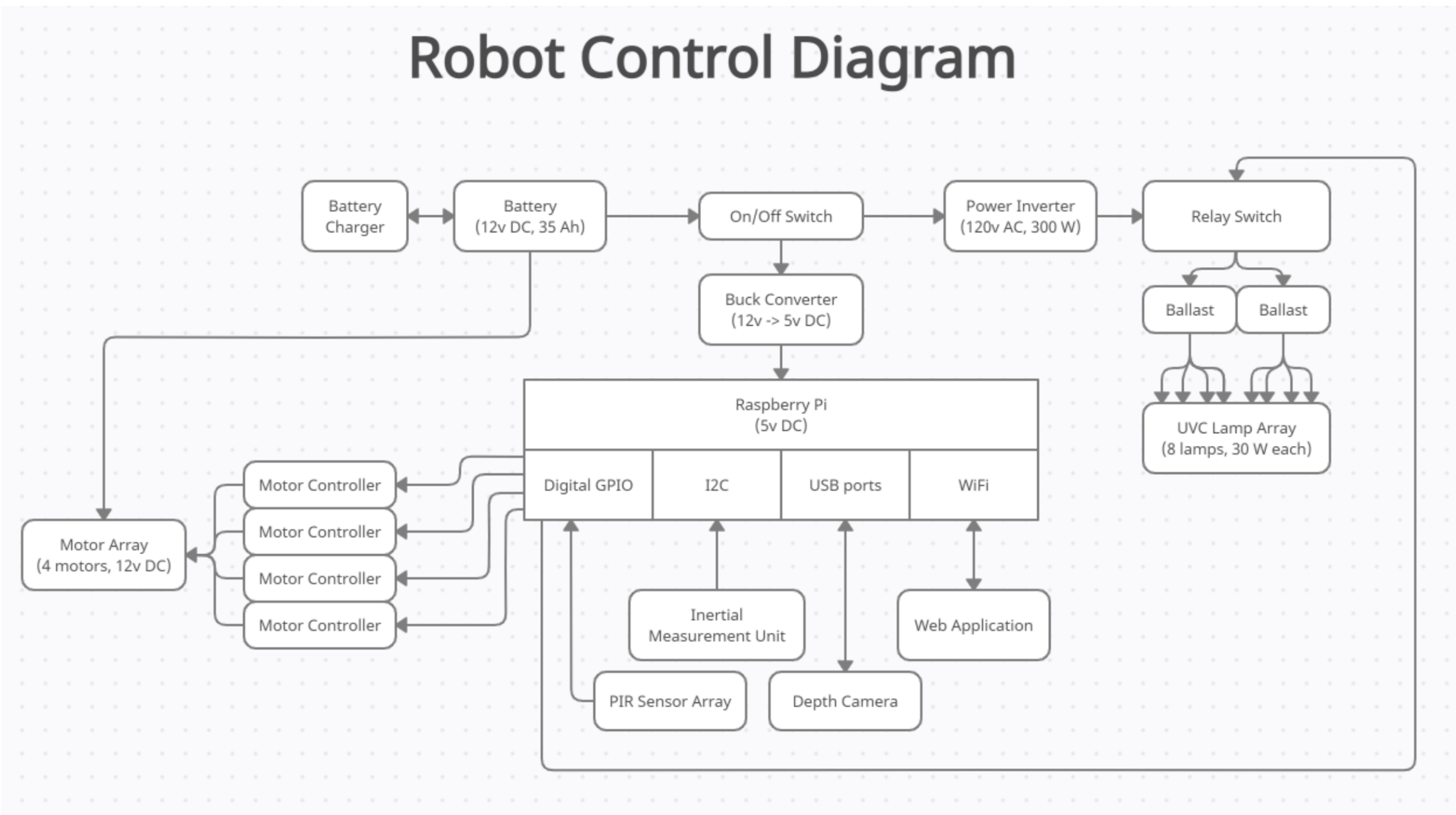
May - July
- Purchase mechanical components
- Prepare material for presentation (publication, donation, etc.)

