Team 8

Deployable Prototype Documentation

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Team 8: Population Tracking for Covid

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Elevator Pitch

Reduce the spread of Covid by monitoring symptoms and human movement patterns through a device with various sensors.

EXECUTIVE SUMMARY

This project started out with the intent to aid in preventing the spread of covid through the use of a security system with various sensors which would prevent people from entering a setting if the conditions were unsafe. We defined an "unsafe environment" as one which exceeded the limitations set regarding capacity or one in which a person had entered with a high temperature. We decided to use a human detection camera for the purpose of measuring the quantities of people in the setting as well as to start the process of measuring people's temperatures. We figured once the camera reported that there was a person entering, the processor (we used a Raspberry Pi) would prompt the user via an LCD screen to wait such that a thermal sensor could measure their temperatures. From there we decided that the thermal sensor would measure their temperature and record that data to a cloud server and tell the user if they were safe or unsafe to enter through the use of some LEDs and a Buzzer. Beyond that we made sure that the data being sent to the cloud could be used for future business purposes besides measuring Covid such that this project had a more long-term use case, as businesses could use these population metrics as a way to schedule their employees more effectively. Our project was a success as we met each of our measurable metrics. We could effectively measure people's temperatures through the use of the thermal sensor, count the number of people in the setting and differentiate between a person and an animal or some other object entering using the camera, we could alert the users based on their temperatures through the use of the LCD screen, LEDs and the buzzer, record data via the API connection to the cloud server, and finally we had a compact design that could comfortably fit into the majority of stores in a secure manner.

Though we did have our fair share of issues in implementing the final prototype, the majority of the project went according to our initial plan. We deviated from the initial plan as we switched a couple of approaches and components like which camera we choose, but beyond that each of the components went precisely as expected. As expected, the integration of the project came with the most trial and errors, however, we were still able to meet every requirement we set for our project. The project took a great deal of planning and adjustment to get to the final product. This report helps detail exactly what preparations we took to ensure our project's success. Not only did we have countless assignments that helped us research and plan our project, but we also analyzed the risks and the design approach to our project that helped us complete our project.

All in all, this project was a success as we found people not following Covid restrictions to be a problem in society, planned to create a device to address this issue (our prototype), and successfully engineered a solution which delivered on everything that we had initially decided to indicate success on this project. This project fulfilled all the technical requirements and was able to function autonomously as we had hoped. In addition, the knowledge and experience gained in this experience was invaluable and helps prepare us for our future engineer career and projects that we will face.

Abstract

We chose to create our project to help against the spread of Covid, specifically the monitoring of human people and common Covid symptoms, in order to help businesses or stores reopen during or after this Pandemic. Specifically, our project uses a processor connected to a camera, infrared sensor, cloud server, and alert system held within a secure case in order to monitor human movement patterns and detect if anyone entering the store has a fever, a common Covid symptom. In addition, all data measured is stored in a server which can help future planning and preventative measures. We chose to use an infrared sensor, webcam, LED's, LCD screen, and a processor to carry out these functions. The components are stored in a plastic box that is mounted onto a plastic pipe to keep the components secure and the product mobile. In the fall semester we focused on meeting our basic measurable metrics, while in the spring semester we focused on testing and integrating our system. In addition, we analyzed any risks with the design process, and made sure to avoid those risks. As well we analyzed our design philosophy focusing on the difficult decisions we made during the project. And finally, we analyzed the possible market impact and realized how our product was unique and could be marketable. Through this year-long project we were able to meet our measurable metrics and create a fully autonomous system that could be set up and used easily in any buildings.

Keyword Index
Covid-19, Thermal Imaging, LED, Infrared Sensor

I. INTRODUCTION

This report will explore and explain the design process of our senior project, Population Tracking for Covid, throughout the 2020-2021 school year. We were assigned the task to build a deployable prototype that could help solve a large societal problem. Throughout this year our team which consists of Micah Biggers, Nick Patten, Dennis Trotsyuk, and Paul Dye have worked on our project called Population Tracking for Covid. Throughout this report we will go through our entire design process starting from our societal problem choice and concluding with our final design. This project was done amidst the Covid pandemic which caused the school to be held in a virtual manner. This created some difficulties for our project, but we were able to still complete our project in a virtual manner.

The first step in our project was deciding our societal problem. All of our projects we choose were required to solve a large societal problem that affects millions of people. We choose the societal problem Covid for our project to address. Covid has been one of the largest problems currently in the world, so we decided it would be a problem that could use a technical solution. We choose Covid as our societal problem, but we had to choose a more specific area to devise a technical solution. We are not doctors and cannot cure Covid, so instead as engineers we choose to focus on one aspect of Covid which was the reopening of businesses and stores as a problem to address. Covid has caused many stores and businesses to be shut down initially, but as time went on stores started to open up in varied manners. This process needs to be a safe process, such that Covid does not continue to spread. As businesses and stores reopen, they need to verify that people coming into the store do not have Covid, as well as make sure their capacity is at the appropriate level. Many states implemented capacity limits such as 50% capacity or 30% capacity max. Therefore, our specific problem was to address both of these concerns in the process of businesses and stores reopening amidst the Covid pandemic. However, it is essential to also realize that our problem is addressed to Covid but could be applied to future pandemics. Covid has shown a lack of ability for society to control a pandemic. If future pandemics were to result, our solutions we implement as a response to Covid could also be applied to prevent the spread of future pandemics. Choosing a societal problem was the first step in our process such that we could implement a technical solution that could help address the problem we choose.

The next step was to determine our design idea for our project. As mentioned, our societal problem was Covid specifically the reopening of businesses during a pandemic. The two main functions we wanted our project to have was the ability to detect Covid symptoms to prevent people with Covid from entering the business or store and risk spreading Covid. In addition, we wanted the ability to track and detect people as they enter the buildings such that the business or store could manage capacity limits as well as realize when their capacity is at their peak. Not having overcrowded buildings is essential when trying to prevent the spread of Covid. Those were the functions we needed our project to accomplish, but that is not the basis of our design philosophy. Our goal was to create a device that could accomplish the goals while being able to be used autonomously. This added to the design idea the ability to be easily used by a user as well having a safe and secure design. In addition, we decided our design idea should record the data we calculate. With the Covid problem of Covid, a large part of the problem is understanding how Covid is spreading. Even throughout Covid there has been much debate over how severe it truly is, and the measures required to match the severity. Therefore, it is critical to our design to record our temperature data and when people come into the store to be able to determine how Covid is actually affecting people. With the temperature data businesses and stores can determine how many people have Covid symptoms that enter the store, and with data that records how many people come in the store the store can adjust and learn when their capacity peaks during the day. These functional items became the basis of our punch list which was in essence the checklist for our project. We determined the need for each item, and then assigned measurable metrics for each item as a requirement to meet. This punch list helped guide our work throughout the semester and set a goal which in the end we were able to meet. Determining the design idea was not a simple task. We had determined our societal problem, but in order to figure out the design idea we had to consider not just what could help solve the problem, but also what we as engineers had the ability to solve. This punch list in the end was a great help and was able to guide us throughout the year.

We planned out our funding as well for our project. We tried to keep the costs minimal when possible. We expected to spend around $100 per member for a total of $400. This came to be about what we spent for our project. The most expensive items were the infrared sensor, camera, and raspberry pi. There were also some smaller items that required purchasing, but overall, we made sure to pick devices that could give our project the full functionality required while still being smart with our money. Our original funding estimate ended up being not as accurate, however, the overall amount was similar because some items were more expensive and others less expensive than expected.

The next step was the project timeline. In some ways this was similar to our work breakdown structure, but it involved creating a visual representation of our tasks for the year. This forced us not just to create a list of tasks, but also a timeline for the tasks to get done. When we worked through this year-long project we realized there was an order to which tasks had to be done. Our project we designed such that each member could work on their individual part which helped add some flexibility to the design process. However, there were still items that had to be done before other items could be accomplished. This timeline helped us visualize how the work was going to get done, and when each item had to be complete. The organization of the class also greatly helped planning out our project. The class has many assignments structured in a way that we used the assignments to guide us through the project. In addition, work is required on the project and sometimes that work is unexpected. So, in our original plan we used the assignments as deadlines to create a timeline. We did not exactly follow the timeline due to unforeseen challenges, and tasks that were required for our project. However, this plan helped have a basic outline and let everyone be on the same page when working on the project.

After determining our design idea, we had to come up with a work breakdown structure that would guide our work throughout the year. One thing we learned throughout this project was the necessity of planning. When working on a yearlong project the ability to look ahead and plan was crucial to guide our work and make sure we were working toward the end goal. In order to help us further plan we created a work breakdown structure that detailed the workflow throughout the year. The first item in this work breakdown was to determine the parts and devices needed for our project. It became evident early on that in order to have any productive work for our project we needed to have the devices that we were going to use to build our project. In the beginning of the year, we had only a rough idea of what devices we needed, so we had to do significant research and look for the best products. This process was also rushed, because there were deadlines early on that required us to make the purchase much faster than we were prepared. This was our initial item, because without the devices we could not make progress on the technical aspects of our project. The other items of our work breakdown structure were guided by our punch list. Our requirement for the fall semester was to have a deployable prototype that could meet our punch list items without complete system integration. Therefore, our other items were based on the punch list and the individual features of our project. We divided the project early on such that each person could contribute to one item of the punch list. We also divided the work because senior design was in a virtual format. We wanted to all be able to work on the project independently such that the project did not have to be passed between members constantly. Therefore, each item was each item that each member was responsible for. At this point during the semester when analyzing the work for the spring semester we really had no idea what was in store. We simply estimated that testing, integration, and spring assignments would be the major tasks for the spring semester. This work breakdown structure was critical for us to outline the project as a yearlong task so that we could see the long term and short-term goals separately.

The next section of our report outlines the risk assessment for our project. This part is the first time any of us had ever considered analyzing the risks before starting a project. In school most projects are a month long at the most, while Senior Design is a yearlong project. This difference is what requires us to analyze the risks prior to the project. It was important to predict any difficulties that would happen before they arise such that we would be prepared in case the problems come up. For our project we analyzed what the critical path was, or in essence what was essential for our project to be able to do. These critical paths were in essence the core to our punch list being, camera detection, temperature reading, communication between the devices, building the structure, and sending data to the cloud. Each of these paths were analyzed to determine if there was any major risk for each part. At this point fortunately we had done enough work with our project to know that each functionality was possible, and that risks were still possible but not large risks that would derail our project entirely. We then analyzed the risks of our project as a whole and identified any technical risks, broad technical risks, and systematic risks. Some risks would have proved to be difficult. For example, if the infrared sensor could not read the temperature to a high enough accuracy, we would have to find a new infrared sensor at that point. This encouraged our group to focus on verifying the temperature sensor as quick as possible in case the device needed to be replaced. With each of these risks we also looked at possible mitigation strategies. These mitigation strategies often would involve buying a new device or come up with a new solution or method. For example, we analyzed that we could use a different cloud in case the website we choose proved not to be functional in the way we had planned. In addition to these risks, we analyzed how the handling of social distancing could derail our project. Initially in our project we made sure that our design was modular, and that each part of the project could function independently for the most part. This modularity helped limit the negative effects of the virtual environment. However, even with this step taken we had to analyze the effect if one of us was unable to work on the project due to Covid how we could respond. These solutions often resulted in leaving extra time before a deadline to minimize the risks. In addition, we planned out our trade off policy which we used throughout the year. This policy involved passing off the physical device to another team member. This was done by sanitizing the project and then passing it off while keeping social distancing. This helped during our integration of our project such that one member could have the entire project without us all being in the same place physically together. Overall, this risk management helped us greatly realize the scope and magnitude of our project. Fortunately, we dealt with few of these risks, however realizing the risks helped us plan out our project better and leave less room for stress or major concern. By analyzing what could stop us, it helped prepare us to complete our project early and, in a way, where risks would have less effect.

Next is the design philosophy. This section was written retrospectively when analyzing our design choices. Overall, in our project we had a smooth design process and were able to meet every deadline. This success of our project can be contributed to our wise decisions that we made for our project. It was important to look back on our design philosophy and determine what caused us to make each decision. One common theme we strived for was the simplest option that would solve our goal. As engineers sometimes we have the tendency to want to add more and more to the project and make it this impossible problem. Instead, we focused on whatever we could implement simplest that would still solve our problem at hand. For example, originally, we wanted our system to have an adjustable height so that a person entering the store could be any size and still use the device. However, knowing that none of us were mechanical engineers we decided that was beyond our expertise and did not pursue that part of the project. Another part was the cloud data transfer. Originally when we used thingspeak we were concerned that data could only be sent every 15 seconds. We considered using another cloud database server or possibly spending money to improve this delay. However, instead we found a way to modify our project to meet the limitation. We instead sent our data together in one packet which helped the sending of data. As well we realized the process of someone entering the store, measuring their temperature, and awaiting the results would be the 15 seconds regardless. People would not have to be waiting longer than before for the 15 seconds to pass. As well we realized that for a deployable prototype the short delay would not be a huge detriment to our project. Since it is still in essence a prototype, we could show off the full functionality of our project without having to switch servers or spend money. Instead of spending time on unnecessary items that are not essential to our project, we instead spent time on testing and developing the items in our project that were essential. This helped us meet every requirement for our project in the time required. This design philosophy section helps walk through each major choice we made in our project and explain what led us to each decision.

In the next section we analyzed the testing we had done for our project. This testing was leading up to the final demonstration of the prototype. During the fall semester, we had met each punch list item for each feature to a minimum level without extensive testing. In the spring semester we focused on the system integration and testing of each component. The testing component was critical to prove that we had met each punch list item as we thought. For the testing, each member took part of the project they had done the most work with and developed a series of tests to confirm the functionality of their part of the project. The testing was also essential to be completed before the system integration. If the items proved not to meet the requirements it was better to know before, than if problems arise after the system integration. Therefore, we made sure the testing period was extensive and covered any areas of concern such that we could be confident in our project and that it would work correctly after system integration. The process for testing was that back in the start of the spring semester, we created a testing timeline. This was where we had a timeline for each item we were to test. After we carried through the tests, we documented the results in this section. For the infrared sensor, the distance at which it could measure temperature accurately was tested. As well the higher bounds and lower bounds of temperature we measured. By this we mean temperatures between 92 and 110 degrees Fahrenheit. Finally, the temperature of a standard human as well as verifying the functionality of the error detection. These tests proved that the temperature sensor had a verifiable accuracy that was within the 0.5 degrees Fahrenheit required. In the testing we saw that it met and often far exceeded these requirements. This extensive testing was critical, because a large portion of our project relied on the reliability of the temperature sensor measuring accurately. For the camera we tested it could read faces up to 95% accuracy. As well that it could count the face as a person and keep a total count of people that proved to be accurate. Finally, the camera was tested so that it could detect people up to 10 feet away. For these tests Micah walked in and out of the camera’s vision and verified that it detected the person as required. These testing elements were also essential, because our device only starts the sequence when it detects a person. It will not measure anyone’s temperature without first detecting the person. So therefore, this critical functionality of our project had to be tested and proven such that the rest of the project would work. Next, we tested the alert user section of the project. This test was based on functionality. Nick had used a variety of LED and LCD screens in this section, so he verified that each device would work as intended so they could easily be integrated into the final design. The next item was testing the produce and record data for the system. This involved the cloud connection. We simply verified that if we sent data to the cloud that it would receive the data at the time it was sent and store all the data. This connection proved to be reliable and meet its requirement. Finally, the last testing was the compact and safe design. Dennis worked on making this physical design. The testing involved simply verifying that it was a stable design and fit within the parameters in the punch list being less than 25 pounds and within 2’ by 2’ by 6’. The physical structure met those requirements and held the project safe and compact. All these testing results met the expectations and often exceeded the requirements. This testing was essential for proving that our function met the requirements and giving our team the confidence to integrate the system knowing that each part was working as intended.

The last part was to determine the marketability forecast for our product. Although we are likely only creating this as a prototype, it is important to analyze whether our product has a possible market forecast. Our projects in senior design serve to solve a problem. So, if we solve a problem in a unique or efficient way, we can expect to have a market for our item. We analyzed the market forecast for our product and believe our product to have a great market. First, our problem we address is a problem for each and every store or business concerned with Covid and preventing future pandemics. This means that our product truly has an enormous market. As well we found few other products can accomplish what we do at our costs. Currently either the building has no Covid measures, or it has a person with a handheld thermometer. The other solution is these kiosks we found that are able to do what our product does to some degree. However, these kiosks are thousands of dollars while our device could be made for less than $500. As well our product has additional functionality considering the cloud storage model as well is easier to use. So, after analyzing that the competition currently in the market is weaker compared to our product, and that our product could have a nearly infinite market. It is safe to presume that our marketability forecast is quite strong. However, we also realize that the process to start a business and produce these devices is likely outside the range of our expertise as students and in addition would prevent us from pursuing our careers. Therefore, we are unlikely to start producing these devices, however, we can have pride in our project and realize that there is a great market for our product. Marketability forecast is a priceless skill that will help all of us in industry. If we have to make a product in industry, it is essential to analyze whether our product has a market and what it truly offers. By analyzing our senior project, we gain the skills to analyze the market for any product we design.

This senior project has been a great learning experience in a variety of ways. When students think about a senior project, they often think that they just design a cool product and write a small report. However, after completing the senior project we realize the amount of work that goes into a yearlong project and how many different aspects there are in creating a prototype. We have learned so many skills that we did not expect, such as risk management, market forecast, and how to work with others. One of the most valuable skills we learned was the ability to plan and the importance of planning our project. This report helps walk through each and every step toward making a prototype in the end. It is important to realize that each and every section works together to make a deployable prototype. This year-long project also helped us for our future careers in engineering fields. In the real world you cannot simply design an idea and just call it good. Rather you have to go through all the steps of designing a prototype and clearly have a plan and follow through on the plan. Senior project helps model this experience for us as students. In school we often are given a problem and we have to solve it. However, in industry that is never as easy as it seems. By completing a yearlong project, we gain the understanding of how truly important each part of the project is. This process is detailed in this report as we walk through each part to show the full journey to how we reached the deployable prototype. This year long project has been a great learning experience throughout and is a project that we can be proud of our work that went into this project.

II. SOCIETAL PROBLEM

A. Spring Update of Societal Problem

Our problem has not changed or been adjusted after our prototype was built during the first semester. However, we better understand the problem and how specifically we are going to address the problem. Our problem is to help address companies or businesses trying to reopen during a pandemic specifically the Covid pandemic currently affecting our world. This problem has not changed and still is the focus of our project. Reopening businesses is still a major concern and will require proper care and hopefully our project can make this process safer and prevent further spread of Covid.

It is important to analyze the effect Vaccines will have on our societal problem. First, we realize that with vaccines the problem does not completely go away. There is a possibility of alternate strains of Covid that the vaccine may not address. Also, not everyone can get the Vaccine at the exact same time so while reopening there will be vulnerable people who may get further exposed. We can expect businesses to be reopening within the next few months (though some may be longer). This will be when our product has the most effective use.

However, the other idea to keep in mind is that even if Covid no longer becomes a problem at some point, which at this point is an unknown time, our product will still be useful for businesses. Covid has shown a great lack of preparation and knowledge of our country being able to deal with Covid and therefore we as Engineers should try to prevent the spread of future pandemics. With this product it could easily be a permanent feature of stores which could help prevent future products even simply the common cold. Our hope is that society has realized the importance of stopping the spread of disease, so therefore our product will continue to have a positive and essential impact on our world.

The exact components of our project have slightly changed after research, but the effect and general purpose has not changed. We have a D632L infrared sensor which uses an I2C connection to measure the temperature of a person that enters the store. In addition, we have a camera that is able to use human detection to tell people who enter and leave the store. This is so that the building can track its capacity and keep records of when people enter the store. It also tracks when the times of the day more people come in so that the businesses can plan around these statistics. We also have basic alerting functions which will light up a green or red LED to depict if the person has an acceptable temperature. All of our devices uses the Raspberry pi to communicate with each other and send their data through the use of API keys to a server called thingspeak. This site has the capability to correlate the data and depict it on graphs to show it more effectively.

Our team problem statement was determined at the beginning. After a semester building a test prototype, we have largely stayed consistent with our vision and kept our focus the same. Our problem still exists and is a serious problem that our product will hope to solve. Our devices we ended up using were slightly different than we first thought, but the effect is the same. We were able to create a strong initial idea and therefore we did not have to change much as we went along. Our project is still on target and we believe will help solve our problem.

B. Literature Review

We reviewed several news articles as well as peer reviewed sources to give us more knowledge surrounding our project specifically our team problem statement. First, we researched the journals and articles that could help us understand our project better. In the first article we found, Non-contact temperature sensors detect infrared energy emitting from an object; in this case a human. It then sends a signal to a calibrated electrical circuit. This signal helps determine an object's temperature [34]. Next, we looked at an article regarding contact tracing. Contact tracing is a tool that helps slow down the spread of covid-19. Our team's device can help people recognize when they may have covid-19 thus helping the possibilities for contact tracing to exist. The sooner health officials can alert close contacts, the lower the risk of spreading to other people.[37] We also found an article relating to our processor we used, the raspberry pi. We found that Raspberry pi has helped change the world in other ways than our group has used this device. Our goal is it helps us change the world in a positive way again. Ways it has helped change the world by making language transition easier, owning a security camera is cheaper, owning a laptop is cheaper, etc. [32]. Finally for the articles we found one relating to cloud data storage. Cloud storage takes data from hardware and stores it into another physical location called the cloud. The cloud can be accessed via the internet by other devices. This data can be manipulated to show stats that are useful. [33]. Next, we found IEEE articles which are known to be peer reviewed and analyzed articles that could help us understand our project better. An application programming interface is rather a unique code that is passed into an API to identify the calling application or user interface. It gives the user a safe secret access key to access and manage a cloud-based system with the stored data. It is critical to keep these keys safe [36]. Next one article related to a core concept in our project which was I2c connection. I2C is very commonly used to allow one chip to talk to another. Since the Raspberry Pi can talk to I2C we can connect it to a variety of I2C capable chips and modules. The I2C bus allows multiple devices to be connected to your Raspberry Pi, each with a unique address, that can often be set by changing jumper settings on the module. It is very useful to be able to see which devices are connected to your Pi as a way of making sure everything is working [35]. Next was an IEE article on the raspberry pi processor. Raspberry Pi is an efficient and cost-effective piece of software that can reach embedded systems and produce very good data. It acts as a power source to many things like the thermometer sensor in our project. It has many features like a multicore processor, GPU for graphic display, Bluetooth, USB, and Wi-Fi. With the right coding it has lots of possibilities to compute all intensive tasks [39]. Finally, the last IEEE article related to using a camera for facial detection A camera with an integrated facial recognition feature installed in it can help for human tracking. This is very helpful to allow people to collect information about when are the busiest times in a certain area or store. The facial recognition aspect of it is just to verify that a human is walking in rather than a camera that can detect animals or other living things. This can also help with security purposes in many ways if something happens in a store there is video proof of that person coming in or out of the building. [38]

C. Largescale Effects of Covid

Our societal problem is the Covid-19 epidemic. It is important to define our societal problem, Covid-19 which has had tremendous effects on society. The Covid-19 has affected more parts of our lives than expected and has created some new difficulties that require innovative solutions. Understanding exactly what Coronavirus is, and how exactly it has affected society is essential to creating a solution that truly helps solve problems. Our group decided to pick this societal problem, because of how big the impact has been on society. In addition, Covid-19 has caused a nationwide quarantining, which has led to additional economic and social hardships. One of the requirements for picking a societal problem was that it had to affect a large group of people, and long duration. The Covid19 has affected the entire world which fulfills the requirement for our societal problem to affect a large group of people. In addition, however, our solution could be applied to future pandemics. Although we would like to think this is a onetime problem, with an increasingly interconnected society the chance of future pandemics seems likely. It is our task as society to not simply try to focus on solutions for this pandemic, but also keep our solutions in mind to make sure that a future pandemic does not occur or hopefully is more limited and controlled. Currently the Covid-19 is still spreading and causing a large number of deaths. The CDC Covid-19 data Tracker [1] shows trends in the USA of new cases and deaths. These two images show the impact Covid-19 has had on the United States.

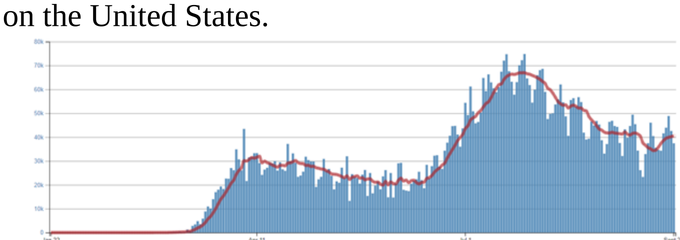

Figure 1 Covid Cases: Shows new cases of Covid in the USA [1]

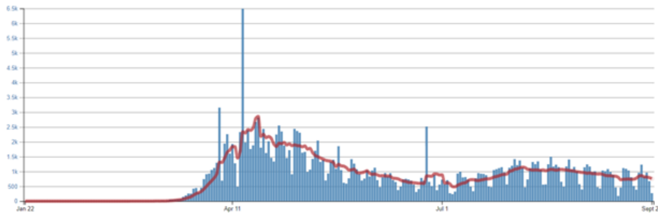

Figure 2: Covid Deaths Shows deaths from Covid in the USA [2]

Analyzing these two graphs it is clear that Covid-19 has not gone away and is still abundant in society. The trends continue to remain steady which unfortunately show how the continuing problem of Covid-19 and its lasting duration and problem to society. Another helpful source to track Covid-19 is the worldometers website [2].

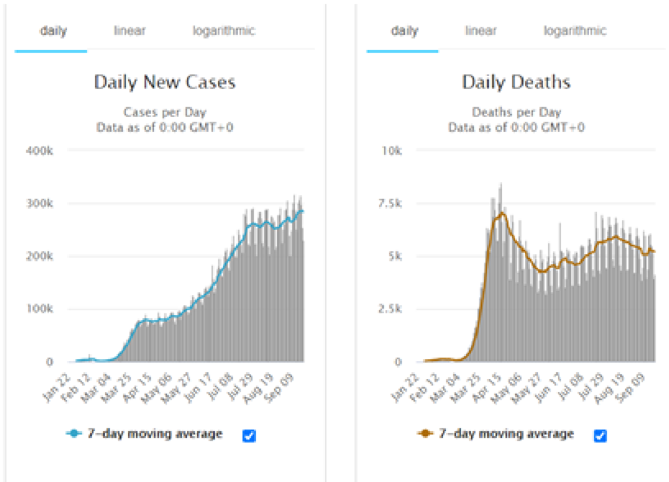

Figure 3: Covid Worldwide Shows new cases and daily deaths from Covid worldwide [2]

Here these numbers are much greater since they are measuring the new cases and deaths from Covid-19 worldwide rather than simply the United States. It is important to keep multiple sources and stay aware of the real impact Covid-19 has and will continue to have on this country. Understanding the 2 severity should cause us as society to realize the importance of creating helpful solutions to ease the negative effects of Covid19. Covid-19 has not also had a health impact on this nation, but also an economic impact. Below are graphs that show the employment in the United States [3]

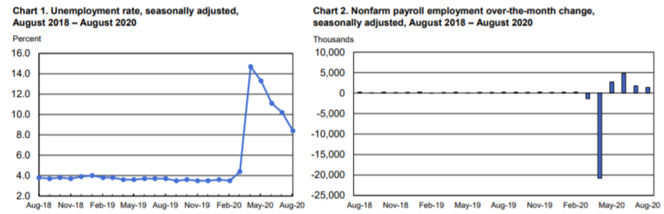

Figure 4: Unemployment: Graph of the unemployment and Nonfam payroll employment in the last 3 years in the United States. [3]

As clearly shown a large spike in unemployment was caused by Covid-19. The societal problem of Covid-19 is very com- plex and is shown to have a large economic impact on our society. This idea of unemployment is just one example and reason to make creative solutions to not just help the safety and health of our country, but also in addition to hopefully make businesses returning a viable solution and decrease unemployment. Another effect of the Covid-19 is an economic decrease. A helpful site to find all sorts of information is the US Bureau of Labor Statistics [4]. Below are some examples that show the dramatic economic effect of Covid specifically the gross domestic income [5].

Gross Domestic Income	
Quarterly - Change From Preceding Period	
Q2 2020	-33.1 %
Q1 2020	-2.5 %
Annual - Change From Preceding Period	
2019	+1.8 %
2018	+2.6 %

Figure 5: GDI The GDI in the United States from 2020 Quarter 1, 2 and from 2019 and 2018[5]

Here we can see that quarter one the gross domestic income only decreased slightly at 2.5 percent, but in quarter two it decreased by 33.1 percent. When quarantine started and created a big hit economically and as a solution it undoubtedly helped the health of the country, but in an economic sense definitely created challenges. Now to look at a more comprehensive table of the US economy [6]

Industrial production	2012=100						Percent change						
	2020						2020						Aug. '1
	Mar.[r]	Apr.[r]	May[r]	June[r]	July[r]	Aug.[p]	Mar.[r]	Apr.[r]	May[r]	June[r]	July[r]	Aug.[p]	Aug.
Total index	104.5	91.0	91.9	97.5	101.0	101.4	-4.4	-12.9	1.0	6.1	3.5	.4	
Previous estimates	104.6	91.2	92.0	97.2	100.2		-4.3	-12.8	.9	5.7	3.0		
Major market groups													
Final Products	96.7	81.8	85.5	92.8	97.5	98.2	-5.8	-15.4	4.5	8.5	5.1	.7	
Consumer goods	100.0	87.1	90.8	98.3	103.2	103.6	-5.5	-12.9	4.2	8.4	5.0	.3	
Business equipment	90.2	69.3	74.3	83.1	88.6	90.3	-8.0	-23.2	7.2	11.8	6.6	1.9	
Nonindustrial supplies	104.6	91.7	93.7	96.7	98.4	99.6	-4.8	-12.3	2.2	3.3	1.8	1.2	
Construction	115.5	100.6	104.2	106.6	107.5	108.8	-3.8	-12.9	3.5	2.3	.8	1.2	
Materials	111.2	98.9	96.7	101.6	104.4	104.1	-3.0	-11.0	-2.2	5.0	2.7	-.2	
Total industry	79.8	85.1	78.8	85.0	66.7	77.8	73.6	64.1	64.7	68.7	71.1	71.4	
Previous estimates							73.6	64.2	64.8	68.5	70.6		
Manufacturing (see note below)	78.2	85.5	77.3	84.6	63.7	75.7	71.4	59.9	62.2	66.9	69.5	70.2	
Previous estimates							71.4	60.0	62.3	66.9	69.2		
Mining	87.2	86.3	84.3	88.6	78.3	90.6	87.7	81.5	72.6	75.0	76.2	74.5	
Utilities	85.2	93.2	84.7	93.2	78.2	76.3	71.1	72.3	71.7	72.4	75.0	74.5	
Stage-of-process groups													
Crude	86.2	87.8	84.7	90.0	76.4	88.6	86.3	80.3	73.9	75.9	77.0	75.8	
Primary and semifinished	80.3	86.4	78.1	87.8	63.9	75.8	71.3	62.4	63.7	67.0	69.0	69.7	
Finished	76.7	83.3	77.3	80.6	66.5	74.9	70.1	58.5	61.4	67.1	70.5	71.1	

Figure 6 Industrial Production: Various IP values are shown from the past year in the United States [6]

In the varied categories, all the values have a common pattern which is in April the percent change was decreased across the board which again is due to Covid. By showing many categories it is clear that this affected the entire economy, individuals, and businesses were affected by Covid. It is crucial when analyzing a societal problem to see all the impacts it truly has created. When realizing that this virus causes a giant health and economic problem it creates more reason to attempt to solve problems related to Covid and help adjust the best we can to it as a society. Covid-19 is our societal problem, but it can be too large of an idea to find an engineering solution for. Not a single solution will eliminate Covid-19 so therefore it is helpful to narrow the societal problem of Covid-19 to guide us as engineers to developing a technical solution. As student engineers it is not practical for us to attempt to find a cure or medical solution to help with Covid-19. So instead, we focused our societal problem on helping one of the effects of Covid-19, social distancing. Non-essential businesses were shut down due to Covid-19. However, now slowly more businesses are coming back to business and need to implement health and safety measures to make sure Covid-19 spread is limited and does not continue to come back. There is a great importance in these businesses coming back. As businesses start to come back in person these businesses are able to stay in business and not have to lay off more workers. It is essential for the transition from quarantine to in person to be safe and smart. This transition is the specific part of the societal problem of Covid-19 our team has decided to attack. So, by narrowing the large societal problem of Covid-19 to the transition from quarantine to businesses reopening we have many ideas on how to approach the problem and multiple problems to solve that can help improve the overall situation. One challenge of reopening is making sure reduced capacity limits are fulfilled. In many states' capacity is limited for inside buildings. This is a requirement that has to be measured and recorded. Another requirement is oral temperature checks. This 3 is an additional screening process also is essential to reopening businesses safely. The process of reopening is complex and essential which is why our team decided to attempt to fix and solve problems regarding reopening of businesses. So, to conclude, our societal problem is Covid-19, and it is essential to remember all the health and economical effects it has caused to the United States. Our societal problem isCovid19 but our specific area we are targeting is the reopening of businesses. It is important to make sure that the reopening of businesses is safe to prevent further exposure. To help with this safety we will be addressing any and all issues resulting in reopening businesses by having limited capacity or managing social distancing within indoor locations. Covid-19 is a clear and abundant problem in our time which is why we choose the societal problem and try to address any possible problems that we can

.

