CALIFORNIA STATE UNIVERSITY
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COLLEGE OF ENGINEERING &
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CPE 191 /EEE 193B
Senior Design Project

Project Athena - Objection Detection Robotic System

Team 2
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ELEVATOR PITCH

Project Athena is a quadrupedal system designed to assist recovery efforts designated towards wildfires with sensors and electronic communications.

EXECUTIVE SUMMARY

For our senior project, we decided to work on a robotic system dubbed, Project Athena. Project Athena is a robotic system designed to assist in recovery efforts mainly in fires. To do this, this robotic system is equipped with sensors and electronic communications. Now, after bringing this project to life, we write this documentation. As such, our goal by writing this report is for this report to be a valuable reference for us and to clients. Through this report, you'll find a variety of topics that helped guide us through this collaborative effort. The first topic is our team's problem statement. Following this, we shall allude to our design idea. Then we will walk you through our work breakdown structure. And since there are many risks associated with this project, we have a section that walks you through our risk assessment analysis. After this, we consider every possible way in which we could test and verify the expected behavior of our system. This will be what makes up the device test plan section of this report. Lastly, the market review section will be the last topic we discuss.

The problem that inspired us to work on Project Athena is the recurring wildfires that have impacted us here in California. Climate change has contributed greatly to a change in weather patterns that have led us into elongated drought periods and heat waves that create the perfect environment for wildfires to thrive. Wildfires not only affect the environment but also impact the lives and belongings of thousands of individuals across the state. Due to increasing population and settlements within new terrains, communities are not prepared to evacuate in case of a fire. A solution is needed to aid in recovery efforts when fires are moving at a pace faster than the public can react to. This is where project Athena comes in. For our design idea, we visualized a robot that makes use of a machine learning architecture that is used to detect humans trapped in buildings and a temperature sensor to record data. This system would be controlled with a mobile device via web service. In essence, this robot would be geared towards helping firefighters during search and rescue missions. Now, in order to bring this project to life, our team of four was divided into sub teams of 2 whereby Daniel and Gabriel worked on the GUI, web server, machine learning architecture and the embedded software. While Justin and Nestor worked on designing the motor circuit plus a sensor circuit. In addition, there were quite a few unexpected issues we had to solve as a team. When that was not possible, we had to find workarounds. The main risk we faced was the pandemic. We had to try to stay away from each other and work on different modules separately until those modules were ready to be handed over to the next person that had to work on them. Additionally, another risk that concerned not so much our health, but mainly our project was finding sturdy materials that would endure the risks that the environment would pose. For example, finding adequate material for the creation of our robot's chassis. This material would have to be able to at least somewhat endure high temperatures. Finding high quality electrical tools was another issue. As we would come to find out later, breadboards are a no go. The wires that are inserted into a breadboard's sockets won't stay in the sockets. Short circuits may arise from this. There were many more issues that will be detailed later in this report. However, all things considered, this project was definitely a good idea. This project will compete in a market that is growing and unsaturated and our clients will be first responders

ABSTRACT

Wildfires are evolving and becoming a staple in the realm of natural disasters. They have become a constant and recurring force that affects larger areas every subsequent year. This has led to entire towns and communities being caught off guard and struggling to deal with evacuations and rescue efforts for their populace. Our solution to this problem has emerged as the creation of a quadruped robotic system that can maneuver through harsh and varying terrains while identifying and classifying humanoid objects through the use of Artificial Intelligence in the interest of saving human lives. The quadruped system is reliant on three essential components coming together to build a resistant, efficient and intelligent system. The structure of our project is vital to its success as it will be required to enter dangerous environments where obstacles may become present. Some of those obstacles will be debris, small openings, and extreme temperatures. We will be preparing for these with strong resilient materials that can repel the effects of excessive heat. Our system must be efficient as it will be operating a multitude of motors and onboard sensors that will require a substantial amount of processing power leading to a draw in energy that will need to be accounted for. Calling for multiple high capacity batteries that will give the system enough time to be deployed and return to a safe point for retrieval. We will employ a lightweight carrying case for those batteries that protects them from extreme conditions to have an adequate amount of run time before having to recharge. Ultimately the artificial intelligence our robotic system will have solidifies the selling point for our device as it demonstrates its ability to proactively search and locate victims of wildfires without having to put our first responders at risk. Our project reached a rapid prototype stage to show every step of the design process and inclusion of features. Project Athena is a fully functioning product that is both cost effective and beneficial to society over a long period of time while impacting the lives of many.

Keyword Index— Automation, GUI, quadruped system, Raspberry Pi, structure software, and software

I. INTRODUCTION

Wildfire impacts have increased exponentially due to various effects of climate change such as drought, irregular weather patterns, and increased temperatures. This trend has been in continuous increase as shown by academic literature. The deployment of our system needs to be modular in the dimensions of temperature and environmental changes in longitude and latitude. Wildfires have expanded from being simple forest fires to engulf entire cities and counties in a way that has never been seen before. This can be attributed to many different reasons but the main ones are an ever increasing population and climate change. While population has increased throughout the world, in certain high risk areas such as California, entire towns and agriculture plots have burned down which can be attributed to being located in wildfire prone locations that may not have been accounted for in previous years. This has led to thousands of individuals being unprepared for the coming of wildfires and have become trapped as the infrastructure of our state never took into account evacuation routes and procedures for natural disasters like these. With major wildfires affecting the world reports have been published that the public is not truly aware of how dangerous and rapidly a wildfire can expand under the correct conditions. In the case of California fires (camp) many individuals opted for staying in their homes not realizing that the fires would reach them faster than they ever imagined. This led to people and pets to be trapped within their homes or stuck in their vehicles hoping for first responders to find them. Thus our robotic system will be vital in aiding in solving and hopefully preventing these issues in the future of inevitable wildfires. Our prototype will consist of a quadrupedal robot that will traverse terrains and be able to identify people and high importance targets that first responders will need to attend to.

Therefore the deployment of our system needs to be modular in the dimensions of temperature and environmental changes in longitude and latitude. Wildfires no longer merely affect forests but also engulf entire cities and counties in a way that has never been seen before. This can be attributed to many different reasons but the main ones are an ever increasing population and climate change. While population has increased throughout the world, in certain high risk areas such as California, entire towns and agriculture plots have burned down which can be attributed to being located in wildfire prone locations that may not have been accounted for in previous years. This has led to thousands of individuals being unprepared for the coming of wildfires and have become trapped as the infrastructure of our state never took into account evacuation routes and procedures for natural disasters of this scale to occur. With the large amount of wildfires affecting the world, reports have been published stating that the public is not truly aware of how dangerous and rapidly a wildfire can expand under the correct conditions. In the case of California fires (camp) many individuals opted for staying in their homes not realizing that the fires would reach them faster than they ever imagined. This led to people and pets to be trapped within their homes or stuck in their vehicles hoping for first responders to find them. Thus our robotic system would have been vital in aiding in search and rescue operations for such an unprecedented event. Eventually leading our product to become a staple in search and rescue operations for any wildfire that may occur in the future. Our prototype will consist of a quadruped robot that will traverse varying terrains and be able to identify people and high importance targets that first responders will need to attend to. Making our product a key instrument in aiding in the solution to wildfire dangers and recurring incidents.

While population has increased throughout the world, in certain high risk areas such as California, entire towns and agriculture plots have burned down which were established in wildfire prone locations that may not have been accounted for in previous years. This has led to thousands of individuals being unprepared for the coming of wildfires. Causing many of them to become trapped in emergency evacuations as local governments did not take into account evacuation routes and procedures for natural disasters of this scale to occur. With the large amount of wildfires affecting the world, reports have been published stating that the public is not truly aware of how dangerous and rapidly a wildfire can expand under the correct conditions. In the case of recent years' California fires, many individuals opted to stay in their homes not realizing that the fires would reach them faster than they ever imagined. This led to many individuals being trapped in their homes or within their vehicles stuck in traffic hoping for first responders to get to them before it was too late. Thus our robotic system will be vital in aiding in search and rescue operations during wildfire season and any other unprecedented situation. Our prototype will consist of a quadruped robot that will traverse varying terrains and be able to identify high importance targets that first responders will need to attend to. Making our product a key instrument in aiding in the solution to wildfire dangers and recurring incidents.

The Project Timeline activity was an essential part of our team coordination. The assignment was to record all our previous tasks as well as our future ones. This called for us planning out our entire project for the remainder of this semester and the next. We needed to decide upon Milestones for our project. Milestones are a marker that signifies some achievement in the project. They aren't a task that is assigned over a period of time, but instead symbolize the important amount of progress that has been accomplished. The Timeline section in our report was us breaking down these milestones in detail. This assignment overall was very good for team synergy and coordination. We all needed to agree on the timeline and milestones as well as recall all our past tasks.

The final assignment for the fall semester of our senior design course presents to us the risk assessment section of our End of Project Report. While as a team we have taken into account the risks presented to us through unaccounted for global situations, this assignment also gives us a chance to find and describe risks that we may not have thought of or encountered yet. Giving us a chance to brainstorm on risks within the project and externally as well. Some of these risks stem from the inability to collaborate and meet up in person to work on our project. Because of this we have created a risk assessment chart to easily visualize our problems and how we can mitigate them to complete our project in a timely and effective manner. We also break down all of our risks and go into detail within our risk assessment section of our project report. Some of the main risks we have seen as a team include the resistance and sturdiness of our projects' structure and limbs considering that the unit is planned to be used in extreme environmental conditions that no ordinary materials would be able to resist for a set amount of time. We need to be aware that our materials may not resist the conditions that we plan on putting them through and will need to account for a change in materials once we get to test them under a controlled environment. This also means that we need to be aware of the changes that a real world environment poses in comparison to our test environments. Connectivity issues relating to networks and the reliability of live streamed footage may prove fatal in the problem our project is aiming to rectify. While our project's completion is one of the main factors being considered we also have to consider that it is a team effort and without the availability and work put in by each individual team member we will be left with the risk that missing features and unfinished components will be present in our final product. This means our acting team leader and team members have to keep an open and live discussion on the status of their systematic risks that may be personal or team wide. For example we would like to know the status of each team member's health considering we are living through a global pandemic, both physical and mental. We also have to be conscious of the societal problem of wildfires that directly affects all of our group members considering that we all live in a high risk wildfire prone state that has repeatedly affected all of us through our academic journey at our institution. As a team we will work together to mitigate and look for all potential risks within our project and outside of the scope of our project to ensure we create a safe, responsible, and effective working environment to create a marketable and appealing product.

Returning from our first semester of senior design we came with a better understanding of the robotic system we envisioned to address our societal problem. We discovered that we needed to refine our outlook. The entirety of this assignment was taking what we did in the previous semester and adjusting what we'll do in the spring semester based on the knowledge we collected. Our societal problem was far too broad. It was on wildfires as a whole. In order to focus it more, we wanted to change it to wildfire relief. This will help us as a team approach a more specific problem when we continue the design for the rest of the semester. The design idea needed some major changes because some of the aspects didn't apply to our societal problem and were unrealistic. There were some measurable metrics that were far too specific and therefore unattainable. We needed to completely remove quadrupedal movement from our Punch List. These changes were reflected in all our documentation. This assignment was a perfect way to get our team on the same page for Spring 2021 and ready to finish the project out strong.

Our second assignment for the second half of Senior design helps solidify our confidence in our design and component choices. We are to prove the laboratory prototype works as expected over a convincing range of factors such as temperature, humidity, voltages and other pertinent factors to our design. Due to the ongoing pandemic we are still limited in the amount of test equipment we have to experiment on our prototype. We are also lacking in the ability to test our equipment in an adequate environment. For our robotic project we have planned the design around being deployed in extreme conditions due to fires which entail high temperatures and dangers from falling objects within buildings affected by these flames. To begin our testing we need to rank each of the factors from most critical to least. In the first place we have the effect of temperature as our entire project is directly affected by it and each component will react differently. We can conduct testing of our project's exoskeleton with sample pieces and expose them to direct flames and see how long and for what amount of exposure it is able to withstand before crumbling. Secondly we would like to test the durability of our components by stress testing them in the scenario that an object fell or was putting enough pressure onto the prototype that it would render it unusable. To do so we can test weight limits on our project in regards to its structural rigidity. Third we would be very careful to take into account the amount of power consumed by our product as it would need to have enough battery capacity available in order to enter a high risk building and exit all within one charge. Lastly we would consider the factor of humidity in the case that fire suppression systems or active fire fighting is taking place as water is usually present in the scene of a fire. To enable those tests we could check whether our components are already water resistant certified or if there are ways for us to achieve that on a full project basis.