August - September
- Assemble robot gradually
- Verify robot's performance at every stage of assembly
- Upgrade components if testing reveals necessary changes

October
- Purchase finalized PCBs
- Test robot in diverse environments

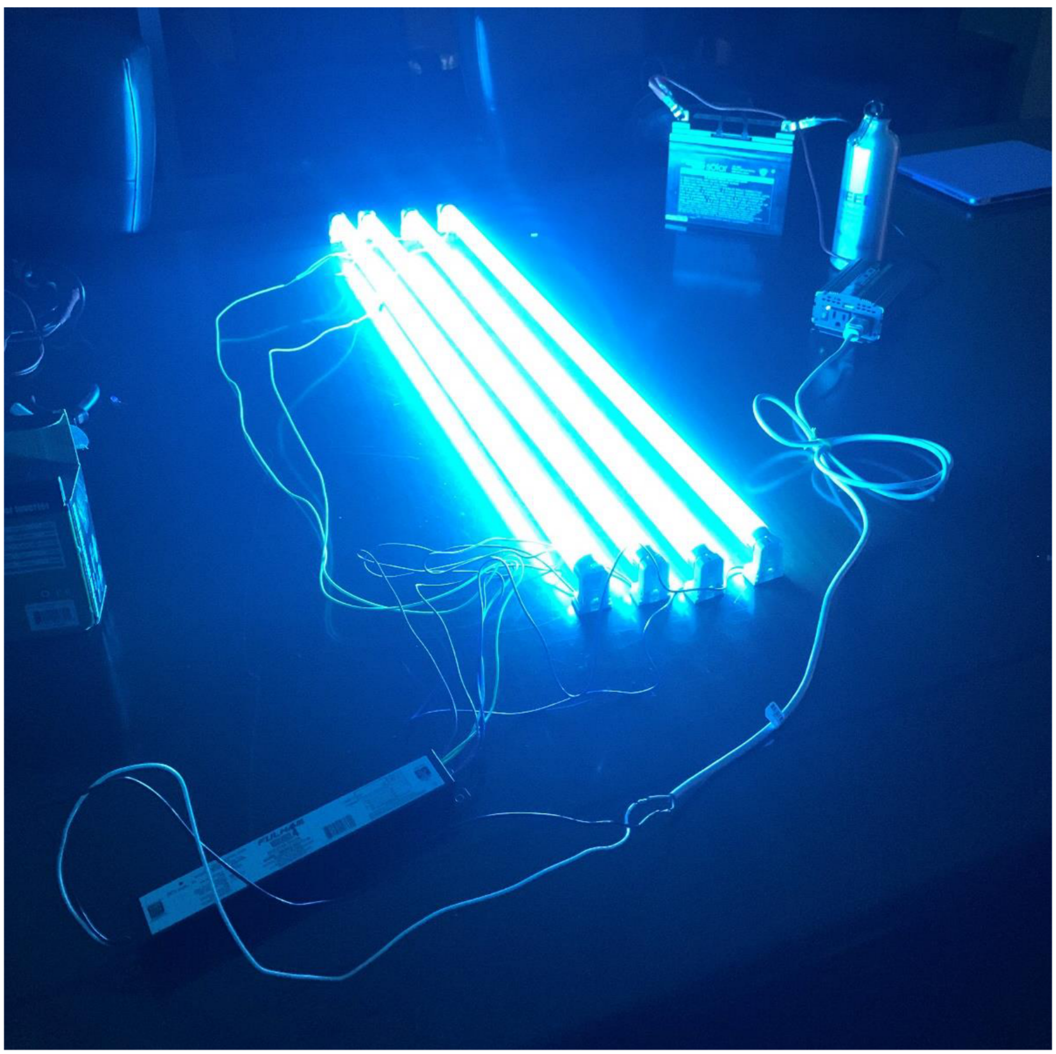
November
- Complete final testing
- Make final preparations for the project's real world implementation