D. Preventive Measures

There are several methods that have been found to be effective in preventing the spread of Covid-19. These include, but are not limited to, wearing a mask, social distancing, and basic hygiene. These have been found to be the most effective methods so for this portion of the report we will focus on them exclusively. The first method mentioned, wearing a mask, has been gaining significant popularity in regard to dealing with Covid-19. Effective, CDC (Center for Disease Control) and FDA (Food and Drug Administration) approved masks have been found to reduce the probability of getting the virus by anywhere from fifty to ninety-eight percent [7]. It is important to note however, that many of the masks that greatly decrease the probability of getting infected come from statistics tracking the effectiveness of N95 respirators, a surgical mask most commonly used in the medical field. This affects these probabilities greatly because these masks are said to stop ninety-five percent of particulate matter from passing through and may be much more effective than a general mask you might find commonly in stores. Additionally, the CDC has stated that these masks are not made in quantities large enough to support a whole country, so it is best to leave them for the medical professionals who are in close proximity to those infected and need them the most [8]. All this means is that some of the statistics that have been all over the news and other media sources may have skewed information regarding how effective your mask will be in preventing Covid-19. With all this misinformation, it is important to take a closer look and do research on the masks you choose to buy and use as well as continue taking other preventative measures. The next method, social distancing, has been found to greatly reduce the risk of infection as well. In fact, one of the only ways to be completely safe from the virus is having no contact with other people, but since this is hardly an option for most people, limited interactions with a six-foot distance between people is the next best thing. Many experts, including some of those at the World Health Organization (WHO), have found that three feet apart is sufficient based on studies done on previous diseases [9]. Harvard researcher William Wells, came to this figure based on studying how far large, airborne, exhaled droplets travel before significantly reducing in quantity [10]. Other experts including those at the CDC recommend six feet due to the uncertainty of how Covid-19 behaves. Obviously, the further apart you stay the safer you will be so any additional distance over three feet is recommended, but in certain scenarios such as workplace encounters, that may be nearly impossible. There have been few statistics surrounding the success of social distancing, but there will likely be more coming in the future due to how well certain countries have applied this technique in response to Covid-19. Another important thing to note is that we have found most cases of Covid-19 to disappear within two weeks of contamination so if people get infected, the best course of action is to self-quarantine for that duration so as to avoid spreading the virus to others surrounding them. Some cases have lasted longer and can continue surviving inside an infected person for well over that period and in some cases without a sign of symptoms so when infected it is best to continuously test and quarantine until a negative test appears. The final method researchers have found to be effective in preventing the spread of Covid-19 is general hygiene: frequently washing hands, sanitizing common areas, covering your mouth and nose during sneezes, etc. Covid has been found to survive on surfaces for days after initially being placed, so it is critical that people consistently sanitize common areas to kill the virus [11]. Many stores have taken the initiative to sanitize consistently throughout working hours, but that can easily be extended to others simply living at home. Studies have found that washing your hands can have a drastic effect on the likelihood of getting a disease based on the spread of previous pandemics of similar magnitude. Being that we still do not know much about how Covid behaves, it is safe to assume that washing hands and using hand sanitizer consistently will have a similar effect. Additionally, there is little cost in doing both of these regularly and could possibly also prevent other illnesses as well which could harm the immune system. Beyond this, covering your nose and mouth while sneezing is a great way to reduce the spread of germs because it acts very similarly to the way a mask function. You stop the germs from shooting outwards into the open air and instead only infect a small area which could easily be sanitized.

E. Pandemics of the Past

Most pandemics in the 20th and 21st centuries have been either caused by influenza virus or the coronavirus. With the spread of Covid-19 it is more compared to the previous flu pandemics like the Spanish flu or the swine flu. Ebola and the Black plague are also two major pandemics that have caused a lot of deaths. With all the surrounding data about these previous pandemics we learn and predict the outcome not only of the current pandemic but also for future pandemics that we have not seen.

These pandemics have been seen as big global issues in the past and with Covid spreading at an alarming rate 4 throughout the United States, it has become more comparable to these past pandemics. Dating all the back to the 1300s the Black Plague was discovered. It is also known to be named as Black Death because over one third of the continent's population died about 25 million people. The mortality rate was 100 percent and it traveled through the air from person to person. Rats and fleas were also a big part of the spread, with one single bite a person would get infected and die soon after. These two species could be found almost everywhere in medieval Europe but mostly on ships. Studies say that it was viral hemorrhagic fever that lasted up to 32 days in quarantine which allowed it to spread widely even with the limited transport in the Middle East. This pandemic was on a scale that had never been experienced before and the rate of infection increased faster than ever. Travelers got infected and carried the disease to different main trading routes across roads and rivers. According to the Health journal the Bubonic plague aka the "Black Death" wiped out 50 percent of Europe's population in the 14th century. By comparison with Covid-19 there are more than 21 million confirmed cases around the world as of August 18, 2020. The only thing related between Covid and the Black Plague was the human transmission and the way it was spread. Covid-19 is caused by a virus that is transmitted from person to person usually from being close to person within six feet. If the plague were not treated quickly enough, the bacteria could spread to other parts of the body and result in the more serious illness such as pneumonia. This illness has similar symptoms to Covid such as shortness of breath, cough, and chest pain. The plague killed millions of people around the world centuries ago and it is safe to say that this type of plague is unlikely to become a global health threat like Covid-19 because it can be easily prevented, and a treatment exists to cure it. Another global pandemic was the Spanish flu that affected over 500 million people back in 1918 and killed over 50 million people. This flu spread quickly across countries especially with the soldiers who fought in WWI. The cramped conditions with soldiers spread the sickness and the poor nutrition intake during the war. It all started with a cook at a military camp where he developed the sickness and was afflicted by coughing, fever, and headaches. Within three weeks later over 1100 soldiers were hospitalized and many more were affected. This flu came in waves and each wave was more deadly than the other. The virus strain was called influenza, which had symptoms of nasal hemorrhage, pneumonia and many more. The Spanish flu hit different ages displaying a so called "Wtrend", with infections typically peaking in children and elderly and having an immediate spike in healthy young adults. Some scientists believed that one of the causes of the epidemic was the poor quality of food, which was rationed at the time of the crisis. In the pandemic we struggle with today also deals with social distancing and how that can help prevent the spread of the virus. According to the CDC the difference between the Spanish Flu Influenza and Covid that they are both different viruses but are contagious towards the respiratory system. Both have similar symptoms, but the flu can cause mild to severe illness. Both viruses can spread from person to person, between people who are in close contact with one another. The spread is mainly by droplets made when people with the illness, cough, sneeze, or talk. The possibilities that a person can get infected are by physical human contact or by touching a surface or object that has the virus on it and then touching his or her mouth, nose, or their eyes. During the war all of these effects happened therefore a lot more people died. Today we have better awareness of what to do to try to prevent that from happening by social distancing and wearing a mask. A recent pandemic that we have overcome was the Swine Flu. This flu originated in Mexico of 2009 before it spread to the rest of the world. It was a new infected strand of the Influenza H1N1 virus. The Swine flu is a respiratory disease of pigs caused by type A influenza virus. The flu affected mainly animals but was transmitted to humans when coming in close contact with pigs. According to CDC, in over one year the virus infected as many as 1.4 billion people across the globe and killed between 150k-600k. Many deaths were in people younger than 65, because the older people have already built up enough immunity to the group of viruses that

H1N1 belongs to, so they were not affected much. The symptoms are similar to the Spanish flu as it comes from the same strand of virus. There was a case study with 334 medical staff to test the symptoms of the virus and the most common symptoms were fever, upper respiratory infection, body aches and vomiting shown in figure 6. The period quarantine of infection was 10 days to effectively prevent the spread of infection. They also ran tests regarding the speed of spread of the swine flu shown in figure 7. Covid-19 has precautions of wearing a mask to prevent the spread as did the case study they learned that patterns of the use of a mask if it actually helped prevent the spread and the results are shown in figure 8. The data indicated that the health care providers are very intellectual, but they do not practice what they advise for others to do.

Symptoms	Doctors (*n*=161)	Nurses (*n*=173)
Fever	157 (97.5)	169 (97.7)
URI (upper respiratory infection)	160 (99.4)	172 (99.4)
Bodyaches	138 (85.7)	110 (63.6)
Vomiting	106 (65.8)	95 (54.9)
Diarrhea	93 (57.8)	67 (38.7)
Pneumonia	77 (47.8)	50 (28.9)

Mode of spread	Doctors (*n*=161)	Nurses (*n*=173)
Eating	20 (12.4)	53 (30.6)
Blood	75 (46.6)	55 (31.8)
Mosquito bite	0 (0.0)	10 (5.8)
Sexual	1 (0.6)	4 (2.3)
Droplet infection	161 (100)	161 (93.1)

Pattern of using the mask	Doctors (%)	Nurses (%)
All the time on duty	19 (11.8)	30 (17.3)
Intermittently	80 (49.7)	76 (43.9)
During potential contact	18 (11.2)	11 (6.4)
During OPD	16 (9.9)	30 (17.3)
NA (not use)	28 (17.4)	26 (15)

Figure 7 Swine Flu : Breakdown of symptoms, mode of spread, and use of mask in response to the Swine Flu [6]

The last pandemic that happened a few years back in 2014 was the outbreak of Ebola virus in West Africa. The Ebola virus is a zoonotic disease which involves animals and humans. Bats seem to be the reservoir hosts for carrying the Ebola virus. Bats can transmit it to other animals like apes, monkeys and to humans. This kind of contact can happen when hunting or preparing the animals meat for eating. Once the virus has infected the first human being, the transmission from one person to another can occur through contact with the blood and body fluids of sick people or those who have died of Ebola. Around 28k cases and 12k deaths were confirmed by the CDC department. Symptoms of the Ebola can appear anywhere from two to twenty days after contact with the virus. This is similar to Covid-19 where there is an average 8-10 days before feeling the symptoms of the virus. The prevention of both viruses was various contact situations and to self-quarantine for about 21 days after living in or traveling an area affected by the Ebola outbreak. Studies show that survivors of the Ebola virus infection have antibodies which are proteins made by the immune system that can identify and neutralize invading viruses. The virus was quickly contained, and a vaccine was made to prevent the virus from spreading to the United States. The FDA approved of the Ebola Vaccine in 2019 where a single dose regimen that has been found to be safe and protective against Ebola virus. In conclusion all of these past pandemics have become global issues. The common issue was that a lot of people were ill and have died due to close contact with one that has been infected. The human-to-human transmission is the current situation we are facing with Covid-19 and the spread continues to grow every day. Each pandemic had a handful of symptoms that were closely related to Covid with the respiratory system. Some ways that we can prevent this virus from spreading is being socially distanced about six feet apart at all times, wearing a mask, and keeping up with basic hygiene like washing your hands. These are all ways that can help prevent the spread because the less contact we have with others, the less chance to exchange microbes and spread the virus. As a society we should realize just how dangerous pandemics truly have been and can be in the future without proper planning and innovative solutions.

F. Solutions and Approaches

Similar to the world's previous viruses and pandemics, Covid has significantly changed the way we live our lives and been critically difficult to contain. Covid-19 has become hard to contain due to the fact that it is highly contagious and the lack of awareness in the early stages of being infected. To combat this highly contagious and stealthy virus, the Center for Disease Control and Prevention (CDC) has advised the world to practice social distancing.

Additional advice the CDC gives is washing hands with soap and water for 20 minutes and wearing a protective face mask. While the ultimate solution to completely eradicating Covid-19 is obtaining herd immunity through an effective vaccine, scientists as well as government officials around the world have taken the approach of practicing social distancing. The ultimate effective solution to the Covid-19 pandemic is finding an effective vaccine to achieve a term called herd immunity. Herd immunity occurs when a sufficient percentage of the population has become immune to a virus; thus, blocking the spread of the virus and slowing infection rates. The noncolored dots in Figure 9 show people who are healthy as well as at risk of contracting the virus, while the red dots show infected people. The blue dots show the healthy vaccinated people who cannot contract the virus. When adjacent blue dots completely surround a red dot, then the red dot is theoretically contained and cannot spread to other white dots. Taking a closer look at how herd immunity slows down the infection rate can be seen in Figure 10 By limiting the available paths a virus can travel, the transmission of the virus becomes less likely.

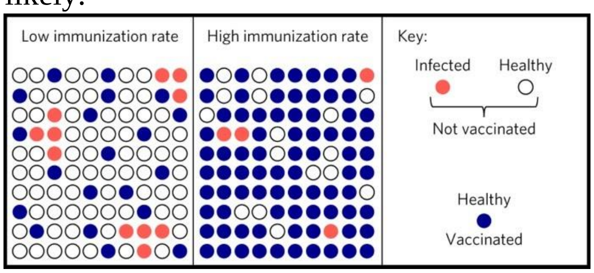

Figure 8 Herd Immunity: Visual Representation of Herd Immunity [7]

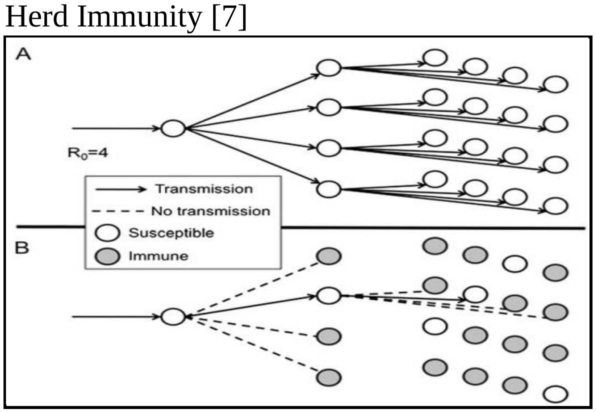

Figure 9 Herd Immunity Transmission: Visual representation of how herd immunity reduces the spread of a disease [8]

Eradication through vaccines causing herd immunity can be seen throughout history by observing smallpox, and rinderpest. On the other hand, an effective vaccine does not always ensure herd immunity. For instance, polio was one of the world's deadliest diseases and within the last twenty years has only been partially eradicated. A person contracting polio is unheard of in North America, South America, and Europe; however, parts of Asia and Africa still currently see new cases. These parts of Asia and Africa struggle to meet the herd immunity threshold needed to eradicate polio. To better understand how to achieve a herd immunity threshold that is needed to eradicate viruses and diseases like polio and Covid19, scientists use an epidemiologic term called the basic reproduction number. The basic reproduction number, alternatively denoted using the notation R0, represents the number of expected cases directly generated by one case in a population where all individuals are susceptible to infection. The R0 is dependent on the exponential growth rate of an outbreak, the infectious period, and the latent period. The latent period is the amount of time from infection to infectious; for Covid-19 that number is between 2.2 and 6 days. The infectious period is between 4 and 14 days. For instance, China's exponential growth rate was estimated to be between 0.21 to 0.3 per day according to a CDC report in January 2020. Combining this data together, scientists are able to construct an estimated median R0 number.

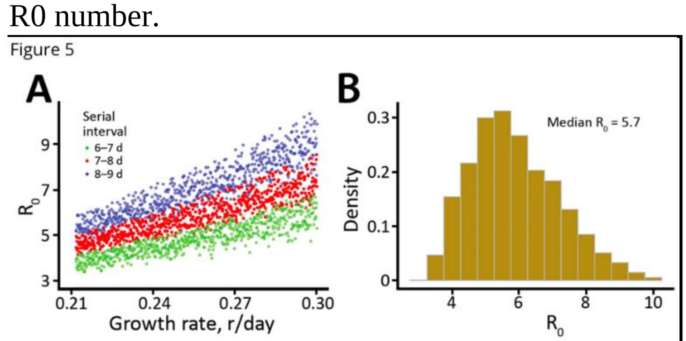

Figure 10 Growth Rate: Shows the growth rate of Covid. [9]

The basic reproductive number for Covid-19 given by the CDC was R0 = 5.7 as shown above in Figure

11 Using the R0 number, scientists can determine the effects of pharmaceutical and non-pharmaceutical interventions. For example, the threshold for combined vaccine efficiency as well as herd immunity needed to eradicate a disease is calculated as 1 -1/R0. When R0 equals 5.7, the threshold is at a whopping 82 percent. This means that greater than 82 percent of the population would need to be immune in China to effectively eradicate Covid-19. While scientists do not have an effective and safe vaccine yet, they do recommend the practice of non-pharmaceutical interventions such as social distancing. Social distancing includes limited travel and maintaining a six-foot distance from other people at all times. Government officials around the world have been staggering bans on travel from foreign nations, closing schools, office buildings and non-essential public gathering places like restaurants, theatres, and casinos. Min W. Fong from University of Hong Kong and policy review author for CDC claims evidence from six government measures that effectively reduce influenza transmission in a community: isolating ill persons; contact tracing; quarantining exposed persons; school dismissals or closures; workplace measures, including workplace closures; and avoiding crowding. Regarding isolating ill persons, out of the fifteen studies reviewed by Fong, eight studies showed that isolating ill persons reduced the infection attack rate. One out of the eight studies showed that case isolation of forty percent of cases could delay the epidemic by 83 days compared to when no intervention methods were taken. The intended impact of all six of these social distancing measures is depicted in Figure 12. The figure shows that the daily number of infections would be less with interventions than if we did not implement interventions.

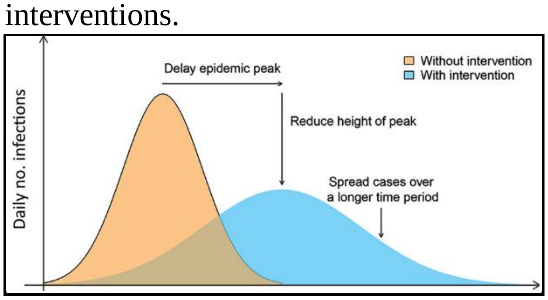

Figure 11 Effect of Interventions: Shows that interventions to decrease the daily infections [10]

measure to reduce the transmission of coronavirus, but also is the practice of avoiding crowding. Fong identified three studies suggesting that implementing timely bans on public gatherings had a positive effect in reducing the excess death rate in the 1918 United States pandemic. However, she does add that the evidence for avoiding crowding is limited and could be difficult to study further in some countries because of religious and cultural reasons. Another study in the form of computer simulations was performed by the US National Library of Medicine showing the effect of social distancing interventions. Interestingly, the results from starting social distancing interventions during the exponential phase of the pandemic differed from the results from starting social distancing before the epidemic curve. When starting the interventions on day 50, the study showed a delay in the epidemic with little change in magnitude of cases. However, when starting the interventions on day 80 during the exponential phase of the epidemic, all interventions flattened the epidemic curve. The day 50 intervention simulation corresponds to the approximate date of interventions set by Washington. As you can see not only is the type 7 of non-pharmaceutical interventions important to reducing transmission, but also the timing of these non-pharmaceutical interventions plays an important role in reducing the transmission of Covid-19 and possibly future epidemics.

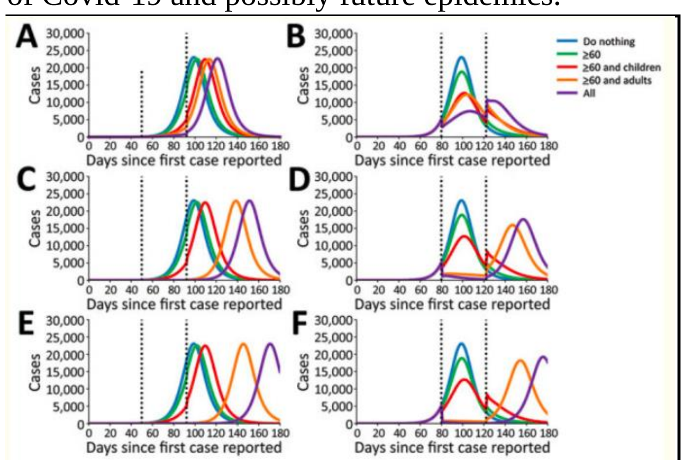

Figure 12 Social Distancing Effectiveness: Shows the effect social distancing had on the spread of pandemics [11]

The study used a constant R0 value of 3. For A, C, E intervention started at 50 days after the first case. For B, D, F intervention started at 80 days after the first case. All in all, while the ultimate solution to completely eradicating Covid-19 is obtaining herd immunity through an effective vaccine, scientists as well as government officials around the world have taken the approach of practicing social distancing. By using the basic reproduction number, R0, scientists can determine the risks people in our world face. While the people of the world wait for an effective vaccine to help achieve herd immunity, following the rules and guidelines of nonpharmaceutical interventions is the best thing we can do to help solve the issue of the epidemic.

III. DESIGN IDEA

A. Project Proposal

1) Design Idea Description:

Our design approach seeks to combat the problem of rapid transmission of the deadly disease: COVID-19. Our team has come up with a design approach that would combine thermometric infrared sensors to detect a person's temperature and a device to track the number of people entering a building. Our team has discussed implementing a laser sensor and/or camera with a complementing algorithm for the tracking device. The tracking device would calculate the current number of people inside a building by counting the number of people entering and leaving a building. Our design would have a square heavy-weighted base to anchor our design. Perpendicularly to the square base, a polyvinyl chloride (PVC) pipe will stand about 6 feet. A PVC pipe was chosen because of its ability to hide wires within. At the top of the PVC pipe, a flat sheet of metal will be placed so both sensors can sit on top of it. In addition to both the temperature sensor and tracking sensor, our design approach includes adding a way for the user to interact with the device, by either using an audio system or a character LCD with LED backlight screen. Or maybe both approaches can be combined together to fit into our design. Connecting to each component together will be the central processing unit (CPU). The CPU will be at the bottom and inside of the PVC pipe. In short, our team has not decided the best and most effective design approach regarding the user interaction aspect. Going more in-depth, the user interaction aspect is an important piece of our design. Our team realizes that any direction we take regarding our user interaction design has to be non-contact. Our team has come up with three options. Option one is using only an audio system to interact with the user. The audio system would consist of a speaker, as well as a microphone. Additionally, our team would write software to intertwine the audio system to interact with both sensors. The benefit of option one is the distance from our design to the user. This could help keep the design cleaner. However, the disadvantage of option 1 is the lack of privacy for each person. Some people might feel uncomfortable having other people hear their temperature result through speakers. Option two is using only an LCD with LED backlight screen to display messages with instructions and each person's results. The benefit of option two is the added privacy of each person's temperature results. However, the disadvantage of option two is the distance between the user and the device. Some users might have to stand close to the machine to read the screen and there is a risk of the user touching the screen. This could affect the cleanliness of our design. Finally, option 3 includes combining both the LCD with LED backlight screen with the audio system. The benefit of combining both could be a better user interaction experience, while the disadvantage is the added cost to the design.

A crucial part of the design is having some sort of a sensor with a camera that will count the people walking in or out of the store so that the capacity would never hit the limit.

This design will be more of a security measure to help reduce the spread of Covid in stores or high populated buildings and places. The camera will send the data it receives to be stored on a cloud and it will produce graphs of times and amounts of people entering or exiting the building.

Our team envisions the design working quickly and efficiently. In short, the design would require a person to walk up to the device, get scanned and instantly receive results whether they have a high temperature or regular temperature. Green and red LED lights would signal a high temperature or regular temperature. This would provide a safe environment for people entering the building and alert building authorities if someone sick comes in. The person would continue walking into the building and our device design would add plus one to the total count of people currently inside the building.

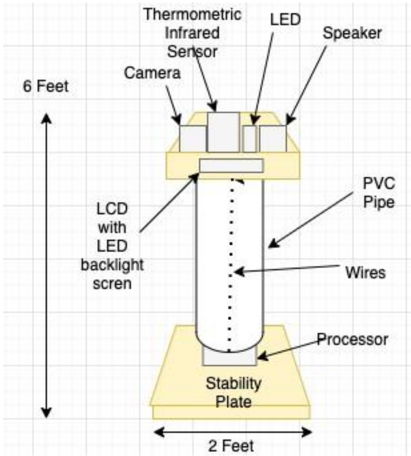

Figure 13: Sketch of Design Idea. [12]

2) How this idea addresses the problem:

Our design idea is attacking the world's rapid transmission problem of the deadly disease COVID-19. Infectious people with COVID-19 are multiplying day-by-day and people lack the self-awareness to know when they are contagious. On top of people's lack of infectious self-awareness, businesses struggle to keep a count of people entering and leaving their store unless they pay a person to stand outside and count. Numerous times my group and I have noticed the lack of people getting counted at the door or taking a temperature check before entering our local Safeway or Bank of America. Relatively inexpensive technology can help our society combat this issue.

Our design idea looks to increase awareness of infectious people, as well as helping people in charge like business owners and school officials to easily keep track of how many people are inside their buildings at one particular time; ultimately hoping to slow the transmission rate of COVID19. When people enter buildings like schools, supermarkets, doctor offices or banks, there should be a device near the door with thermometric infrared sensors and scanners to check each person's individual temperature as well as keep track of how many people are inside the building. Slowing COVID-19's transmission rates mean adding more layers of protection and security for people when going out into a public setting.

Thermometric infrared sensors help combat the lack of self-awareness because if somebody has an unusually high temperature then the sensor's program will kick in displaying a person's risk to others. According to an article published by the United States of America National Library of Medicine, the average body temperature for humans is generally accepted at either 98.6 degrees for Fahrenheit or thirty- degrees for Celsius. [26] The article continues explaining that any temperature either over 100.4 degrees Fahrenheit or 38 degrees Celsius most often means a person has a fever caused by an infection or illness. For our design, our team envisions the non-contact thermometric infrared sensor to scan a person's forehead, however our team is also open to the possibility that the sensor could detect other body parts if necessary. The CDC describes the benefits of a non-contact temperature scanner in an article on June 16th, 2020 saying that measurements and display are quick so large numbers can efficiently have their temperature checked. [27] The added benefits are that a non-contact thermometric infrared sensor requires minimal to no cleaning between uses. These benefits are described to potentially help reduce the risk of spreading COVID-19. As you can see, implementing a simple thermometric infrared sensor would add one more layer of security that may reduce the transmission of COVID-19.

Not only will our design implement a simple thermometric infrared sensor as a layer of security, but as our design will implement a way to track the number of people entering or leaving a particular building; thus, adding a second layer of security to reduce the transmission of COVID-19. Our team has multiple design approaches to this idea. For instance, our team has discussed placing a camera and writing a complementary algorithm to detect the shape of a person coming in or out of a building. While our team liked the camera and algorithm design approach, our team also liked the design approach of using physical sensors similar to the ones used on garage doors called through-beam sensors. The sensor would have lasers pointing directly at it alerting our device when the laser is interrupted. When the laser is interrupted this signals that a person is entering. Implementing lasers in our design approach would help keep track of how many people are inside the building. While we know that many

States like California have allowed businesses to re-open, we also know that businesses are allowed to re-open at a fraction of their maximum occupancy; sometimes being as little as 25 percent of the maximum occupancy. Limiting the number of people inside a building helps limit the problem of the rapid transmission of COVID-19 because of avoiding crowding.

All in all, our design approach attacks the problem of limiting the transmission of COVID-19 through two security layers: a simple thermometric infrared sensor and a device to track the number of people entering and leaving a building.

3) Resources needed to complete the project:

There are several components to the idea we have suggested in order to properly address the problem statement. We must first have some cameras which can upload their videos in real time to some other device. Additionally, we will need to have some sensors, more than likely thermal but we are still deciding on the details, which can in short catch people who are infected and entering the building, and we also have to have a computer or microprocessor which can run all the operations such as keeping track of how many people are in the building and recording the data for future use. Beyond that, we will need something which will alert the main user when their "business" is at maximum capacity more than likely just a speaker or alarm system and some place to implement our prototype.

So, the first major component that we need for our approach is the camera. After we did a few hours of research and found that there are several options for cameras in the market currently that have all the aspects required for our solution. The specifications required are relatively simple; the camera needs to be able to record with a resolution high enough that we can accurately do facial recognition, it needs to be able to send data to another device, and it needs to be able to store data itself. The first aspect, high resolution, is important because we need to be able to have the camera distinguish between a person entering versus an animal or random debris entering. Obviously, we do not want our system to be comprisable by a random leaf blowing in the area or someone's pet wandering in. This is why we need to be able to have a higher quality picture coming out of the camera and why we need to have some form of facial recognition. The second portion is that it needs to be able to send data to another device. This is important because we need to be sending the recording over to another device like a computer or microprocessor such that it can do much of the computation and data storage for the project. Lastly, it needs to be able to store data itself because on the off chance that our computer/microprocessor shuts off for some reason we need the camera to be able to store that data by itself such that once the computer/microprocessor comes back online, it can restore that data and not lose any information.

The next item we need is the sensors we plan to use for tracking whether people are sick. We have not absolutely decided on which approach we want to use to identify sick people but currently we are leaning towards thermal. We want to use a thermal sensor because they are cheaper than most other solutions and we could potentially get a camera which also has thermal sensing built in. Beyond that it is one of the easier ways to measure whether someone is infected because oftentimes their temperature rises as one of the symptoms. Additionally, this solution would allow us to measure when people have other illnesses as well in the future like the common cold or flu which could come in handy when we are not facing a severe pandemic but rather in everyday life. This solution does come with its drawbacks however because it would not be able to distinguish between a Covid patient and a person with the common cold because the symptoms it is looking for are the same between the two. This led us to another solution which would take random samples from the air and be able to test them for traces of Covid. We are leaning away from this solution because we simply do not know the procedure for testing for Covid and this could end up being rather expensive in general. Additionally, if someone wanted to continue to check for Covid they would likely need to keep replacing whatever is testing for Covid which could get expensive for the person using the solution. We still have not done enough research to accurately decide on one singular solution and plan to do more as we are actually implementing but for the time being we plan to just use a thermal sensor because it has a wider breadth and more functionality in the long term.

The last major component of our solution is the microprocessor or computer we plan to use in order to do informatics.

4) What is unique about this idea:

The thing that makes our idea unique is that it is going to be a combination of temperature sensor as well as population tracker embedded within it. Therefore, it will serve two purposes to check people's temperatures and track the traffic coming in and out of the building. Our idea will keep businesses safe from people with high temperatures that can also possibly have Covid19 because the two have similar symptoms. Our project will include many sensors which will all serve multiple purposes. We will have a thermal imaging system that will detect heat signatures that can show if a person is sick or not. A voice system will be programmed to speak to the person whether they pass or fail the test. And lastly a camera will be added to track the population of people who entered the building. With the data from the camera and the temperature sensor both will be sent to a cloud storage for further analysis. Comparing our idea to other ideas we have looked at they include a face recognition system that can detect a face mask. A non-contact temperature checking system that would send a notification via email or SMS when a high temperature was detected. It works quickly and safely with the highest level of accuracy, which makes it an ideal option for high volume locations. The several steps included were to simply stand a few feet in front of the screen, the temperature instantly pops up displaying a pass or fail color display on the screen. They have an encrypted database for their employees that would make identifying the employees easier. The cloud database is also optional on mobile.[28] The second idea we saw was a little bit different: it would enforce social distancing and identify high temperatures on account to Covid-19. This method would involve a person sitting behind a computer and monitoring the screen and checking people's temperatures. It also included a biometric identity verification system that would help protect guests and employees from airborne pathogens and bacteria. The downside can be that this will not allow guests to have any sort of privacy because the camera data is collected and stored into a cloud.[29]

Table i
Punch List Features and Measurables

Feature	Measurable Metric
Thermal Sensor	Able to read human temperatures accurately
Speaker	Able to produce noise when temperature is unsafe
Camera	Be able to recognize people come in
Predictive Analytics	Take data from camera and produce graphs that help interpret the data
Processor	Communicates with all devices properly
Physical Covering	Keeps all electrical components safe and neatly contained

B. Features and Measurable Metrics

1) Punch list:

We need a thermal sensor such that we can detect if a customer is showing symptoms of an illness. Thermal imaging cameras are designed to detect and measure the invisible infrared radiation that flows from objects, frequently referred to as a "heat signature". The hotter the object is, the more radiation it releases. The infrared sensor array will detect infrared frequencies, converting the data to electronic signals, which can be viewed as colored images that vary the level of heat being emitted.[30] The potential uses for thermal cameras are nearly limitless. It would provide a safety solution and keep businesses open after closures because local governments are requiring parties to be tested for a fever. The device would be 100 percent non-contact and would require zero participation. It would perform accurate and efficient temperature readings instantly. Additionally, this solution would allow us to continue measuring people showing symptoms of other illnesses aside from Covid like the common cold such that this system could be used in future pandemics as well.