Our third assignment for the second half of Senior design is meant to help us figure out if our project is worth all the sweat and tears that we’ve spent on it. In a real life project development environment, if a product you are working on has no marketability, then there is no point pursuing it. Thus, through this assignment the goal was to identify with absolute certainty who the customer and client for our product would be. Furthermore, we also had to identify the kind of market environment Project Athena would compete in. After identifying all of these things, we employed a SWOT analysis strategy to identify the strengths, weaknesses, opportunities, and threats that our project would face. Ultimately, from all of these considerations, we drew the conclusion that our product is fairly marketable. Albeit, the market Project Athena will compete in is in a growing market that isn’t well developed just yet. Furthermore, the customers of our product are people trapped in burning buildings while our clients are first responder teams.

Our fifth assignment for the second semester is one of the most critical as it confirms whether our feature set is working to the specification that we stated it would be at in this stage of the project. In our original test plan we had 4 main tests that we wanted to conduct. The first was to test the 4 DC motors that would be driving our robot across different terrains. We needed to confirm that our output current to the H-bridges that drove our motors were within the max specification of 2 amps. The second test we needed to conduct was to ensure that the TCA9548A i2c multiplexer was outputting a clean signal that was not creating a voltage gain. The third test we conducted was to validate the logical blocks of the executable file we created to drive our locomotion hardware. The final test we conducted was to document and stress test the machine learning implementation to discover the limits of our hardware performance and what to expect when running the project as one unified project. Throughout the course of the semester we made changes to our overall project that would improve performance and take into account the finalized weight of the exoskeleton once it was printed. The first of these changes was moving to bigger and more powerful servo motors that would be able to move our system joints with ease. This required new and updated testing to accurately set the operating frequency and voltages for the new motors with different specifications. This was especially important when we opted to change to a more powerful microcontroller as it would require new software libraries in order to communicate with the hardware. The final change we had to make to our testing plan was to account for the performance boost of the new microcontroller as it would affect the object detection implementation we initially created as we would have to begin from scratch but see drastically improved results at the end of it through faster performance, more accurate results, and faster network transmission.

II. SOCIETAL PROBLEM

A. Fall 2020

For this fall semester we have decided to focus on wildfires as our societal problem since this has been a recurring issue and since this is an issue that has affected millions. Moreover, wildfires have brought upon a lot of collateral issues. For example, wildfires have damaged residential areas, ecosystems, wildlife and financial sectors of society. And even though wildfires may seem like a problem that merely affects us, it is not. It is an issue that affects humans as well as every part of our world. This is not a bold statement at all. For instance, let us draw your attention to the recent wildfires that have been on the news recently. According to various sources, the smoke that was released from the California wildfires managed to make its way to Kansas. As shown by NWS Dodge City weather forecast, The NWS reported reduced air quality on Sunday as temperatures climbed toward the upper 90s across the state [1].

As mentioned above towards the beginning of the paragraph, wildfires have been a recurring issue. Additionally, wildfires have had an increasing longevity that has become more and more transparent in how they are managing to stay “alive”. Wildfires were once considered natural disasters that would occur throughout nature as a regular cycle of the environment. But nowadays we are experiencing wildfires that last multiple months and are no longer being considered “natural” in their nature. Wildfires are occurring during seasons that should be low risk causing for investigation on how these fires are originating. One of the deduced issues is global warming, in the case of California climate change has drastically altered the weather and the terrain to become arid and dry during certain seasons due to the lack of rain and excessive temperatures. This leads to an abundance of “fuel” consisting of dried out brush and plants that can ignite with just a spark. One of our examples being lightning as it has the capability of reaching the ground and striking the ground with the power of up to one billion volts of electricity. Naturally occurring wildfires are not the only issue we will be taking a look at as in recent years it has been discovered that a majority of wildfires are born from accidents or purposeful acts by individuals and or objects. Some of these include fireworks, cigarettes, smoke bombs and campfires. While most can be attributed to accidents some are started intentionally leading to a longer span of life for our societal problem as our populations continue to increase leading to more and more chances for fires to be initiated by humanity.

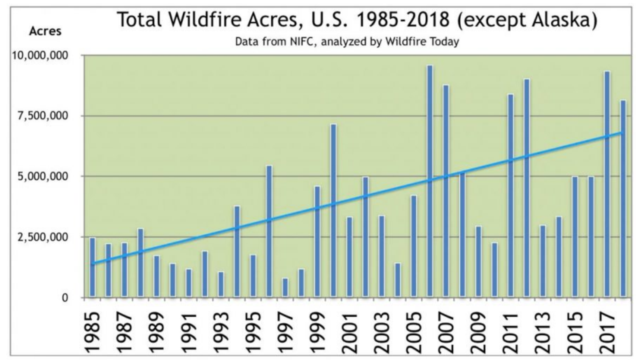

Fig 1. Wildfire Trend Over Time [2]

More lives are affected by wildfires than ever before, and this is evident by the California Wildfires. As of August 2019, the years 2017 through 2018 were the most destructive years for California wildfires on record [3].

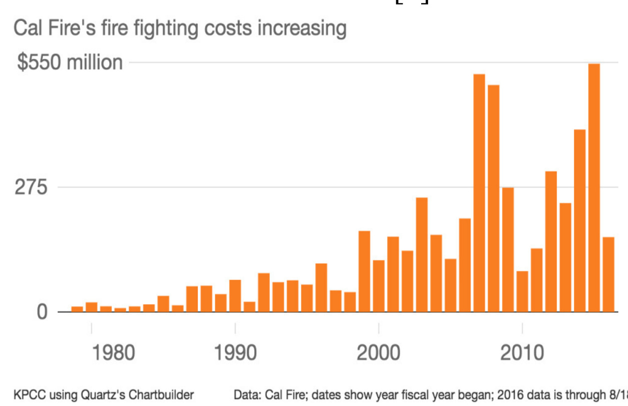

Fig 2. Cal Fire expenses over the years [4]

While California has always been a state ridden by wildfires, the last several years are a dramatic uptick of damage. This alarming increase of cases directly affects more Californian lives than ever before. During 2017 and 2018, these devastating wildfires killed hundreds of people, destroyed thousands of structures, led to evacuation of hundreds of thousands of people, and caused severe air quality problems in downwind urban centers far away from burned areas [3]. The amount of lives lost and livelihoods destroyed from property damage by these uncontrolled wildfires are catastrophic. The wildfires are directly a threat to the lives of many Californians. The less direct effects of these uncontrolled wildfires, however, are negatively impacting even more people. As previously mentioned, the smoke from these fires spreads across almost the entire state. According to the California Air Resource Board [5], the 2020 wildfires have been resulting in air quality levels regularly reaching ‘Unhealthy’, ‘Very Unhealthy’, and ‘Hazardous’ across the state, leading even healthy people to experience symptoms in smoky conditions and after exposure.

Air Quality Index - Particulate Matter	
301 – 500	Hazardous
201 – 300	Very Unhealthy
151 – 200	Unhealthy
101 – 150	Unhealthy for Sensitive Groups
51 – 100	Moderate
0 – 50	Good

Table I. AQI Table [6]

Wildfires produce a range of harmful air pollutants, including known cancer-causing substances, with the principal pollutant of concern being particulate matter (PM), which is known to cause heart and lung health effects [5]. Because these uncontrolled wildfires are taking many lives, destroying livelihoods by forcing people to relocate and destroying property, and are affecting people’s health through state-wide pollution, the California wildfires are threatening the safety of the vast majority of Californians.

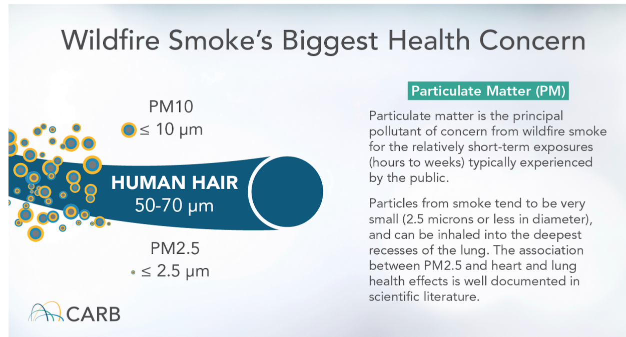

Fig 3. Particulate Matter Data [5]

In late 2019 to early 2020 Australia experienced some of the most catastrophic wildfires in its history. Wildfires burned through every single state in the country ultimately leading to an air quality that measured 11 times the "hazardous" level. While most of the causes of the fires were determined to be natural causes such as lightning and dry spells in the environment, it was reported that the state of New South Wales charged 24 people with fire related offenses for purposely starting fires. These fires were covered under international news for being so large. Experts claimed that climate change was one of the biggest factors due to breaking the record for highest nationwide average temperature, with some places above 113-120 degrees Fahrenheit. Constant heat along with strong winds create the ideal conditions for fires to thrive and the arid-like environment of certain parts of the country are even more susceptible to fires. In total, more than 7.3 million hectares (17.9 million acres) were burned across Australia's six states. In comparison California, which is known for its deadly wildfires, burned just over 100,000 hectares (247,000 acres) in 2019, and about 404,680 hectares (1 million acres) in 2018.

Such was the devastation left behind by the Australian Bushfires that 34 people died directly due to the fires while 417 individuals died due to the smoke that they inhaled; additionally, “3,500 homes and many buildings” were engulfed by the flames [7]. With this, we’ve only considered the direct effects of the Australian Bushfires on Australians. However, the Australian Bushfires didn't merely affect Australians. Apparently, the Australian Bushfire's smoke made its way to New Zealand [8]. Furthermore, in [8] a lot of New Zealanders' tweets were compiled. These tweets put into perspective the effects of the Bushfires. These tweets illustrated the point that in many parts of New Zealand, smoke haze obscured the sky. The smoke even covered a mountain's snow with a thin coat of smoke which left the mountain with a brownish color [8]. This being said, smoke reaching other countries that aren't at all part of Australia is a big deal because the smoke is hazardous to anyone that inhales it. The "bushfires devastating swathes of Australia have already pumped out more than half of the country's annual carbon dioxide emissions" which is extremely bad because Australians and New Zealanders inhale these pollutants [9].

Fig 4. Mountain's Covered with in Brownish Smoke Substance [8]

From an engineering perspective, approaching this problem would require an adequate mechanical system and efficient software to complete real time computations which can then be sent to the robotic system. As shown by Laura Celentano and her team in Italy, a PWM would be best to control the amount of torque produced by the Servos of our system. These Servos would be controlled with a PID controller in order to ensure our system functions accordingly and ensures stable controls with external variables in consideration with the sensors previously mentioned. A proportional–integral–derivative controller (PID controller or three-term controller) is a control loop mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control.

A standard PID controller is defined as a "three term" controller whose transfer function is written in parallel form given by the following equations from [10], in "parallel form" as well as "ideal form" respectively.

$$G(s) = K_P + K_I \frac{1}{s} + K_D s \tag{1}$$

$$= K_P \left(1 + \frac{1}{T_I s} + T_D s\right) \tag{2}$$

Fig 5. PID Function [10]

The first term represents the proportional gain, second integral gain and lastly derivative gain. This implementation provides an overall control action professional to the error signal through the gain factor. The effects of PID tuning are explicitly explained by the following table and will be useful when determining the transfer function of our system.