2022


Robot Control Diagram
Battery Charger
Battery (12v DC, 35 Ah)
On/Off Switch
Power Inverter (120v AC, 300 W)
Relay Switch
Buck Converter (12v -> 5v DC)
Ballast
Ballast
UVC Lamp Array (8 lamps, 30 W each)
Raspberry Pi (5v DC)
Digital GPIO
I2C
USB ports
WiFi
Motor Controller
Motor Controller
Motor Controller
Motor Controller
Motor Array (4 motors, 12v DC)
Inertial Measurement Unit
Web Application
PIR Sensor Array
Depth Camera

Progress: Electrical Components

Last month's estimate of the power necessary to run the robot came to a total of 269.4W. Accounting for this, our team selected a 12V, 35Ah lead-acid battery to provide power to the entire system. Additionally, we selected a 300W power inverter to power the AC components. Because the robot has not yet been built, it is impossible to definitively stress test these parts. However, we were able to verify their performance in a test running four UVC lamps.



Four UVC lamps powered automatically by a lead-acid battery

Progress: Software Components

In the past month, our team began testing the capabilities of a 2D LIDAR sensor. The data it collected was unreliable and difficult to interpret. More importantly, concerns were raised about the height of the robot in regards to 2D sensing. Because the robot is meant to stand several feet tall, it is likely to encounter tall obstacles such as tables and countertops. Such obstacles do not necessarily have visible profiles in a 2D plane. If we were to rely strictly on a 2D LIDAR sensor, then the robot could end up failing to recognize these obstacles. The alternative we are now exploring is using a 3D depth sensor rather than 2D.

The Intel RealSense depth camera appears to be the premiere device currently on the market for 3D depth sensing in robotic applications. We are now moving forward with the understanding that the robot will gather information about obstacles in the outside world from one of these cameras mounted on the top of its body. The system will work by capturing a 3D point cloud of all the space in front of it, and then rotating to capture point clouds in a full 360° view. All of these point clouds will then be projected onto a 2D map (which is easier for the Raspberry Pi to store in memory). Currently, there are two proposed methods of implementing this map. One is to adapt the existing polygon model from the previous report. The other method is to represent the world map as a 2D grid with each cell containing a probability of being occupied. These mapping algorithms are still in the early stages of development. They will be explored further in the next month.