A voice or audio system which will give the results of the temperature scan. If a person enters with a temperature above a certain threshold, it will show a red light and alert the business that a person with a fever has entered the building. The audio will be programmed to tell the person the next steps to do if they have a fever. This will help with decreasing the transmission of Covid-19 in that certain building or warehouse.

A camera which will detect the amount of people who enter a certain building. This will allow business owners to collect data on when their busiest times occur and limit the maximum capacity that is enforced in many states. This would make it easier so that employees do not have to stand by the door and count the number of customers walking in or out of the building. It will be more efficient and will be computerized to get the exact numbers that will be sent to a cloud storage service to later be put onto a graph for analysis.

The predictive analytics will record the amount of people coming and going at all hours of the day in order to show data regarding the peak times. This will allow store owners to notify customers when their busiest times are and when there is hardly anyone in their store or building. With this information, it will let people choose when they want to go to that certain store and have the least amount of contact with other people. With this pandemic it is advised to be socially distanced so this solution allows people to be aware of the capacity of buildings at any given time such that high risk customers can avoid the threat of coming into contact with others.

Adding a processor which will communicate with all the devices and send data to a cloud database where it puts together a graph based on the data given. A cloud database is a service built and accessed through a cloud platform. It serves many of the same functions as a traditional database with the added flexibility of cloud computing. Users can install software on a cloud infrastructure to implement the database. The storage involves at least one data server that a user connects to via the internet. The user sends files manually or in an automated fashion to the data server which forwards the information to multiple servers. The stored data is then accessible through a web-based interface. Using the data collected, the user can make charts which will reflect their peak hours.

Covering of wires and sensors to provide protection for the sensitive electrical components. This will consist primarily of PVC pipe to protect the wires and a steel plate to provide a surface to place the necessary sensors. The idea for this physical covering is to be as simple, yet structurally sound and protective, in order keep our components safe from any human or other such contact.

2) Hardware to implement feature:

The hardware required in this section will include a thermometric infrared sensor. Instead of buying an expensive thermal imaging camera we will simply use a common infrared sensor. There are many options so we do not currently know which sensor we will buy, but some examples we have looked at include the ZTP-148SR, ZTP - 135SR, and ZTP-115M. The benefit is that these sensors are very cheap and appear to be reliable. Additionally, we would like to stay away from using the camera as our only sensor because doing all the analytics using a single sensor could get confusing. This component will have to be placed on a circuit board with wires leading from the sensor to the processor.

This will also require a simple speaker component. It should generate a high pitch if the person entering has a temperature decided to be too high for an uninfected individual. In addition, an LED will flash red, further alerting the owner that the store has an infected individual. Instead of making this a complex system, we decided that making it as simple as that will be all that is necessary for a store or business to have. The more precise data will be sent to the cloud and analyzed but will not need to be shown to the user.

This part has several different approaches, and we are not sure at this time which to pursue. In order to detect people coming into a store we could install a camera with an algorithm to detect people as they enter. It is important to check whether the entity entering is a person because if someone’s dog or another animal wanders into the store we do not want that counted towards the maximum capacity. This camera will need to be placed near the temperature sensor such that we can record accurate measures on the people as they enter as we want the person’s entrance timestamp to be as close to the time, we check their temperature as possible to avoid confusing customers in our data. Again, this sensor will have to be connected to the central processor.

This part will require no hardware. It will receive information from the processor and make calculations and show it on the cloud.

The hardware for the processor will simply be to choose which processor we want to use. Our group has some experience using a raspberry pi and know that the newest iteration is relatively inexpensive, so that may be easiest. Our group also has experience with Arduino and a variety of other boards that we may decide on, however, the processor has to communicate with multiple electrical devices. This complexity may cause us to choose a different processor in the future. In addition, we will try to use a single processor, but if necessary, we might use a combination of processors due to the fact that we have multiple different sensors communicating as well as the cloud which the processor will have to be sending data to. Our current plan is to use the processors we currently have such as the raspberry pi and see if that is sufficient. If it turns out changes need to be made, we will look into other processors. Choosing a processor is also difficult as we have not picked out our exact sensors so we still do not know what connections they will require. Once we have more information, we will be able to make a better choice for our processor.

The hardware for this part will involve PVC pipe and a metal plate, and possibly screws or some way to fasten these pieces together. There will have to be a custom made covering for the sensor itself while the connection to the sensor will be a single PVC pipe to protect the wires. This part will require some ingenuity and design to make something that looks appropriate and protects the components completely.

3) Software to implement feature:

The software in this part should not be overly complex. The sensor is an electrical component so once it sends the information back to the processor there will be code required to read the data and decide whether the temperature is in an acceptable range. So, in essence, there will not be any software we have to deal with in the sensor as it is all in the processor.

The software in this part will be very simple as well. Once the temperature sensor receives a reading that is deemed unsafe the software will send a signal to the processor which will then communicate with the speaker and LED letting them know to make a noise and light up, respectively.

b) The software in this part will be rather minimal. This is because the camera will constantly be recording and sending the video to the processor which will do all the recognition. The other solution we were considering would have a camera designed to do facial recognition and would simply have a trigger that occurs when someone enters, and the camera detects movement. When it recognizes that it is actually a person that came in it would send the data to the processor, but this would also not require much software because it would come ready with the camera. We wanted to write the facial recognition software ourselves so for this reason we plan to go with the first approach, but regardless the software is going to lie almost extensively on the processor.

c) The software on this part will be extensive. After a day or some other time interval still to be determined, this part will analyze the data. First, it will show the data as a graph one that shows the time of day versus how many people are actually in the store. Another graph will be generated which shows the data of when someone with an unsafe temperature enters versus time of day. These two graphs will be daily, but also once there is enough data there will be graphs that can show weekly, monthly, or even yearly periods. Once these graphs are completed there can be additional data that will be calculated. For example, the peak hour can be calculated or other specific statistics that can be beneficial to the business's efficiency. This part has some flexibility as we do not know exactly how we are going to implement the graphs and indicators, however at the moment we are leaning toward using Power Bi a data analytics tool popular right now in the industry.

d) The software on the processor will involve writing code that communicates with each of the devices. When the processor reads information, it must know several things, which device sent the data, what to do with the data, and how to send the pruned data to the cloud. For example, if the camera recognizes a person is approaching and is triggered it must start to read the temperature from the infrared sensor as well. From there it must have software which will decide whether the person entering is sick or not and take a timestamp and store all that information in the cloud. The software will be quite extensive as the processor has to successfully read data and communicate to all the different electrical components in the system.

e) This part is a physical part only so there is no required software.

4) Who will work on which feature:

a) Dennis
b) Nick
c) Micah
d) Micah
e) Paul
f) Nick

5) Estimated total hours on each feature:

30 hours. The initial part of setting up an infrared sensor may be straight forward. However, finding the best type of sensor and the best circuit to make the data accurate will take some testing. I estimate 10 hours for the initial setup. 10 for trying different approaches and 10 hours of debugging.

10 hours. To set up this speaker it should not prove to be too difficult. It will have to be wired to the processor and be in a circuit. I estimate 5 hours for building the circuit and wiring it and 5 hours for debugging.

20 hours. I expect it will not be too difficult to set up the camera, the time-consuming part will likely be getting the facial recognition working. We have not done much in terms of actually setting up a facial recognition camera as since we are still undecided about whether we want the facial recognition to exist on the camera or the processor we are allocating some time for that. The breakdown comes down to about 5 hours for setting up the camera, 5 hours for getting the data to send over to the processor and 10 hours for debugging and possibly setting up facial recognition.

20 hours. This part is primarily writing code that will analyze all the data. This will be somewhat simple because the data is being provided to this part and it simply has to analyze the data. Creating a graph system and complex analysis will require some time to learn more about Power Bi. Around 15 hours for the coding and learning Power Bi and 5 hours for debugging.

b) 50 hours. This part will be hard to work on until the other parts are done. Since so much of it involves communicating with the devices, the work on this part will have to be after the electrical components are completed. This part I also expect to require significant debugging when dealing with multiple devices receiving and sending data. 20 hours for device input, 20 hours for signal output to devices, and 10 hours for debugging.

c) 35 hours. This part requires some ingenuity and unique design. It will require cutting PVC, measuring dimensions, and creating custom fittings for our design. I estimate 10 hours for the PVC part, 10 hours for attaching a secure steel sheet/making sure the wires are hidden, 5 hours for testing to make sure it is safe/secured away from people, and 10 hours for fixing any problems that arise.

6) Measurable Metrics to determine feature is complete:

When the processor is able to receive the data and determine whether the temperature is dangerous. The physical construction is less concrete, but the metric would be that no components are revealed and are protected. In addition, a person could walk up to this device and stand near the sensor.

As long as the speaker and LED are able to receive a signal from the processor and make a noise and light the LED that will be sufficient.

For this we will input fake data into the processor and make sure we can view the results on the cloud. We will also make sure the graphs are accurate and show the correct data.

This part is hard to determine when it is truly complete. Currently the metrics are that we receive the data and are able to plot the information on two separate graphs. However, more data and analysis can be done if time provides so part of this section is open ended.

This part will be completed once the processor is set up to receive data from the thermal sensor and camera and can communicate with the speaker, LED, and cloud. Additionally, once completed, it should be able to produce the aforementioned charts and indicators for the user.

This part will be done once the entire device is protected. This will have to be constructed after we know exactly which devices we are using. This frame should be a single piece that the electrical components will be able to be added into or removed if necessary.

7) Connect Team Members and why they have the necessary skills:

As the sole Electrical Engineer, Dennis' experience with creating circuits will be useful in creating a circuit for the infrared sensor.

Nick has enough experience in creating basic circuits that building the speaker components should not be too difficult. Nick is confident in using a breadboard and to connect a LED and speaker to it.

Micah has experience in using camera software to have facial recognition and is confident in being able to complete this part.

This part is similar to part C so Micah again has experience using software that is able to detect people and record the information so will be able to complete this part. Additionally, Micah has briefly used Power Bi and should be capable of generating some of the charts.

Paul is confident in using a processor to connect all the electrical components together. He has used many different processors and feels confident in being able to connect all the devices together.

Nick has worked on physical construction projects in the past with his Dad. He feels comfortable in putting together the covering.

IV. FUNDING

Table ii
Design Idea Item Funding

ITEM	COST ($)
Processor	$50
Camera	$150
Thermal Sensor	$20
LED Lights	$0 (Already have)
2x16 Character LCD with LED Backlight Screen	$0 (Already have)
PVC Pipe	$50
Connecting Wires and Breadboard	$10
Speaker	$10
Metal Plate	$20
TOTAL:	$310

The table 2 shows the initial estimates for funding, however, costs did change once we purchased the items. The funding for our project was divided amongst our team members. The total cost of our project ended up being $440. The construction cost was $44 total, the camera $100, the LEDs and buzzers $30, the raspberry pi was $95, and the infrared sensor was $170. Nick was responsible for buying the features in the user alert system. Nick used Amazon to buy a pack of LEDs that looked like a stoplight for $10. These LEDs had a yellow, red, and green LED attached to a strip. Nick also bought the 16x2 character LCD screen on Amazon for $15 and a piezo buzzer for $5. The user interface system cost a total of $30. Paul was responsible for buying the infrared temperature sensor. The infrared temperature sensor was the most important part and most costly part of our design. We needed an accurate sensor, or our project would not be feasible to achieve the societal problem we were aiming to solve. Paul bought a 32x32 matrix infrared temperature sensor on Mouser.com for $170. This infrared sensor came with a strap to anchor the sensor and a cord to connect it to the Raspberry Pi. Paul also paid $95 for the Raspberry Pi 4B on Amazon.com. In total Paul spent a total of $265. Teammates later reimbursed him for the products he purchased to make things even. Dennis paid $44 on the construction of our project. Dennis purchased a waterproof case on Amazon.com for $18, and zip ties for $2. He also paid for PVC pipe for $10 and a metal base for $10. These items were needed to make the device stand 6ft high, be stable and not fall down. Dennis purchased the PVC pipe and the metal base from Home Depot. Micah was responsible for buying the camera. The camera he originally purchased was $100 from Simcast’s website. One thing our team would have changed is researching more cameras before buying one. We ended up buying a $100 camera called the Sim1 Camera which was not what our team really needed since it already had all the facial recognition software pre-built inside of the camera. We realized that using this camera would not allow us to change the software to how we needed it. As a result, our team used a free camera our teammate Micah already had. However, this camera would have cost $25 if we did not already have it available for free.

Overall, our team ended up paying $440. Our team went into this project aiming to spend around $500. That was the budget we thought was necessary to complete the project how we wanted to. In the end, we achieved that goal and actually spent $60 less than our initial predictions. This was a plus for our team and if we wanted to make improvements in the future, we would have about $60 to spend. The entirety of our project was carefully planned and the only part we ended up needing to change was the camera. The infrared temperature sensor ended up working great for the price we paid. In the future if we were to mass produce these devices, we would probably need to include another $20 on top of the $440 per device for wires and breadboards. This is because our team already had wires from previous classes to use for the circuit design. We also had breadboards that we used in previous classes. Having these two items lowered the price of our deliverable project. If we were to build another device our total would cost our team $485 to buy all the parts needed like the camera, wires, and breadboard.

V. PROJECT MILESTONES

A. Fall Semester Milestones

For the initial part of this project, a lot of research was done about the parts that were needed to complete this project. There are four major parts that were needed first being the body temperature sensor which has a few specifications that can measure a bigger grid and potentially get better and more accurate measurements of body temperature than just measuring the forehead. The next part is the camera which will be used to track the amount of people who come in and out of the building. This would allow business owners to know specific data of when they are the busiest and when they are not. The next part we purchased was a raspberry pi which would work as the processors with the camera and the temperature sensor. The other parts were the lcd screen, audio system, and the stand that it will all be put on to stand up straight.

After most of the research was done, it was time to put the pieces together. First one team member had to install the sensor and test the connection on the raspberry pi and wire it up properly for it to work. After that, a code was found online and was inputted on the pi and it needed to be edited so that it can output a certain temperature that we are looking for. The initial code was just a basic code that would run the temperature sensor and output a few temperatures and be very inaccurate. With a few edits and tests, we got some progress done with it being more accurate than it was before but not to the full effect that we want it to be. The goal is to get readings in the range of a +/- 0.5 degree Celsius. We tried working with the 32x32 specifications that are listed with our temperature sensors and we are getting lots of inaccurate data. The sensor is reading a lot of temperatures at once and is outputting all the temperatures within the grid all at once. We are trying to modify the code to have it output a smaller number of temperatures or work around with the zoom function. Modifications for the algorithm will need to be made in order to get the best accurate measurements. The sensor itself has an infrared heat signature which is used as a better detection instrument. The thermal infrared sensor would be capable of scanning a person's forehead and determining their current body temperature. Looking for fevers, the thermal infrared sensor will alert the customer and the business owner if a person has a fever, since fevers are symptoms of Covid-19. We plan to implement this into the present algorithm and test out the results. The goal of this measurement is to determine whether the person's temperature is in an acceptable range or is too high and has a COVID-19 symptom. If that is the case, the person would be notified and not allowed in the building. In order to get this measurement right however, there are several aspects we must make sure is correct so that the data is valid.

The next part was to implement the face recognition system with the pi and the goal was to differentiate people from objects. One of the team members has been given this task and they have confirmed the connection with the raspberry pi and have been doing tests and coding to get the camera to detect at least five human beings within the range of view for the camera. We plan to add an algorithm to the camera and with its thermal infrared sensor placed at the entrance to a building, it will keep a running count of the number of people who entered the building and alert owners when that number is equal to the maximum limit. The camera would collect data to be later translated into statistics for that store. Certain statistics like popular times people visit the store could help people make informed decisions about when to shop and further reduce the spread of Covid-19. The camera will help store owners and people stay safe and covid-19 free. With this system in play a person will not have to stand by the door and do a tally of people who enter or exit the building. We plan to have a system that will alert the business owner when they have reached a certain capacity and it can show when the store has its peak hours and when there are not many people in the store.

Following that we plan to do a small integrated system to alert the user when an unsafe temperature is measured with a sound and a traffic light system. First, we need to install the LCD screen to the pi and write code for it. Adding the lights and the sound was the second step. The light system would work with a color green as the temperature read was safe and the user can go ahead, yellow being it is in the process of being scanned and red is when an unsafe temperature is going to be measured. This system was first tested out separately in order to see if it worked with the pi and the sound system. The sound would be a different order of beeps and one order would mean they are good to go and the other would that they would need to stand aside and wait for further instructions by a store assistant. We plan to integrate this sound system and the lights with the actual temperature sensor. This will bring us closer to meeting our goal for this project. Then we want to wire up the display at the end that will be showing all of this data on the screen and make sure everything is working together as one.

The next part will be the system to store all the data that we receive from the camera and or the temperature sensors and import it to a cloud system. It will involve getting the right IP address connected with the raspberry pi and possibly make it wireless or connected to the same Wi-Fi. We plan to create a configuration to sort out the data and create a few graphs and charts with the data it receives from the pi. The graphs will need to be showing accurate data analysis that it receives through the pi. We will need to create a safe program to secure all the data that will be sent to the cloud. Storing the data onto a cloud-based system will allow the owner to check on the data and the flow of people who come to the establishment. This will also allow the owner to put up certain sales at certain times when he does receive data about the peak hours, and it will help the business in many ways.

The last part will be to create the compact and safe design that will hold all the sensors, screens, and processors together in one place. We plan to build a PVC frame and create a custom box that will hold all the equipment together. In the future we plan to get an adjustable height for the frame so that it can move up or down based on the person's height. The design is supposed to be about six feet high and have the custom box attached to the top with the LCD screen facing outwards towards the user. The system will be fully contactless so that the user will be able to just stand in the designated area and get scanned and move on.

That is the basic description of the different parts for the punch list. If we focus on milestones, it will help show how we intend to complete this project. Our first milestone is 11/1 where we have finished our project research. Although we always will be looking up new information and finding new ideas, this project research is more about getting us started. We have spent most of our work up to this point on research and planning. For example, we had to purchase all the required parts for our project. In addition, with most of these parts our team had little to no experience working with these devices. So, part of the research was understanding how to use them and developing skills to get the devices to operate how we intend. One example is with our sensor it required an I2C connection which required pull down resistors from the five volts to the different pins. This was something I had not done before and required research in. At this point in the project our research has enabled us to get all parts to be operational in the minimal sense. There will be more work to get the parts to operate how we intend, but our research enabled us to get the products and devices operating with the Raspberry pi. The next milestone is completed data analytics on 11/8. For this part we intend for the Raspberry pi to send data through the Wi-Fi to a website. We have already found the site that will receive this data and we need to make sure the pi can talk and send this data to the pi. Our next milestone is to complete the human body temperature on 11/15. This is already being worked on and needs to be simply fine-tuned. With our sensor it has the capability to measure a certain number of pixels and measure at different speeds and rates. We will continue to test and see which is appropriate to get our temperature sensor to read accurately. Our next milestone is complete facial recognition and complete alerts both 11/22. Both these parts are making good progress. For the facial recognition we have already got the camera to detect a person. We now have to code it to detect a total person count and make sure it does not trigger on incorrect objects. For the alert system we already have made progress on acquiring all the parts. The next step is to connect it to the pi and code the pi to use these alerts correctly. The last milestone is to complete the prototype. Our project is currently on track and we would meet our goal of completing our prototype on 11/29. These milestones are on task and should help get our prototype completed as intended by the intended date.

This project has a lot of milestones that we want to complete in an orderly manner. The first three were to create a team problem statement, make a design idea contract, and complete a work breakdown structure. First, we had to find team members and when we did, we each had an assignment to do which was the individual problem statement. With that finished and presented by each team member, we chose one or two of the team members' individual problem statements and made it into our team problem statement. With a lot of other tasks completed we managed to write a design idea contract that was approved by the professor so that we can continue our work and start building the design of our project. A lot of time was taken to do research about each item we needed to purchase and when that was all finished, we wrote a work breakdown structure. This breakdown allowed each team member to figure out what part of the project they were going to do in a timely manner to finish the project in time. This led up to completing a project timeline with a list of activities we needed to complete for both fall and spring semesters and to present our project in the spring. The next three milestones we are planning to complete as they come up in the next few weeks which are the risk assessment, the technical evaluation, and the lab prototype that we will present this fall. For the risk assessment we will identify the critical paths and risks that our project will portray. We will need to prepare for these certain risks and make a list of possible solutions that will countermeasure these risks. For the technical evaluation we will prepare a video presentation that will be our project evaluation overall. Lastly, we will need to prepare an oral presentation and present our working prototype virtually. This will complete our fall semester of events.

The fall semester is focused on the punch list. The punch list is the set of functions we seek our device to complete by the fall semester. The Gant chart helps breakdown exactly how and when to seek to complete these items. The Pert diagram shows the milestones of the fall semester which include the required assignments and the punch list items being completed. The spring semester is a bit different in that there is no easy punch list which is needed to be completed. Instead, the spring semester is for putting all these individual items together and improving areas of our project that are not sufficient. These changes are not currently apparent, so we created our milestones to be focused on what we know which is the spring assignments. These assignments will help guide us through the spring semester.

B. Spring Semester Milestones

For the spring semester we have made a PERT diagram that will involve a list of tasks and milestones that we will need to do in order to complete our project. The milestones in the spring semester are more focused on the assignments required. In the fall semester our punch list of items will be complete. In the spring semester we have to develop our separate parts into a single cohesive device. The assignments in the spring semester help guide us to this goal. The major workload will be testing and modifying of the specific parts to achieve higher accuracy. In addition, we will be increasing the interactions between the punch lists. In the fall semester the product will not be fully integrated with each other. In the spring semester our plan is to integrate our product fully and have a single device that can be easily operated and work as intended. The PERT diagram shows the assignments in the spring semester as the milestones, because in the assignments it has tasks such as testing and market review that will be the focus of our work. Some milestones and tasks are unknown for the spring semester. As we develop our punch list, we will undoubtedly find new areas of our project to be milestones in the spring semester. Our end goal is a useful product and device. We have an idea of how this will be done, but there will be changes and modifications to our milestones and tasks to make sure this product is as intended. For example, once we complete the market preview assignment, we might find an area of our project that is lacking and then focus on that part.

The spring semester is designed to achieve our final goal. However, unlike the fall semester which goal is clearly outlined the spring semester is not quite that way. The different assignments help us see where our project lacks and where it needs to improve. Also, in the fall semester our punch list will be complete, but there may be aspects that need to be improved to be put in a final product. Therefore, we choose our milestones to be focused on the assignments. It would be difficult to predict which exact parts we decide to work on and change, but by focusing on the assignments they will lead us to the parts of our project that need improvement and enable us to create a single final integrated product.

This project timeline assignment was a helpful exercise in planning the rest of our project out. It makes our group more confident in what we must do. We now have a better understanding of how our project will get done and the steps necessary to get it done. These timelines and dates planned for each part will greatly help the individual and team. Each team member can now know what they must accomplish, and when they must do so. Our project is currently on time so we believe we will be able to meet the deadlines and complete the required assignments. We can now more easily see the big picture which will help guide us in our work to make sure we complete our task on time. The Gantt chart and Pert diagram both greatly helped our group to see the full picture and the small details of what is necessary to complete this project.

VI. WORK BREAKDOWN STRUCTURE

A. Task 0 Initial Project Research

The first item included on our punch list is narrowing down the different parts we research to one and finding the lowest prices. The parts we purchased were a raspberry pi, simcam 1s camera, Omron’s d6t-32l-01a infrared sensor, a 16x2 LCD character screen, a stoplight shaped LED strip, and a piezo buzzer. The model for raspberry pi we bought was a raspberry pi 4B with 8 gigabytes of RAM. After doing much research, we decided to buy Omron’s d6t-32l-01a because of its ability to accurately read body temperature up to 6 feet away, as well as its ability to sensor temperature in a 32x32 matrix. The importance of the 32x32 matrix is that it can accurately ignore other temperatures not a part of the human body. On top of that, each matrix takes the temperature and then averages all of them out. We can have the 32x32 matrix look at only the forehead to accurately measure the temperature of a human. The LED traffic light strip was chosen because of its aesthetic design and competitive price point. We bought every component for under $400, which can to about $100 per person. All in all, our team is excited to use these parts we purchased.

B. Task 1 Recording Human Body Temperature

Our second item in our punch list is recording human body temperatures. In this part of the project, we are using a sensor, specifically the D6T-32l, to measure human body temperatures as they enter the location with our project installed. The goal of this measurement is to determine whether the person’s temperature is in an acceptable range or is too high and has a covid symptom. If that is the case, the person would be notified and not allowed in the building. In order to get this measurement right however, there are several aspects we must make sure is correct so that the data is valid.

First we have to connect the sensor to the Pi. As of this assignment that has been completed. We connected the sensor through a bridge connector that split the outputs using the 12c connection. The sensor does work on the pi and we were able to see that it does output data correctly.

To make sure we have accurate readings we must take into consideration multiple factors. We will write an initial algorithm and test how accurate the initial results are. This also will require taking the temperature readings and converting them to internal body temperature readings. In this initial coding we also must determine how often we record the measurements and the time intervals in which we take the averages. The data will not be constant so choosing how we find the value we want to display to the user is essential for initial accuracy and precision.

After we do our initial algorithm, we have to test whether our data is accurate. Our goal for our punch list is within +- 0.5 F degrees. Testing will be a little difficult since we will have to compare our data to accurate data. The exact process is still undetermined, but we may have to use other thermometers and such to compare our results.

After testing we most likely will have to improve our results. If we do not meet our goal, we will have to make modifications. If it meets that goal, we still will seek improvement. This will be done by adding an algorithm to our code. With enough testing and adjusting we should be able to get our results more accurate. For example, if we see our data is always low by a degree, we can increase all our measurements by a degree. This is a basic example but one of many options we will investigate when measuring temperatures. This will take some research and in-depth coding.

In our various testing phases, we will try to remove any outside interactions. This will be done by having the sensor in an enclosed space away from light and heat. This also requires lots of testing to determine what factors affect the measurements and ways to prevent those factors. These external factors we will work to remove to make sure our data is accurate.

Finally, we can work on detecting heat signatures. Our sensor has the capability to measure more than just a forehead temperature. We can also detect heat signatures coming from people. This is important because we are detecting the amount of people coming in. This will primarily be done by the camera, but we eventually will explore the possibility and functionality of our sensor to determine if we can add any parameters to our project.

C. Task 2 Facial Recognition to Differentiate People from other Objects

Our next feature item is to use facial recognition to differentiate people from other objects. This in our project is to track pattern movements. With the reopening of business some buildings need to have limited capacity, and our system will track the people who come and exit the store. In addition, tracking the people can help businesses know when they are crowded and at what times they are busy. This can help in changing policy in order to spread out the crowds and keep the numbers even across the board. Overcrowding is dangerous and can spread covid. By keeping the crowds down, hopefully with our camera system, we will be able to reduce the spread of covid and keep the inside of buildings safe for everyone.

So, the first step in our process is to test connection to the raspberry pi. This is currently being worked on and should not be too hard as it will most likely require a USB connection. The camera we are using has not been decided on, but we have many options. We will test these options and determine which camera is best and most effective for our design.

Once the camera is installed, we will have to work on coding it, and detecting people. The first goal is for it to detect 5 people within a given space. This space will be the area where the people enter the building. We want to detect 5 people so that if a group of 5 people walk into a building, we will be able to track them and record that they entered the building.

This initial part will require the ability to differentiate a person from any other object. This will be done through several identifiers that will help identify people. The more factors we add the more accurate this detection will be. These factors are not determined currently, but will be explored and changed if necessary, depending on testing which factors are most accurate. Some factors will be just the shape and face structure of a person. Other factors will be achieved through movements that only a human could do. Again, this will require some editing and revising to determine the best factors to identify humans from objects.

After we differentiate a person from an object, we have to determine whether a person is exiting or entering the building. This is essential in determining how many people are in the store. It also is essential that once someone enters the camera sends a signal transmitted to the temperature sensor depicting how many measurements it will take. We do not want the temperature sensor to output results when no one is there. So, we will have to detect that a person is entering so the sensor is prepared to make a measurement.

Next, we will keep a count of the total people in the building. This initially will just be comparing the people leaving to the people entering. However, those results are likely to be inaccurate so we will again have to add more factors to our detection system. For example, if people are bunched up together or leaving and entering at the same time we will need to figure out when is the best time to detect people. The doorway may not be the best time for example, because it is hard to tell the way people are facing. It might be better to wait till the person enters several more steps into the building. These small factors we will explore in order to increase our accuracy of the total count.

The final part is to notify the store once the total capacity is reached. This will require the camera to send a signal to the pi which will then redirect that signal to somehow notify the store when it is full. This might be as simple as a beep noise once it is full or could be a message through Wi-Fi to the manager for example. This will require real time communication between the camera and the pi. This connection will have to be tested and confirmed to make sure that there is stable data being sent back and forth between the two devices.

D. Task 3 Alert user when unsafe temperature is measured

The next step in our process is to notify the user once an unsafe measurement is detected. This will be done in a few ways, through an LCD screen, LED lights, and sound generator. It is important that the user easily can determine how to use our device without any struggles. The goal of this device is to have it at an entrance and not require any person to operate the machine. It should be such that it can be left on and operate correctly. For this to happen the user experience has to be as easy and seamless as possible. If there is confusion human interaction will be required and then our device will have lost its purpose. Therefore, the user interface must be simple and easy to use

The first step is installing the LED lights with the raspberry pi. This will require connecting the LED lights to the correct pin and making sure that the pi can turn the LED lights on and off. This will also be required for the screen and sound generator. With installing each of these devices we will have to plan out an appropriate pin and position the device correctly so that the wires can reach to the desired location. This will take some adjustment to make sure in the end everything is wired correctly, and in the correct location.

The next step is to integrate the LED lights with the raspberry pi. This will most likely be a simple code that when an unsafe temperature is recorded the green LED turns off and the red LED turns on, and otherwise keeps the green LED on. This will require the pi to be able to detect an input signal and display the output signal instantaneously.

Next, we will integrate the sound generator with the pi. The sound generator will output a high-pitched sound for a safe reading and a harsh low sound for an unsafe reading. As well when the max capacity or some other error is reached, we may have the sound generator produce a loud output to alert the store that some error has occurred.

Integrating the LCD screen to the Pi is also required. The LCD screen will have multiple functions. First it has to alert the user that it is ready to take the person's temperature. This may be as simple as a "ready" or possibly "step forward". Once the measurement is recording it may display "stay still" or "...'. These decisions will be made to produce the clearest output and can easily be modified. Finally, the LCD screen will display the temperature results and finally display if the output is in the safe range or not. This screen interaction can be easily modified.

All these interactions are simple output interactions for the raspberry pi. The hard part will be the processor deciding what order to send the output signal to these devices. Our system is doing many things in a short period of time, so there will be some coding to order these outputs to be done in a certain output. There Pi will have to be constantly waiting inputs and send the correct signal to the correct output. In addition, this part will require a physical positioning of all the devices such that the screen LEDs are in an easy to see location for the user. This punch list item is initially simple but will require fine tuning to make sure that it is as simple as possible and displays the right information at the right time.

E. Task 4 Produce and record data for the system

This item of the punch list is to produce and record data for the system. One of our goals for this project is to take all our data we receive and send it through the Wi-Fi connection to a site where we could analyze this data. Our current plan is to send the data through the Wi-Fi to a site where the data could then be analyzed. This data will have multiple purposes. First, we measure the amount of people coming in and at which time they enter. It would also measure when any high temperatures are recorded. Finally, it could also measure the average temperature to see if the data is accurate and if it correlates to a certain time of day.

The first step is connecting the raspberry pi 4 to the Wi-Fi system. This setup may change on location but requires configuring the Wi-Fi with the pi. We also must make sure that the pi can send information through the Wi-Fi to a server or site. We will have to determine the best way to send this data and where to send it to. That will depend on where we are making calculations, and that information will be finalized once we have a better idea of what sources are the best.

The next step is to create graphs and tables from the data. Once we determine where to send it, we will have the capability to translate the data into a clear form. These graphs should be simple as they will show the timestamp of the input. However, there will be several different types of graphs showing the average across 1 day, 7-day, 1 month and other increments. This will be explored more and fine-tuned to determine the best way to display all the information.