Closed-Loop Response	Rise Time	Overshoot	Settling Time	Steady-State Error	Stability
Increasing K_P	Decrease	Increase	Small Increase	Decrease	Degrade
Increasing K_I	Small Decrease	Increase	Increase	Large Decrease	Degrade
Increasing K_D	Small Decrease	Decrease	Decrease	Minor Change	Improve

Table II. PID Tuning Table [10]

The GUI of this project would be deployed on a web service (Apache) to ensure modulatory in said system communications, and the internal systems controls would primarily be done in C++ with an XML file serving as the API between our backend and GUI. TensorFlow being deployed with a hardware accelerator in order to boost the efficiency of the AI platform. The physical system would be capable of movements in all three axises and a motor to power the movement of the system. The physical system covered with fire resilient material to ensure longevity when deployed.

B. Spring 2021

For the second half of the senior design course, the societal problem that we as a team decided to delegate our attention to and tried to solve at least partially was wildfires. However, now that we've had time to work on the hardware and software aspects of the project, we've been able to refine our focus a lot more. As a result, we have a better understanding of what problem to focus on, and thus we decided to focus on one of the effects of wildfires. We can't solve wildfires. Therefore, we will shift our attention to the trouble that fires cause for firefighters' search and rescue efforts. Firefighters' search and rescue efforts are made difficult by fires because they are dangerous and life threatening to work in and enter to attempt their search and rescue efforts. Although, this is the nature of their line of work, we as a society should have the technologies available to help facilitate firefighters' search and rescue efforts.

As illustrated by an article by the US National Library of Medicine National Institutes of Health, "between 2001–2012, over 100 U.S. firefighter line-of-duty deaths occurred annually" [11]. This is one of the main issues we are attempting to prevent. Fires pose a threat to the lives of firefighters, thus a robot that is used for reconnaissance, or in other words, to search for individuals during a wildfire would be the ideal way of preventing more firefighter casualties. Our robot is a remotely controlled unit that will act as the eyes and ears of an operator that will dispatch his team to an area after he has found survivors and individuals in danger within burning vicinities.

Fires not only pose an immediate threat to the lives of Firefighters during their search and rescue missions. Rather, there are other secondary factors as a result of wildfires such as structural collapse that create an unpredictable environment for rescue teams and victims as a whole. It often occurs without warning and can easily cause multiple fatalities [12]. A study examined data from structural collapse incidents that occurred from 1994 to 2002 and noticed that the number of deaths caused by structural collapse has steadily declined. But the dangers of being trapped or struck by a large object such as a falling support beam are still very present and in order to help combat this societal problem our robot can help reduce the exposure of firefighters to these dangers and streamline their rescue routes in the case of victim detection.

Another secondary effect of fires is that they make asbestos found in everyday products airborne and thus expose firefighters to them. According to the article 'What Is Asbestos and How Does It Cause Cancer', "Asbestos is a group of six naturally occurring minerals composed of soft, flexible fibers that are heat-resistant [13]. Asbestos is still used in hundreds of U.S. consumer products." The reason why asbestos is so dangerous is because "Asbestos is an established cause of mesothelioma, an uncommon cancer that arises in the mesothelial cells lining the chest and abdominal cavities, and of lung cancer" [14].

Because of these effects we continued to research communication lines available to firefighters during search and rescue missions and discovered that while they are present they tend to lose connection and lead to accidents that could be avoided by using our product as a primary. Getting lost in a mission inside an unknown building is a common cause of accidents in firefighting . Currently, very limited pervasive technology, if any, comes into play for preventing this kind of accident [15] . Thus our robot will help pave the way for risk free entrance into burning buildings while also helping set a predetermined path for firefighters to get in and out as efficiently as possible during rescue operations.

While our societal problems focus has changed our ultimate design has not changed much and is still dependent upon an adequate mechanical system and efficient software to complete real time computations which can then be sent to the robotic system. As shown by Laura Celentano and her team in Italy, a PWM would be best to control the amount of torque produced by the Servos of our system. These Servos would be controlled with a PID controller in order to ensure our system functions accordingly and ensures stable controls with external variables in consideration with the sensors previously mentioned. A proportional–integral–derivative controller (PID controller or three-term controller) is a control loop mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control.

A standard PID controller is defined as a “three term” controller whose transfer function is written in parallel form given by the following equations from *Fig 5*, in “parallel form” as well as “ideal form” respectively.

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The GUI of this project would be deployed on a web service (Apache) to ensure modulatory in said system communications, and the internal systems controls would primarily be done in C++ with an XML file serving as the API between our backend and GUI. TensorFlow being deployed with a hardware accelerator in order to boost the efficiency of the AI platform. The physical system would be capable of movements in all three axises and will use various kinds of motors some which will be servos and others will be DC brushed motors to power the movement of the system. The reason why we are using servos instead of another kind of precisely controlled motor such as steppers is because servos “ run significantly faster than stepper motors” this allows “servo motors to be used with gearboxes to deliver much higher torque at useful speeds [16]. They also deliver more consistent torque across the speed range of the motor.” The physical system is covered with fire resilient material to ensure longevity when deployed.

One aspect that has changed dramatically within our design is the decision to implement a new microcontroller to make up for the lackluster performance of our initial microcontroller selection. By looking through multiple specifications and articles we have seen that the Raspberry Pi 4 and NVIDIA Jetson Nano are similar, but there is one unique distinction. The biggest difference lies in the graphics capabilities between the two boards, specifically their graphical processing units (GPU). The NVIDIA Jetson Nano has a 128-core Maxwell GPU at 921 MHz. Compared side by side, the Jetson Nano has a much more capable GPU than the Raspberry Pi 4. This makes the Jetson Nano more suitable for AI and ML applications, which could be a specific advantage, depending on your intended end-use [17]. Thus in the end during our halfway point through the design we opted to choose a stronger and more efficient microcontroller because timing is critical during search and rescue operations.

For the majority of our system, rechargeable lithium-ion batteries are our choice to ensure the electronics and motors are properly charged. Lithium polymer rechargeable batteries are used, but only for the heavy duty servo motors required to maneuver our robot with more power. Lithium Polymer batteries “have applications in electrical vehicles” and are generally more powerful “because of their very high energy density" [18]. This will allow for our system to perform adequately for the final deployable prototype phase of development required by our desired societal problem.

III. DESIGN IDEA

In this section we will be outlining our design idea contract where we will discuss how as a team we will physically address our chosen societal problem that we laid out in the previous section. We will briefly mention similar existing solutions that have inspired us to tackle the challenge of solving this problem ourselves. Our design idea contract will become an essential part of our project as it will be our "beacon" in case we begin to stray or forget about the focus of our project. By committing to a specific design we agree to follow through on a set design that will allow us to complete a realistic and complete project in the amount of time that we have available to us. Since this is a joint project of computer engineering and electrical engineering majors we will have a very technical and specialized section on the chosen and desired hardware and software that our project requires to be realized.

Since wildfires impact millions of people and are recurring, we decided to address this issue by developing a robotic system that is designed to assist in aiding firefighter's search and rescue efforts. More specifically, this is a project oriented towards the deployment of a robotic system capable of reading temperatures and detecting wildlifes or humans within the scope of its vicinity. By developing this system, we hope to reduce the loss of human lives and those of emergency rescue personnel. If there ever is any doubt as to whether or not a subject is surrounded or trapped by wildfires, project athena would be deployed to scope out the area. It will be in charge of distinguishing lifeforms from fires. This system will operate through machine learning architecture used to recognize certain objects and a temperature sensor to read temperature data. Our system will be controlled with a mobile device via web service and operate within different external environmental changes with multi-terrain capabilities. Our robotic system will also use it's array of sensors to transfer essential data it collects to the remote user. This data will help with the fighting of the fire.

There are many design approaches that we could have adopted. For instance, thermal imaging cameras are one approach. In fact, these are already widely used by firefighters. These thermal imaging cameras make infrared radiation visible. By displaying objects of different temperatures in different colors, these cameras help firefighters see. Moreover, there are so many other things that we could have considered. For example, there is a robot that could suppress small scale fires by launching fire fighting foam. That is one approach we could have adopted. Another approach we could have adopted is making our robot airborne. There are various examples of airborne robots that are used to detect fires in enclosed facilities. However, we decided to go with our approach because this design approach enhances firefighter's rescue efforts. If ever in a rescue mission, our robot would quickly identify the best path to follow in order to successfully rescue a victim. If we need to find the actual location of the source of the fire and want to collect data, our system can traverse the terrain, collect the information, and wirelessly send it to the user.

The Technologies needed for our design consist of a Raspberry Pi microcontroller for our prototype to be replaced by a Nvidia Jetson in our final design, an HD camera, a PID Controller, a Temperature Sensor, HTML, C++, Python , Servo Motors, DC brushed motors, H-bridges, and a multi-channel PWM.

A. Fall 2020/Spring 2021

1) Hardware

The first of our technologies is the microcontroller. For our initial prototype we will be using a Raspberry Pi which we will then replace with an Nvidia Jetson. Regardless, the Raspberry Pi 4 is a powerful microcontroller that runs a lightweight operating system capable of running our set of 16 motors and interface devices such as our camera and sensors all on a cost efficient and flexible unit. The Raspberry Pi we are using is an Rpi 4 which has increased processing power and higher random access memory capacity that is essential in allowing us to test our machine learning software capabilities as it takes a fairly powerful processing unit to identify and classify objects in real time. The Rpi 4 has I2C (SCL and SDA) pins and GPIO pins which we can use to connect with a multi-channel PWM and an H-Bridge for our motor control, USB to connect to camera and temperature sensors, and network capabilities to host and operate our Graphical Interface Unit. The Rpi 4 has everything we need for our prototype but cuts performance for a lower cost entry point. Thus we would like to transfer all of our testing and work to the Nvidia Jetson in our final build once we get our system up and running to take advantage of the increased performance it offers.

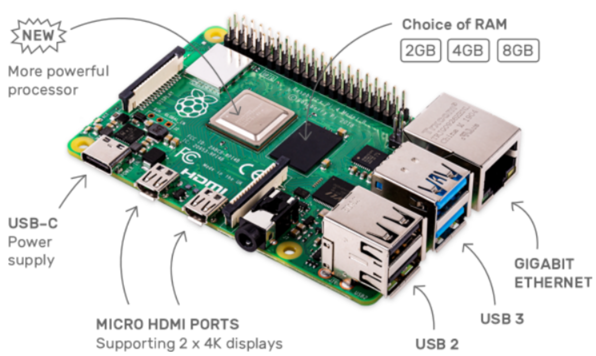

Fig 6. Rpi 4 Overview [19]

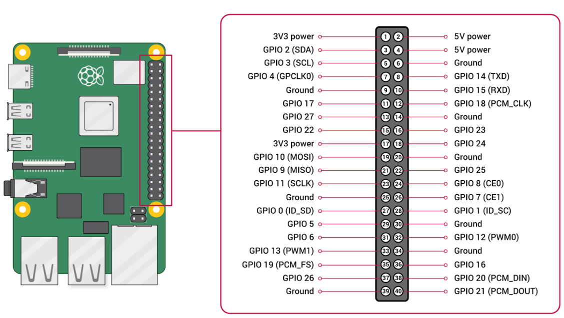

Fig 7. Rpi 4 Pin Layout [19]

Fig 8. Nvidia Jetson Overview [20]

The next of our technologies is an HD camera for image processing. This is going to be one of the key features of our robotic system because the camera will be used for image processing and recognition. Initially we will be resorting to using a standard HD webcam to test our initial video feeds. We will be using a logitech c920 webcam which records footage at a resolution of 1920x1080 pixels, allowing the user to see a clear image and creating a more accurate environment for our machine learning software to identify and record objects that we have trained it to identify. For our deployable system we will upgrade to a highly powerful full HD camera.

A PID controller is one of our technologies because it ensures our system functions accordingly and has stable controls when taking eternal variables into account with sensors. A PID controller is a control loop mechanism that receives feedback and is commonly deployed in industry control systems. A PID controller can be considered as an extreme form of a phase lead-lag compensator with one pole at the origin and the other at infinity [21]. Essentially, this PID controller will allow for our system to operate more precisely, especially taking into account it's surroundings.