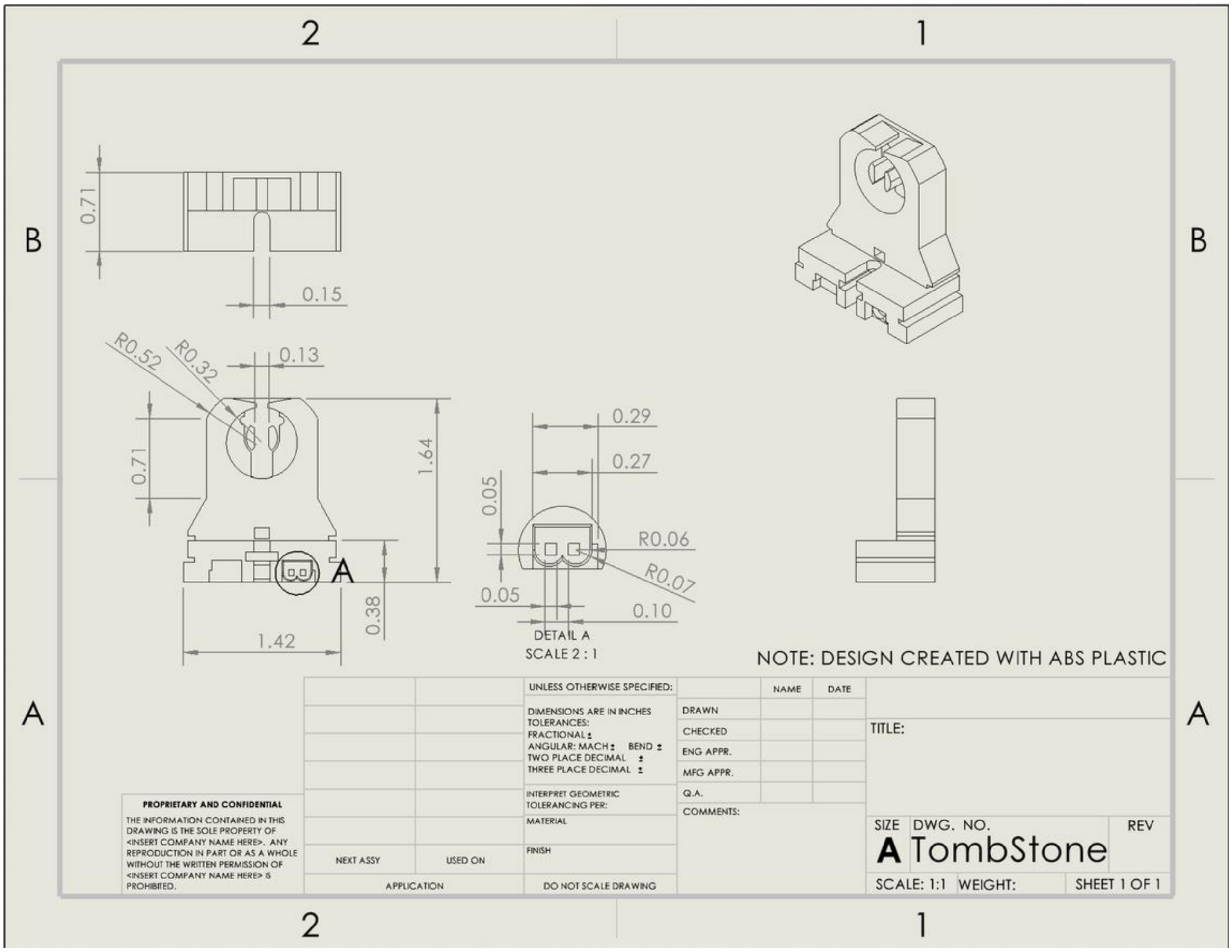
Thinking forward to the user operation of the robot once it is completed, our team began work on a web application that allows operators to check on the status of the robot as well as to begin its disinfection algorithm. The app currently is being designed with functions for the operator to start the robot's disinfection process, monitor its progress, and receive alerts/error messages during the robot's operation. For the front-end of the app, we will be using Vue.js. The back-end of the app will be using C++ REST SDK. Currently, we are working on interfacing with the Raspberry Pi. A small-scale demo of the app uses LEDs on the Pi to indicate the status of the theoretical robot that is transmitting and receiving data over WiFi. This prototype is also in the early stages of development. Over the next month, more details will be finalized and made available.