Finally, we will have to make sure our connection is secure. This may be later in the project, but we want to make sure that our data is secure possibly by adding an encryption. In addition, we want to make sure that our data is not lost if the Wi-Fi goes out and other preventive measures. We want to make sure our data is safe and protected. This data is essential to informing the building of everything that happens in the store.

F. Task 5 Compact and safe design

The next part of our design is the safe and compact design. We are building a product that is transportable and can be brought to various buildings. Therefore, we need a secure design that will make sure the important parts of our system do not get damaged by any outside effects. Our goal is to enclose our entire device into a single structure that can be moved without having to disassemble and reassemble each part. Our plan is to enclose most of the fragile components in a small box. We also want to be able to move the temperature sensor up and down in order to measure temperatures of people at various heights. This enclosure may have to be modified, but our goal is to cover all the important parts so that everything remains secure.

The first step is to purchase and assemble PVC into a frame. The frame for our project will likely look like a lamp. The base will likely be two or three outshoots of PVC pipe to provide stability. Then in the middle we will have a single PVC pipe for the body of the frame. The frame at the top will just be made so that a box can be mounted at the top. The PVC pipe is a key material, because we may need wires and connections across the devices and the wires can go through the PVC pipe if necessary. The frame should be simple and basic looking, as it is just to provide a base for our devices.

The next step is to attach the camera. We may attach the camera to the box where the sensor and pi are located. However, this will have to change if we enable our box to move up and down. We need the camera to be at a high visible spot, so that it can see people come in and out of the store. Likely the camera will be attached to the PC frame separately from the box. To start off we will simply attach it to the frame in a simple way, but later on might create a small containment zone so that the camera is protected. It is important to note that we want to make sure that the camera's view is not obstructed by glass or any other material to make sure it can view the people accurately.

The next part is attaching a box to the frame. This box will most likely be around 12x12x3 inches. This box must contain the PI, temperature sensor, noise generator, and LCD screen. The LED lights will be attached outside of the box so that they are in clear view. This box we will purchase independently, and we have already looked at possible products. It is still unclear how exactly we will attach the box to the frame. We may be able to screw into the PVC pipe, however, we are still open to other options. Once we purchase the box and PVC pipe, we will determine the best way to attach the box to the frame.

The next step is to attach components inside the box. This also includes the LED's that will be attached to the outside of the box. The main aspect in this part is to determine the best way to have all the parts fastened inside the box while at the same time making sure everything can be wired up to the pi. There will be wires connecting every device to the pi, and therefore a breadboard where all the connections will take place. We do not want a mess of wires in this box, so it is important to plan out and determine the best spot for each of the components and keep everything fastened so nothing moves around inside the box.

The final task is to install a motor to move the sensor box up and down. This would be during the spring semester as it is not part of the punch list. However, this part is essential because if our sensor is to work it needs to record the temperature of people as they come into the store. Our device needs to be able to be adjustable height so that it can accommodate everyone who enters. The beauty of having all our components inside a box is that this box can be moved up and down while keeping all the devices secure. The tricky part will be to have the box move up and down while the wires stay connected to the devices. However, if the wires are contained in the PVC pipe it should be able to stay connected the entire time. In order to move our box up and down we will most likely use a simple motor, but the details have not been finalized at this time. The device will have to be controlled by the PI which results in even more loose wires.

This section is all about making our product as neat and secure as possible. With so many components that each need wiring it is certain to get messy. That is why we need to make sure with everything we build we make sure it is secure and, in a place, where it cannot be disturbed. This part also will take some modification afterwards to make truly presentable. After our initial design there will likely be adjustments made to make the design better. These adjustments are essential so that the system is easy to use, modify, and protected from outside forces. Our project has a lot of sensitive and vulnerable parts that need to be protected.

G. Task 6 Assignments Fall Semester

There are many assignments required in senior projects that are helpful and essential for our project. First, we will focus on the assignments in the fall semester. These assignments helped us get started on our project. Our team could not just start building day one, but instead we had to plan and research for many hours to determine what our project was and how exactly we were going to accomplish our goal. These assignments varied in their description and requirements, but all the assignments helped us better understand our project. Therefore, they are essential to our project.

The first assignment was the individual problem statement. This assignment each team member chose an individual problem statement and researched how exactly the problem was. This helped us first come up with various ideas and areas for our project to go. This is where we developed the problem statement of Covid19 which was the foundation to our project idea.

In the team problem statement, we as a team chose the corona virus and started to narrow down what exactly we were trying to solve. We decided to pursue the reopening of businesses as our more specific problem. With Covid one of the largest issues is reopening buildings, this led us to choose our exact project to help solve that problem.

The design idea contract. In this assignment we determined our punch list of features for our actual project. This punch list is in essence the goal of the fall semester. We listed all the components we plan for our project. This was in essence when we figured out exactly what we were going to do. This punch list also let us start purchasing our parts that we needed. The design idea contract was when we also started to divide the work. Each team member purchased different parts based on each part assigned to them. This assignment was when we slowed down our planning and transitioned more into the building phase of our project.

The work breakdown structure, which is this assignment, helped us realize our entire project. Before we had goals and items to be completed, but the work breakdown structure helped narrow each of those items into smaller divisions. These work packages are helpful as they will direct us throughout the year on the building of our project. Dividing the work into smaller divisions is essential to helping everyone know what they are responsible for and clearly state the work required.

The project timeline is a continuation of the work breakdown structure. Since we listed out all the parts of the project in the work breakdown structure, the timeline helps organize these lists. When seeing a long list of the requirements it can be overwhelming and difficult to know where to begin, so with a timeline it helps visualize the project and create goals and deadlines to get parts of the project completed.

The risk assessment assignment is helpful to prepare before testing and building of our project. Up to this point we will have started on each of the individual parts of our project. However, when we start to put different parts together and test our project it is important to keep in mind any risks. In addition, with this semester taking place during Covid there are additional risks that have to be considered. When building a project of this scale over a long duration surprises are going to happen. It is our goal in this assignment to be prepared as possible and avoid any damaging events from occurring.

Next is the project technical evaluation. This is where we will demonstrate what we have progress we have made in the fall semester. Our goal is to complete our punch list in the fall semester, so we will hopefully show each of the parts we have made and demonstrate their functionality. We will also revise our timeline based on any progress we made that was unexpected or progress that still needs to be done.

The final assignment is the lab prototype presentation. This is where we will make a video that describes our project. Some companies and organizations will view our project, so it is our goal to show off our project. We want to make sure we present our project well and fully describe the work we have done.

H. Task 7 Assignments Spring Semester

The spring semester has a list of assignments prepared that we have started to look at and understand. By the spring semester our punch list of tasks should be complete. However, the spring semester is focused on further testing of our design and refining our project. Our project will continue to improve throughout the semester.

For the spring semester we start off revising past assignments. The reason for this is our project will continue to change and modify as we work on it. Although we have initially planned out our project and detail, it is likely that modifications will be required based on the success and implementation of the project. It is important to remain flexible and adapt, because our goal is to solve our societal problem not to copy our design idea contract. The spring semester is a time to reevaluate where our project is, and where it still needs to go.

The first three assignments are to revise the team problem statement, design idea contract and project timeline. Here we will reanalyze what we originally chose and determine if these reports need updating. This is important, because since our project is a yearlong assignment, a lot will change. We initially created our team problem statement, design idea contract, and project timeline before serious construction of our project began. In the fall semester we will attempt to complete our punch list, but this has not been done yet. After working with the devices, we may find unknown obstacles or difficulties that require modification of our assignments. That is why at the start of the spring semester it is a great time to pause and reevaluate where we are at. There will undoubtedly be changes necessary.

The device test plan is essential to testing our project. In this assignment we develop our testing plans and create a timeline to test our project. With our device's accuracy is essential, which will require extensive testing to make sure they are truly accurate. We hope our accuracy is very good which will require testing after we adjust. This assignment will help us determine how our project is, and if we need to improve the accuracy.

The market review assignment helps us determine if our product would be marketable. Our project is designed for any businesses reopening currently or in future pandemics that require such measures. Our goal is to make this a product that could be sold and used by businesses. This assignment will help us determine how our product would be marketable, and where we could change our product to make it marketable. This will largely be dependent on how much progress we have made and will give us great insight on product design.

The feature and report presentation are where each team member details what they have done and worked on the project. This helps us all stay accountable and prove that we have been working on the project and making good progress.

Next will be the midterm progress review where we again reanalyze our test plan and results. This is essential as at this point, we are getting close to the end of the year, so we want to be working on our final testing and determine which parts of the project need to be focused on in the end to finish our project.

The deployable prototype review is the technical review where we show off the project in its final form. This is when our project should be finalized and integrated and fully operational.

The end of project documentation is where we finalize our end of project report. We have already started working on our end of project format as we will continue to do so throughout the year. After we show off our project, we work on finalizing our report. The report is likely to be extensive, but hopefully with the consistent work throughout this year we should not have too much difficulty revising the report.

Finally, the deployable prototype presentation is where we show off our project to businesses or organizations that look at our project. It is important here that we show off our project well. Many people when they look at something judge it instantly, so we have to make sure we do a good job in our presentation and it is immediately clear what our project is and how it can be used.

These assignments help guide us through the spring semester. Likely we will have a raw product after the fall semester, so the spring semester helps us refine and test the product to create a great product by the end. We do not simply want to put a few components together and call it done, but rather create a product that achieves our goals and is integrated simply. Through these assignments we will be able to make some punch list items turn into a complete product.

I. Task 8 Additional features

This task was put in place such that if everything else goes according to plan we can implement minor changes that will increase the efficiency or usability of the product. The first change we would like to make if time permits is an increase in the accuracy of our temperature sensor. We initially decided that being within .5 degrees Fahrenheit of the actual temperature was sufficient to measure whether someone is sick or not but if we had the availability, we would like to make it closer to .2 or even .1 of a degree. We plan to test different distances, types of software, and potentially even different sensors in order to find the one which can give us the most accurate reading with the least cost. We do not have a person assigned to this or a date yet because we are not certain whether we will get to it (as it is a stretch goal) but we imagine that it would be done close to the final due date and be done by either Dennis or Paul being that they were the main people working with the temperature sensor.

The next change we are looking to make is a change in the cost of the camera. We decided that we would start by trying a couple of cameras such that we could test different sizes and resolutions but, in the future, we wanted to make the final product use an optical sensor used in industry. We want to make this change because it would give us experience with industry tools as well as it would decrease the cost and size of the overall project. As was with the previous task, we do not have a due date because this again is a stretch goal, but Micah would probably do most of the testing for this part because he has done much of the research on the cameras and has access to a couple industry grade optical sensors.

The final change we look to make is an overall decrease in the size of the project. Currently, we are working with basic components that we know should work, but we want to make the product as compact as possible such that it has a more commercial use. We plan to decrease the size of the camera as well as possible the thermal sensor and if all that goes according to plan, we should be able to decrease the size of the container for all the parts as well. This is a cumulative team effort as each component will have a separate person working on it (Micah on the camera, Dennis on the thermal sensor, and Paul and Nick on the overall casing) with a due date close to the final project presentation.

VII. RISK ASSESMENT

A. Project's Critical Paths:

The project's critical paths are primarily related to the punch list. The punch list is the concise list of features that our product is going to have by the end of the fall semester. This is like the main functions of our project. When we look at the critical paths, we will focus mainly on the punch list. This is because smaller details and integrations can be easily adjusted or changed depending on unforeseen risks. The punch list, however, is essential to our project so we will make sure to detail the possible risks to avoid any major complications. Our societal problem is to prevent the spread of covid in the reopening of stores. These critical paths are essential to ensure the societal problem. We must make sure the critical paths are complete in order to achieve our societal problem.

1) Getting camera to detect people from objects

Our first critical path is to get the camera to detect people and differentiate them from objects. Our goal in our project is to detect human migration patterns so we hope to be able to know when people come in and out. We are using a camera to be able to detect people when they come in and leave. This is one of the main aspects of the project and therefore is important to consider the risks and make sure it is done smoothly. There are two main aspects to this critical path. First is getting the camera to detect the people. This is mostly done by coding through the camera. The risk here would be that the algorithm is simply ineffective and is not able to detect the people to a high enough accuracy. The other part is communicating the camera data with the raspberry pi. We plan to connect the camera to the pi through the pins, and then send the data to the cloud through the internet. This in theory is a simple connection and coding, but there are some risks. Whenever you are connecting multiple devices, they have to be compatible. In addition to sending the data in real time through the Wi-Fi will require some coding techniques. We also have to guarantee the Wi-Fi is fast enough to send the data, and that the camera data is not lost. This critical path we have planned and should work as intended, however, until the process is complete there are risks and so this critical path needs to be ensured for the completion of our project.

2) Temperature sensor to read accurate data

The next critical path is the temperature sensor. The sensor is critical to detect whether people entering the store have a fever or not. This requires a precise measurement to make sure the system is accurate and not read false positives or false negatives. We choose the D6 32 L infrared sensor. We have already connected the sensor to the pi and confirmed that it can read data. However, right now we are adjusting the number of pixels it measures as it relates to the accuracy of the results. This critical path is all determined on how accurate we can get our data to be. This critical path is the other main component of our project and is essential to be accurate. There again are major risks for these critical paths. One is the limitations of the sensor we picked. Temperature sensors can only be so accurate. We believe we picked a sensor accurate enough, but until testing it is a risk of a critical path. Some of this risk we can manipulate with coding techniques, but there are physical limitations. The other major risk is sending the data to the processor. The connection has been confirmed, but we must make sure the sensor is sending the temperature data it receives at the right time. We do not want it to send data when it is measuring empty spaces for example. This critical path is essential to detecting high temperatures which is a Covid symptom.

3) Processor to communicate with each device

The next critical path is to have the central processor to communicate with each device. The processor we chose was the raspberry pi 4. The processor's function is to communicate with each device which includes, the camera, temperature sensor, piezo beep maker, LED's, and LCD screen. This critical path's main risk is dealing with all these devices in real time. It is simple enough to connect each device individually with the Pi. However, once we get all devices running, we need to make sure they can operate in real time. Our devices need to have the ability to communicate with each other in real time and send data between each other. These complex integrations are essential to this critical path. This critical path is important to turning our project from independent working parts into a marketable product. Our goal to solve our societal problem is to have a product that can be used not just a collection of ideas. The purpose of our project is to have a system that can do multiple functions at once conveniently. Therefore, it is a critical path to have the processor able to communicate with all parts at the same time and operate as planned. It is also essential that the processor can work with each individual part. This critical path is what connects each other's critical path together. Therefore, it is even more essential that this critical path avoids any risks that would hinder its completion.

4) Building physical contaminant structure

This critical path is creating an enclosed structure that our device can go in. This critical path is less essential simply in the fact that the completion of this part will not affect the functionality of the project, however, it is still a critical path because it is an essential part for our project. We need to have something built that will keep our sensitive camera, sensor, and processor safe from outside forces. This is essential, because when we deploy this product, we need to make sure it can be easily transported and secure. We have many sensitive parts in our project. These parts could be disrupted, or wires could loosen with a simple nudge. Therefore, we need to keep every part safe and secure to make sure our product stays functioning. This critical path will be completed after the other parts are completed, but still is essential for our project.

5) Sending Data to a cloud

This critical path involves sending the information from the temperature sensor and camera to the cloud. Our goal is to create not just a device that can measure temperature, but also record information such as migration patterns and temperature patterns. We are going to accomplish this by using the raspberry pi's Wi-Fi connection to send data through the cloud to a website where the data can be stored and analyzed. When we connect the camera and sensor to the pi, we will program the pi to periodically send data. This data will be stored at a website where we can analyze the data through graphs and other representations. This critical path is essential for these businesses when they deploy the product. By saving the information people who have this product will be able to see who enters the store and take that information and apply it to their business. During this reopening they will be able to schedule their hours and plan according to the amount of people which can help businesses reopen during this pandemic. This connection we need to make sure is reliable and stable to make sure that the data is recorded.

There are five major critical paths to our project related to our punch list. These critical paths are the most essential parts to our project. With each critical path we must consider all the risks associated with them in order to make sure they are not slowed down by any unforeseen challenges. We have separated the critical paths among group members to make sure each part is being worked on at once so not one part falls behind. These paths are essential to making sure our project completes our societal problem and our device to work as intended.

B. Possible Events and Risks to hinder completion:

1) Technical risks

Our first technical risk is that the temperature infrared sensor is not accurate enough to display temperatures within 0.5°C of actual body temperature. While our team has continuously progressed to raise the infrared sensor accuracy, sometimes the sensor gives out an inaccurate reading of a degree or more. If our team cannot fix this problem, the impact may jeopardize our project's success. A fever is described as a temperature greater than or equal to 100.4°F. This might become an issue; for example, if somebody has a temperature of 99.4°F, then the temperature sensor might give an inaccurate fever warning of 100.4°F. On the other hand, if somebody has a temperature of 101°F, then the temperature sensor might give an inaccurate reading of 100°F and not give off a fever warning. As you can see, our team needs to fix this issue so our design can be used as intended by business owners.

Not only is the infrared temperature sensor's accuracy a technical risk, but also the issue of the camera not keeping an accurate count is a technical risk. Our team faces the issue of our camera not being able to use facial recognition if more than 10 people walk in or out at a single moment; granted, the probability of this occurring is low. If our camera's count is too high or low, the impact can be astronomically negative to our project. is putting business owners at risk of being in trouble by state authorities, as well as, heightening the risk of people inside stores.

Next, the third technical risk our team faces are that our processor, the Raspberry Pi 4, is not sufficient in handling all the components at once, or at our team's desired speed. Running constant video from a camera, an infrared temperature sensor reading body temperature data, and uploading constant data to a cloud is a lot happening at once. Our team believes this issue is very improbable because our processor has a Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz and 8GB LPDDR4-3200 SDRAM. These specs should be sufficient enough to handle all the components of our design, however due to covid-19 we have not been able to run each component together at once.

Lastly, our fourth technical risk is that a component, like the LED Traffic Light, infrared temperature sensor, or camera, burns out or breaks. The probability of this is relatively low, however it would jeopardize our project's success in that obviously we need each of these pieces for the final project to function as we stated in our punch list. If something minor like an LED breaks there is little concern as they are easily replaceable, and we already have other components that alert users. However, if something like the Raspberry Pi breaks, there is absolutely no way to finish the project without replacing it. So, depending on what breaks the risk can be higher or lower.

2) Broader technical risks

The first broader technical risk will depend on the outside temperature readings that can affect our temperature readings. So, for example, it is either super-hot or cold in an area and someone comes into the store and their temperature is either really hot or cold based on the outside temperature, the sensor could potentially give false information about the temperature and alert store owners of the issue. The risk here is that when it comes to reading people's temperature, we want to get the most accurate temperature readings even if the weather outside is completely different. So, if a person has a fever and the temperature outside is freezing cold, we do not want the temperature to measure that the person is cold and allow that person to walk into the store with a fever or even potentially covid19. Vice versa when the temperature outside is very hot and the person who is healthy walks in and gets a high temperature reading this could cause a lot of confusion.

The second risk is about the cloud losing data, which can present a very unreliable source. This risk is very important because we want to collect data from the sensor and the cameras and allow the business owners to get an exact statistic of how many people come in or out of the store, it will show peak hours when the store is very busy and when it is not. So basically, without the data there is no way of having this information and will not allow store owners to get their statistics. Having a secure network is also a risk where the potential data can come out and somehow affect the business. It can also present a security risk with having the camera data accessible to anyone, so that is why the cloud data is important to be stored and on a secure network.

The third risk is the wiring of the sensor to the breadboard to the pi as the power source. As of right now the wires are naked coming out of the sensor and slightly wrapped around male connectors and put into a breadboard. With little to no movement of the sensor those wires can come out and affect the sensor with reading the temperature. If the prototype is secured in a box and somehow one wire slips off the male resistor it can harm the whole project and feed the LCD screen the wrong inaccurate readings. Having exposed wires can lead to electrical problems and potentially cause an electric shock or fire.

3) Systematic risks

One of the systematic risks would be if a team member gets Covid. This sort of problem will not allow the team member to work on the project. They would not be in a good working state to do anything. There are many effects that come with Covid and some are not pleasant. With this being a team project, each member has their certain tasks to complete and if one person is out of the picture the workload increases to the other team members. The process of Covid is two be quarantined for 2 weeks, then get some more tests done after to see if the symptoms have gone. Some other risk would also involve a team member getting into a tragic accident and them being in the hospital for long periods of time. This would be unfair for one of the team members to get dropped mid-course because of what can happen.

C. Possible Mitigation Strategies:

1) Technical risks

If we find that the temperature sensor cannot obtain measurements that are accurate to +/- 0.5 degrees Celsius, we have a couple of options. The first idea is to try and contact the supplier to see if they have any help because the product, we decided on says that it should be able to do accurate readings to half a degree. The other mitigation strategy would be to simply find a new sensor, as there are plenty in the field and we can easily find a replacement. This however could lead to a slight delay in the final project simply because of shipping delays and having to reconfigure the new component. We do have time as we planned ahead to try and finish the project ahead of schedule, but it will just set us back to completing the project closer to the final due date.

If the camera cannot keep an accurate count, we have tossed around the idea of using another camera with better resolution as that would likely increase the ability of the program to recognize faces. Additionally, we have discussed using two cameras, one to see people entering the building and one to measure people exiting because it is difficult for the program to detect the back of people's heads, at least in its current state. Beyond that, we could mess around with different libraries because there are more out there that can handle doing facial recognition besides open.cv which is what we are using currently, and they may be able to read faces/the backs of people's heads more accurately. This once again would likely cause a brief delay in the final project, but we already have a couple other cameras to use as well as an optical sensor which we were already planning on trying to implement into the project.

If the Raspberry Pi cannot handle all of the parts necessary, we have a couple of other options of processors which may be better at handling the intensity of the workload. The initial one that comes to mind is a cheaper Intel NUC which is basically a smaller computer. This would allow us to add more ram relatively cheaply to the processor while still holding many of the same functions as before. This would likely cause a delay in the final project due to shipping delays but nothing too major. We have worked with Nuc's before so the transition between the Pi and the Nuc should not be too major.

If parts burn out, depending on the part, we will likely have to either switch it out causing a minor delay or order a completely new one resulting in a larger delay. If something like the camera or LEDs break, we have replacements ready and could simply switch the older piece for a new one, however if the temperature sensor or the Raspberry Pi breaks, we will likely have to order a replacement which could take upwards of a week. Luckily neither of these pieces would be too difficult to put back in place so either way the final project should only expect a weeklong delay maximum as the result of a broken piece. Beyond that, the likelihood of anything breaking other than something minor like an LED is relatively small because most of the other pieces are manufactured to last and survive in much harsher conditions than we are putting them under.

2) Broader technical risks

In the case that our temperature sensor does read outside temperatures versus the human body temperature as it is supposed to do, we have a few options. First, we can contact the supplier and maybe get a new sensor, because it can be labeled as faulty equipment and not doing what its programmed to do. Secondly, we can potentially look for a new sensor that will have a better chance of reading only the body temperature and not any outside temperatures. This will only delay the building process of our prototype because every sensor runs differently, and new coding will be needed and so on. The sensor we are using now is supposed to be the best human body temperature sensor which is used in many of the current handheld temperature scanners.

If the cloud loses data, we can look for a more secure reliable network that can produce the data we need. Another option would be to have the data be sent to two different clouds so that if one misses some information the other one surely would have it. Some clouds work through an IP address and some work wirelessly. The best option would be to use the network inside the store and store the data on that IP address and have a secure username and password so that only certain people can access it. Programming the pi to send out clear data would be the last option because if the code is not right nothing will work as wanted.

There is only one option for this situation, we need to get the wires clipped and into the casing. This would require special tools that can be purchased to fix the naked wires and make them safer to use. We would need to purchase the casing and the male pins to secure the wire and for it to have a connection.

3) Systematic risks

If this sort of situation does happen there are a few ways to handle this. One being let the person quarantine themselves for 2 weeks then have a workload of new assignments to work on to fill in the parts that they missed. Usually, the class is based on the number of hours you spend on each task, figure whether that task is completed or needs more time to complete. If a tragic accident does happen one solution would be to make some sort of deal with the professor because this is out of our hands to deal with. If the accident is minor then some type of work can be done by that team member, if the accident is major then we are not sure what we can do and what we can work around for that person to get all the credit for each week.

D. Risk Assessment Charts:

Table iii

Risk Assessment Matrix

Risk Matrix						
Probability	1			Cloud loses data/is unreliable.	Processor insufficient speeds.	Tragedy causes teammates incapable of working.
	2		Temperature Sensor isn't accurate to 0.5°C.		Camera inaccurate count.	Parts burn out or break.
	3	Team member gets Covid-19.	.	Outside Temperature affects readings.		
	4			Wiring of breadboard moves out of position.		
	5					
	0	1	2	3	4	5
	Impact					

Table IV

Level Impact Descriptions for Risk Assessment Matrix in Fig 1

Level	Impact
1	Minimum, or no impact.
2	Impact can be tolerated.
3	Limited impact.
4	May jeopardize the project.
5	Will jeopardize the project.

Table V
Level probability description for Risk Assessment Matrix in Fig 1

Level	Likelihood	Probability
1	Not Likely	0.1
2	Low likelihood	0.3
3	Likely	0.5
4	Highly likely	0.7
5	Near certainty	0.9

E. Handling of Social Distancing:

Social distancing has greatly changed the work environment and experience of senior design. We have had to adjust how we work on projects and work with each other in unexpected ways. Fortunately, we were aware of the social distancing requirements before we started our project and were able to plan around the challenge of social distancing. Therefore, we have already adjusted the way we work, and are prepared to complete the rest of this project amidst social distancing requirements. Therefore, while we assess the different risks, we fortunately feel confident about dealing with the risk of handling social distancing. This is due to a series of strategies that we have developed and will implement to ensure completion of our project amidst social distancing challenges.

1) Have multiple Pi's

Since each part of our project is connected to the raspberry Pi, we are using two separate pi's. One is the official pi for our project, and the other pi is from the personal supply of one of our team members. With the two pi's there has been a handoff between the two other group members only when necessary. This handoff has been done in as safe a way as possible. When we have to swap, we place the pi in a box, drop the box at the person's house for them to grab all without seeing each other. This is to prevent any danger of spreading Covid. In addition, containers and parts have been sanitized to ensure no Covid spread has occurred. With multiple pi's we have increased work efficiency and kept everyone safer from having to constantly switch off. In addition, we have avoided any physical work together, as that is not safe in these times and will be avoided for the duration of this project. This is one strategy we have implemented to work on our project separately.

2) Each team member has individual part

When we created our project initially, we made sure to design a project that had separate parts to help during this social distancing year. Our project was very modular in design so that each person would have something to work on. With the ability to separate our projects into individual parts we are all able to work on our own part and need less intervention from other teammates. For example, Micah bought the camera and has been the only person using that device while I bought the temperature sensor which only Dennis and I have used. Nick bought the piezo beep noise and the lcd screen and has been only working on that part. Since each person has been working on their own part, we have had less intervention. Minimal parts have to be passed to each other until the final product is assembled.

3) Trade Off Policy

We have developed a tradeoff policy to ensure the least human interaction possible in this project. This is used for example when trading off the raspberry pi's and temperature sensor between group members. This tradeoff is done in a way to be as safe as possible. We are extremely aware of all the potential risks that Covid has to our personal health especially after researching Covid for this project. We are all on the same page in the importance of team safety and therefore have developed a tradeoff policy. This policy has resulted in dropping off whatever item in a secure box at the doorstep and then texting to let the other group member know when they have arrived. That way no physical contact is necessary. Once the parts are received each team member is responsible for sanitizing the parts and making sure they eliminate the risk of Covid exposure. This trade off policy will have to be used to a larger extent when we assemble the project. We will have to bring each part together to demonstrate a physical working product. When this arrives, we will choose a group member to have all the parts. Then each member will drop off their parts. The parts will then all be sanitized. The goal is to have all the individual parts working perfectly on their own before they are all assembled. That way the person assembling the project should not have much difficulty and be able put the entire project together. This trade off policy we will implement to reduce Covid spread and enable each member to effectively work on the project.

4) Frequent team and individual meetings

One part that has been harder is to help each member in the project. In years past teams have been able to meet in person and can physically help on various obstacles. This year since it is all virtual, we have placed an emphasis on team and individual meetings to help each other. We schedule team meetings as a general checkup and to make sure we are all on the same page. These meetings have helped make sure everyone knows the direction we are going and what each person is working on. Often times when completing our writing assignments, we have worked together so we can ask each other questions and work on the assignment together. This has helped us not make as many mistakes and complete the required parts without forgetting to do something. However, when there have been obstacles for a specific person often, we have two or three person meetings where we can more easily discuss and help the other student. There has been a mixture of these team and individual meetings which has helped us work together in a social distancing environment. We have increased the importance of meetings as a strategy to help handle social distancing.

Social distancing has been a challenge to senior project. However, we have implemented specific strategies to make sure that we can complete our project. By implementing these strategies, we have maintained efficient workflow and stayed safe in these unsafe times. We plan to continue these strategies throughout the year so that there are no unforeseen risks that could come with covid spread. Our team has adapted well and will continue to adapt to social distancing while working on this project. With some simple planning early on we have been able to stay safe and efficient as the project has progressed.

VIII. DESIGN PHILOSOPHY

In our design philosophy we will discuss many aspects of our project that took extra thought and decision-making process. One of the best learning moments in Senior design is the requirement to make decisions on your own with limited information. This design philosophy is to help explain why we made the decision we did. Decision making is also a process essential to engineers who constantly have to make decisions based on limited information. In our project we have full control of the decision-making process which is a lot of responsibility as well as very tough. This project is different from nearly anything we work on during school. Projects in school are given to us with all the instructions included. However, in senior design there are no instructions, we simply have to figure out the best way for our project. That is why it is important to have a design philosophy. When making tough decisions we have to gather what information we have, and logically make the best decision. This decision-making process happens continually in our project. Therefore, we analyzed the reasons behind the choices in the initial design philosophy, changes along the way, and our final integration. This project is nearly a year long project which means there are many decisions along the way. When we first started, we had little to no clue what our project was and would be, so along the way as we gained information and experimented with different designs, we adjusted. I think our group is a little unique in the fact that our initial design and final design were fairly similar in nature. We did a good job initially planning our project and were able to follow through on our design. However, even when we had roughly the same idea, we had minor changes along the way for every single facet of our project. It was a focus when making decisions to consider not just the short term but long-term implications of our project. We made sure that in all of our design philosophy that we had the big picture view for our entire project and did not get narrow sighted on our project. The design philosophy helps details exactly what we were thinking along each phase of the project, and how we started with a design and how we came to our final product. At the start I will discuss the design philosophy behind our initial problem statement and design idea. Next, I will discuss the philosophy behind which components we chose to purchase for our project. After that we will discuss the specific changes that were made throughout our project, and finally describe the changes that came with integrating our design. This process will help walk through our time in senior design and all the choices we made and continually adjust.

In this Senior design project, we have made many choices based on the information and predictive assumptions to help guide our project. We were assigned a task at the beginning of the project which was to find a solution to a large-scale problem that affects millions of people. Our group chose Covid, because of its uniqueness and its current importance among other major problems. With the large-scale problem, we then had to focus on how we were going to design something to fight against Covid. As engineers the solutions are endless, but at the same time limited because Covid is a medical problem. To brainstorm we thought about the impact Covid has had and how it has changed everyday life. In the summer prior to starting senior design Micah had the idea to set up sensors for a parking garage that could detect cars and help with parking and building capacity. However, that problem seemed to have already been solved and the amount of engineering seemed limited to solving that problem. Therefore, we started to consider how to implement that idea in a better way. At the start of the year I, Paul Dye, thought of the idea of making a temperature sensor that could be used automatically and measure people's temperature. At the time, these two seemed like different ideas, but eventually we combined them into one idea. The philosophy behind our design was simply taking multiple good ideas, combining them into one, and integrating the two ideas into a plausible design. This was the start of the project, at this point we had an idea but no practical or specific details for the project. The initial problem statement and design approach simply took a problem, and we thought about what we as engineers could make and program and adapt that to a solution. We already knew that we could have cameras detect people, and a sensor that could take temperature. Knowing that there would be multiple devices we then realized that we would need to have a display and notification system to help the user operate the device. As well we would need a secure case to keep this device in one place. Finally, we added the cloud connection as a concept that we had little experience in but wanted to experiment with and figure out. We thought of this product as a system rather than a device. For this system we wanted it to store the data such that the store could analyze the data for their records. With data of exactly when people went in and the people's temperature it could lead to stores' planning their hours differently or even knowing the best time to limit customers. With our design we started with two simple ideas, take people's temperature, and detect people as they came in, but we ended up with a device that had a large functionality and integrated the ideas together.