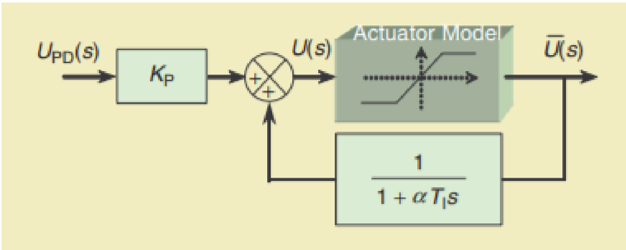

Fig 9. Common PID Controller Schematic [21]

Another one of our technologies is an Temperature Sensor. When we deploy our robotic system, it will need to be equipped with a Temperature Sensor to collect the data from its surroundings. Since the system is expected to aid in firefighting relief, we need to ensure gauging the surrounding temperature is a priority. The MCP9808 Temperature Sensor is the sensor we decided on for our project because it has a typical accuracy of ±0.25°C over the sensor's -40°C to +125°C range and precision of +0.0625°C [22]. Our system is expected to detect up to 200°F which is well under the specs for the MCP9808.

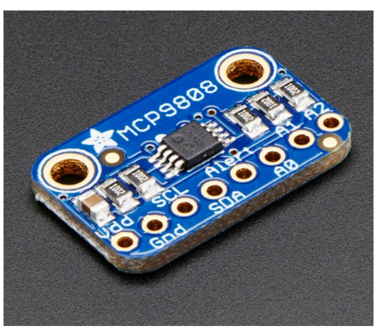

Fig 10. MCP9808 Temperature Sensor [22]

2) Software

HTML (Hypertext Markup Language) is the standard markup language for documents or in this case GUIs designed to be displayed in a web browser. It can be assisted by other technologies such as CSS, PHP, JavaScript, and other scripting languages. Our HTML code is used as the bare bones for the logical processes of our interface and is supported by CSS and PHP. CSS (Cascading Style Sheets) is used to provide a description for how the interpreter displays our HTML. It is also important to note that HTML5 although modern and common as consortium recommendation, it still comes with slight differences from browser to browser. In this case, we plan to utilize Safari as our primary browser and BootStrap CSS for a responsive, mobile first fluid framework.

Python is a high level and general purpose language commonly used for industry. Python emphasizes code readability and supports i2c abstraction for this project by the use of the *smbus2* package. This package lets a user write, read and process calls within i2c functionality. It is an improved version of *smbus* but does not contain all the same functions as its predecessor. We plan to utilize the source code and package of *smbus2* to create a 16 channel servo driver which will be driven by our C++ environment.

C++ is a general-purpose programming language which derives from C, hence its name and was previously referred to as "C with Classes". C++ will be carefully utilized for our project and will continue many of the controls mentioned previously. We plan to take full advantage of C++ and will implement a header file which will initialize our needed Objected with *#pragma once* and needed libraries at the top mentioned. This command is a preprocessor directive and designed to cause the current source file to be included only once in a single compilation. By doing so, we ensure efficiency since our interpreter will initialize a dedicated set of memory for our corresponding objects which can then be invoked upon by *pointers*, a powerful and helpful concept for this project. The memory of a computer is like a succession of memory cells, each one byte in size and each a unique address. These memory cells are ordered in a way that allows representations of larger than one byte to occupy addresses. By implementing pointers into our design we are able to obtain the address of an object during runtime in order to access data cells that are at a certain position relative to it, hence making our RTC (Real Time Computing) more efficient.

Yet another one of our technologies is DC Servo motors. Servos are motors that don't usually spin more than 360°, but they instead move to specific locations when they receive a signal with a certain pulse width. These are perfect for the turning mechanisms of our system. When we want a precise movement, we can send a specific pulse width and get the precise response we desire. DC Servo Motors are perfect for our system's mobility.

No.	Item	Specification
6-1	Control system	Change pulse width
6-2	Amplifier type	Analog control
6-3	Operating travel	90° (at 1000 → 2000 μsec)
6-4	Neutral position	1500 μsec
6-5	Dead band width	4 μsec
6-6	Rotating direction	anticlockwise (at1500 → 2000 μsec)
6-7	Pulse width range	800 → 2200 μsec
6-8	Maximum travel	About 165°(at 800 → 2200 μsec)

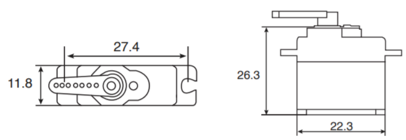

Table III. Servo Specifications [13]

DC brushed motors are another of the amazing technologies we'll implement in our design. DC brushed motors work in a very straightforward way, but have the power we need for our design. The higher the average velocity being supplied to the motor, the faster it spins, and vice versa. DC brushed motors are a perfect fit for the wheels in our system. They are not too powerful or complex. The fix our specific needs for a simple yet powerful enough motor.

DC brushed motors do not have built in direction control, however. To implement direction control, an H-bridge circuit is required. H-bridges work by changing which direction the current flows through the motor. When the direction of the current changes, the motor spins in the other direction. This is achieved by the transistors acting as switches. When transistors in opposite corners of the circuit are turned on, it forces the current to flow one way, but when others are turned on, it forces the current to flow the other way. This provides us with precise direction control in our DC Brushed motors. This will be helpful in our system for needing to reverse wheel direction while traversing terrain.

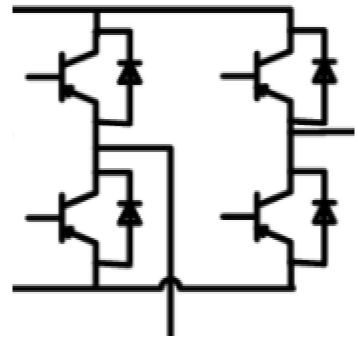

Fig 11. H Bridge Example[24]

One more of the technologies our design will use is a Multi-Channel PWM. With 16 motors needing PWM, our system requires a multi-channel PWM. A Multi-Channel PWM is controlled by an Rpi with the I2C (SCL and SDA) pins. Each channel is programmed independently and outputs a separate pulse width. A 16 channel PWM is the best fit for our system because it can control each motor independently.

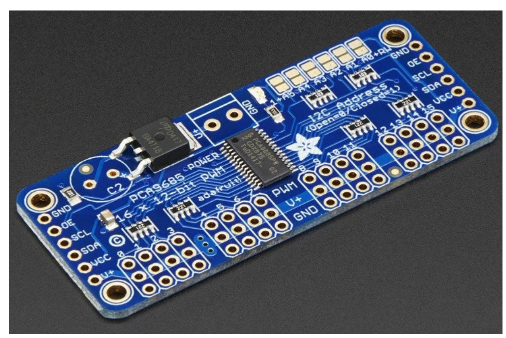

Fig 12. 16 Channel PWM [25]

For our project due to special circumstances and the need to social distance and prevent large gatherings of individuals our consultants will all be referenced through virtual means, currently we have our senior project advisor Russel Tatro as our main consultant and as we go further on into the building aspect of our project we will be able to consult with the companies that are currently sponsoring us to receive feedback and implement ideas that they present to us to create a stronger, reliable and marketable product. Unfortunately this year we will not be able to do any conference traveling as health restrictions do not allow us to travel outside of our current locations thus we will implement technology as our aid in virtual conferencing to keep not only us but our contacts safe. Luckily we will be creating most of our software and will mainly have to rely on the option of an operating system being present to allow us to compile our code and run our desired functions throughout our robotic system. In our case our technicians will be our own group members as we are attempting to limit physical contact with each other and will only be able to assist with design features and components through a virtual aspect. For the EEE end, we'll be using soldering irons at home, which are adequate. We'll also be using an Analog Discovery 2, which does not have the power needed to analyze our circuit. This is a roadblock for us. We need to access a fully functioning Oscilloscope. We are planning on accessing one in the Spring semester. Thankfully, through hydra all the EE software, such as PSPICE, is available from home. We've needed to purchase circuit elements and batteries to test circuits from home.

3) Requirements

The needed software technologies for our system rely on HTML5, Apache HTTP Server 2.4, BootStrap CSS, and PHP 7.2 to deploy our current GUI. Project Athena Interface operates best on an IPad display on Safari Browser. The backend consists of C++11 and XML 1.1 and the STD library and related libraries for I2C communications such as WiringPi and Python-Smbus, all operating on Raspbian OS and Debian Linux OS Minimal.

Measurable and feasible metrics will encapsulate the following attributes: Operating System Time, User Requested Direction, Pulse Width, Acceleration provided from Accelerometer, as well as Position. The motivation behind retrieving the Position and Acceleration is to compute a Project Velocity, this value will be used to dictate how our Control System functions and which pipelines we will invoke during runtime. The Operating System time will provide the delta between User Input requests, this data is valuable since we can retrieve the rate of change of direction and design our controls system with this variable in consideration. PWM (Pulse Width Modulation) efficiently chops a signal into discrete partes, the average value of voltage fed to the load is controlled by turning the switch between supply and load. This rate will dictate the magnitude of change in DC servo respectively. The features will be fully implemented when a provided result can be retrieved on the C++ environment. We can utilize the GNU Debugger and see all variables in runtime and correlate these variables to our physical system and recognize potential errors and measure this variance until satisfactory. The values mentioned are projected and will come with propagated error, if our physical system and runtime variable operate in synchronous we can continue forward and conclude our design works accordingly.

Since this is a joint project, everything we work on for this will be done as a team. However, naturally, the EEEs in this team feel a lot more comfortable in their domain and just like the EEEs feel a sense of comfortability with their domain, the CPEs also feel a sense of comfortability in their domain. Thus, each pair will work on the features of this project that they feel most comfortable and knowledgeable in. For instance, the EEEs will primarily work on the hardware aspect of this project such as properly powering DC motors and Servos so that they spin adequately. In addition, they will work on ensuring proper power transfer throughout every circuit network. On the other hand, the computer engineering pair of members are a lot more comfortable with tackling our software needs and graphical interface that our customers and evaluators will see. While the setup and wiring of our technology will need to be done before any of our software gets implemented as computer engineers we are proficient in all aspects of technology and are able to make the distinction between hardware and software development. As CPE's our main focus will be to work on our artificial intelligence software that will be vital to making our project stand out from the rest. We will be working in python code to implement a model that can be referenced by our software to categorize objects seen through our camera sensor. They will also implement a fully functional and visually pleasing graphical interface unit that will allow any user both technically inclined or not to easily access the features and movement of our robotic system for both testing and real life deployment. We will expand on these responsibilities as we go through the semester.

For this project we estimate that many hours will need to be contributed by each team member both individually and collaboratively to implement each and every one of the features we are committing to including at the end of the project. Overall to complete this project we estimate that we will take about 700 hours per semester as a team to finalize our project. Our main features which allows a user to remotely connect to our robotic system and control movement and initialize system sensors and components is estimated to take 100 hours per semester. Servo Control essential to the movement of our system which we estimate to take another 100 hours to build and connect properly per semester. Linear locomotion from our 4 dc motors for movement will take about 50 hours per semester. Visual identification of objects through our visual sensors will require 100 hours of implementation per semester. Setting up an infrared sensor to read and display our working environment temperatures appropriately will require 50 hours per semester. Synchronizing our live feed video not only to our user but our machine learning software will require 200 hours per semester. And finally storing identified objects for reference and model training will add an extra 100 hours to our project time per semester.

Nestor Garcia is one of our Electrical Engineers. His focus is on Electronics. He is a vital part of this project because of the skills he provides. As an electronics focus, he has been well studied in circuit design and analysis. For parts of our project that require proper circuit techniques, Nestor is well equipped. From supplying our system with power, to wiring the hardware, to implementing the H-Bridge circuit, and to designing the motor control system, Nestor's skills are essential. He also has experience with digital circuits and micro controllers. His experience with this will be essential to getting our motor system working and out of the schematic phase.

Justin Bolles is one of our Electrical Engineering team members. His focus is electronics and controls. Due to this, he has taken a few robotics and controls classes which is vital to our success in this project. He has troubleshooted various kinds of electrical circuits and networks and thus because of this and because of his quite vast experience, there is no doubt in our minds that this project will be accomplished successfully.