Progress: Mechanical Components

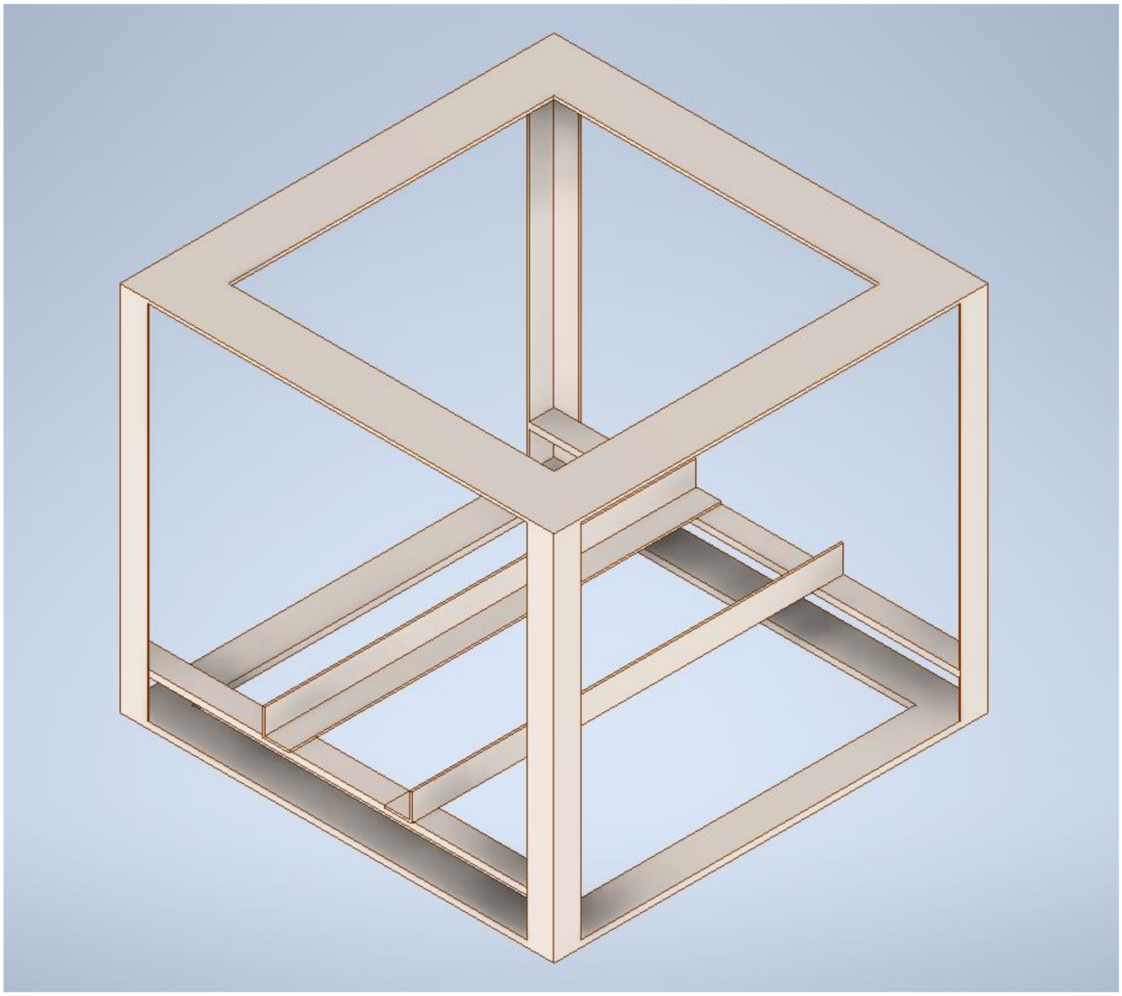
Our mechanical team has now begun the process of creating 3D models for all of the parts in the robot. The intent of this is to assemble a lifelike model of the robot virtually so that we can see potential errors in the design before they are implemented in the real world. The following is a tentative list of the parts that we intend to model for this assembly.

- Ballasts: the parts that regulate AC power to the UVC lamps
- Base: the box at the bottom of the robot that holds all the electronic equipment
- Lamps: the devices that emit UVC radiation
- Power Inverter: the part that converts DC to AC
- Shell: the enclosure that goes over the base to conceal sensitive equipment
- Tombstones: the devices that plug into the ends of the lamps, connecting them to power
- Top: the part that holds all of the lamps in place at the very top of the robot
- Tube: the central column that connects the bottom of the robot to the top of the lamps
- Wheels: the mecanum wheels that will support the weight of the robot