Once we came up with our problem statement and general idea, we had to determine which parts we were going to buy to build the product. We had to buy the parts very early in the process, and since we picked concepts, we had minimal knowledge it was a bit of a process to determine what to buy. For the infrared sensor, we knew that we wanted an infrared sensor, but which one was hard to determine. There are many infrared sensors that were very cheap, under 10$, but those sensors did not have the accuracy that we needed. Our goal was to get within 0.5 Fahrenheit degrees of reliable accuracy. We could not guarantee that accuracy with cheap sensors and would limit our project to the accuracy of those sensors. Therefore, we expanded our search to find another infrared sensor. One other condition for our sensor was that it could connect to the other devices through our microcontroller the raspberry pi. Finding an accurate sensor that could easily connect to our pi proved to be difficult and there were few options. Very few products existed, and many products were obscure or hard to find much information about. We eventually found that Omron made sensors that used many pixels to improve accuracy. Even in these Omron sensors we found that there were several choices. We chose the option that was the most expensive just under 200$ because it gave the greatest accuracy. Having decided on our sensor we had to decide which microcontroller to get. We decided between the Raspberry Pi and Arduino which were processors we had the most experience with. I remember at the beginning of the project we were advised not to use the raspberry pi since it is known as a hobby board and that Arduino board was better for our project. However, we ultimately decided to stick with the Raspberry Pi board because it was what we were most familiar with. When learning new concepts and new devices it was important to have a board that we all knew how to use and had some familiarity with. As well we bought the newest raspberry pi 4 which had 8 GB of ram which is an increase from previous boards. Up to this point we have had no problem with our processor, and it has run as expected. When building a design, it was more important that we made something that could function and work as expected than pick the board that is more professional. I believe this decision was the right decision because it has never yet limited our design. We also knew that the devices could talk to the Pi which was essential for our project. To decide on the camera Micah took the lead and picked out an option. He ended up using a different webcam than he initially purchased because it could connect to the pi easier. We learned throughout our project that the camera did not need to be an expensive or elaborate camera, but rather nearly any USB webcam could function in our project. The camera has a USB connection and has therefore been easy to use with the Pi. Our next area we had to determine was the alert system. For this section we did not end up buying many products, because we already had most of the required components. In previous Electrical Engineering courses at Sacramento State, we had already purchased and used LED's, Piezo buzzer, and an LCD screen. Therefore, we were prepared and knew some background knowledge for this part of the project. Next, we planned the cloud connection to the Pi. We knew that a cloud connection was possible, but we had no idea of the specifics. After researching we found that API keys would be the easiest and found the website thingspeak. We chose this website because it was free and was operational right away. Very little had to be set up with this website which was a big reason for us using this website. There were some basic tutorials for how to send data from a temperature sensor to the website, so we were able to learn quite a bit and know how to implement the cloud storage into our project. At times we considered switching because there was a 15 second waiting period between sending data. However, in the end we stuck with the website because for our project that was more than practical and could still be shown and demonstrated easily. These design choices in the end we decided to go with what we were confident would work rather than the perfect design. The point of senior design is to build a project that solves the problem. If we redesigned our product to sell privately, we may switch out some components, however, with a single prototype it is more important that we were successful in getting a product that accomplished our goal. Our project could easily be switched to new components without much difficulty, the real challenge and difficulty of our project is integrating each component with each other and coding on the individual devices. We have been fortunate to not need to upgrade any devices throughout the year and have stuck with our initial design choices. For our case we came up with a rough idea but left the physical construction mostly till the end. Due to the limitations of taking senior design in a virtual world we made sure to keep each part of our project separate at everyone's residence. Because of this we did not design our physical structure until later in the second semester. The design we initially had was a tripod design, and in the end, it switched to a simple tube. This was done for simplicity and what Dennis decided was easiest. The physical components are not one we put limited design or engineering decisions into, because that is not the focus of the project or us as computer engineers. However, it was still crucial that we had a physical structure such that we could show off our product and the practicality it possessed. We also purchased a box that rested on the top of the tube that could store all the individual components. This helped us store everything together and keep it all secure. Our initial hope was to create a stand which height could be adjusted. This was so that when people entered a store it could be easily used by any person. However, this was not really within the scope of our ability or expertise. We decided to make it a single pole which was stationary. However, if we implemented the design, we might change our physical structure then. In addition, some groups had a mechanical engineer in their group, if that were the case, we likely would have assigned that person to create a stand that could move up and down. Overall, the design process was filled with engineering choices that we honestly knew little about. We were forced to use our limited knowledge and what we had found from online to come up with decisions and buy our devices. This experience I believe was like the real world in which we will have to make the best engineering choices based on our knowledge which may be limited. I believe we made smart choices and have little regrets, which has helped our project develop into a working product,

There were some changes to our project we made along the way to adapt to what we learned. The first thing that changed was switching our camera from facial recognition to human facial recognition. This change involves the way the camera detects people. Initially we thought we would use facial recognition and scan each person's face as they came in. However, we changed the algorithm to human facial recognition for a few reasons. First, it is a simpler and more accurate approach. Instead of having to analyze people's faces which require detail, human facial recognition simply looks for something close to a human face. This would detect a picture of a person which is not ideal, however, we decided this was an acceptable condition such that when people enter the store, we should have simply people walking through the door. Next there is also an issue with privacy. We did not want to store any information that could be later used to identify people as that would cause a major concern and problem. Instead with human facial recognition we do not detect a person's individual features and therefore do not store any private information. Human facial detection has proven easier to implement and been more accurate and we do not have any privacy concern.

One area that we also had to adjust our thinking was the cloud connection to the server. Originally, we had little to no idea how we were going to implement this part of the project. We started using thingspeak which was a free website in which we could send our data using API keys. At first, we discovered we had a limit of 15 seconds between sending data. We viewed this originally as a problem, but then later realized it was acceptable. First, since this is a prototype if we implemented this project on a commercial scale, we could purchase a membership on this server and not have the time restriction. As well we determine how to combine all our data into a single packet of information that we could send. By sending the data in packet form we can send the timestamp, temperature reading, and person count all at once. This way by sending all our data at once it makes the 15 second restriction less restrictive. At a time, we considered switching to a different server, but in the end, we decided to stick with what we were comfortable with. The restriction did not seem large enough for us to use a different server, as well the tutorials with thingspeak were very helpful and helped us learn the process to send data over. This decision has not restricted our project in any major way, so therefore we elected to stay with our original choice.

One area which we had to modify along the way was also the physical structure. Originally our plan was to have a tripod design, but we did not know the specifics. We did not start constructing the physical structure till late in our project, because we kept our project separated if possible. This was to let everyone be able to work on the project independently. In the end Dennis ended up constructing the physical structure. He elected with a single pipe as the main structure and a plastic box at the top of the pipe. This was simpler than the original tripod approach and very transportable. The structure takes up less room this way and is just as stable. We decided to purchase a plastic box that is made for systems. This box is designed such that the cables and wires can pass through the edges of the box and lets us have all the sensors and cameras on the top of the box. This way all of the internal mechanisms are secure, and all the sensors that need to not be obstructed can be placed on top of the box. This box makes our product very secure and safe as well.

One area that took the most calculating and thought was the integration of the system. In our project for most of the year we were working independently on our devices. When it came to integration, we had to determine the best way to combine each part. For my part specifically with the infrared sensor I had thought I would have the sensor run continually. However, we changed the programming such that the devices would run in a single iteration. Once the camera detects a person it waits 5 seconds for the person to walk up to the device. Then it takes the temperature of the person and based on the results flashes a green or red LED. Once this measurement is taken it then sends the data to the cloud. This is the single iteration process for our project. This will trigger once any person enters frame. However, if a person enters frame but does not want to take their temperature such as a worker or employee. In this scenario the infrared sensor will take the temperature of air, and it being outside normal human body temperature will state a message saying, "person not detected" and no data will be sent to the cloud. By changing the system to a single integration, it simplifies our code, as well as makes the process straightforward to the user. The user can enter the store, see the device, see the message saying to step up the sensor and take their temperature. The way we implement our device is crucial to making it as simple as possible for both the user and administrator. At times we were concerned with exactly how we were going to integrate our design, but by simplifying it to a single iteration helped us visualize and understand exactly how our program would run.

One other part of integration that we had to make decisions on was how to integrate our code. The infrared sensor was written in C, because the Omron sensor had some basic tutorial code that was written in C. For simplicity we chose to write and modify the infrared sensor using C. However, the alert user system and the camera were both written in Python. In addition, the camera's code was written on the computer not on the Pi, because it was easier to access the open CV files needed for human facial detection. Knowing this scenario there was some uncertainty on how we would integrate our code and get it to all run together. Initially we thought we would run the two different parts independently. However, this would lend problems making it difficult to communicate between the two running codes. So instead, we realized we had to get the code running on a single command prompt. We were able to figure out how to integrate our code. Instead of trying to switch our code to a different language last second or some other solution, we simply researched on how to combine the code. First, it involved moving the python code for the camera on to the Pi. This involved downloading open cv to the Pi. This was harder than expected, because we had the wrong version of Python installed on the Pi. Once we updated the python version and downloaded the open cv files the code was able to operate as intended. For the C file we learned how to run a C executable. It is helpful that the infrared sensor is written on its own independent code. This way we can run the executable separately and not have to combine the codes. It would have been much harder to write the codes on the same file. By keeping the files separate it is also helpful for debugging and modularity. Ideally, we could transport our code to a new system or devices much simpler by having our code written on separate files. The integration did prove a bit challenging with combing all the code, but by approaching the problem simply we were able to integrate the code without any major changes or revisions to our previously written code.

In conclusion when looking at our initial design philosophy it was very solid and helped us with starting our project. Although there were changes to our design along the way we mostly stayed with a single design and followed through that design. We had to make specific choices and implementations for each individual function, but no major changes were required for our project. Our initial design idea started with deciding a problem and thinking of what we as Engineers could design and make that would help fight against that problem, Covid. After we decided, we were going to help businesses reopen, we determined the sensors and devices that we could use to achieve that goal. After having that idea, we divided our project into individual parts such that each person could work independently on the project in a remote environment. Each person was then responsible for making design choices such that they could accomplish the requirement we laid out for that part. Once we integrated the system, we had to determine the best way to operate our system, and how exactly to combine each individual part. Our goal was to complete our punch list and the measurable metrics associated with the punch list in the simplest and most efficient way. In the end we have been able to always accomplish this goal and create a final product that met all our goals. Our design philosophy when we came up with challenges or difficulties, was to keep things as simple as possible and change as little as possible. We made sure not to panic or make drastic changes, and instead look for simpler different ways to solve the same problem. For example, the integration of the code we researched how to run c and python codes together when we did not even know if that was possible. We elected to make the structure a single pole rather than tripod design when that proved to be the easier solution. These individual choices lead to a smooth project with no surprises and no drastic changes were required. The simplicity of our design and project enabled us to completely satisfy our measurable metrics in the time required.

IX. DEPLOYABLE PROTYPE STATUS

A. Determine Necessary factors that need testing

We decided that the necessary factors needed in our testing is the infrared sensor, camera, connection to cloud, alert system, and the compact and safe design. These are in essence the different items in our punch list and therefore need to be verified and tested to confirm that they are operating as we planned. For the infrared sensor, we must make sure that we can make an accurate reading with an error allowance of 0.5 degrees Fahrenheit. The camera needs to be tested and confirmed that it can accurately detect 3 people at once and have a 95% accuracy. The connection to the cloud needs to be tested to determine the connection speed and validity of data. As well we need to test to make sure we can portray the data in a way that is easy to understand. The alert system needs to be tested to confirm that the alerts happen only when certain requirements are met. In addition, we will use the alert system as error checking if an invalid measurement occurs for example. This will require us to make sure that error checking occurs at all parts of the project, so an unexpected data result does not mess up our project. Finally, we will test the compact and safe design. This will involve making sure that the design we come up with is not overly fragile and can contain all the desired parts to our project.

B Test Timeline

I, Nick, am testing the alert user function part of our project. I have divided my testing into five parts. Each of the five parts test a certain aspect of the alert user function that will in the end if all five parts work complete the system. The first phase I will test the alert system to read data from the IR temperature sensor. This is important because our device needs to determine when temperatures are too high and alert the user.

The next part of my device testing plan is getting the alert system to read data from the camera. I plan on working on this stage for about 3 weeks. The first week of this stage will overlap with stage 1. This stage is important because the camera is one of our two major components that send data that we need to use.

The third part of my device testing plan is testing that the correct LED color triggers for the correct temperatures. I plan on working on this stage for about 2 weeks. Once I can confirm that the user alert system can read the data from both the infrared sensor and the camera then I will test that the LEDs turn on when the temperature is greater than 100.5 degrees Fahrenheit. I will test that a red LED is turned on when somebody has too high of a temperature, a green LED is the temperature is okay, and a yellow LED when the device is reading the temperatures.

The fourth part of my device testing plan is to test that the correct buzzer sound plays for each LED color. I plan on working on this part for 2 weeks. The buzzer will play a gross low pitch sound when a temperature is too high. On the other hand, the buzzer will play a pleasant clean sound when a person passes. I will test that the correct sound is played during the correct temperatures.

The fifth part of my device testing plan is to test that the camera, infrared sensor, and alert system all work in unison. I plan on working on this part for 2 weeks. This part is just to make sure that each part works together. There are a lot of components I am testing in this plan, so I want to give myself 2 weeks to work out any problems when putting everything together. After this step is complete the project should be complete.

All in all, I have 5 steps to completing my plan and about two months to complete these tasks since we present on April 5th.

I, Paul, am testing the infrared sensor component in our project. I have divided my testing into five stages each testing a specific component. First, I will test how accurate the infrared sensor will measure standard human temperatures. By this I mean I will compare it to a thermometer reading and see how accurate and close it is. This will simply assume that the person is healthy and have a standard temperature. This should be a precise measurement, because we do not want it to read a healthy person as having a fever. This will be a major step of testing so I estimate I will spend the next three weeks on it.

The next phase will have two phases testing at the same time. That is testing the upper and lower measurements. I want to make sure that a low temperature is measured as low, and a high temperature is measured as high. Since these are related, they will be tested at the same time. I am estimating three weeks for this section which combines both measurements. However, this does overlap with the previous testing so if the first stage of testing runs long or short, I may have to adjust. These measurements are essential for detecting an error in the system.

The next phase is testing the appropriate distance for the sensor. I want to be aware of how close you must be to the sensor, and how far away you can be. I want to make sure the results stay accurate and determine the best range for the sensor. This is essential to know the limitations of our product precisely. This phase I estimated two weeks for, but again it overlaps with the previous phase.

The final phase is testing the error detection and out of bounds handling. I want to make sure no measurement value received crashes the program. I also want to confirm the range we want to accept data and what range we send to the cloud. These error checking is essential because if there is for some reason an incorrect reading, we do not want to have to raise alarms if it is not reading in a plausible range. This testing will be at the end and I estimate two weeks for this phase.

In conclusion, I have planned up and divided the testing into five parts. I created a timeline to help me determine how fast each part needs to be tested. However, some parts overlap since I should be able to test multiple functions in each week. The testing is flexible, but I still developed a timeline such that I can make sure I stay on pace. A large portion of the spring semester is spent on testing, so I want to make sure it is done precisely, well documented, and efficiently so that we are not stressing near the end of our project to debug or fix our project.

I, Micah, am testing the camera for our project. I plan to split the testing of the human detection portion of our project into about 5 parts: Testing that it can accurately read faces, that it can count the number of people on the screen, that it can count the number of people who have entered the system, that it can collect data like the date/communicate with the other sensors to gather their temperature, and finally test that it can store said data and send it to the cloud.

The first portion should be relatively easy, as I currently have a program that can read faces, but I plan to make sure I can have it measure that a person is in frame up to 10 feet. I plan to do this by simply running the program and seeing how far away I can get from the camera before it stops recognizing me.

The next portion, checking that it can count the number of people on screen should also be easy because my program as it exists is capable of recording three people accurately. I want to see how many people it is capable of measuring in total however, such that I can put limitations and allow users to know to what extent it is effective.

This part is where it gets interesting. Measuring the number of people that have entered is a little bit more involved, but I plan to make my program stall every second and measure how many people it sees on screen. When that number decreases it should add the number of people by which it decreased to the running total of people in the store. I plan to test this by walking in front of the camera and then walking away from it and seeing if it can accurately measure that I have "entered the system".

Next, I plan to test whether it can capture data, simply by seeing if I can get the program to grab the correct date information as well as communicate to the Raspberry Pi to get it to run a program which will get the temperature of the person. This may be a little bit more involved, but it will essentially be the same test; have someone walk in front of the camera and see if we can get the Raspberry Pi to print to the screen the temperature the thermal sensor reads.

Finally, I plan to see if I can get the Raspberry Pi to send all the data my camera receives to our cloud server in order to see if we can correctly store the data for future endeavors, such as if the owner wanted to look at historical data regarding how many people entered their stores on certain days.

All in all, I have devised a 5-step plan to make sure that my portion of the project is functioning correctly at each individual step of the way.

I, Dennis, am testing the compact and safe design part of our project. The most important part of the project is the physical structure, so that all of the pieces can come together. The idea is to have a stable structure to hold the PVC pipe. The structure should be about two to three feet wide and about six feet tall. First, I will be doing research on how I want to build the design. I have a few different ideas and will see which one works best. Next, I will need to find the exact measurements of each device we plan to use and where each part will be placed.

The next stage is to purchase all of these parts and start to assemble it. Within the assembly I need to make sure that it is a safe design and has stability. Within having a compact design

For this testing, the connection Paul and Micah are going to work together on testing this part. The reason for this is that we are working on the infrared sensor and camera which will each be sending data to the cloud server. We will be working together on verifying this connection to make sure all data sent to the server can be displayed on graphs and stored correctly.

Our first part we will be testing that the script can send data to the server. We will make sure that our cloud server thingspeak is the best option. We will try different server systems and verify that the server we choose is the best and we can send data to the server.

Second, we will make sure that the script can collect time information. When we receive the information as tested earlier, we will verify that we can accurately display the time stamps and record the time information. We want to make sure that when we receive the data, we can store the data with respect to time so our graphs can show various effects of our data at different times of the day for example.

Third, we will test that we can get data from the thermal sensor. This we will confirm that we send only the data we want sent, we do not want the readings when the device is to be idle for example. So, we will confirm that the data is being sent in the appropriate way.

Finally, we have to determine the best way to send this data as well. We could send the data separately from the camera or try to write a programming file that combines the data to send to the server. This we have to confirm and properly determine through testing, the best way to send the data from the thermal sensor. We likely will attempt to combine the data so that the information can be sent at the same time with reliability, and this will be tested and confirmed.

All parts of this testing are two weeks long in the order that they are stated here. This testing is essential, because one of the main aspects of our project is to store and display our data. This is important for the businesses and stores to track people coming in and out of the store as well as the frequency of high temperatures. We will make sure that this data is easily accessible and reliable.

C. Testing Results

1) Infrared Sensor

The testing for the infrared sensor was extensive to make sure that it was working as intended. I have been testing the infrared sensor throughout this project to make sure as I was modifying the code it was still operating as intended. For this testing I focused on testing different temperatures than I normally tested such that I could confirm that the infrared sensor worked with every temperature. In order to test this part in an orderly and complete fashion I divided the testing into different parts. First, I determined the distance at which the infrared sensor device would optimally test. This is to determine how far back someone should stand when coming near this infrared sensor. Next, I confirmed the accuracy of the standard human temperatures. This has been my main focus of testing throughout the year such that when I measure my own temperature it is within the 0.5 degrees of the expected human body temperature being 98.6F. Next, I tested the upper and lower ranges of temperatures. I measured from 90 to 110 degrees at certain intervals. The reason I chose this range was because my personal thermometer had this allowable range, so I was able to test and confirm the validity by comparing the temperatures measured by the infrared sensor to the personal thermometer. Finally, my final stage of testing was showing the error detection and handling to be working properly. This is to make sure that if the device is not sending a proper signal that it would send an error message. These different testing areas were to guarantee that the sensor was working as intended and it was able to pass all areas of testing without rework or redesign.

The first area of testing was to determine the distance that this device should be away from the subject in order for it to work as intended.

Table VI
Testing to find temperatures measured at varied distance [16]

Testing 2/12			
Distance	Valid Pixels #	Invalid Pixels #	Temperature F
1"			
Run 1	730	294	99.49
Run 2	806	218	99.2
Run 3	741	283	99.2
3"			
Run 1	534	490	98.76
Run 2	488	536	98.72
Run 3	467	557	98.72
6"			
Run 1	216	808	98.4
Run 2	210	814	98.38
Run 3	208	816	98.33
12"			
Run 1	76	948	98.05
Run 2	78	946	98.09
Run 3	88	936	98.08

I was able to see that there is a correlation between distances and temperature. The farther away the infrared sensor the lower the temperature is and the closer it reads a higher measurement. There are likely a few reasons for this, being that it measures heat and up close can detect heat stronger than from farther away. However, it also is important to note that the variance is not particularly large. It is around 1 degree of difference between 1 and 12 inches. So ideally as long as you are somewhere in between around 5 inches or so it will be the most accurate. This data is particularly useful as when we set up the sensor, we will make sure to operate the device in the appropriate range.

The next area of testing was to confirm the accuracy within 0.5 degrees of standard human body temperature. This testing is one that I have by far done the most often and throughout the entire project.

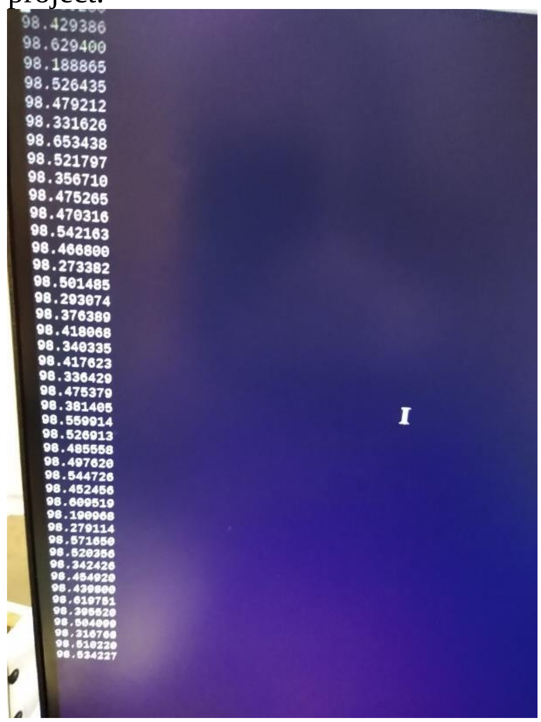

Figure 14: Testing of standard human body temperature [16]

This image shows the text file of where data is being written after it is measured. It stores all values that fall within an expected range of human temperatures. For this testing I took the temperature of myself many times and it always fell within the expected range and within 0.5 degrees F. This was the easiest way to show the testing, but I have tested this functionality many times where it always has got the correct data. During my presentations and demo, it also has performed as expected and measured accurately the temperature.

I tested the upper and lower bounds for the infrared sensor. In order to accomplish this test, I heated up water and as it cooled, I took the temperature across different intervals from 110 to 90 degrees. I compared the infrared sensor to my personal thermometer and found it to be within the 0.5 degrees expected range.

Figure 15: Thermometer Reading [16]

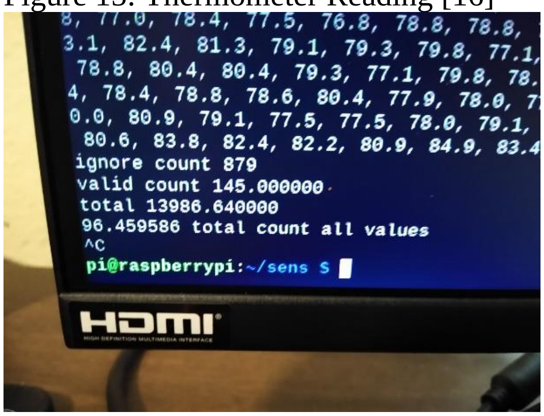

Figure 16: Pi Temperature Output [16]

Table VII

Temperature Measured at high and low bounds [16]

Temperature Measured by Thermometer	Temperature Measured by Infrared Sensor
108.0F	107.9F
106.8F	106.79F
105.4F	105.26F
102.2F	102.04F
96.4F	96.45F
94.8F	94.9F
93.1F	93.09F

Showed above our testing results of the upper and lower bounds of the temperature sensor. For simplicity I included them in the table form instead of including every picture and measurement. The accuracy was far better than expected measuring within 0.2 F degree rather than the 0.5F that is required for our project. I had measured a large variety of temperatures such that I could guarantee the accuracy across all temperatures. This part of testing was essential, because I had previously only been testing the sensor on human temperatures which do not vary. However, people with temperatures that have fevers will vary and therefore my sensor needs to detect the difference between the two measurements. The accuracy in these measurements was beyond my expectations giving me confidence in the results and in the infrared sensor accuracy.

The final area of testing was confirming the error detection and error handling. To test this, I tested cases where the code should produce an error. First, I tested the temperature measuring basic air and not pointing at anything. The sensor will not output the temperature if it is not close to the standard human body temperature. To clarify this functionality was commented out when I had to test temperatures far beyond the range of normal temperature. The purpose for this is to not display a temperature if no one is standing in front of the device. This was the first area of error detection which I made sure was working properly. The next error detection I tested was if the infrared sensor was disconnected. I was able to write code that if the sensor were dislodged or a wire pulled loose an error message would appear stating that it had disconnected. This is important to detect, because if the IR sensor is unable to measure data, we need to let the business know as soon as possible. These were the two main areas of error detection and handling. If the sensor can detect a good connection and the temperature is measured to be within human standard temperature it is working as intended. This testing was essential to guarantee functionality of the Infrared sensor.

These several different testing functions lead to an increased confidence in the validity of the infrared sensor. Some testing proved to be more accurate than expected or required. As well I did not have to modify any code after this testing. This was due to the fact that I have been testing the Infrared sensor along the way since the beginning of the year. The testing proved the work I had done until this point was valid and met the necessary conditions for the project. This testing was essential and proved helpful in confirming what I had believed about the infrared sensor up to this point. The infrared sensor has met the measurable metric which was to measure within 0.5 degrees F of certainty. As well to report any temperature over 100.4F to be unsafe and any temperature less to be safe. This punch list item I have proved over my various testing procedures and can confirm its accuracy.

2) Camera

The testing for the human detection camera followed a similar path that the thermal sensor took. Before we started testing, we had to find a camera which could possibly achieve all the functions required. As for the actual testing, we first had to make sure that the camera could perform human detection as that was absolutely necessary for our project, then we tested the limits of the camera such as quantity of people it can measure at once, the distance at which it could accurately measure people, and then finally we checked to make sure that the script that we were working on to capture the data could record the number of people in the setting.

We started the search for our camera looking at a few cameras which were made for facial recognition because we figured it might be better to use a camera which was intended for such a purpose but found that many of them had built in software which would do facial recognition. This was a problem because we wanted our own program to do human detection as our other components might have needed to rely on certain information about the person in order to run their operations (i.e., the thermal sensor might have wanted to make sure that it was measuring the correct person). Additionally, we wanted to avoid doing actual facial recognition as that could lead to a serious privacy concern and we wanted to focus more on human detection and the tracking patterns of people as a whole rather than the tracking of a single person. We finally decided on the Jelly Comb 1080P webcam shown below as it was a cheap option that had high enough resolution to allow the program, we planned to run to accurately record faces for human detection at ranges of up to ten feet.

Figure 17: Jelly Comb 1080P Webcam [13]

After we decided on the camera it was onto the testing. The first test was rather simple because the script that we made for testing essentially made a pop-up window that would display what the camera was seeing and then outline objects that it detected as human. This made the testing for this process relatively easy as we just needed to run the code and hold various objects up to the camera to see if it would put boxes around objects that were human and whether or not it would put boxes around other objects which were not. These tests can actually be seen below where there is a picture of one of the users in the view of the camera with a box around their face indicating that the camera is seeing a person’s face in its view.

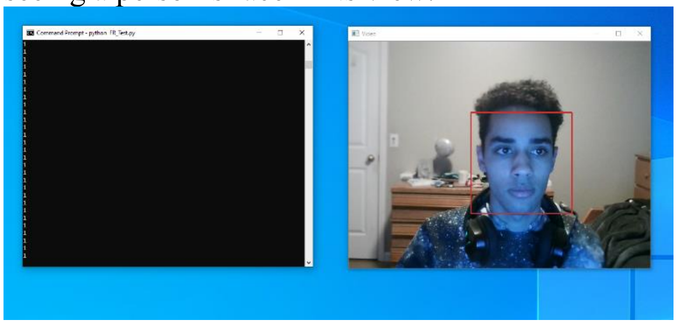

Figure 18: Testing box surrounding face for human detection camera [14]

Then we had to test the quantity of people that the camera could measure at a time due to the fact that multiple people could be entering the setting at a given time. We tested this by putting pictures of people's faces up to the camera (so as to avoid breaking Covid restrictions) and having the program print out the number of faces that it sees on screen out. A picture of this testing can be seen below. As you can see, the program is consistently printing out threes because there are three people that it is seeing on screen. It is important to note that the camera technically does read pictures and printouts and such as people due to the nature of Open.cv, the python library that we are using to do the human detection, but we ruled that this was not too large of an issue because people should rarely be walking around with life size humanoid cutouts or mannequins. With the help of our family members, we tested that the camera could accurately measure upwards of five people without dropping people but since we stopped our testing there (as that was all that was required of our testing) we still do not know the upper limitations of the quantity of people that the camera can measure at once.

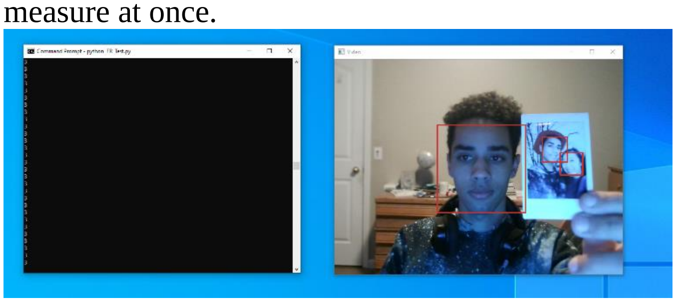

Figure 19: Testing quantity of people for human detection camera [14]

After that, we tested the distance at which the camera could accurately measure people's faces. With the help of my younger brother, we tested that the camera could accurately measure people's faces at roughly ten feet, the predetermined minimum acceptable distance at which the accuracy could fall off, at approximately ninety-seven percent accuracy. This was done by having my younger brother stand ten feet from the camera and having it print out the number of people that it was seeing on screen for a few seconds and then checking to see how frequently it was seeing the correct number of people. Pictures of that can be seen below in figure 4.

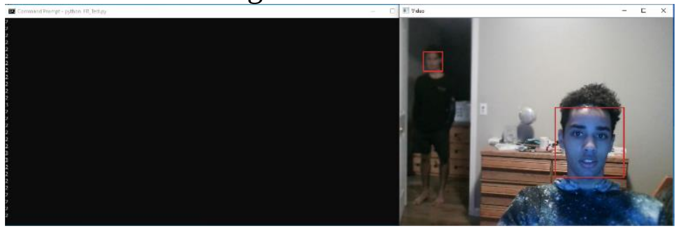

Figure 20: Testing distance for human detection camera [14]

So, the testing for the camera was successful as we showed that it could handle above a ninety-five percent accuracy for measuring upwards of five people at a distance of at least ten feet consistently. This was absolutely necessary for our project being that the camera was the key indicator required for the Raspberry Pi to know when to signal the remaining components to make their measurements. This component needs no further testing as the incorporation of it into the rest of the system will not diminish the success which has been seen in these previous tests.

3) User Alert System

Testing the user alert system included testing each hardware component with the python code, as well as making sure each hardware component acted in the manner our team had intended. The hardware features of the user alert system included a 16x2 character LCD screen, a piezo buzzer, and a traffic light LED strip with green, yellow, and red colors. The testing involved us to test the circuit's design and use multiple GPIO pins. The user alert system was divided up into a plan involving eight weeks of testing. For the first three weeks of the plan, I spent that time testing that the user alert system's python code could interact with the C programming language code and the 16x2 LCD screen would print the data that the infrared sensor collected.