Gabriel Rodriguez is a Senior Computer Engineering major with a strong background in Linux Operating Systems and Micronctollers. He has a versatile background in implementing hardware component communications and will be essential for troubleshooting both electrical and software issues. He also has technical experience with linux environments outside of academia which will greatly benefit the completion of Project Athena. His Knowledge in these fields will assist the entirety of the project and help any barriers the team comes across. His skill set outside of technicality will be of use, leadership and resilience are vital and go beyond any minor issue. These interpersonal skills will greatly assist his classmates and completion of Project Athena.

Daniel Gonzalez is a graduating Computer Engineer with an extensive background in software development and real world experience through internships and full time positions with companies whose' focus and goal is to take technology and mold it into our daily lives to advance our quality of life. Because of this he is bringing to the table leadership and insight into how the industry approaches and plans projects to produce a reliable, efficient, and marketable project. Through this project he will be showcasing his strengths with software development and graphical interfaces for end users as he has built and developed multiple projects in coding languages such as C and Python. His main areas of focus for this project will be the development of our user interface through the use of a locally hosted web server and will also solidify all the wireless and communication aspects of our robotic system.

Punch List

Table IV.
Team 2 Spring 2021 Punch List

Feature	Measurable Metric
Directionally controlled system from individual user input and system normalization	Directional movement from user for +/- 65 degrees over 3 seconds according to current direction and stability algorithm to normalize system from sensor readings. -Current Directional State (L,R,U,D) used to invoke 13000-15000rpm Torque DC Motor -Servo Frequency (700 - 2400 MHZ) executed through PCA9685 (I2C BUS)
Locomotion from wheels on each limb to allow for quick movement across flat terrain and acceleration modulation	Robotic system will be able to move at a top speed of 4 mph when on generally flat terrain -Delta from last Input (ms) -Motor Frequency (1000 - 2400 MHZ) executed through PCA9685 (I2C BUS)
Visual Identification of humanoid like figures with additional analytics	Machine learning software will display a percentage rating on how confident it is a humanoid like figure is present in live feed video and retrieve real time variables such as coordinates and OS time. Our model uses the MSE loss function to assess the quality of error with a 70% training set and 30% validation from the total data pool. $\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(\hat{Y}_i - Y_i)^2$ -OS time (EPOCH) -System Coordinates (X,Y,Z)
Temperature gauging of surrounding area	Temperature sensor will be used to monitor temperatures surrounding the robotic system and warn of extreme temperatures above 200 degrees Fahrenheit. This will alert the operator to pull the robot out of extreme environments. -Temperature (Fahrenheit)
Live video feed for user to control unit remotely	Live feed video will be showing live statistics to keep streaming delay under 500ms -Apache HTTP WebService State -DELAY (USER EPOCH TIME - SYSTEM EPOCH)

Table IV. Punch List

IV. FUNDING

Our proposed budget for this project as a team of four members has been established to be $1000 that has been split evenly among the four of us to total a contribution of $250 each in order to research and develop the design contract that we committed to.

We have made it a goal to reach out companies for funding that fit our project's needs and goals. So far, we have received funding from Hawk Ridge Systems and Swinerton builders.

To do so we have created presentation material and a website where we can promote our product and showcase it to interested parties so that we may continue building and potentially fund our project enough to obtain components that allow us to create a reliable and efficient project.

We have also enrolled our teams project into the Sac State Carlsen Center university wide entrepreneur pitch competition in which we showcase and convey our ideas and project in a way that shows we are motivated to create and market a product in a competitive and highly detailed business sector. We have advanced to the final round and will continue to work towards receiving the top prize in this competition as we believe our project is capable of winning and becoming marketable.

Ultimately we ended up receiving support from educational foundations and private donors who wanted to see our project come to life. Now that we have completed our project we have a list of the support given by each of these individual companies/sponsors. While we did not get a dollar amount from Hawk Ridge Systems they comprise a large part of our project for taking on the manufacturing of our designed model by taking the time and resources to create Project Athena's exoskeleton. The full list of funded items we received is in the following table:

Source	Amount
Hawk Ridge Systems	3D printed parts manufacturing
Swinerton Builders	$1000
Lee Education & Heritage Foundation	$200
Private Donors	$250
Motogloss	Vinyl Stickers

Table V. Project Athena Funding

V. PROJECT MILESTONES

For this project to be successful, we had and still have various milestones to reach on schedule in order to stay on top of things and not be overwhelmed. But, most importantly, we need to reach these milestones at the right time if we want to have a working end product by the end of the school year. Thus, through this section we will go over the most important milestones that we have to reach by the end of this semester. These milestones can be found in our Gantt chart.

A. Hardware

The very first milestone that we have listed in our Gantt chart is labeled as motor control system demo build. This; essentially, is a fancy way of writing motor control demonstration. Through this demonstration, we demonstrated that we could control the direction in which a DC brushed motor's shaft spinned. We also demonstrated that we could control the speed at which the shaft of the same motor spinned. This was an important milestone for us to reach because this demonstrated that we understand how to control motors and thus could upscale. What we mean by this is that we demonstrated that since we understand how to control motors, instead of using small 5V DC motors, we can replace those with 12V DC motors.

The second milestone that we have listed in our Gantt chart is labeled as sensor reliability demo. This means that we have to demonstrate that we can reliably retrieve data of interest to us from sensors without much lag. This is a milestone that we have yet to reach but this is important; nonetheless, since a large portion of what our robotic system does depends on real time sensor data. For example, we need to know if our robotic system is lopsided because a slight imbalance that our system goes through could have it tip over and potentially destroy our robot.

As for the last milestone that we have to reach this semester, it's the following. It's labeled as prototype electronics build. This means that we have to demonstrate our system's internal circuitry works. Not all sensors or motors, for that matter, have to be present in the preliminary circuit network. The goal is to prove that our circuit delivers an adequate amount of power to all of the electrical components that compose the circuit. This is important because if there is anything going wrong with our circuit then this could potentially create a hazard such as a fire.

B. Software

In terms of software we have quite a few milestones listed that we would like to achieve by the time our rapid prototype is developed. The first of these is to have a working web server that hosts our local user interface webpage. This will be done with an Apache HTML server, with a UI developed in HTML/PHP allowing for control of the physical system, supervision and feedback from the system displaying potential error feedback by representation of sensor analytics. We have now demonstrated that we have a user login page providing a layer of security for our robotic system that once successfully logged into takes us into the landing page of our project. This allows the user to see a live feed video of the robotic system that is categorizing objects detected in real time. The user has access to movement controls for the robotic system. Reaching this state was an important milestone for us to complete as it was the main end user experience that would be showcased for potential buyers and evaluators. This would demonstrate that we were taking a reliable and secure user experience seriously and understood what had to be done to provide a complete and thorough product.

The next milestone that had to be reached for software was to implement a live video feed that took input and analyzed it through machine learning software that would provide our microcontroller with lightweight and accurate object detection. We have reached this milestone and have provided sample video

analysis results to the team showcasing our machine learning capabilities.
The final milestone for this project on the software side of things was to provide controls for the motors and servos that would be controlling movement across the entire robotic system. This would all be handled on the microcontroller through the use of I2C connector capabilities allowing the user to input specific movements while the microcontroller would assist in microadjustment to prevent the unit from losing balance and tipping over.

C. Structure

Project Athena relies heavily on the structure of its exoskeleton being resilient and sturdy to prevent the influence of rough terrain and extreme temperatures from damaging the unit. Because of this the first milestone in the structure of this project was to pick out a lightweight, but sturdy material that could be used to implement our design accordingly. Because of this we chose to 3D print our structure and incorporate stronger high resistance components wherever necessary. Leaving us halfway to completion on this milestone as we have not printed out and utilized these materials in our rapid prototype yet.

The second milestone relating to the structure of the project is to implement extreme temperature resistance materials and components to deal with the excessive heat we will be exposing our proposed project to. To do so we are collaborating with one of our sponsoring companies to have them build and coat essential components in our robotic system to be high temperature resistant and reflect heat to prevent unnecessary damage to components that may not be easily accessible or replaceable without full service repairs.

The third and final milestone of the structure to our project is to source and utilize heavy duty components ready to face the elements and work under extreme conditions. This means to take a longer and careful look at sensitive components such as batteries as our power source considering they have the potential to erupt and damage the rest of our robotic system. This also means to be careful with the wiring and motors we choose to implement within our project as they will need to be operating under load, and during excruciating conditions such as heat and moisture. We are close to the completion of this milestone as we are building our rapid prototype and will need to be conscious of the dangers of one of our components reacting negatively to adverse effects.

VI. WORK BREAKDOWN STRUCTURE

Project athena is a year long project running over 2 semesters of college that begins in August 2020 and will terminate in May 2021. A project of this scale only means that the amount of work required will be appropriate for the time period available to create a working product along with a full length report on the entire project. This project is a collaborative one consisting of 2 computer engineers and 2 electrical engineers that will work together to implement a working electrical system along with hardware and software needed to implement the features promised in our final product. To do so we have worked as a team to do a multitude of assignments that act as the pieces to a complete puzzle.

The first of those assignments is "Problem Statement - Individual". The very first assignment presented to us as senior designers was to clearly define a problem statement, also known as the "Societal Problem". Although we were a team our first task was to individually outline a current social issue that can be at least partly addressed by a technical solution in our specific engineering expertise. Our problem statement had to emphasize that the issue was one of long duration (six months or greater) and of high severity (affecting 20 million people minimum).

The second part of the first assignment is "Problem Statement - Team". This continuation to the first assignment was to clearly define a problem statement, also known as the "Societal Problem." The only difference this time is that we would choose as a group a single societal problem to tackle for our senior design project. Our team's final selection formed the basis for the team's project.

The second assignment is "Design Idea Contract – Project Proposal with specified feature set". The second assignment we were tasked with was to decide on a design idea contract as a team. This design idea statement was fairly specific and covered the technology employed, the resources needed and our skills applicable to the design.

The third assignment is "Work Breakdown Structure – August 2020 to May 2021". The third assignment which consists of this specific section is important to define the specific tasks of the project. The work is broken down into related tasks that, if successfully completed, will lead to a completed project. This Work Breakdown Structure is often called the "WBS". As senior designers our goal is to design and create a project in a set amount of time while providing deliverables by expected due dates. In order to do this we have to plan and assign each team mate a section of the project to do. Or else there would be no project. To do so we need to be organized and conscious of every task required to implement the features we have stated will be within the final product. Each team member is held accountable for reporting how many hours they have spent on each task they were assigned and whether they have completed it or not.

The fourth assignment is "Project Timeline – August 2020 to May 2021". This assignment will consist of visually providing the time sequence information for the chronological order that the tasks of the project were accomplished.

The fifth assignment is "Risk Assessment Report". In this assignment we identify the project's critical paths. Identify potential events and risks that may hinder the completion of a critical path. List possible mitigation strategies if that risk occurs. Prepare a risk assessment chart for the most significant risks your team identified. And ultimately address how the team will handle "social distancing" and other impacts to the project from possible public health mitigation strategies.

The sixth assignment is "Project Technical Evaluation". In which we will demonstrate the integrated components of our design idea in a complete laboratory prototype. Using the design idea feature set as a guide for the review flow, and presenting the technical details of our laboratory prototype. We will also demonstrate our project's hardware and software in a system that includes all the functional blocks of your design.

The seventh assignment is "Laboratory Prototype Presentation". This is the final assignment for the first semester of senior design. For this assignment we will demonstrate a working laboratory prototype that performs the functions of our design idea feature set as a coherent system. All while showing the functionality of our design idea. We are presenting real hardware and software in a system that addresses the societal problem by implementing our design idea.

In order to successfully proceed forward and change our mental focus from the planning stage to a building stage mentality, we must develop a game plan. We are all very busy. Hence, the reason why developing this game plan is of utmost importance.