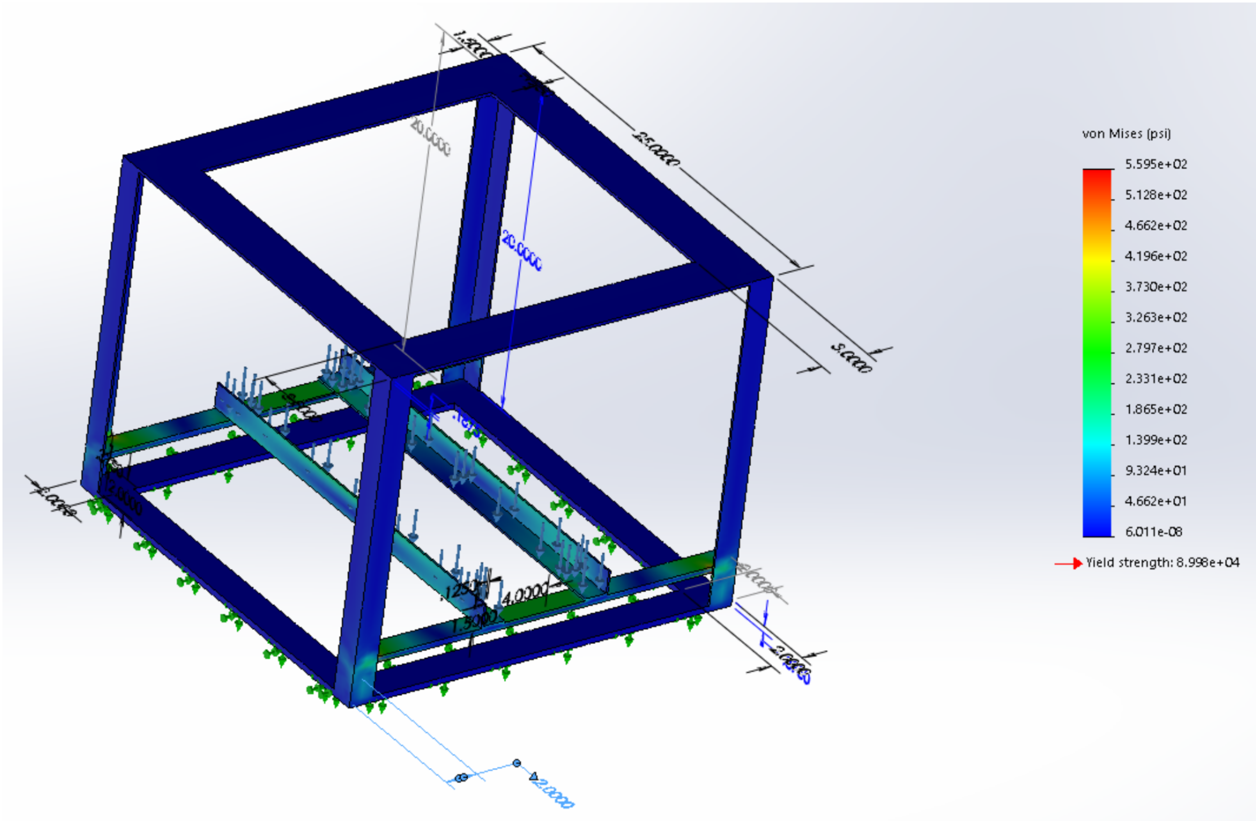
Some of these parts have already been modeled or at least early revisions have been drafted.



The drawing above is the model for the “tombstone.” These devices already exist, so they do not need to be manufactured. We created the model so that we can better understand how to mount them onto the rest of the robot.



Above is a prototype model of the robot’s base. It is a 24”x24”x20” box made of steel bars and brackets welded together. The following image represents the stress analysis of the part.



According to early stress analysis, the base will be able to support a weight of over 500 pounds, which should be much greater than necessary.

Next Steps

The following weeks should be spent heavily in the design phase for most aspects of the project. We will begin PCB design to connect all of the electrical parts together. We will also put a serious focus on ensuring that our robot has the power necessary to meet its design specifications. The software algorithms should be programmed and simulated using ROS soon. Finally, all of the mechanical designs should be modeled so that assembly can begin.

Certification

I, Taylor Barnes, hereby approve of this documentation of the IEEE Orlando Section's pandemic project sponsored by IEEE Region 3, and I certify that the above information is a true and accurate depiction of the project's current progress through the month of April 2021.

4-1-21	Taylor Barnes
Date	Signature