Afterwards, the next two weeks were spent testing that the traffic light LED strip colors worked at the correct times. This involved testing the python code and tweaking the times the LEDs turned off and on. Also, it involved how we wanted the LED light to interact with each user, whether that be the LED light blinking fast or holding a long flash of that LED light. At the same time, I was working to get the camera's python code to work with these LEDs. For example, we wanted the yellow LED light to turn on when a person stepped into the camera's frame. This signified a "Please Wait..." prompt on the character screen. Below is a picture of part of the LED traffic light strip python code. This part of the code was responsible for blinking the red LED light. The red LED light blinks when a user fails the temperature test from the infrared sensor. The blinking red light is supposed to get the user's attention that they failed the test. I set the GPIO pin connected to the red LED high and slept for 0.3 seconds and then set the red LED low for 0.3 seconds. I tested how long the blink should be and how many times the LED red light should blink. Too fast of a blink and the human eye cannot tell the difference very well. At the right speed, the human eye can easily tell that something is not right and that they have a high fever. Overall, this test was successful.

```
def blinkLED(pin):
    # Blink LED Light
    for i in range(0,3):
        GPIO.output(pin,GPIO.HIGH)
        sleep(0.3)
        failBuzzer(23)                 # calls failBuzzer
        GPIO.output(pin,GPIO.LOW)
        sleep(0.3)
```

Figure 21: Red LED Light Blink Testing [15]

While testing the LED lights during those two weeks, I worked on making sure the user alert system could interact with the facial recognition feature of the camera. I wanted the 16x2 character LCD screen to print out "Please wait" and "SCANNING TEMP…" once a person entered the frame of the camera and triggered the facial recognition feature. After two weeks of trying and working with Micah who was working on the camera testing, I got this to work how our team intended.

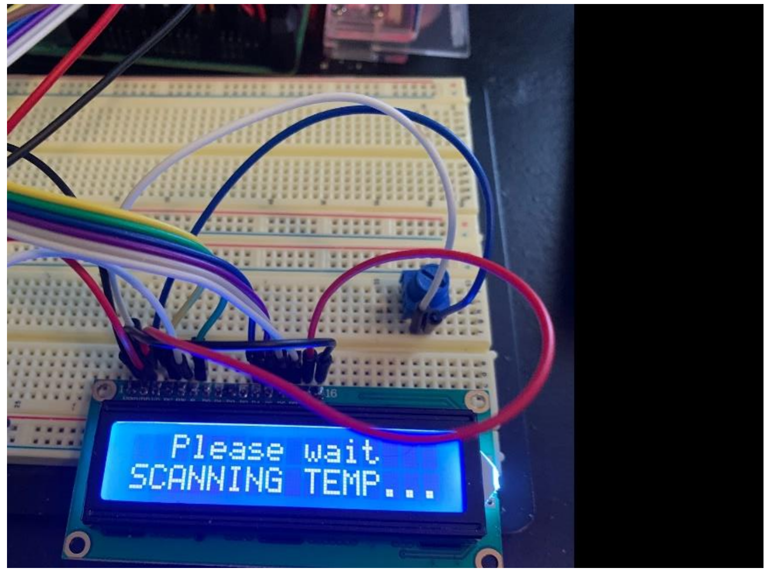

Figure 22: 16x2 Character LCD Screen Testing [15]

The final portion of testing the user alert system included testing that the piezo buzzer worked in the manner our team intended. Our team wanted the piezo buzzer to play an ugly noise when a person failed a temperature test, and a nice, pleasant sound when a person passed. The ugly noise was so the person would obviously notice that they failed the test. During the testing phase, I tested different buzzer sounds for the piezo buzzer. I wanted a buzzer sound that sounded ugly when a fever was detected. I decided to mess with the frequency and the pulse width modulation. I decided that the best sound was 100 pulse width modulation and a frequency of 50. This gave the piezo buzzer a really ugly noise that a user cannot miss. I feel confident if somebody has a fever this noise will instantly get their attention. Below is a picture of the code I wrote for the buzzer if a user has a fever. Overall, this testing was successful.

```
def failBuzzer(pin):
    # Alert user if failed with piezo buzzer
        p = GPIO.PWM(pin,100)
        p.ChangeFrequency(50)
        p.start(50)
        GPIO.output(pin,GPIO.HIGH)
        sleep(0.3)
        GPIO.output(pin,GPIO.LOW)
        sleep(0.1)
```

Figure 23: Piezo Buzzer Python Code [15]

The user alert system did not have any number measurables for the testing. This testing included trial and error of writing code and doing the basics of the integration process. Since the user alert system interacts with each major feature, I needed to make sure that the user alert system could read the data taken by the camera and the infrared temperature sensor. Overall, the testing for the user alert system was a success. We got the piezo buzzer, LED traffic strip, and the 16x2 character LCD screen to interact with the camera and temperature sensor in the manner we intended it to interact.

4) Cloud Connection

For the cloud connection our testing primarily involved testing its functionality and reliability. For our project we used a server website called thingspeak to store all of our data. I, Paul, and Micah primarily worked on this part of the project because we worked on the camera and infrared sensor, the two items which send data to the cloud. We found that for the free version we have a limit to 15 second intervals between sending data. This is a constraint, but after consideration we think it is still acceptable for our project. If we were to implement our project in a large-scale business or store, we may have to upgrade our plan, but for the purposes of this project sending data within 15 second intervals are acceptable. The reason for this we found was that we can combine all our data and send it in one discrete packet of information. The information we wish to send is the temperature value, count of the amount of people that have entered, and the timestamp to when the data was measured. This is important to note that the server thingspeak records the timestamp to when the data was received, but we wish to record the timestamp when it was recorded on the raspberry pi. This data is more useful, because its timestamp corresponds to when someone actually came in and eliminates the delay. To test this component of the project we primarily sent data from the pi and verified that the data was received from the cloud server with the data intact.

Our first area of testing was to confirm that simply data could be sent to the cloud server. For this test we simply wrote random numbers to a data file and then sent those values to the server. This was our initial and most basic test to confirm the connection. This functionality we have presented in multiple senior design presentations. The testing was successful as expected and we were able to see the data that was sent. As well we confirmed that it recorded the time it received the data. We tested it several times on different occasions and have not experienced any error or accuracy.

The next element was confirming that the script can collect time information. By time information we mean when the data was measured on the pi, and not when the data was received on the thingspeak server. To have this functionality inside the code on the pi we had to record the system time and save that variable to send to the pi. This added some more code to our functions but was able to be successfully implemented and seen to be accurate on thingspeak.

The next element of testing was to confirm that the data could be sent from the infrared sensor component of the project. This required me to add functionality to my code and write all the data measured to a text file. I decided to set a limit and only record data that was within reasonable human body temperature including someone with a fever. Any data that was measuring just air for example would not be written as it is unimportant and can be discarded. As well this testing required to make sure that the camera could also send data as well. This code is in the main loop so its data needs to be stored in a temporary variable which will be sent to the cloud.

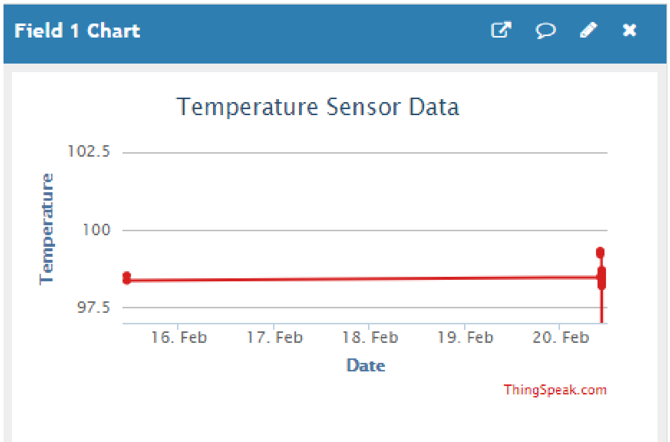

Figure 24: Thingspeak output for temperature sensor data [16]

Table VIII
CSV file of thingspeak output [16]

created_a	entry_id	field1
2021-02-1	1	98.68928
2021-02-1	2	98.68928
2021-02-1	3	98.65554
2021-02-1	4	98.68928
2021-02-1	5	98.68928
2021-02-1	6	98.67674
2021-02-1	7	98.68928
2021-02-1	8	98.59443
2021-02-1	9	98.42938
2021-02-1	10	98.62940
2021-02-1	11	98.18886
2021-02-1	12	98.52643
2021-02-1	13	98.47921
2021-02-1	14	98.68928
2021-02-1	15	98.42938
2021-02-1	16	98.62940
2021-02-1	17	98.18886
2021-02-1	18	98.52643
2021-02-1	19	98.47921
2021-02-1	20	98.33162

The above images show the output from when we sent the infrared sensor data to the thingspeak server. The first image is the graph it produces, since all the data is very close in value it appears as a straight line. The next image is the CSV file in which all the data can also be viewed. Each value sent has a timestamp corresponding which is shown in that image. This was our main area of testing to confirm that we can send data from the Pi to the thingspeak server.

We have tested the connection is reliable and we are able to send data from the Pi to the server thingspeak. Part of our final integration involves sending the data from the camera and sensor in one packet at a time. For this we simply have combine the data and send it over in order to store our data in the best way possible.

5) Physical Structure

Following the requirements for the physical structure, the PVC pipe is about 6 feet in height and 3.5’’ thick. It is bolted to the base of the structure, which is a 16’’ by 11.5’’ piece of wood. The first test was to weigh the structure and make sure it falls within the twenty-five-pound limit. The structure weighs about 7.6lbs without the case and the components inside. I did not get the chance to measure the weight of the case because I had to hand it off to Paul and Micah during spring break for them to finish the integrations of the camera and the sensor together. The second test was to test the stability of the structure, first I did a rocking test which I tilted the structure about 15 degrees from left to right and let it go and it did not tip over but bounced back and forth until it stopped moving. I did the same for forward and backward movements. I did this test five times and it has the same result, if the stand is tilted more than 15 degrees based on the law of gravity it will fall down. In other words, if this becomes an issue in the future there is also a solution which is to bolt the structure to the floor making it more stable. The next test is to test the structure with the case attached to it, this is not possible at the moment because the team is testing their integrations with all the parts together which is the last step for our project. Once the integrations are done and approved then the case will be handed off to me to continue my testing.

Some of the testing for the case has been done, first we need to make sure all the parts fit together. Next, I need to make sure that all the parts are secured to the box, this can be done by gluing the parts in or securing them with zip ties. Following that the wires need to be secured tightly to the sides of the box, the wires that are going to be outside of the box need to be taped so that no damage can be done to them. After that we can attach the box to the stand to continue further testing with stability, this has to be the last step for the project because once it is attached to the stand it will not be able to come off. Finally, I will need to cut holes within the bottom of the stand so that an extension cord can be pulled through to get the power on to the devices.

X. MARKETABILITY FORECAST .

A. What our Product Innovates

The first step in reviewing the market is to determine what truly our product brings to the table, and what it has to offer. In order to truly gage the impact that our product would have in the market, we must first analyze what makes our product unique and what it provides to the customer. This is essential in determining the demand in the marketplace.

What does our product innovate? After asking this question we asked ourselves what type of innovation does our product offer. Disruptive innovation is a whole new market. Considering that neither our processor, camera, nor infrared sensor were originally designed our product would not fall into this category. Application innovation refers to using existing technologies for new purposes. This would describe our project. In our project we are using existing technologies such as a raspberry pi, python human detection for the camera, all together in a new way. However, simplifying our project to simply being an example of application innovation would not quite work because there are some high-tech devices which can measure temperatures and detect human faces as well. So, this leads us to our final innovation, product innovation. This refers to upgrading an existing product to the next level. We have taken the products of the raspberry pi, D6-32l infrared sensor, and camera and upgraded them in a sense to create a product that can help detect Covid symptoms and detect people as they enter the store. However, again product innovation does not completely describe our product because we are not modifying any of the individual products but rather bringing them together. We are improving the product of a temperature screening kiosk. Our device brings together product and application innovation by using existing technologies and using them in a new way together which is a much more efficient way than seen in the market. Understanding what exactly our product has to offer is essential when analyzing the possible market our product would have.

After analyzing our product's innovation, we looked into the possibility of patenting our product. If we were to sell the product ourselves a patent would be a must. Although we are not currently planning to sell our product ourselves it is important to analyze the process of getting a patent to determine the process that it would require. This assignment is to open our eyes for the possibility of selling our product in the market so we must do our due diligence and consider all the options such as patenting the product. The patent our product would need is a utility patent. "This type of patent covers processes, compositions of matter, machines, and manufactures that are new and useful. A utility patent can also be obtained for new and useful improvements to existing processes, compositions of matter, machines, and manufactures." [40]. After reviewing the patenting process, it is clear that there is great time and work that must be put into creating a patent, however, we could be reasonably sure to be able to get a patent. One thing we learned is that to get a response from a patent would take minimum one year, and likely longer. As well, patents are expensive especially if you need to hire legal help. However, the benefit of Senior design is that we are creating a report that in essence could be shown as proof and all the necessary information to get a patent approved. This class is not just an exercise with creating a new idea, but also a class that gives real world experience with designing a product and the process needed in real world companies to document all the steps in the project. As engineers we are responsible for not just coming up with new ideas or solving problems but there is also documentation and testing that is required when coming up with new engineering solutions. In this class we have practiced all these skills which gives us experience as well as a report that would serve to help file a patent. Filing a patent is expensive so our group does not expect to file a patent, but we are now aware of the process and know exactly what would require creating a new product with a patent.

If we were to try to patent our product, we could look into receiving grants for our project. Various organizations such as the UEF (United

Engineering Foundation), Project Lead the way, and National Society of Professional Engineers are a few examples of organizations that pay for innovative engineering ideas. With a brief search I saw that there are many examples of grants that could help cover costs of a patent or of starting a production. [41] It is important to note that patents could serve a multipurpose. If we were to pitch our idea to a company it would be very useful to have a patent as a way to show that our product truly is innovative and could be sold. On the other hand, if we were to develop and make our own product a patent would be helpful as well to decrease competitors in the industry. Although the process of getting a patent or selling our product is not likely, it is important to not just consider all the possibilities but also realize the steps needed for a patent. As engineers we may design our own products or even start our own business. If we do, this class has prepared us for the process of creating an idea and doing the necessary documentation and testing of the product. This assignment is designed to prepare us for the marketing of our product and realize all the necessary steps needed to market

In conclusion, our project is application innovative and product innovative. Receiving a patent is possible for the work we have done so far, and there are grants designed for engineering projects. We likely will not pursue this option as we are about to start our engineering career looking for work, not starting our own business. However, researching the possibility did enlighten us as we found the process for marketing an engineering product. I did not realize how much of our senior project report could be used for applying for a grant or patent. I realized that the process we have completed so far would be similar if as an engineer we designed our own product that we wanted to market.

B. Identifying possible Competitors

As you may know Covid 19 temperature scanning kiosks have been bought all over the world and have been the new and safe method of containing the spread of covid. With the kiosks in places like gyms, stores, warehouses, it is a helpful strategy that will ensure safety in all high-traffic areas. The kiosks can read thermal imaging and convert it to body temperature measurements. The prices on these kiosks range between $1300 up to $3000 and a lot of small businesses cannot afford it. These automated kiosks are contactless and are a much better alternative in comparison to the handheld body temperature measurement devices. This makes it safer since it reduces the risk of infections from person to person. It also makes it easier so that employees do not waste their time having to stand by the door checking everyone's temperature as they walk in, especially in high traffic areas.

Now we introduce our design idea for population tracking for Covid. Our product has more perks than the advanced kiosks. First off, we designed hardware architecture using off shelf components, this allows our product to have a low cost and more affordable for many small businesses. We integrated a camera that will have real time imaging, this will help by tracking the amount of people who enter the building and will abide by the capacity laws enforced by the state government. This will allow each store owner to see what the high traffic times are and allow them to post updates to the staff when they need them more. We will have a real time alerting system that will alert the user when a healthy or unhealthy temperature is being read by showing a few different colors green for safe measurement, yellow for still in progress, and red for unsafe measurement. Measurements are accurate up to +/- 0.5 degrees of normal human body temperature.

We also added an open software for the camera and sensor to send data to a private cloud system that will have a real time analysis of what is being read from the sensor. The cloud system will provide charts based on daily, weekly, monthly, or yearly readings from the camera and temperature sensor. The camera function will only track the amount of people entering and exiting the building making our design privacy friendly. The cloud-based system is completely private. We have a raspberry pi that will be sending the information that it is receiving from the infrared thermometer sensor and the camera to a secure location. We are designing the physical structure and adding a case to place all the equipment inside. The structure is going to be around five to six feet tall with a casing at the top. It will be a safe and compact design that will allow the owner to place near the front of the store.

C. Identifying the Market and Consumer

The market we are trying to tap into with our product is similar to the market for security. With the increase in Covid, we have seen that oftentimes business owners have trouble measuring the quantity of people that are closely interacting with each other. Since we have seen pandemics in the past similar, we can expect that more are to come in the future, so our product is paramount in both helping prevent Covid from spreading further and preventing the pandemics of the future from having the same negative effects that Covid did. Our product serves to help business owners in both the short and long term, adding to the health/safety of the store's workers and customers, while at the same time providing valuable population metrics to the store owner.

The product helps with regards to the safety and health of the customers and employees in that it can assist in limiting the number of people in a store at any given time so as to abide by the recently mandated limitations. This is a valuable market because it would allow employers to show that they are looking out for the health of those inside their stores while at the same time spending little money on the actual product. Beyond that it is not a very limited market as pretty much any store, large or small, should be able to use the device to measure their metrics as it can record data for upwards of five people entering or leaving a building at a time so unless the store frequently has tens of people entering it can greatly benefit them.

As mentioned earlier, the product also helps in the long term with regards to general use outside of pandemic times. This market that we are trying to enter is not solely involved with benefiting people during times currently, it also has uses long term because it will collect data surrounding the number of people that are in the store at any time and record the legacy data to a cloud server. This will allow business owners to have historical data showing the quantity of people in their stores such that they can schedule the correct amount of people for the time slots, see when their most profitable times are, make sure their stores are constantly abiding by the Covid regulations, etc. This is invaluable data that many stores could benefit from long term, meaning that this product will have a nearly endless market to be sold to.

Lastly, this market is somewhat untapped because there are few products currently that can measure the quantity of people in a system, the temperatures of those entities in the environment and store/present said data for such an affordable price. The largest competitor currently would be a simple camera system which fails to keep historical data, fails to present the data in a clear fashion, and in a lot of cases, is more expensive due to the ongoing costs of storage for the data.

So clearly, this product has both short term and long-term benefits that can help a plethora of business owners with Covid concerns as well as their own personal data tracking. Thus, it has a nearly endless supply of potential consumers in a relatively untapped market resulting in a necessary product for sale.

D. Determining the price and sell point for our product

What is the price vs sell point of our product? To figure this out we added up the cost of buying all the current parts for our project. The construction cost was $44 total, the camera $100, the LEDs and buzzers $30, the raspberry pi was $95, and the infrared sensor was $170. These costs totaled up equates to $440. We could sell our original product for $500 flat to businesses. After some improvements we could get the price down even further. The original camera was $100 that we bought, but we also got the product to work just as good with a $20 camera that our teammate Micah picked out. We can cut costs with the camera. This could cut the cost by $80 and now our total price spent would equal $360 in total money spent. That is not the only cost we could cut if we decided to sell this product.

After making our original prototype we figured out we could make a cheaper product with more practice and repetition. One way we could cut costs is with the raspberry pi 4 we bought on amazon. Since October, the price of Raspberry Pi 4 has dropped significantly from $95 to $65 on Amazon.com. This could cut our costs by another $30. Another way we could cut costs would be to buy a cheaper infrared sensor. We paid $171 for a nice 32x32 matrix infrared sensor to make things easier for our group to learn how to get accurate results. We learned we could make a less premium model our product for $130 less by buying a 4x4 matrix infrared sensor for $40 on Mouser.com. Our team has not tested using this 4x4 matrix with our product. Using this other infrared sensor for $40, the $20 camera Micah found, and buying the new raspberry pi's for $30 less, we could get our price down significantly. This price cut would be in total a value of $240. If we subtracted this $240 from the $440, we could get the price down to potentially $200 for a slightly inferior product.

Obviously, the goal of selling our product would be to make some sort of money. We do not know how profitable our product would be in the real world. We can only speculate based on educated guesses. Our first stop would-be privately-owned shopping stores like Safeway and Walmart. Our team could also target Med 7 Urgent Care Centers to see if they would be interested in this product. Our goal for this project was not to maximum profit, but to maximize helping the world with the problem of Covid-19. With that said, we have to make some profit for this product to make sense for us to continually make and sell.

In short, we could have a premium model for $400 that basically includes a better and more accurate infrared sensor. On the other hand, we could have a more price-attractive model for $250 that had a worse infrared sensor. That would mean we would make $50 profit on the premium model and about $40 profit for the premium model. This has been a learning experience for how to efficiently make a product. With more experience I definitely believe our team can keep getting the costs down and down more and more. Also, our team does not know how to equate how much buying wholesale would cut the costs of our product, but we do know that is a valuable option if we decide to sell our product in the future.

XI. CONCLUSION

In conclusion, our project *Population Tracking for Covid* has been brainstormed, developed, and tested by our team during the past nine months of the 2020-2021 school year. Our completed device aims to combat the spread of COVID-19 by monitoring human movement patterns and symptoms through multiple sensors: an infrared temperature sensor, and facial recognition camera that keeps a count on the number of people within a store a single moment. Over these past nine months, we have defined the societal problem our project aims to tackle, created a design idea, a work breakdown structure, created a project timeline, assessed the risks impeding the completion of our project, and finally built as well as tested our design. Our team learned greatly from the project in many aspects. We learned the technical abilities and requirements to make a device with multiple sensors that can communicate with each device fully integrated. We also learned the value of communication in teamwork through this year long project. Often in our schooling we work on short term projects, so by switching to a long-term project our approach had to change. We had to constantly reevaluate and consider if there was a better way to approach the problem. As well the importance of communication was shown, as it is much harder for each person to stay informed when working in a group of four. With most projects there are one or two people, however, with a group of four it requires that each person participates and that the entire team communicates effectively among the team. These valuable skills were a great conclusion to our learning process as well prepared us for our future career as engineers. These projects are the closest thing we have done in school that is like true industry work. The importance if this project cannot be overstated, which is why we went through great lengths to make sure our project was one that not just satisfied our requirements, but was also something that we could have pride in.

First, our team started this project thinking of a societal problem related to COVID-19 that we could aim to fix. Our team learned helpful information about the effects of Covid-19. We looked at not only how much Covid-19 has affected not just the health world, but also the economic world. We discovered the root of the problems associated with COVID-19 as a lack of testing and knowing a person had COVID-19. This affected businesses by making them close down. After researching the problem, we wanted to tackle, we redirected our focus on preventative measures to fight the spread of COVID-19. We spent hours of reading academic reports and analysis associated with pandemics and how they spread rapidly from person to person. More in-depth analysis of social distancing was researched to better understand the effectiveness of social distancing and all the benefits that comes with it. After this research, we felt much more prepared to start fighting the problem of COVID-19 quickly spreading from person to person.

Next, we worked on a design idea that helped combat the issues that we researched in our societal problem of COVID-19. We landed on a design that would essentially help slow the transmission of COVID-19 through an infrared temperature sensor that would measure people's temperature and a camera that would keep a count of the number of people within a store at a certain time. As stores started to reopen, businesses have to make sure they open safely and do not continue to spread COVID-19. Our design approach looks to improve people's ability to safely go out into society to go to stores. The complete design idea includes using a Raspberry Pi, a thermometric infrared sensor, LEDs, camera, 16x2 character LCD screen, PVC pipe, a metal base plate, and piezo buzzers. The user interaction experience is through the 16x2 character LCD screen, LEDs, and the piezo buzzer. Ultimately our goal is for the design idea to check people quickly and accurately. Our team envisioned that our design requires a person to walk up to the device, get scanned and instantly receive results on whether they have a high temperature or regular temperature. On top of that, the business owner or authority figure will be able to keep track of how many people are inside through data sent to the cloud by our device. By pursuing this design idea, we will greatly help businesses open safely and hopefully reduce the spread of COVID-19 and future pandemics.

After creating a design idea and getting it approved by our team, we had to figure out funding and project milestones for our project. We basically ended up splitting up who would buy what during our team meetings. Nick was responsible for buying the features in the user alert system. Micah was responsible for buying the camera. Paul was responsible for buying the infrared temperature sensor. Dennis was responsible for buying the parts needed to assemble to physical structure or the case of the project. The hard part of this funding was to determine which devices we actually wanted to buy. We had to do a great deal of research to determine which devices were the best and would let our project be able to function as intended. After we had determined these devices, we made the necessary purchases and was able to start working on the project.

The milestones for the project were basically broken up into two major milestones: a prototype by December 15th, 2020 and a deliverable design by May 3rd, 2021. The milestones within the first major milestone in the first semester were to create a problem statement, make a design contract, and complete a work breakdown structure. The milestones within the second major milestone include testing and integrating each part together to make a cohesive product. This project timeline was essential for our project. Since as students we are not used to working on a long-term project, creating a timeline helped us visualize the work required and plan out when each part of the project need to be completed. As well the project seemed stressful and overwhelming at first, but once we created a concrete plan there was a sense of confidence that came from knowing the timeline and milestones for the project. These milestones helped guide us throughout the project and stay on track. In addition, by creating the Gantt chart and Pert diagram we helped visualize all the tasks necessary to complete our project. These visualizations are key so that every group member does not feel overwhelmed and can have a better understanding of when they have to complete the given requirements. The Gantt chart was very helpful in planning out our work. By dividing the work into the given weeks, we can see how much work is required each week and if we stay on schedule. Since COVID-19 limited the ways, our team could meet to work on this project and class was online, the plan was important to make sure every team member had the parts they needed to work on at the correct time. We devised a plan to share the Raspberry Pi and pass it around. By setting up the Pert diagram we were able to see the dependency chart and avoid these bottlenecks. Our goal with this project was to have a functioning device by the end of the year, which was achieved. This planning is essential to making sure everyone is on the same page and to make sure that the project gets finished.

The work breakdown structure was a six weeklong mission to complete various tasks created by our team. Before the end of the Fall 2020 semester, our team worked to complete seven of the nine tasks written throughout our work breakdown structure. The tasks described in this portion of the report are in the respective order: our initial device research, the infrared temperature sensor, the facial recognition camera, the interface to alert the user, producing the data to create graphs and statistics, our compact design, fall semester assignments, spring semester assignments, and lastly additional features that will be implemented in the spring semester. The additional features we implemented included the sending data to the cloud aspect for business owners. The three major tasks included completing the camera, infrared sensor, and establishing the alert system for the user through a LCD screen, piezo buzzer, and LED lights. Our team worked hard to complete all three of these tasks described in the work breakdown structure. This assignment took what we determined in our project milestones and created a more in detail work breakdown structure. This detailed work was necessary to plan out each and every detail. We were able to divide the work in a greater detail and therefore be able better plan out our project.

The goal of the risk assessment was to find the potential problems our team could encounter during our project. We discussed that we have found our critical paths to complete this project in a timely manner to be the following: getting the camera to detect people from objects, getting the temperature sensor to read accurate data, getting the processor to communicate with each device, building physical contaminant structure, and sending data to the cloud. We discussed issues from components not functioning, to our data being inaccurate, to even issues involving our teammates not having the capability to fulfill their portions of the project. Finally, we discussed how we intend to face these challenges if they arise and what each of them could mean for the project. Our team was able to navigate the issues with thought we would encounter during this project. Although no major issues came to our project the risks determined were important such that we could be prepared if the issues had occurred. With our project we tried to make sure that the essential tasks we were confident could be accomplished as soon as possible. We made sure that if any risks did come up, we would have time to adjust and change our project, as necessary. This risk assessment helped us be more prepared for any unforeseen risks.

Next, we analyzed the design philosophy for our project. This is where we looked at our project retrospectively and look back at the decisions, we made to ensure our project's success. In the end we were able to get a fully functioning prototype that accomplished the entirety of our punch list. This was due to many decisions we made in our project that ended up proving effective. Sometimes these decisions resulted in simplifying our project. For example, in the beginning we were hoping to let our thermometer be an adjustable height, so that any person height could be acceptable. However, this was not in the skill range of us as Computer and Electrical engineers. As well this was not part of the core to our project, so we decided that this part was not essential for our project. This process is described in the design philosophy which helps us analyze these decisions. For the most part we made smart decisions that let us complete our project. This skill of making these decisions we were able to develop and will prove useful in future projects.

During the testing portion of this report, our team is testing the 5 things: recording human body temperatures, facial recognition, alerting the user when unsafe temperature is measured, producing, and recording data for the system through the cloud, and creating a compact and safe design. It took our team about 8 weeks to complete this portion and was separated into smaller tasks that were broken down into week-by-week assignments. The testing was done during the beginning months of 2021 in the Spring semester. The infrared sensor after this test plan is over should read body temperatures accurately under 0.3 degrees accuracy and the facial recognition should accurately read faces and count the number of people who have entered or left a building. Once everything was tested, we spent the majority of our time finishing integrating every part together. This part was a lot harder than we initially anticipated. Luckily, we planned to finish the project a week before we actually needed it done so we had an extra week to integrate everything together.

In the market review, we researched how much we could sell our device for and how to get patents for specific parts of the device. Our product is unique in that it can both take live measurements of people's temperatures and the number of people in a system at any given time, but also record that data and provide it to the users in an intuitive functional manner, while at the same time minimizing the costs. It offers more than most current temperature kiosks or camera systems do in the market today and at minimal cost to keep similar accuracy and reliability. We tallied up the total cost that we spent on the project which was $440 and picked a target selling price of about $500. This research was important in figuring out how well our product would do in the real world.

Overall, the project *Population Tracking for Covid* was a fun project our team enjoyed tackling. At the end we were able to complete the design we aimed to achieve. The device our team envisioned that required a person to walk up to the device, get scanned and instantly receive results on whether they have a high temperature or regular temperature was achieved. Our team showed off these results during our demo to the class and professor on Monday April 26, 2021. This project was a great learning experience as well as a great success for our team. The year long project took a lot of work and planning, but in the end, we were able to create a project we had hoped for and meet every requirement. This project was a great success due to each team member's hard work they put in, and the necessary planning and foresight to create a year long project. We seek excellence for our project and were able to produce a technical product that proved the project's excellence. This project was a major accomplishment, and one that our team can be proud of the work that went into the project as well as the final result.

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GLOSSARY

Thermal imaging - Temperature assessment device that uses heat signatures to form an image or video based on differences of temperature.

Covid-19 - Can be called Coronavirus as well is a virus that has spread in the last couple of years. The symptoms can vary and can take form in a cough, fever, or other symptoms. It has spread throughout the world and is extremely contagious.

Infrared Sensor - An infrared sensor detects infrared radiation to sense temperatures.

LED - Stands for Light Emitting Diode, and is a basic light source.

APPENDIX A. USER MANUAL

This is the user manual which will help walk through how to operate the device and how it operates. Our project is designed to be simple such that a person can walk up to this device and know how to use the device without much difficulty. Therefore, the manual is simple, run the file, follow the prompts, and the output will be seen in real time and on the cloud. Our goal for this project was to make it as easy as possible such that any person could use this device without being instructed to do so.

To run the code, you simply need the file FR_Final.py and the executable file first2. The executable comes from a c file which is the infrared sensor code. The rest of the code is contained in the FR_Final.py python file. Simply running the python file with the executable in the same folder is all that is required to run the code.

Once the code is running it will run infinitely. When the camera detects a person, the yellow LED will light up and a message will appear on the LCD screen saying that the person needs to step forward. After five seconds the infrared will take the temperature of the person. If the person did not step up in time it will produce an error which is shown by the red LED and a buzzer noise. It will display a message stating that there is invalid data, and the person will have to walk up again to the device to get their temperature measured. If a person records a high fever temperature the red LED will turn on and a buzzer will sound. The LCD screen will display that it detected a high temperature. If the temperature is in an acceptable range, then the green LED will turn on and a buzzer noise will sound. The LCD screen will output the temperature and that they are safe to enter. After each phase of this process there is a small delay such that a person can read the response and adjust accordingly.

Once the process is complete the data will be written to the cloud thingspeak. To access this data, you would need permission to view the file. In real time the data is sent and the temperature as well as the total person count will be uploaded to the cloud. This can be viewed at any time after and will be saved to the cloud.

Next, on how to assemble the device. First verify that the infrared sensor is connected to the mini breadboard such that the SDA and SCL inputs connect to the raspberry pi. All the LED’s and buzzer and LCD screen need to be on the breadboard, and outputs connect to the PI. The camera plugs into one of the USB spots on the raspberry pi as well as a keyboard and mouse if needed. All components are mounted inside the case and should be secure. The box should be mounted on the pipe securely. The LCD screen, infrared sensor, and webcam should all be on top of the box so that they are not obstructed by anything.

Overall, the user guide should be straight forward. The design was created in such a way that for the user the process is very simple and straightforward. There is a setup process, but once it is all connected there is nothing else required.