A. Hardware

For starters the hardware side of things is composed of the following tasks. Ensure the proper function of an H-bridge module for DC brushed motor control. Additionally, we have to make sure that the PWM IC circuit can be embedded into our circuit in order to control the speed of DC brushed motors. Moreover, we must also ensure ourselves that various sensors work in an extremely reliable way.

As mentioned before, the H bridge circuit is an extremely important component for our robotic system. The research for this was done by Justin Bolles and Nestor Garcia. This is a component that is really easy to use if bought. We've had it up and running for a while. However, the PWM IC complicated things. The wiring is awkward. In addition there isn't much support for this with regards to C++ libraries. There is a short tutorial that explains how to use this IC using the Python coding language which is less than ideal since our plan is to use C++ instead of Python. However, Justin has managed to implement both of these components while our CPE team mates will seek out a way to circumvent the Python issue. The H-bridge was assigned May 2020 and completed October 2020.

The Gyroscope and Accelerometer will be paired together in order to implement the Integral gain of the PID Controller. These components have been researched thoroughly and confirmed to work from both an electrical and software perspective. For the initial stages of our prototype we will be using an ADXL345 accelerometer and then switch it up if need be or if we find a much more suitable accelerometer. Although we've thoroughly researched accelerometers and gyroscope components, we have come to the realization that there is an IC which combines a gyroscope sensor, an accelerometer and a magnetometer into just one IC. This IC is called an IMU. Thus, much more research will be conducted in order to determine if we will use individual accelerometer modules and gyroscope modules or if we'll use an IMU to decrease the amount of space that electrical components will take. However, we will focus on using separate modules this Fall semester. Much more research has to go into this and thus research will be conducted as a team while appropriate signal implementation will be researched by Nestor while the appropriate control and software implementation will be done by Daniel and Gabriel. This is a task we've recently started working on. We plan on getting this done as soon as possible.

DC Brushed motor control will primarily revolve around controlling the motors used to give locomotion to our system. These motors are controlled with an H-bridge for direction and PWM for speed. DC Brushed motors were researched by Justin Bolles. The research for selecting a DC Brushed motor and implementing it was high priority. The research began June 2020 and concluded in September 2020.

The Servo motors were directly controlled by our PWM IC. The pulse width outputted by the IC correlates to an angle position for the Servo. Justin Bolles focused on the task with high priority. The research for this was assigned June 2020 and ended September 2020.

The Raspberry Pi 4 was used for our prototype build and will be replaced by a Nividia Jetson in our final version. Daniel was the main researcher for this. His work on the Rpi 4 began in May 2020 and concluded December 2020. He will transition to the Jetson from December 2020 to May 2021.

1) Hardware Testing Plan

In order to move forward from laboratory prototype to deployable prototype, we as a team, had to devise a testing plan that would help ensure the functionality of each component that makes up Project Athena. Before doing so, we first had to identify the parameters that affect our robotic system's hardware. As such, the parameters that affect our robotic system's hardware are the following main ones: they are temperature, voltage, and current. Obviously, there are much more parameters, but these are the main ones. Now that we have identified the main parameters that affect our robotic system's hardware, we had to come up with a test timeline which can be seen in a narrated form in section IX. DEPLOYABLE PROTOTYPE STATUS. Furthermore, this timeline can also be found in Appendix J as a table.

B. Software

The GUI implementation has been carefully developed by Daniel using HTML, CSS, and PHP programming. The development has resulted in a deployed and functional interface with the ability to receive user-input and OS time and feed it back to the controls system. This work began in June 2020 and finished in beta version as of September 2020.

C++ will be used to invoke our GPIO (General Purpose Input/Output) pins. We will be using an uncommon library which differs from most implementations (libgpiod). The motivation behind this is to ensure our code functions according to a variety of microcontrollers, both PI4 and NviDia Jetson. Further options involve invoking the directory where this data exists which is /sys/class/gpio on the OS. Implementation will begin in November 2020 and end December 2020.

Tensorflow Lite is the library our ML architecture will be utilizing. This library paired with a training set will give our microcontroller the ability to detect objects in question and document them respectively. This approach will be developed in Python3 and involve other frameworks for data handling. Development has begun September 2020 and will be deployed in preliminary form at the end December 2020.

1) Software Testing Plan

The software development for this project will be critical to reaching the functionality defined by our punch list. The software parameters that will be of question are delay time, user input, as well as frequency signal. These will be cautiously deployed and analyzed by invoking pre-existing software libraries existing to integrate our UI directly to the electrical system by creating a I2C layer of abstraction. Furthermore, the *i2cdetect* command can be used on the shell of the OS in order to confirm the output of our sensor respectively.

C. Structure

The structure of our robot was designed by our ME team. They began the design in August 2020, will have a prototype ready by December 2020. Their deployable structure design should be ready by May 2021.

D. Team Leaders and Course Assignments

The team leaders were Gabriel and then Justin Fall 2020, followed by Nestor and Daniel Spring 2021. It can be observed in our WBS table from Appendix G that we have all broken up our responsibilities into different features of our project and have included each of those steps in our table.The course assignments from Fall and Spring semester are also noted within the table although they are well defined and documented above.

VII. RISK ASSESSMENT

In this section we will identify and consider any events that may negatively impact our workload, team members, assets, and or the environment. This will all be based on the idea that we consider all possible scenarios when designing and building our project. Implementing the various components to our project will present different risk factors involved while developing. These factors will vary from mechanical, hardware, and software such as insufficient network and program security, inefficient signal communications, and component malfunctions. These factors affect the project and overall performance of Project Athena so detecting and mitigating anomalies will be valuable.

Project Athena is made up of three main subcomponents as mentioned above which are hardware, software, and mechanical. The hardware presents alarming risks which include incorrect circuit implementation. Our electrical design has been validated in a virtual setting but will have to be cautiously implemented since theoretical implementations differ from experimental. Insuffice electrical components could also lead to hardware failure, our servos/motors/sensors have a projected performance shown by the manufacturers description but these variables may differ when implemented causing unpredictable performance. Furthermore, the software presents several risk factors as well. The current Software Architecture presents several pipelines of communicated data, any significant latencities or incorrect values in this data flow will lead to errors. The backend software implementation will be invoking the different servos and motors and will rely heavily on the controls system and feedback control loop. Poorly developed implementation of this control system will lead to several issues and is another important risk factor to mention. The broader technical risks of Project Athena will involve the physical integrity of the system. External variables will take a big part in this, light, temperature, humidity, nutrient levels, and geographic landscape may lead to issues when attempting to retrieve external data from both sensors and camera. Deploying our system in a populated or hazard location with unpredictable variables may affect our system and the environment. Systematic risks are also worth mentioning and may arise which might include an individual or family crisis that could distract a team member and impede their progress or responsibilities, as well as environmental crises such as earthquakes, fires, and pandemics that have shut down universities.

After taking these possible risks into account from both external and internal variables, we constructed the following risk matrices listed below divided into three parts: Hardware, Software and Mechanical each in a [Probability X Severity] format with brief explanations of each possible risk respectively.

A. Hardware Risk Factors

Hardware risk factor over probability and impact level illustrated in Table VI below.

Severity

Probability	Acceptable (1)	Alarming (2)	Limited Impact (3)	Unacceptable (4)	Intolerable (5)
5				Punctured Battery	
4			Batteries Not Holding Enough Charge		
3		Overheatin g Due to Power Overload			
2		Short if Cables are Exposed			
1	Temperatur e Effects on ICs				

Table VI. Hardware Risk Matrix

For the hardware side of Project Athena, there are many factors that could negatively affect our project. For that reason, we have compiled a table that lists factors that could put at risk our ability to deploy this project. This table can be found above. It is table V. Anyway, the first of these factors that pose a high risk to our project is the high probability that one or more batteries get punctured. We will use lithium ion batteries to power all the electrical components present in our system. Thus, knowing that these batteries, if punctured, can explode causes worry. Puncturing batteries is a possibility because our robotic system is being designed and geared towards usage near wildfires. If by any chance a tree falls on our robot, that can puncture our batteries and cause the batteries to blow up. This would jeopardize the credibility of our entire design and would destroy multiple components. For this reason, a protective casing that fully encloses our batteries and protects them from debris is important.

Another risk that is present and is highly likely to occur is the possibility that the batteries we buy discharge quickly. This is what we mean by “batteries not holding enough charge.” If this were to happen, this would leave our robot without any power and completely immobile. This is cause for concern because if the batteries that power our robotic system run out of power quickly, that would leave our robotic system potentially stranded by wildfires and this would render our project useless. If our system runs out of power quickly, it won’t do much. For this reason, considering components’ rated power is vital. We must consider how much voltage a battery is designed to supply and how much current a battery or a combination of batteries can provide per hour before we choose whatever batteries or battery we will get because all of our electrical components depend on our battery selection.

Overheating due to power overload is another big risk that we as engineering students must account for. Power overloading is a technical way of saying too much power is being supplied to an electrical component. When this happens, electrical components heat up due to too much current going through them. When this happens, if a component is supplied too much current for a long period of time, the component heats up and the component can burn. Ensuring that power overloading does not occur in our system has proven to be one of the most difficult aspects of the project because there are so many things to consider. We have to consider how much current each port of a power supply can supply. Once that is settled, we then also have to account for the size of that power supply. The smaller the power supply is, the better because that eliminates the amount of filament needed for 3D printing and thus, we save money. Moreover, there are a lot of components that we must consider when ensuring no power overloading will take place. In addition, we must consider circuit arrangements such as series or parallel arrangements. However, to ensure that power overloading will not happen, we are using CAD software to simulate circuit behaviors and to ensure proper power distribution.

Short circuits are another risk that we have to account for. Although, this is not as likely as all the other things previously mentioned, it is still something we must consider because if it were to happen this would not be good at all. To prevent shorts, we will use wire sleeves as an extra measure to prevent the stripped side of our wires from coming into contact with other wires.

Although not very likely for our project, different temperatures could affect our robot. Usually, in our engineering classes we use room temperature as the ideal temperature at which we analyze different circuits and just like in school, different electrical components’ datasheets specifically specify the range of temperatures at which different ICs should be used. If we were to exceed the temperature range in which the ICs are designed for, that can affect their performance. However, we are going to use temperature sensors that will monitor the temperature around our robot. We still have to do a little more planning, but the temperature sensors will alert us of when we should retrieve our robot from its location.

B. Software Risk Factors

Software risk factor over probability and impact level illustrated in Table VII below.

Probability	Severity: Acceptable (1)	Alarming (2)	Limited Impact (3)	Unacceptable (4)	Intolerable (5)
5		System permission issues in linux environment			ML Implementation using too much processing power
4			C++ Library not functioning as predicted		Data transferred through pipelines is incorrect User input not retrieved Slow Video Feed
3		OS Problems due to varying dependencies			Network Issues leading to slow performance
2	Security Efforts not fully functioning				
1					No Internet Connection

Table VII. Software Risk Matrix

Software risk factors differ from the other two sections since they do not rely on components, mitigation plans are composed of troubleshooting and debugging on an application and OS level.

Our current GUI design directs a user to a login page and prompts for credentials. The comparison for this user-inputted login cannot be made within the HTML scope, a layer of abstraction will have to be implemented. This can be done but sophisticated approaches utilizing linux digital certificates may interfere with other processes. The network layer of implementation varies for this project but most institutions and companies provide sufficient network layer protection making the overall project secure since these protocols exist within this layer making this particular issue acceptable.

Development for Project Athena has been conducted on different microcontrollers and environments due to the need to constraint memory and resources on the existing microcontroller. This has a chance of leading to dependency issues, documentation is essential for development so we do not waste time on debugging differences in library/application versions. Furthermore, the EEE has tested GPIO capabilities on a Python environment using specific libraries tailored for their demos. The main environment is developed in C++, all capabilities in Python will exist in WiringPI in C++ but if this is not the case we can implement a multi-programming language topology for the back-end software.