APPENDIX B. HARDWARE

The hardware we used for this project mainly included the raspberry pi, the Omron D6T-32L temperature sensor, a piezo buzzer, a lcd screen, a stoplight light system and a facial recognition camera. We produced a feature punch list and measurable metrics that we needed to follow to meet our requirements. Our first feature on our punch list is the recording human body temperature which we are able to measure an accurate reading to at least 0.5-degree Fahrenheit of certainty. This temperature must be lower than 100.4 F to be considered safe and anything above is unsafe. We connected the sensor to a separate smaller breadboard and added several resistors to give us control of our circuit. Then with the jumper wires we connected the sensor to the raspberry pi. The way we did the coding was mentioned in the previous section.

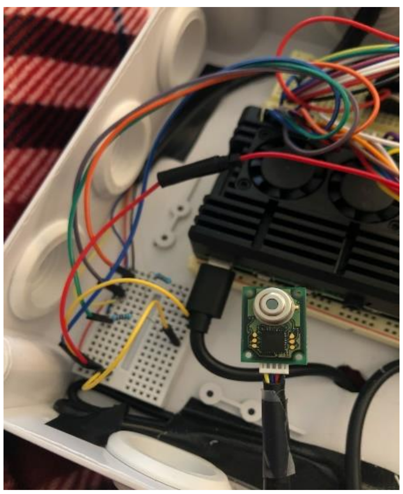


Figure 25: D6T-32L Temperature Sensor [17]

Our second item on the punch list was the facial recognition camera system. The camera has the ability to differentiate at least 3 people at once. It has a 95% accuracy of detecting humans compared to other objects. So, 95% a human will be identified correctly when coming into the location. Within running the code when the camera detects a human it will output a 1 and then the rest of the code will begin to run. The camera was a simple USB attachment to the raspberry pi and fit perfectly on the case. The cable was long, so I folded it and taped it to the side of the box shown below.

Figure 26: Facial recognition camera [17]

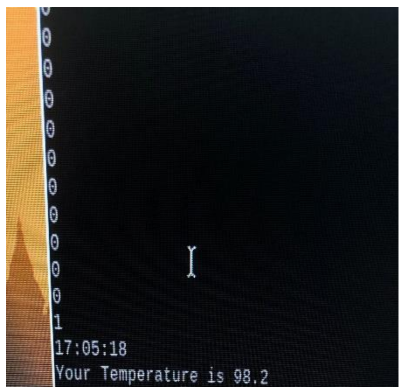


Figure 27: Code ran on Pi with detection of one human [17]

The third item on the punch list is the alert system which consists of three parts, the piezo buzzer, the light system and the lcd screen. These three items will alert the user when an unsafe temperature is measured. The LCD screen is connected from the pi to the breadboard, then I used more jumper wires to connect from breadboard to the LCD screen. I had to pull each wire through the rubber gasket and used electrical tape for the wires for more protection. When the program runs the LCD produces various types of prompts such as telling the user to face the device about one foot away, once the camera sees a person it outputs a 1 and starts to scan the temperature. After that it outputs the temperature of the user and prompts them with the next command.

Figure 28: LCD screen [17]

Figure 29: LCD prompts when code is running [17]

The stoplight light system also has a similar connection like the lcd screen. I used extra jumper wires so that I can position the lights on top of the casing, I also added electrical tape to cover the wires. The way the light system works when the user is prompted to step up to the kiosk, the light is green, as the temperature is being measured the light turns yellow and when a safe temperature is measured the light turns green and if an unsafe temperature is measured the light turns red.

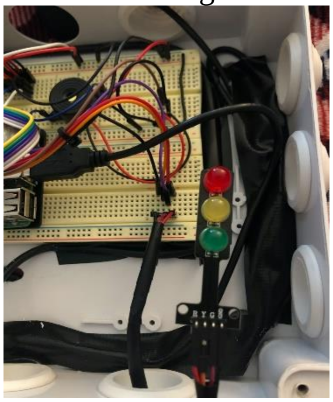


Figure 30: Stoplight system light [17]

The piezo buzzer has a small function, it plays a sound after the temperature is measured. It is connected straight to the power source of the pi.

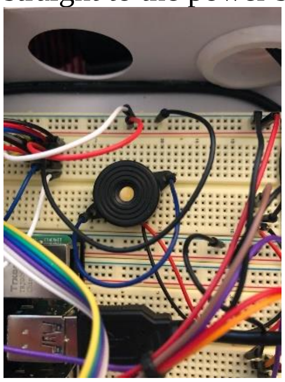


Figure 31: Piezo buzzer [17]

The last piece of hardware is the raspberry pi itself. It is the power source of all the components within our project. Having the pi was essential for our project because it allowed multiple devices to communicate to each other. The pi is taped to the top of the breadboard and the plug will come out the back of the box and go through the PVC pipe and attach to an extension cord. I centered the pi closer to the middle, so all the other connections are not jammed up in a corner of the case.

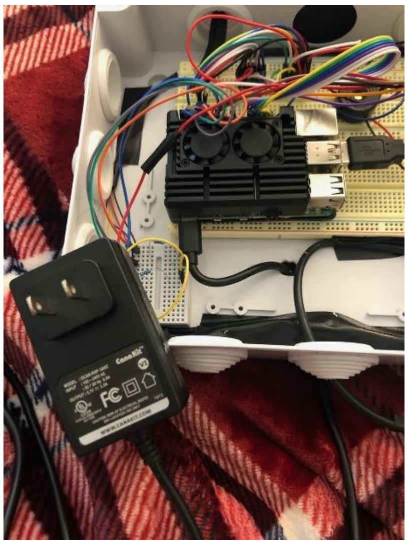


Figure 32: Raspberry Pi [17]

To sum up, the hardware makes up most of the project. We followed a certain punch list and completed the measurable metrics. This includes getting the camera to detect people from objects, getting the temperature sensor to read accurate data, getting the processor to communicate with each device, and sending data to the cloud. This will allow us to detect when a human has a fever upon entering the store and help reduce the spread of covid.

APPENDIX C. SOFTWARE

The software side of this project was rather intensive because most of the actual operations that we wanted to do: the human detection, the temperature sensing, sending data to the cloud, and keeping count of the number of people in the system, was all done from scratch. We wanted to make sure that we had a solid understanding of each of our components such that if we ran into problems, we would have the code to support the issues.

The main component that we have running on the system is the Python code which does human detection. It is essentially just a loop that runs constantly and does not do anything except wait until it sees a person. This was implemented using “Open.cv”, a public python library which focuses on object detection. For the purposes of our project the object that we are focusing on is humans. We started the coding of this part by looking into their documentation and example codes to better understand how Open.cv works. Essentially, Open.cv looks at the output from the camera and compares it to tons of pictures stored in a file some of which are humans and some of which are not and makes an educated guess as to whether the input from the camera is similar enough to the pictures of humans in the file to say it is a person or not. I decided for testing purposes to initially output what the camera was seeing and try to place boxes around the people that the camera saw in order to make sure that we could actually do human detection. Below is the code I used to test that the human detection could actually see a person as well as a picture of it measuring my face.

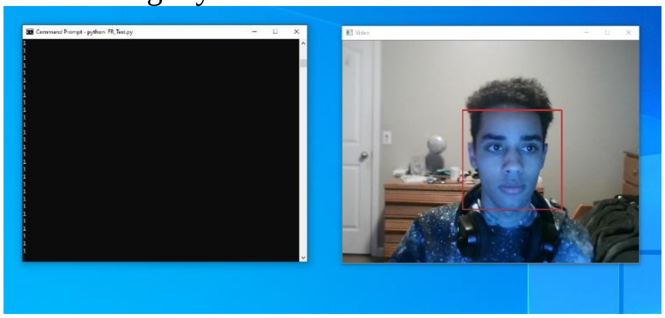


Figure 33: Testing Human detection [14]

```python
import cv2
import sys

faceCascade = cv2.CascadeClassifier("haarcascade_frontalface_default.xml")
video_capture = cv2.VideoCapture(0)

while True:

    # Capture frame-by-frame
    retval, frame = video_capture.read()

    # Convert to grayscale
    grayscale = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)

    # Detect features specified in Haar Cascade
    faces = faceCascade.detectMultiScale(
        grayscale,
        scaleFactor=1.1,
        minNeighbors=5,
        minSize=(35, 35)
    )
    i=0
    #Count faces
    for face in faces:
        i = i+1
    print(i)
    # Draw a rectangle around recognized faces
    for (x, y, w, h) in faces:
        cv2.rectangle(frame, (x, y), (x+w, y+h), (50, 50, 200), 2)

    # Display the resulting frame
    cv2.imshow('Video', frame)

    # Exit the camera view
    if cv2.waitKey(1) & 0xFF == ord('q'):
       sys.exit()
```

Figure 34: Python code to do Human detection [14]

In this initial test, I just confirmed that human detection was going to be possible with the camera and Open.cv, but I also had to make sure that it could measure multiple people. So, my next test was to do the same code, but to have it print out the number of people it saw (the variable I in the code above) as well as to put multiple faces in view of the camera for it to measure. A picture of that is below.

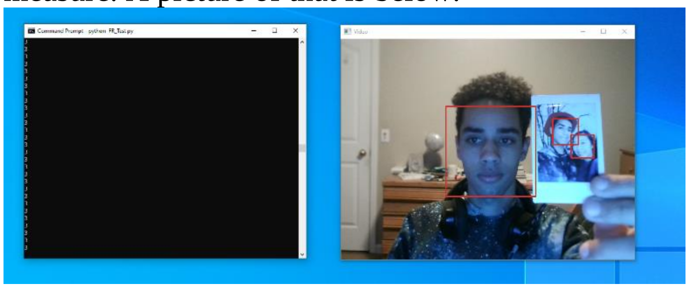


Figure 35: Testing human detection with multiple people [14]

After this test, I had to test the distance at which we could measure people's faces, so I enlisted the help of my younger brother who stood approximately ten feet from the camera and made sure that the camera could still capture his face.

Figure 36: Testing human detection distance accuracy [14]

Finally, I had to check that the camera met our ninety-five percent accuracy rating that we established so I essentially had the code run for a few seconds and exported the output of it printing the number of people on screen to a text file and counted up the number of times it measured the correct number of people versus a wrong count of the number of people on screen. It came out to approximately ninety-seven percent success which was easily surpassing our required metric.

The next focus was on getting the thermal sensor to actually record data. This was done in C as it was much easier to communicate with the thermal sensor with C code and essentially the way that the thermal sensor worked was that it would take a 32x32 grid of what it saw and found the temperatures in each of those sectors. It would then throw out any values that were not close to the average so as to avoid including temperatures that were not actually associated to the person on the screen and then averaged it all out, resulting in the average temperature of the person. After finding this temperature the C code would then copy that value into a text file called data.txt such that the rest of the code could actually reach it. Being that the majority of the code was going to be written in Python, we turned this C code into an executable file such that it could be prompted within the main Python code.

The last component which required code written for it was the alert system which was done in Python. Essentially, we made a list of different operations for each of the LEDs, LCD screen, and the buzzer such that we could just place and call these methods within the main body Python code. We made methods to turn the LEDs on and off, make the LCD screen print lines as an output, and make the buzzer make a positive and negative sounding buzz. Snips of each of those are below as well as the mappings for each of the pinouts on the Raspberry Pi to each of the corresponding components.

```
# GPIO to LCD Mapping
LCD_RS = 26
LCD_E = 19
LCD_D4 = 13
LCD_D5 = 6
LCD_D6 = 5
LCD_D7 = 11

# GPIO to PIEZO Mapping
buzzer = 23

# GPIO to LED Mapping (Red, Yellow, Green)
red = 22
yellow = 12
green = 27

# LCD Constants
LCD_WIDTH = 16
LCD_CHR = True
LCD_CMD = False

# LCD RAM address for Line 1 & 2
LCD_LINE_1 = 0x80
LCD_LINE_2 = 0xC0

# LCD Timing Constants
E_PULSE = 0.0005
E_DELAY = 0.0005
```

Figure 37: GPIO Mappings for Raspberry Pi pinouts to the respective components [14]

```
def lcd_init():
    # Initialise display
    lcd_byte(0x33, LCD_CMD) # 110011 Initialise
    lcd_byte(0x32, LCD_CMD) # 110010 Initialise
    lcd_byte(0x06, LCD_CMD) # 000110 Curse moving direction
    lcd_byte(0x0C, LCD_CMD) # 001100 Display ON, Cursor OFF, Blink OFF
    lcd_byte(0x28, LCD_CMD) # 101000 Data length, Number of lines, & Font size
    lcd_byte(0x01, LCD_CMD) # 000001 Clear display
    time.sleep(E_DELAY)
```

Figure 38: Initialization of each of the alert system components [14]

```
def lcd_byte(bits, mode):
    # Send bytes to LCD data pins
    # bits = data
    # mode = True for character
    #        = False for command

    GPIO.output(LCD_RS, mode)

    # High bits
    GPIO.output(LCD_D4, False)
    GPIO.output(LCD_D5, False)
    GPIO.output(LCD_D6, False)
    GPIO.output(LCD_D7, False)
    if bits & 0x10 == 0x10:
        GPIO.output(LCD_D4, True)
    if bits & 0x20 == 0x20:
        GPIO.output(LCD_D5, True)
    if bits & 0x40 == 0x40:
        GPIO.output(LCD_D6, True)
    if bits & 0x80 == 0x80:
        GPIO.output(LCD_D7, True)

    # Toggle LCD enable pin
    lcd_toggle_enable()

    # Low bits
    GPIO.output(LCD_D4, False)
    GPIO.output(LCD_D5, False)
    GPIO.output(LCD_D6, False)
    GPIO.output(LCD_D7, False)
    if bits & 0x01 == 0x01:
        GPIO.output(LCD_D4, True)
    if bits & 0x02 == 0x02:
        GPIO.output(LCD_D5, True)
    if bits & 0x04 == 0x04:
        GPIO.output(LCD_D6, True)
    if bits & 0x08 == 0x08:
        GPIO.output(LCD_D7, True)

    # Toggle LCD enable pin
    lcd_toggle_enable()

def lcd_toggle_enable():
    # Toggle enable
    time.sleep(E_DELAY)
    GPIO.output(LCD_E, True)
    time.sleep(E_PULSE)
    GPIO.output(LCD_E, False)
    time.sleep(E_DELAY)

def lcd_string(message, line):
    # Send string to LCD display
    message = message.ljust(LCD_WIDTH, " ")
    lcd_byte(line, LCD_CMD)
    for i in range(LCD_WIDTH):
        lcd_byte(ord(message[i]), LCD_CHR)
```

Figure 39: LCD Screen code to print messages to the LCD screen [14]

```
def liteon(pin):
    # LED light ON
    GPIO.output(pin,GPIO.HIGH)

def liteoff(pin):
    # LED light OFF
    GPIO.output(pin,GPIO.LOW)

def blinkLED(pin):
    # Blink LED Light
    for i in range(0,3):
        GPIO.output(pin,GPIO.HIGH)
        sleep(0.3)
        failBuzzer(23)                  # calls failBuzzer
        GPIO.output(pin,GPIO.LOW)
        sleep(0.3)
```

Figure 40: Code to turn LEDs off, on, or blink [43]

```
def failBuzzer(pin):
    # Alert user if failed with piezo buzzer
    p = GPIO.PWM(pin,100)
    p.ChangeFrequency(50)
    p.start(50)
    GPIO.output(pin,GPIO.HIGH)
    sleep(0.3)
    GPIO.output(pin,GPIO.LOW)
    sleep(0.1)
```

Figure 41: Code to make the Piezo buzzer make a negative sound [14]

With all of these functions out of the way, we just needed to implement a way to send data to a cloud-based server to full-fill our last project requirement. We decided on the ThingSpeak cloud server as it was free, and we could communicate to it through the use of API keys. Essentially, we wrote code that would use the http. client and urllib Python libraries to send a request to the ThingSpeak servers containing information that we wanted to upload. We decided to upload the count of the person that was entering as well as the time in which they entered the setting. Below is a code example of that.

```
def upload(temperature, peopleInside):
    params = urllib.parse.urlencode({'field1': temperature, 'field2': peopleInside, 'key':key })
    headers = {"Content-typZZe": "application/x-www-form-urlencoded","Accept": "text/plain"}
    conn = http.client.HTTPConnection("api.thingspeak.com:80")
    try:
        conn.request("POST", "/update", params, headers)
        response = conn.getresponse()
        #print temp
        #print response.status, response.reason
        data = response.read()
        conn.close()
        #print counter
    except:
        print("Couldn't send data")
```

Figure 42: Code to send data to the ThingSpeak Server [14]

Now that we had each component working individually, we just had to integrate them all together into the same code so that they could work in unison. This began with the initial human detection code, wherein we made the script not just count the number of people that were on screen but rather count the number of people that were in the system. We did this by counting the number of people on screen five times and averaging out the number of people that it saw, so as to limit the number of errors we would see as we only had about a ninety-seven percent accuracy. It would then store the number of people that it had just seen and do the same thing again, this time comparing the number of people that it currently sees to the number of people that it saw last time. If this number went down, we figure that the difference in the number of people that it saw had entered the system and would thus increment the total count of people in the system by that number.

I then decided to implement the alert system which was relatively easy as we had most of the code pre-written. I essentially just imported those prewritten methods into my code and then used them where necessary to prompt the users to step up to the thermal sensor once the camera had sensed that a person was approaching.

After this, I made sure that the Python code could actually run the executable C code for the thermal sensor which took a little bit of time because we had to research how to actually run an executable file within a Python script, but eventually we found a Python “call” library which would essentially just call the executable file for us. We simply needed to download the library and import it in our code. A picture of that code is given below (first2 is the name of the executable file that we made for the temperature sensor).

```
call(["./first2","args","to","args"])
```

Figure 43: Python Code to call the executable first2 which would prompt the thermal sensor to record temperature to the data.txt file [14]

The next step was for the main Python code to be able to grab the data from the data.txt file such that it could give that data to the alert system to check for sick/healthy temperatures and alert the users. This was also pretty simple because we made the executable file always print to the same folder, so we could just use the OS Python library to get into the same directory and open the data.txt file with read access. We basically just removed the data.txt file each time before we wrote to it using the executable such that we would not ever have to worry about the Python code grabbing the wrong data and we did this because the legacy data was already being stored on the ThingSpeak server anyway. A picture of the code to open the data.txt file and read the temperature from it is given below.

```
if(os.path.isfile(os.path.join(os.path.dirname(os.path.abspath(__file__)), "data.txt"))):
    h = open(logfile, 'r')
    content = h.readlines()
    for line in content:
        a = float(line)
        b = line
```

Figure 44: Python code to open the data.txt file and read the temperature [14]

We then used this data and input it into our alert system code such that it could print to the LCD screen the person’s temperature and appropriately prompt the user whether to enter or not. Pictures of that are below.

```python
        lcd_string("Your Temp is:", LCD_LINE_1)
        lcd_string(b, LCD_LINE_2)
        sleep(5)
        if(a < 101.5):
            lcd_string("You are free", LCD_LINE_1)
            lcd_string("to enter!", LCD_LINE_2)
            liteon(27)
            liteoff(12)
            GPIO.output(buzzer,GPIO.HIGH)
            sleep(0.5)
            GPIO.output(buzzer,GPIO.LOW)
            liteoff(27)
            liteon(12)
            sleep(1.5)
        else:
            lcd_string("Your temp is", LCD_LINE_1)
            lcd_string("too high or low", LCD_LINE_2)
            liteon(22)
            liteoff(12)
            failBuzzer(23)
            sleep(2)
            liteoff(22)
            liteon(12)
    else:
        lcd_string("Invalid data", LCD_LINE_1)
        lcd_string("Try again", LCD_LINE_2)
        failBuzzer(23)
        sleep(4)
```

Figure 45: Python code to print the person's temperature to the LCD screen and prompt the user accordingly [14]

Lastly, we needed to make sure that the user's data was sent to the cloud correctly, which was pretty simple being that we had already tested that we could send data to the ThingSpeak server. The only caveat was that we had to first grab the current time. This was done through the datetime library in Python. Pictures of this can be seen below.

```python
now = datetime.now()
current_time = now.strftime("%H:%M:%S")
print(current_time)
upload(a, peopleInside)
```

Figure 46: Python code to get the current time and send the time and temperature of the person entering to the ThingSpeak server. [14]

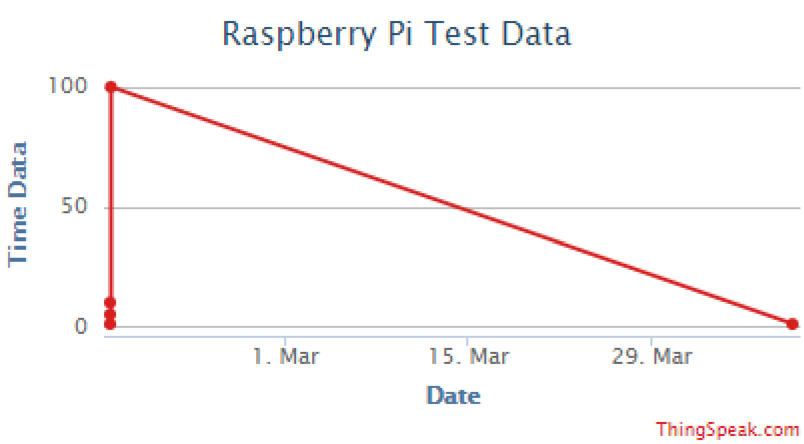


Figure 47: Picture of test data sent to the ThingSpeak server [14]

With all that done, all that was left was to clean up the remaining code and make sure that the error checking was done effectively. Essentially, we made sure that the temperatures could only be within a certain range otherwise the LCD screen would print out that the person's temperature was invalid. Beyond that we made sure that the prompts for the users to set up as well as some greetings were in place on the LCD screen such that it would have a more genuine feel.

So, all in all, our Python code was relatively simple once we got each component working individually as can be seen by the smooth integration process. We met each of our measurable metrics with ease as we were effectively able to measure the quantities of people in a setting with well over a ninety-five percent accuracy; measure and report people's temperatures to them, as well as appropriately prompt them regarding their ability to enter the setting; and sent data successfully to the cloud server. We ran into a few issues and successfully implemented the intended design as our approach required.

APPENDIX D. MECHANICAL ASPECTS

Finally, we have the physical structure design which is a PVC pipe; a low-cost plastic pipe with strength, versatility, durability and widely recognized as an alternative to metal piping. Using a circular base, I attached it to the bottom of the pipe to ensure the stability. It is also fastened onto a piece of wood for more stability. A shoulder head is also attached to the top of the pipe. The PVC pipe will cover and protect the wires and other sensitive electrical components. It is about 5-6 feet in height to ensure that the average height can be measured. The case itself is just an electrical junction box which is a heavy duty, waterproof plastic box that can cover electronics.

Figure 48: Physical structure [17]

The case is a 10x8 box with rubber gaskets on the side to prevent water or dust from reaching the insides. The breadboards and the raspberry pi will be placed inside the box for more safety and the camera is attached to the top. The inside of the case is small and compact so that we can meet the requirements of our punch list which was having a safe and compact design. I purchased a clear plexiglass covering so that we can see the components inside.

Figure 49: Empty Case (Small & Compact) [17]

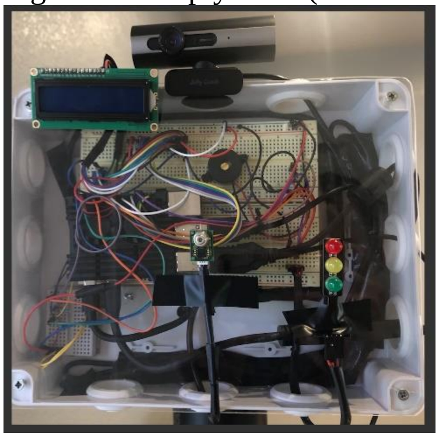


Figure 50: Case with all components inside [17]

Finally attaching the case to the structure, itself, I used a few corner braces to screw into the back of the case. First, I had to remove all the parts out of the box and screw the bolts in. The bolts came out a little too much from inside of the box and I decided to cut out a piece of cardboard where the breadboard was supposed to be. This was so that the breadboard does not get damaged by the screws. I measured everything and made sure the case was straight. I then ran the program a few times making sure that everything was running well in the case.

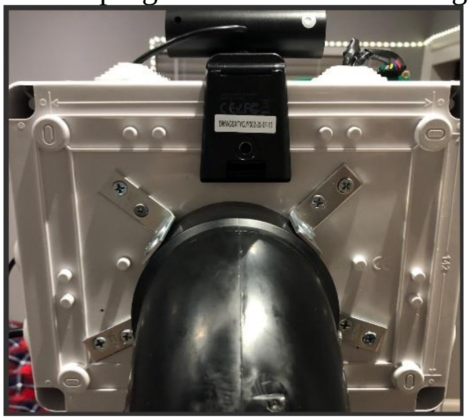


Figure 51: Back of case with case braces [17]

APPENDIX E. VENDOR CONTACTS

No vendor contacts used. All funds were provided by each team member individually.

APPENDIX F. RESUMES

Resume Paul Dye

Education:

I am a Senior Computer Engineer at Sacramento State University.

Courses completed: Network Analysis, Computer Interfacing, Introduction to Computer Architecture, Introduction to Systems Programming in UNIX, Computer Hardware System Design, Advanced Logic and Design.

Skills:

Strong knowledge and practice of various coding languages including:

Java, C, Assembly code (x86 and MIPS architecture), Python, and Verilog and VHDL coding

Proficient with AutoCAD, documentation systems, video editing, and troubleshooting. Excellent communicator, easy to work with, and a quick learner.

Work Experience:

Student assistant for Microwave Unit (MPLS Engineering) under CalOES PSC (Summer 2018, 2019) What I did:

Review and process completed engineering work packages which installed microwave paths and electronics. There were around 8 drawings that had to be examined. I requested the drawings from drafting and revised the drawings to make sure they were accurate.

Documented a radio vault to determine the precise location of the racks and equipment.

Help organize the paths of microwave Routes into separate paths.

Assist in reviewing an inventory task to determine if the right parts had been shipped. What I learned:

Creating and editing drawings with AutoCAD. Including using correct layers, centering text, and changing object's size.

Learning professional communication skills with both face-to-face conversations and email conversations with work peers. Teamwork in a technical environment, how to share information and work with others while being personally responsible for individual assignments.

How to use a centralized information tracking system used throughout the organization.

Play Well assistant instructor What I did:

As an assistant, I taught kids (5-12) engineering concepts through Legos. Such as gear ratios, stability, and creating motorized vehicles with batteries, gears, and axles.

What I learned:

Patience was essential when instructing the kids and keeping them focused and attentive. I learned to explain ideas in simple terms to help the kids understand me and build their creation

Resume Nick Patten

Education

Relevant Coursework
Basic Java, C, Python and Verilog Programming
Data Structures Algorithms Circuit Analysis, Electronics I
CMOS VLSI Design, Signals Systems Introductory Logic Design and Discrete Structures
Introductory Computer Architecture, Advance Computer Organization Operating System Principles, Computer Hardware
Design
Calculus I, IIDifferential Equations ProbabilityRandom
Signals
Physics: Mechanical Electricity and Magnetism
Skills
Microsoft Office Suite Basic AutoCAD Skills Strong written and oral communication skills

Work Experience

California Department of Technology, Student Assistant (September 2019– Present) Member of Network Engineering Operations Team Network troubleshooting and fault analysis; hardware troubleshooting and repair Deployment and maintenance of network monitoring, analysis, and reporting tools
Day-to-day network performance monitoring
Mathnasium, Instructor (September 2018– September 2019) Teaching math concepts ranging from basic addition to advanced calculus techniques Selling Mathnasium's program to parents Time management: balancing grading papers and teaching multiple students File documents in organized manner
Vacuuming, wiping tables, as well as other cleaning duties
American Eagle, Sales Associate (August 2014– June 2015)
(Jan 2018– September 2018)
Clerical Duties in paced environments like Black Friday Happily greeting customers entering store Effectively communicating current promotions and deals Managing fitting rooms with a balance of professionalism and friendly social skills Selling American Eagle Credit Cards and Customer Reward Cards Establishing genuine connections with customers to sell clothing Counting inventory of entire store Help arrange new floor sets
California Parking, Valet Attendant (February 2016– March 2017) Provide outstanding customer service with proper and formal mannerisms Safely drive and park customer vehicles in a crowded downtown San Francisco Handle fast-paced rushes of vehicles arriving at the same time for an event Organize keys with tickets for correct customer

Resume Micah Biggers

Education

Folsom High School

-Graduated May 2017

-AP Calculus AB BC, Honors Physics, AP Statistics, Honors Chemistry, AP Spanish, AP Language and Composition,

Honors Sophomore English, and AP European History

-Received State Seal of Biliteracy (Spanish)

-Played Freshman Basketball and VarsityVolleyball

Sacramento State University

-BS in Computer Engineering, minors in CS and Math -Expected graduation: Spring 2020 -6x Recipient of Dean's

Honor Roll Skills

Java, Python, Verilog, C Coding

Excellent Communicator, Easy to work with, and Hard worker

Work Experience

Application Engineering Intern (Intel)

February 2019 – Present

-Worked on various data analysis, database management, programming, and private hardware projects -Helped with several community service projects and Intel Outreach programs in which I advised university students, specifically Sac State students, and provided input as to how they should approach internships within Intel Mathnasium, Lead Instructor

September 2016 – December 2018

-Taught complex math concepts to students and held leadership roles such as directing other instructors and maintaining positive customer relations. -Responsible for opening, running, and closing Mathnasium of Folsom Wales and Lexington.

Resume Dennis Trotsyuk
EDUCATION:

I am a Senior in Electrical Engineering at Sacramento State
University.
Courses completed:
· Calculus I, II, III and Differential equations · Introductory to Circuit analysis · Physics: Mechanical Electricity and Magnetism
· Electronics I, II · Network Analysis
· Introduction to Feedback Systems · SignalsSystems ·
Introduction to Microprocessors · Applied Electromagnetics
· Probability and Random Signals · Introduction to Logic Design · Modern communication systems
· Electromechanical Conversion · Robotics Education, Licenses Certifications
B.S. in Electrical Engineering C.S.U. Sacramento, 2020 SKILLS: Basic skills in coding in various languages including: Java, C, Assembly (x86), and python. Language: Proficient in spoken and written in English and Russian
Character traits: Excellent verbal and written skills, exceptional time management, able to work independently in a flexible faced-paced work environment.
Work experience

2018
· Sell and market products that are both in store and online. · Engage with customers to ensure that their needs are met. · Assist management in store opening, closing, and item recovery. · Working productively to reach a sales goal of $1900 on every shift. Pieceworker
Impact Photographic, Eldorado Hills, CA, September 2015 –
April 2016
· Assembled refrigerator magnets, adding labels and magnetic strips. · Made 500 magnets per hour, moving up to 650 by the end of my tenure. · Labeled products, repackaged magnets, made boxes for glass cups, etc. · Learned new techniques from co-workers, and applied them to my own work. START
Program Mentor
James Marshall Elementary School, Sacramento, CA, September 2013 - December 2013
· Worked with 60 children in an after-school program helping them with homework. · Assisted teachers with grading papers along with other school related works. · Helped hand out food and snacks during program break times.

APPENDIX G. WORK BREAKDOWN STRUCTURE CHART

Table 9:
Work Breakdown Chart

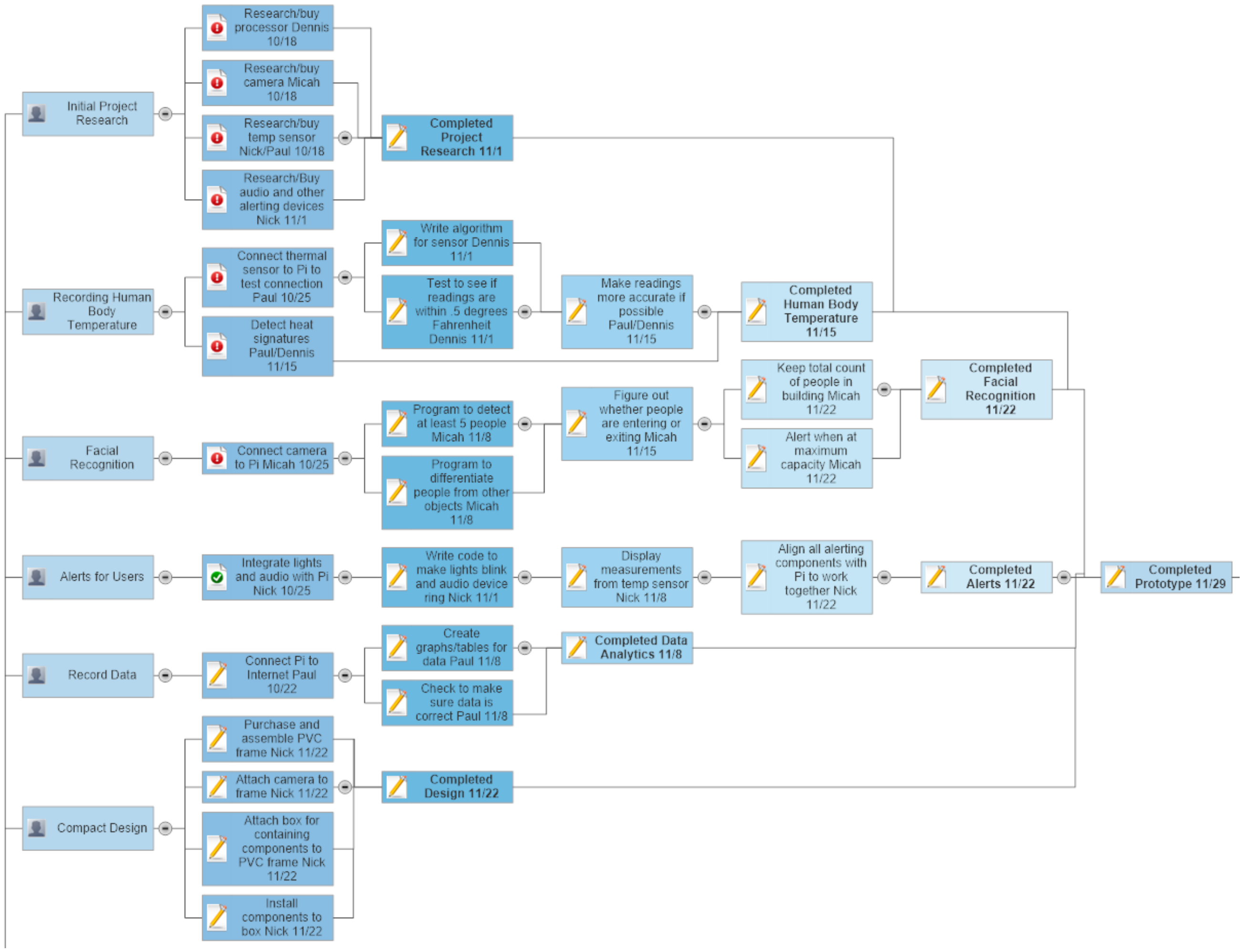
Level 1 (from punch list)	Level 2 (task)	Level 3 (activity)	Name	Date
0. Initial Project Research				
	0.1 Research type of Parts Needed			
		0.1.1 Buy Temperature Sensor	Dennis	10/18
		0.1.2 Buy Camera for detection	Micah	10/18
		0.1.3 Buy Raspberry Pi4	Paul/Nick	10/18
		0.1.4 Buy audio system, lcd screen, pvc pipe, and box for pi	Nick	11/1
1. Recording Human Body Temperature	1.1 Install Sensor and test connection	1.1.1 Connect thermal sensor to Raspberry Pi and confirm connection	Paul	10/22
		1.2.1 Write Algorithim for Sensor	Dennis	11/1
	1.2 Refine Accuracy of Results	1.2.2 Test to see if readings are accurate to at least +/- 0.5 °F	Dennis	11/1
		1.2.3 Modify Algorithm code to make readings more accurate	Paul/Dennis	11/15
		1.2.4 Detect heat signatures	Paul/Dennis	11/15
2. Facial Recognition to Differentiate People from Other Objects				
	2.1 Install Camera	2.1.1 Connect Camera to Raspberry Pi and confirm connection	Micah	10/25
	2.2 Test and confirm connection with raspberry pi	2.2.1 Progam to detect at least 5 humans within the given space	Micah	11/8
	2.3 Write code for high traffic areas	2.2.2 Progam to tell difference between face and other objects	Micah	11/8
		2.3.1 Figure out wether people are entering or exiting	Micah	11/15
		2.3.2 Keep total count of people in a building	Micah	11/22
		2.3.3 Alert when building capacity is reached	Micah	11/22
3. Alert User when unsafe temperature is measured				
	3.1 Installing 20x4 LCD character screen and writing Raspberry Pi code	3.1.1 Integrating lights, sound, and screen with processor	Nick	10/25
	3.2 Installing Sound Generator and writing raspberry pi code	3.1.2 write code for lights to blink or light up	Nick	11/1
	3.3 Installing LED Display and writing raspberry pi code	3.2.1 Integrating Sound	Nick	11/1
		3.3.1 Integrating display with measurements from temperature sensor	Nick	11/8
		3.3.2 wire up the display and temperature sensors so they work alligned	Nick	11/22
4. Produce and record data for the system				
	4.1 Upload data to cloud through pi	4.1.1 Make sure pi is either wireless or connected to a wifi IP address correctly	Paul	10/22
	4.2 Create a configuration to sort out data	4.2.1 Create Graphs and Tables with the inputted data from the sensors	Paul	11/8
	4.3 make a secure network	4.2.2 make sure graphs are showing correct data analysis	Paul	11/8
		4.3.1 program the pi and secure the network in which data is being sent to	Paul	11/22
5. Compact and Safe Design				
	5.1 Create PVC frame	5.1 Purchase and Assemble PVC into a frame	Nick	11/22
	5.2 Create custom box for sensors and raspberry pi	5.2.1 attach camera to the custom box	Nick	11/22
	5.3 Make it adjustable height	5.2.2 Attach box to PVC frame	Nick	11/22
		5.2.3 install components inside box	Nick	11/22
		5.3.1 install a motor spring to move the box up or down based on the person height	Nick	11/22
6. Assignments Fall Semester				
	6.1 Assignemnt 1a- Inidividual Problem Statement			
		6.1.1 Each team member to write it individually	All	9/13
	6.2 Assignemnt 1b - Team Problem Statement			
		6.2.1 Effects of Covid	Paul	9/27
		6.2.2 History of Past Pandemics	Dennis	9/27
		6.2.3 Preventative Measures	Micah	9/27
		6.2.1 Possible Solutions and Approaches	Nick	9/27
	6.3 Assignemnt 2 - design idea contract			
		6.3.1 Features and Measurables Metrics	Paul/Micah	10/4
		6.3.2 Project Proposal Overview	Nick/Dennis	10/4
	6.4 Assignemnt 3 - work breakdown structure			
		6.4.1 Creating Work Breakdown Structure Table	Dennis/Micah	10/25
		6.4.2 Writing out work breakdown structure in narrative form	Paul/Nick	10/25
	6.1 Assignment 4 - Project Timeline			
		6.1.1 PERT Diagram	Micah	11/1
		6.1.2 Gantt Chart	Dennis	11/1
		6.1.3 Assign Teamates, timeline, and milestones to tasks	Paul	11/1
		6.1.4 Add this assignment to end of project report	Micah	11/1
	6.2 Assignment 5 - Risk Assessment			
		6.2.1 Identify Projects critical paths and any events /risks that may slow project	Paul	11/8

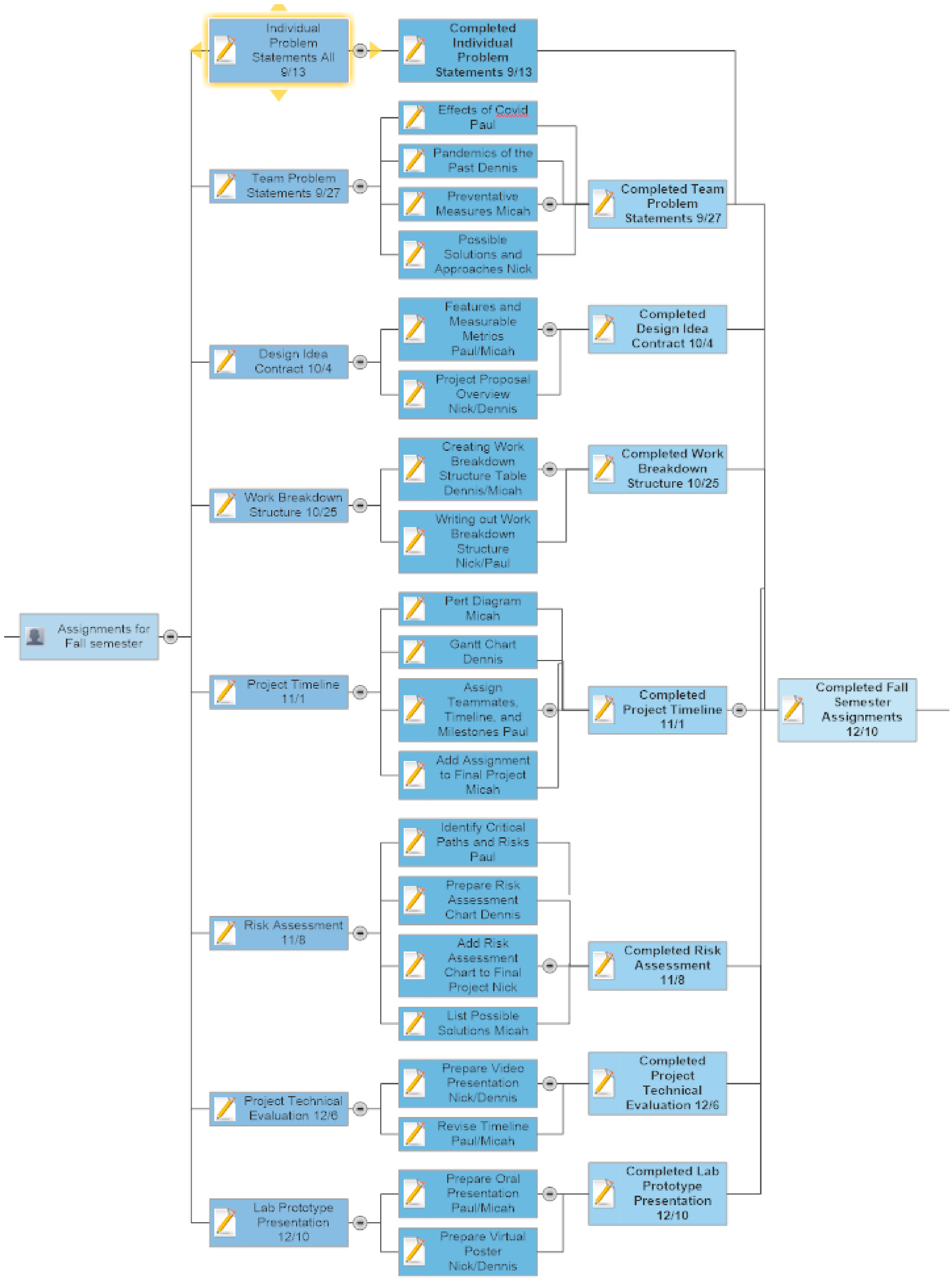
		6.2.2 Prepare risk assessment Chart	Dennis	11/8
		6.2.3 Add risk assessment to end of project report	Nick	11/8
		6.2.4 List possible mitigation strageties for risks	Micah	11/8
	6.3 Assignment 6 - Project Technical Evaluation			
		6.3.1 Preparing video for presentation	Nick/Dennis	12/6
		6.3.2 Revise timeline and WBS for whole year	Micah/Paul	12/6
	6.4 Assignment 7 - Laboratory Prototype Presentation			
		6.4.1 Preparing oral presentation	Micah/Paul	12/10
		6.4.2 Preparing virtual poster and virtual handout	Nick/Dennis	12/10
7. Assignments Spring Semester				
	7.1 Assignemnt 1a Problem Satement Revisions			
		7.1.1 Highlight a better understanding of the problem	Micah/Dennis	TBD
		7.1.2 Find sources that help better understand the problem	Paul/Nick	TBD
	7.2 Assignemnt 1b Design Idea Contract			
		7.2.1 Revise Features and Measurables Metrics	Micah/Nick	TBD
		7.2.2 Revise Project Proposal Overview	Paul/Dennis	TBD
	7.3 Assignemnt 1c Spring Timeline Update			
		6.1.1 Revise PERT Diagram	Nick	TBD
		6.1.2 Revise Gantt Chart	Dennis	TBD
		6.1.3 Revise Assigned group memebers, timeline, and milestones to tasks	Paul	TBD
		6.1.4 Revise end of project format	Micah	TBD
	7.4 Assignemnt 2 Device Test plan			
		7.4.1 Determine the necessary factors that need testing	Paul/Dennis	TBD
		7.4.2 Establish a test timeline and assign tasks to team members	Micah/Nick	TBD
	7.5 Assignemnt 3 Market Review			
		7.5.1 Oral Presentation	Micah/Paul	TBD
		7.5.2 Develop a strategic plan for your prototype through a process of literature revie	Nick/Dennis	TBD
		7.5.3 Develop a strategic plan for your prototype through manager interviews	Micah/Paul	TBD
		7.5.4 Assist in the writing of the report	All	TBD
	7.6 Assignemnt 4 Feature report and presentation			
		7.6.1 Prepare presentation for individual work (group memeber 1)	Micah	TBD
		7.6.2 Prepare presentation for individual work (group memeber 2)	Paul	TBD
		7.6.3 Prepare presentation for individual work (group memeber 3)	Nick	TBD
		7.6.4 Prepare presentation for individual work (group memeber 4)	Dennis	TBD
	7.7 Assignemnt 5a Mid -Term Progress Review			
		7.7.1 Update test plan	Nick/Dennis	TBD
		7.7.2 Report test results	Micah	TBD
		7.7.3 Prepare presentation	Paul	TBD
		7.7.4 Assist in writing of report	All	TBD
	7.8 Assignemnt 7 Deployable prototype review			
		7.8.1 Prepare post project audit report	Micah	TBD
		7.8.2 Prepare for review	Paul/Nick	TBD
		7.8.3 Prepare prototype demonstration	Dennis	TBD
	7.9 Assignemnt 8 End project documentation			
		7.10.1 Write the final introduction, abstract, executive summary, and conclusion	Micah/Paul	TBD
		7.10.2 Revise formatting errors	Nick/Dennis	TBD
		7.10.3 Revise any grammar, spelling, or poor word choice	Nick/Dennis	TBD
		7.10.4 Create end of project video	Micah/Paul	TBD
	7.10 Assignemnt 9 Deployable Prototype Presentation			
		7.11.1 Prepare large poster (possibly virtual) of project	Dennis	TBD
		7.11.2 Prepare one page handouts (possibly virtual)	Nick	TBD
		7.11.3 Prepare talking points to describe project	Micah	TBD
		7.11.4 Prepare project to be fully operational and presentable	Paul	TBD
8. Additional Features (spring semester)				
	8.2 Increase the accuracy of the temperature sensor			
		TBD	TBD	TBD
	8.3 Create more in depth analysis on data from camera detection			
		TBD	TBD	TBD
	8.4 Make final design more compact			
		TBD	TBD	TBD

APPENDIX H. PERT DIAGRAM

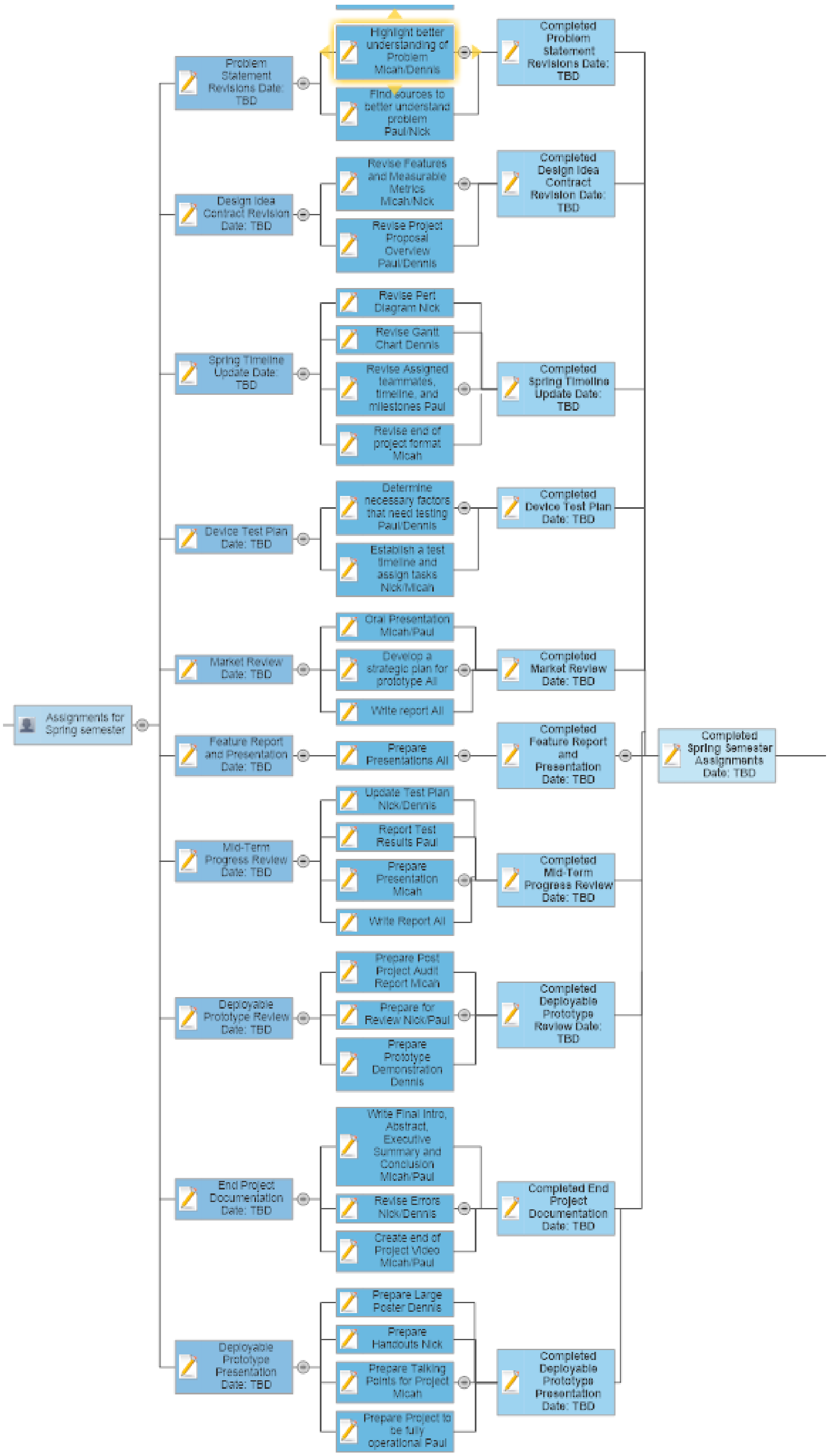
Table 10:

PERT Diagram




Assignments for Fall semester
Individual Problem Statements All 9/13
Completed Individual Problem Statements 9/13
Team Problem Statements 9/27
Effects of Covid Paul
Pandemics of the Past Dennis
Preventative Measures Micah
Possible Solutions and Approaches Nick
Completed Team Problem Statements 9/27
Design Idea Contract 10/4
Features and Measurable Metrics Paul/Micah
Project Proposal Overview Nick/Dennis
Completed Design Idea Contract 10/4
Work Breakdown Structure 10/25
Creating Work Breakdown Structure Table Dennis/Micah
Writing out Work Breakdown Structure Nick/Paul
Completed Work Breakdown Structure 10/25
Project Timeline 11/1
Pert Diagram Micah
Gantt Chart Dennis
Assign Teammates, Timeline, and Milestones Paul
Add Assignment to Final Project Micah
Completed Project Timeline 11/1
Completed Fall Semester Assignments 12/10
Risk Assessment 11/8
Identify Critical Paths and Risks Paul
Prepare Risk Assessment Chart Dennis
Add Risk Assessment Chart to Final Project Nick
List Possible Solutions Micah
Completed Risk Assessment 11/8
Project Technical Evaluation 12/6
Prepare Video Presentation Nick/Dennis
Revise Timeline Paul/Micah
Completed Project Technical Evaluation 12/6
Lab Prototype Presentation 12/10
Prepare Oral Presentation Paul/Micah
Prepare Virtual Poster Nick/Dennis
Completed Lab Prototype Presentation 12/10

Appendix H-2



Assignments for Spring semester
Problem Statement Revisions Date: TBD
Highlight better understanding of Problem Micah/Dennis
Find sources to better understand problem Paul/Nick
Completed Problem Statement Revisions Date: TBD
Design Idea Contract Revision Date: TBD
Revise Features and Measurable Metrics Micah/Nick
Revise Project Proposal Overview Paul/Dennis
Completed Design Idea Contract Revision Date: TBD
Spring Timeline Update Date: TBD
Revise Pert Diagram Nick
Revise Gantt Chart Dennis
Revise Assigned teammates, timeline, and milestones Paul
Revise end of project format Micah
Completed Spring Timeline Update Date: TBD
Device Test Plan Date: TBD
Determine necessary factors that need testing Paul/Dennis
Establish a test timeline and assign tasks Nick/Micah
Completed Device Test Plan Date: TBD
Market Review Date: TBD
Oral Presentation Micah/Paul
Develop a strategic plan for prototype All
Write report All
Completed Market Review Date: TBD
Feature Report and Presentation Date: TBD
Prepare Presentations All
Completed Feature Report and Presentation Date: TBD
Completed Spring Semester Assignments Date: TBD
Mid-Term Progress Review Date: TBD
Update Test Plan Nick/Dennis
Report Test Results Paul
Prepare Presentation Micah
Write Report All
Completed Mid-Term Progress Review Date: TBD
Deployable Prototype Review Date: TBD
Prepare Post Project Audit Report Micah
Prepare for Review Nick/Paul
Prepare Prototype Demonstration Dennis
Completed Deployable Prototype Review Date: TBD
End Project Documentation Date: TBD
Write Final Intro, Abstract, Executive Summary and Conclusion Micah/Paul
Revise Errors Nick/Dennis
Create end of Project Video Micah/Paul
Completed End Project Documentation Date: TBD
Deployable Prototype Presentation Date: TBD
Prepare Large Poster Dennis
Prepare Handouts Nick
Prepare Talking Points for Project Micah
Prepare Project to be fully operational Paul
Completed Deployable Prototype Presentation Date: TBD

APPENDIX I. GANTT CHART

Table 11:

Gantt Chart

Fall Week 1 | Fall Week 2 | Fall Week 3 | Fall Week 4 | Fall Week 5 | Fall Week 6 | Fall Week 7 | Fall Week 8 | Fall Week 9 | Fall Week 10 | Fall Week 11 | Fall Week 12 | Fall Week 13 | Fall Week 14 | Fall Week 15 | Fall Week 16

0. Initial Project Research				
	0.1 Research type of Parts Needed			
		0.1.1 Buy Temperature Sensor	Dennis	10/18
		0.1.2 Buy Camera for detection	Micah	10/18
		0.1.3 Buy Raspberry Pi4	Paul/Nick	10/18
		0.1.4 Buy audio system, lcd screen, pvc pipe, and box for pi	Nick	11/1
1. Recording Hu	1.1 Install Sensor and test connection	1.1.1 Connect thermal sensor to Raspberry Pi and confirm connection	Paul	10/22
		1.2.1 Write Algorithim for Sensor	Dennis	11/1
	1.2 Refine Accuracy of Results	1.2.2 Test to see if readings are accurate to at least +/- 0.5 °F	Dennis	11/8
		1.2.3 Modify Algorithm code to make readings more accurate	Paul/Dennis	11/15
		1.2.4 Detect heat signatures	Paul/Dennis	11/15
2. Facial Recognition to Differentiate People from Other Objects				
	2.1 Install Camera	2.1.1 Connect Camera to Raspberry Pi and confirm connection	Micah	10/25
	2.2 Test and confirm connection with raspberry pi	2.2.1 Progam to detect at least 5 humans within the given space	Micah	11/8
	2.3 Write code for high traffic areas	2.2.2 Progam to tell difference between face and other objects	Micah	11/8
		2.3.1 Figure out wether people are entering or exiting	Micah	11/15
		2.3.2 Keep total count of people in a building	Micah	11/22
		2.3.3 Alert when building capacity is reached	Micah	11/22
3. Alert User when unsafe temperature is measured				
	3.1 Installing 20x4 LCD character screen and writing Raspberry Pi cc	3.1.1 Integrating lights, sound, and screen with processor	Nick	10/25
	3.2 Installing Sound Generator and writing raspberry pi code	3.1.2 write code for lights to blink or light up	Nick	11/1
	3.3 Installing LED Display and writing raspberry pi code	3.2.1 Integrating Sound	Nick	11/1
		3.3.1 Integrating display with measurements from temperature sensor	Nick	11/8
		3.3.2 wire up the display and temperature sensors so they work alligned	Nick	11/22
4. Produce and record data for the system				
	4.1 Upload data to cloud through pi	4.1.1 Make sure pi is either wireless or connected to a wifi IP address correctly	Paul	10/22
	4.2 Create a configuration to sort out data	4.2.1 Create Graphs and Tables with the inputted data from the sensors	Paul	11/8
	4.3 make a secure network	4.2.2 make sure graphs are showing correct data analysis	Paul	11/8
		4.3.1 program the pi and secure the network in which data is being sent to	Paul	11/22
5. Compact and Safe Design				
	5.1 Create PVC frame	5.1 Purchase and Assemble PVC into a frame	Nick	11/22
	5.2 Create custom box for sensors and raspberry pi	5.2.1 attach camera to the custom box	Nick	11/22
	5.3 Make it adjustable height	5.2.2 Attach box to PVC frame	Nick	11/22
		5.2.3 install components inside box	Nick	11/22
		5.3.1 install a motor spring to move the box up or down based on the person height	Nick	11/22
6. Assignments Fall Semester				
	6.1 Assignemnt 1a- Individual Problem Statement			
		6.1.1 Each team member to write it individually	All	9/13
	6.2 Assignemnt 1b - Team Problem Statement			
		6.2.1 Effects of Covid	Paul	9/27
		6.2.2 History of Past Pandemics	Dennis	9/27
		6.2.3 Preventative Measures	Micah	9/27
		6.2.1 Possible Solutions and Approaches	Nick	9/27
	6.3 Assignemnt 2 - design idea contract			
		6.3.1 Features and Measurables Metrics	Paul/Micah	10/4
		6.3.2 Project Proposal Overview	Nick/Dennis	10/4
	6.4 Assignemnt 3 - work breakdown structure			
		6.4.1 Creating Work Breakdown Structure Table	Dennis/Micah	10/25
		6.4.2 Writing out work breakdown structure in narrative form	Paul/Nick	10/25
	6.1 Assignment 4 - Project Timeline			
		6.1.1 PERT Diagram	Micah	11/1
		6.1.2 Gantt Chart	Dennis	11/1
		6.1.3 Assign Teamates, timeline, and milestones to tasks	Paul	11/1
		6.1.4 Add this assignment to end of project report	Micah	11/1
	6.2 Assignment 5 - Risk Assessment			
		6.2.1 Identify Projects critical paths and any events /risks that may slow project	Paul	11/8
		6.2.2 Prepare risk assessment Chart	Dennis	11/8
		6.2.3 Add risk assessment to end of project report	Nick	11/8
		6.2.4 List possible mitigation strageties for risks	Micah	11/8
	6.3 Assignment 6 - Project Technical Evaluation			
		6.3.1 Preparing video for presentation	Nick/Dennis	12/6
		6.3.2 Revise timeline and WBS for whole year	Micah/Paul	12/6
	6.4 Assignment 7 - Laboratory Prototype Presentation			
		6.4.1 Preparing oral presentation	Micah/Paul	12/10
		6.4.2 Preparing virtual poster and virtual handout	Nick/Dennis	12/10

Spring Week 1 | Spring Week 2 | Spring Week 3 | Spring Week 4 | Spring Week 5 | Spring Week 6 | Spring Week 7 | Spring Week 8 | Spring Week 9 | Spring Week 10 | Spring Week 11 | Spring Week 12 | Spring Week 13 | Spring Week 14 | Spring Week 15 | Spring Week 16

7. Assignments Spring Semester				
	7.1 Assignemnt 1a Problem Satement Revisions			
		7.1.1 Highlight a better understanding of the problem	Micah/Dennis	TBD
		7.1.2 Find sources that help better understand the problem	Paul/Nick	TBD
	7.2 Assignemnt 1b Design Idea Contract			
		7.2.1 Revise Features and Measurables Metrics	Micah/Nick	TBD
		7.2.2 Revise Project Proposal Overview	Paul/Dennis	TBD
	7.3 Assignemnt 1c Spring Timeline Update			
		6.1.1 Revise PERT Diagram	Nick	TBD
		6.1.2 Revise Gantt Chart	Dennis	TBD
		6.1.3 Revise Assigned group memebers, timeline, and milestones to tasks	Paul	TBD
		6.1.4 Revise end of project format	Micah	TBD
	7.4 Assignemnt 2 Device Test plan			
		7.4.1 Determine the necessary factors that need testing	Paul/Dennis	TBD
		7.4.2 Establish a test timeline and assign tasks to team members	Micah/Nick	TBD
	7.5 Assignemnt 3 Market Review			
		7.5.1 Oral Presentation	Micah/Paul	TBD
		7.5.2 Develop a strategic plan for your prototype through a process of literature review	Nick/Dennis	TBD
		7.5.3 Develop a strategic plan for your prototype through manager interviews	Micah/Paul	TBD
		7.5.4 Assist in the writing of the report	All	TBD
	7.6 Assignemnt 4 Feature report and presentation			
		7.6.1 Prepare presentation for individual work (group member 1)	Micah	TBD
		7.6.2 Prepare presentation for individual work (group member 2)	Paul	TBD
		7.6.3 Prepare presentation for individual work (group member 3)	Nick	TBD
		7.6.4 Prepare presentation for individual work (group member 4)	Dennis	TBD
	7.7 Assignemnt 5a Mid -Term Progress Review			
		7.7.1 Update test plan	Nick/Dennis	TBD
		7.7.2 Report test results	Micah	TBD
		7.7.3 Prepare presentation	Paul	TBD
		7.7.4 Assist in writing of report	All	TBD
	7.8 Assignemnt 7 Deployable prototype review			
		7.8.1 Prepare post project audit report	Micah	TBD
		7.8.2 Prepare for review	Paul/Nick	TBD
		7.8.3 Prepare prototype demonstration	Dennis	TBD
	7.9 Assignemnt 8 End project documentation			
		7.10.1 Write the final introduction, abstract, executive summary, and conclusion	Micah/Paul	TBD
		7.10.2 Revise formatting errors	Nick/Dennis	TBD
		7.10.3 Revise any grammar, spelling, or poor word choice	Nick/Dennis	TBD
		7.10.4 Create end of project video	Micah/Paul	TBD
	7.10 Assignemnt 9 Deployable Prototype Presentation			
		7.11.1 Prepare large poster (possibly virtual) of project	Dennis	TBD
		7.11.2 Prepare one page handouts (possibly virtual)	Nick	TBD
		7.11.3 Prepare talking points to describe project	Micah	TBD
		7.11.4 Prepare project to be fully operational and presentable	Paul	TBD
8. Additional Features (spring semester)				
	8.2 Increase the accuracy of the temperature sensor			
		TBD	TBD	TBD
	8.3 Create more in depth analysis on data from camera detection			
		TBD	TBD	TBD
	8.4 Make final design more compact			

Appendix J Testing Timeline

Table 12. Revised Testing Timeline

	Date	February 8th-14th	February 15th-21st	February 22nd-28th	March 1st-7st	March 8th-14th	March 15th-21st	March 22nd-28th	March 29th-April 4th	April 5th Presentation on Testing
Testing Item										
Recording Human Body Temperature										
-Determine the distance at which to measure human body temperature							X	X		
Confirm accuracy of human temperature within 0.5 degrees F for standard human temperatures		X	X	X						
-Confrim accuracy to within 0.5 degrees F for temperatures between 103F and 110F				X	X	X				
-Confrim accuracy to within 0.5 degrees F for temperatures between 96F and 90F				X	X	X				
-Test error detection and handling by measuring invalid cases								X	X	
Facial Recognition										
-Test that it can read faces with 95% accuracy										
-Test that it count the number of people on screen		X	X							
-Test that it can count the number of people that have entered				X	X					
-Test that it can collect the date and communicate with other devices					X	X				
-Test that it can store that data/send it to the cloud						X	X	X		
Alert User when unsafe temperature is measured										
-Test the correct LED color triggers for correct temperature				x	x					
-Test the correct buzzer sound plays for each LED color						x	x			
-Test the Alert system can read IR Sensor temperatures		x	x	x						
-Test the Alert system can read data from camera when person in front of sensor				x	x	x				
-Test camera, ir sensor, and alert system work in unison								x	x	
Produce and record data for the system										
-Test that a script can send data to the cloud server			X	X						
-Test that a script can collect time information				X	X					
-Test that a script can get data from the Thermal sensor and Camera						X	X			
-Test that a script can combine all of the data and send it to the server								X	X	
Compact and Safe Design										
-Research parts for the design		x								
-Buy parts			x							
-Assemble the design				X	X	X				
-Test for stability							X	X	X	