Network and connectivity issues are plausible issues that may arise while developing. These issues can lead to slow performance and video feed or even issues in the software variable pipelines. Ensuring development is in a sustainable and powerful network will play a significant part to Project Athena’s performance. This will be done by having a relatively close distance to the host domain and reducing users in the network for minimal traffic. As well as data validation when moving though significant software topology steps. Data validation will not only be constrained to user input, but also the multiple sensors within our system in order to ensure computations do not rely from a singular factor. Our controls system will check the throughput of other sensors to ensure our data is accurate and utilize common “handshake” implementations to establish concrete communications.

Machine learning will be the most resource heavy process of Project Athena.This issue has been rectified by a USB coral accelerator made by google that we plan to implement which will boost the TPU coprocessor of our microcontroller, enabling high-speed machine learning inferencing via USB-C connection. Despite these efforts the multiple additional processes running apart from the machine implementation may still require more processing power from our system. Next semester we will migrate Project Athena to a Nvidia Jetson Xavier NX microcontroller providing a significantly better CPU and GPU to support performance.

C. Mechanical Risk Factors

Mechanical risk factor over probability and impact level illustrated in Table VIII below.

Probability	Severity: Acceptable (1)	Alarming (2)	Limited Impact (3)	Unacceptable (4)	Intolerable (5)
5		Improper heat administration			Geometric dimensioning and tolerancing
4			Inadequate weight distribution		
3					
2	System Fatigue				
1					System invoking environmental damage

Table VIII. Mechanical Risk Matrix

The mechanical risks induced with the deployment environment of our project are severe and noteworthy when it comes to presenting our project to interested parties. As mentioned throughout our pitch and societal problem, our project is designed to be placed in harsh and extreme environments due to the raging wildfires in the vicinity. This means that our project will have to withstand being in extremely high temperatures and be wary of debris and obstacles presented in the course of its intended path. Thus an acceptable risk that this product contains is the one of system fatigue, while mechanical systems are usually resilient and can continue functioning for extended periods of time as long as service and maintenance is provided to them, our project may not have those luxuries during a dangerous and busy wildfire season. This stress would lead to components either failing or breaking due to the repeated exposures to heat and debris that while the robotic system has been designed to resist, may not be fully immune to. Because of this risk, we have thought ahead and looked at a cost effective option for selecting and designing our components so that they can be easily and affordably replaced in the scenario where a component or feature is rendered inoperable.

Leading us to the next risk of improper heat administration which has been a widely debated risk within our team and our partner companies that have decided to sponsor our product because they specialize in building reliable and sturdy components to prevent accidents and failures. Forcing us to analyze and take into consideration the limits of our components when placed into extreme environments that could lead to materialistic failure, or component failure due to operation outside of recommended specifications.

The final and multipart risk presented to us on the mechanical aspect of this project is the one of design and scale to take into account the multi terrain and movement capabilities we are intending to have within this project. This includes looking at a variety of different lightweight and sturdy materials that can be implemented to counterbalance the robotic system as it will be carrying a multitude of components such as batteries, microcontrollers, sensors, and motors that add up in weight and will need to distribute the loads evenly to prevent tipping over or leading to the unit getting stuck due to weight constraints.

D. Systematic Risk Factors

Systematic risks play a huge part in the planning and development of project athena. These risks include but are not limited to family crisis, academic crisis, and environmental events such as floods, earthquakes, or fires that have occurred in the last years tremendously impacting the air quality here in California. If a circumstance where a teammate becomes incapable to help assist we plan to knowledge transfer all relevant data through GIT (Software Versioning Control) as well as extensive documentation existing in our document database.

It's definitely worth mentioning here what we plan to do in order to complete our senior project while socially distancing and while adhering to state guidelines regarding COVID-19. Obviously, the pandemic has affected us. It had made in person meetings impossible which has negatively impacted some aspects of the development of our project. However, as unfortunate as this situation is, we have taken steps to adhere to state guidelines in order to prevent ourselves from catching the disease. Thus, for our reference we will outline these steps we have taken here. For starters, ever since October 9, 2020, outdoor private meetings are permitted as long as attendees live in no more than 3 different households. Moreover, meetings, if held, must not last more than 2 hours. In addition, everyone in attendance must wear a mask and physically distance plus more [26]. We; however, have not physically met but we have maintained constant communication through virtual sites. We have completed all our tasks virtually. However, we will continue to monitor the situation and we will update this section as the situation changes. We will also update this section as soon as our senior project requires us to change our behaviour.

VIII. DESIGN PHILOSOPHY

Project Athena is a project meant to help save lives and solve societal problems present within all of our lives whether we have been directly affected or not. Thus the philosophy behind creating and bringing this project to life was to show that there are ways to implement our ever evolving technology into tools for our first responders to utilize to their advantage and allow victims of these fires to reap the benefits.

Being a quadrupedal remotely controlled system, Project Athena is a scapegoat in a way for first responders to verify that victims are trapped within a building. Through the use of advanced machine learning algorithms we can assist in making quick, efficient, and critical decisions when faced with an unknown structure. The quadruped system is reliant on three essential components coming together to build a resistant, efficient and intelligent system. The structure of our project is vital to its success as it will be required to enter dangerous environments where obstacles may become present.We will be preparing for these with strong resilient materials that can repel the effects of excessive heat. Our system must be efficient as it will be operating a multitude of motors and onboard sensors that will require a substantial amount of processing power leading to a draw in energy that will need to be accounted for. Calling for multiple high capacity batteries that will give the system enough time to be deployed and return to a safe point for retrieval. We will employ a lightweight carrying case for those batteries that protects them from extreme conditions to have an adequate amount of run time before having to recharge. Ultimately the artificial intelligence our robotic system will have solidifies the selling point for our device as it demonstrates its ability to proactively search and locate victims of wildfires without having to put our first responders at risk.

IX. DEPLOYABLE PROTOTYPE STATUS

A. Fall 2020

As of the Fall semester, our project prototype's motor system is working at optimal conditions with no load. In addition, the wireless communications that direct the motors in our system to spin work perfectly.

B. Spring 2021

For the Spring semester, our robotic system will reach the deployable prototype on schedule. The motor control system has the appropriate voltage and current ratings and is running smoothly. The sensor implementation development is on track. The wireless communications are continuing to perform expected. All software development is on track. In spite of these positives, there are some tests we have to conduct to ensure that Project Athena continues to perform as expected. These tests will also ensure the project makes our deadlines. Thus, for our reference we have broken down in detail the tests we will be conducting below.

1) Hardware Testing Plan:

Consider the following: the normal current draw of each DC brushed motor we are using is 320mA. We made sure that the output of our H-bridges could handle that amount of current and more. However, there is a certain limit that our H-bridges' outputs can reach before Project Athena finds itself in an undesirable situation. For this reason, we need to test that the maximum output current of our H-bridges don't exceed 2A. This task will be assigned to Justin Bolles. This is an easy test to perform. All one has to do is hold the shaft of a motor in place and measure its current.

In addition to this, we must test a component called TCA9548A. This is an I^2C multiplexer. We must test this part, because when the voltage is measured across the TCA9548A's SDA pin to ground, the voltage my multimeter picked up was approximately 5V even though I had applied 3.3V to the TCA9548A's V_{in} input. This will be done by Nestor Garcia. The amplification effect might turn out to be normal and could be due to some internal components.

2) Software Testing Plan:

In order to test the software capabilities of our project we can begin on the highest level of abstraction which will be data retrieved from the User. All data retrieved from the user will be stored into an XML file existing in the same directory as our Driver. In order to confirm and measure the latency between communications we will examine the OS time produced from the XML with the existing EPOCH time on the Operating System. The latency between these metrics should be minimal and the values of our Athena State can be confirmed if the existing heap matches the user input. An additional concern will be the existing library implementations not being able to invoke the correct peripherals due to potential discrepancy in the data specifications provided by Nvidia. If this is the case a thorough debug will be conducted to find where such dependencies differ. These software tests will be conducted and documented by Daniel Gonzalez using GDB as well as traditional OS commands. The next potential compilation which can occur is the ML model utilizing too many resources leading to performance complications or page faults leading to an inevitable crash. The stress test and machine learning analysis will be conducted by Gabriel Rodriguez. This performance test will be achieved and cataloged by displaying statistics on how much resources our microcontroller is utilizing with the built in hardware monitoring tools along with displaying the current output performance with live object detections. We will also have to test our output video performance considering length limits, bandwidth limits, and connectivity. This can be done by running a livestream for the amount of time the power limits we will have on board can grant us. To test our bandwidth limits we will monitor the latency and delay of the video stream from the project to the user. And finally we will test connectivity by keeping an eye on the wireless signal strength from the unit to our controller and figure out the limits of connectivity in regards to distance or obstructions in the direct line of path.

C. Testing Results Report

The device test plan was for our laboratory prototype and it was meant to help identify and correct weaknesses in the build of the deployable prototype. We had to ensure that our features were functioning over a convincing set of factors. Thus we came up with an initial test plan that consisted of testing specific components of our project such as motors, voltages, software, and performance. The first of many of those tests began with the User Interface and WebService of our System. Daniel began by invoking various controls and examining the states presented in the XML file to confirm the system was correctly handling different inputs. After cautious code review and careful analysis it was shown that the System could potentially read the input states while also writing, leading to an error since the parsing algorithm would attempt to parse an empty String. Although this edge case was unlikely due to built in delays, we wanted to add efficiency to our system and also eliminate the possibility of critical error. By adding a *while buffer.size() == 0* conditional statement, combined with a timeout counter we were able to mitigate this issue and also create a more efficient system since we alleviated a *500 ms* delay for the future input. Following this, we measured delays between all our software pipelines using EPOCH time and found all measurements to be below threshold. Daniel and Gabriel also examined the CPU performance in full system deployment using *top –i* and found none of the processes to be problematic.

As for the hardware tests, Nestor looked into why there was a sort of voltage amplification effect produced by the TCA9548A IC. This amplification effect turned out to not be any kind of amplification. In reality what happened was that the internal circuitry of the controller Nestor was using at the start of this semester regulated the voltage from the SDA/SCL pins to ground. This voltage was consistently regulated to 5V. Thus, in spite of whatever kind of voltage Nestor powered the TCA9548A IC with, it's SDA/SCL lines that connected to the controller used would always be 5V since the SDA/SCL lines of the controller were internally tied to 5V. Knowing this, Nestor swapped the controller he was using to a Raspberry pi since the rpi's SDA/SCL lines are tied to 3.3V and not 5V. From there on, it was smooth sailing. Aside from this there were other tests that Nestor had to conduct with the team that were totally unexpected. How could we have expected to run root cause tests? Nevertheless, we ran root cause tests.

Testing our H-bridges to ensure their output current doesn't exceed 2A was an essential but thankfully simple task. Justin determined that the maximum current the motors will draw is when they are given the maximum PWM. This is when they are spinning at their top speed. This is an easy test to perform. Justin just needed to make sure Daniel gave the maximum PWM via code to the PCA and then he could test the current. The current was possibly at a dangerous level, so Justin needed to be caution. A multimeter was used to complete the circuit and the PWM was sent, making the motor spin at the maximum speed, drawing the maximum current. Knowing our H-bridge circuits were designed to handle no more than 2A of current, Justin needed to make sure the maximum current was comfortably below this. At maximum speed, the motor drew a max current of 0.83A which is far below 2A. This is way below what was needed to be comfortable with our current output. Our motors and H-bridges can handle this current. While testing, Justin recorded several maximums to ensure his test was accurate. The maximum never exceeded 0.83A and never went below 0.75A. All in all, Justin found testing the maximum current output of the H-bridges successful, with the maximum being well below 2A.

The I^2C protocol turned out to be quite a bit of a hassle. The major problem we ran into as a team is that the PCA9685's channels would not output any sort of PWM signal. The only signal that we could see through the Analog Discovery 2 was noise. This was especially frustrating because the PCA9685 had been working perfectly all throughout last semester. This dilemma left us with two possibilities. Either the PCA9685 was busted or the code we loaded onto the PCA9685 was not the appropriate code. To identify the problem we hooked up two oscilloscope channels to our circuit. Channel 1 of the oscilloscope was wired to the SDA line. Channel 2 was wired to a channel on the PCA9685 that we wanted to output PWM signals. Channel 2 revealed that no PWM signals were outputted. However, channel 1 indicated that the I^2C data that was transmitted from the NVIDIA to the PCA9685. This we know because the I^2C protocol operates by maintaining the I^2C SDA/SCL lines at a HIGH voltage when the bus is free. But, when data is transmitted, the voltage drops to a LOW voltage. During our tests, we saw through channel 1 that the voltage dropped LOW each time we sent data through the I^2C bus which proved that the I^2C circuitry on the PCA9685 was operational. We then decided to test our temperature sensor since this is also an I^2C device. In doing this, if the temperature sensor returned a temperature reading, this would further prove that I^2C communications were operational. Since the temperature sensor was wired to the same bus as the PCA9685, if the temperature sensor returned a reading, this would indicate that reading and writing to the I^2C bus was possible with our full circuit, and that we just weren't sending the correct code to the PCA9685. Once the temperature sensor returned a reading, we knew we were on the right track. In the end we decided to reset the PCA9685 because each time code was loaded to the PCA9685 IC we would get no response. After resetting this IC, the PCA9685 IC worked just as expected.

The final test in our plan was to document and stress test the performance levels in our machine learning implementation. In general machine learning implementations are resource heavy and require many processing threads to perform our desired object detection tasks in a timely and accurate manner. Initially we had designed this test case around our first microprocessor which was a raspberry pi 4, we discovered through basic tests on it that the performance was lackluster due to the onboard hardware. We were able to average a measly 7 frame per second average on our object detection testing. While a slowdown was expected, we did not expect the accuracy of our object detection to also suffer due to the delays in video processing. This led us to look for alternatives in microprocessors that could grant us the performance we needed, while retaining all of the features we needed to invoke our motor controls and sensors. Thus, halfway through our project we opted to swap over to a completely new platform dubbed the Nvidia Jetson NX which was specifically designed for artificial intelligence processing solutions. Leading us to also update the test plan we had originally created for object detection stress testing. In order to test the feature we implemented statistical figures that would enclose our objects of interest and display a confidence rating on how close an object matched the detected object. We also went ahead and included a similar frame per second counter as we had on our previous microcontroller. These two factors allowed us to thoroughly test the changes we expected from choosing a more powerful microcontroller. In our testing we were able to see that our object detection performance increased a little over tenfold, jumping up from around 7 frames per second to about 100 frames per second on average. This also led to an increase in the confidence levels seen on our live object detection stream as the microprocessor could keep up with the video input and conduct its analysis without bogging itself up.

In conclusion our device test plan underwent many changes over the second half of senior design. It led us to make drastic changes in our design and see extraordinary results in performance and functionality that we could not have seen otherwise. Ultimately the revisions made were a success and contributed greatly to the finalized deployable prototype that we will be showcasing at the end of the semester.

X. MARKETABILITY FORECAST

Every product has research and development costs necessary to bring an idea to life. This means that every project to ever exist has had funds appear from somewhere. This could be from the inventor themselves, investors, or paying customers who end up receiving the finished product. Because of this, successful projects are expected to have a wide market reach in order to become sustainable and ideally profitable. One way this can be achieved is by planning a project around a customer base that is vast and time irrelevant. In our case the societal problem chosen for our project was essential in narrowing down our design. It had to affect a large group of people across the world and remain a consistent sellable product for an adequate period of time. Since we narrowed down the focus of our societal problem and opted for helping solve the issue of high risk search and rescue operations for wildfires, we came up with the idea to create a deployable robot with remote control capabilities and the ability to detect humanoid objects within hazardous environments.

The consumers of our work are people trapped within burning buildings. They get to experience first hand the benefits of having a deployable robot to assist in these efforts as it makes it easier and quicker for first responders to locate and retrieve victims.

Our client is first responder teams, for our project we are focusing on fire fighting teams who need to be the first ones informed of and available to enter a hazardous environment in order to save lives. While there is other competing technology available to them, this product is entering a whole new category. Allowing for remote access to buildings without the need to risk extra human lives.

Project Athena would be competing in a new and evolving market for high tech search and rescue equipment. While the market is not yet saturated we believe that it has a chance to become a staple for first responders when choosing equipment for every situation.

Thus for our market review we would like to conduct a SWOT Analysis (Strengths, Weaknesses, Opportunities, Threats) which allows us to see how our project stacks up against competitors while considering that we are introducing a new product to the market.

Strength - unmanned, fast, reliable

For the strengths that our project presents we believe that the unmanned capabilities present a huge advantage to first responders as deploying our project within a hazardous environment mitigate unnecessary risk if unsure that victims are trapped within a structure. This also means that its deployment is rapid and easier to justify when the product is replaceable and a human life is not. Our product is reliable in terms of power, connectivity, and structure. First, our product contains a high capacity portable battery that allows it to operate remotely for a set amount of time that we have deemed adequate enough to enter, search, and exit a building. Second, our local area connection allows for remote control and a live feed video stream with machine learning technology to detect humanoid objects within a burning building. Lastly, our product will be 3D printed with heavy duty plastic filament and coated with a heat resistant resin layer allowing it to operate within extreme temperatures.

Weakness - components are not invincible, terrain, lag

For the weaknesses of our project we have to take into account the hazardous environment we are deploying our product into. There are extreme temperatures capable of melting, and rendering some of our components unusable if left within certain hotspots for too long. We also have to take into account debris and obstacles that may prevent or make traversing the environment difficult for our project as we have strayed from implementing a quadrupedal feature in exchange for a more standard movement setup. The final weakness that our product has is connectivity and response times depending on how far it has to be from the controller for it to effectively communicate and provide live video feedback with an acceptable network delay. We also have to consider that within a structure there are walls and obstructions within the direct path of the remote connection.

Opportunities - reduce risk of unnecessary entry into hazardous environments

While there are other competing robotic systems with video footage capabilities, not all of them utilize machine learning architectures in order to detect high value targets. In our case we utilize this technology to locate and give a confidence rating on whether an object matches the humanoid like figures we have embedded into our model. This is where Project Athena differentiates itself from the rest and showcases next gen technology that will make it a top choice for search and rescue equipment. This project is meant to help firefighters identify individuals trapped in burning buildings therefore reducing the amount of times firefighters have to risk their lives going into buildings that may have already been evacuated.

Threats - hazardous environment, debris, uneven terrain, connection issues

There are many threats to consider when analyzing the environment that this project was designed to be deployed in. The most important of these threats is extreme temperatures as our components were built to resist but not endure high temperatures for extended periods of time. We also take into account the debris and falling objects that may pin our project down and prevent us from recovering it. And finally depending on the size and complexity of the structure we are deploying our project in, we may lose connection or have a time sensitive delay that could render our project useless considering the quickly degrading environment.

Ultimately, this analysis leads us to the discovery that our project in fact has a huge marketability potential due to the substantial amount of search and rescue operations conducted over time. Accidents and natural disasters will occur for the foreseeable future and we will never be able to control the weather or predict events before they happen. Thus if we were to bring Project Athena to the market it would become profitable in a short amount of time. So long as we are showcasing its capabilities and reassuring our customers that this is an investment that they will not want to miss out on.

XI. CONCLUSION

Although wildfires may never cease to exist, our resourcefulness and research on such disasters may lead to improved response times and prevention during natural disasters. As humans we will never be able to control the elements but we look forward to having the technology and tools to be prepared to let nature take its course when disaster strikes. Overall our robotic system will be a breakthrough in rescue operations. It will be a cost effective and rewarding product that will help save lives. As wildfires continue to evolve and grow larger throughout the years our fire fighting technology also has to evolve. Through the combination of many different technologies we will combat an ever changing environment with as many tools as possible to lead us to a better tomorrow.

Our answer for this issue is to make a quadruped framework that can move through brutal and changing landscapes while recognizing and arranging objects using AI on a consistent video feed on board the framework. The quadruped framework is dependent on three fundamental parts meeting up to assemble a safe, effective and canny framework. The structure of our task is imperative to its prosperity as it will be needed to enter a hazardous domain where hindrances may get present. Our framework must be proficient as it will be working a large number of engines and installed sensors that will require a generous measure of torque At last, the insight of the framework will have what makes the selling point for our gadget as it exhibits its capacity to proactively look and find casualties and objects of the rapidly spreading fires. Our system will be essential from origination to attractive including our cultural issue, plan thought, model, testing and subsidizing. Project Athena will be a cost effective and rewarding product that will help save lives. As wildfires continue to evolve and grow larger throughout the years our fire fighting technology also has to evolve.

Wildfires will continue to rage on for both the foreseeable and long term future. But that does not mean that we will sit by idly as a society full of resourcefulness and initiative. research and development of tools to combat such disasters will lead to improved response times and prevention during these natural disasters. Although climate change has radically influenced how wildfires have changed, the main influence in these changes is us, humans. Rapid spreading fires are becoming a staple in natural disasters year after year. As a community and a society we should be educated on the dangers that wildfires pose and how to safely evacuate because while material objects can be replaced human lives cannot. Emphasizing the extraordinary and obscure circumstances that many individuals have faced in recent years because they were unprepared for the magnitude of these wildfires. Our answer to this issue is creating a quadruped based recovery efforts robot that will move through brutal and dynamic landscapes while recognizing and identifying humanoid objects through the use of artificial intelligence. The quadruped system is dependent on three fundamental design elements to assemble a resilient, effective and accessible system. Components will need to stand up to extreme weather and temperature conditions while also being able to withstand impacts and potential falling debris. Our system will be effective in the use of a multitude of electrical motors to move while being conscious of power consumption so as to not compromise our object detection features.Finally, our project will be accessible in terms of cost with a clear selling point that exhibits its capacity to proactively look for and find victims of rapidly spreading fires. Project Athena will be a cost effective and rewarding product that will assist in fire rescue for first responders.

This assignment in the end was a great team exercise because we needed to coordinate all our dates and objectives in one document. This was a time consuming and difficult assignment for us because it demanded this much coordination. In the end, the timeline was a much needed grasp on teamwork for our senior design team.

As senior designers we have had to plan and produce a working prototype representative of our final product that we would like to bring to market. But we have to take into account many risks when working on this project whether they are blatantly obvious or not. We've taken a larger and broader view of the risks associated with our project and have come together to create a narrative from idea conception to a fully working prototype status of our project. Through this process we have discovered that this year's senior design is like no other due to external factors such as global pandemics and remote learning environments forced upon us to mitigate further risks. We have taken those risks into account and discovered ways to collaborate and work on a group project in ways that many never expected to. This has led us to define and prioritize the critical paths needed to have a working product once we brought all of our features together as one. All while being wary of the technical risks presented to us through the delays in shipping times of components, faulty components, and mistakes in our design that were not clearly seen. As collaboration through a virtual environment was not the best way to troubleshoot and look for solutions to an issue. Thus, leading us to conclude that a project of this scale would have its fair share of risks and identifying and going over each and every one of those risks would assist us in mitigating and preventing most of those risks before they even occurred.

In our second semester we were required to reexamine our project and agree on how to move forward in the Spring 2021 semester. Our Problem Statement needed to be fine tuned to address fires more specifically. We have focused our problem statement to be the trouble that fires cause for firefighters' search and rescue efforts. If our robotic system can assist firefighters, it has more of a direct societal impact and is more in sync with our design. After we agreed to adjust our statement, our Change Order got approved so we needed to reflect those changes within the documentation. All in all, this assignment was solely about getting our team refocused on this upcoming semester and readjust our outlook.

We also had to go over the tests we must conduct in order to certify that our project is ready to be deployed within the environment that we specify within our design guidelines. A project that is market ready must be able to perform as advertised or else it would fall under the scrutiny of false advertising. To not fall under this category of market ready "flops" we have written up a device test plan with factors and plans on how to effectively test and account for every possible project operational issues. Considering how we intend to deploy our project within burning buildings we need to account for the extreme temperatures and dangers at every second due to the time sensitive nature of search and rescue missions. That is why we must ensure that this project is as rugged as possible. Throughout this section our test plan will help us check possible ways in which Project Athena could find itself in an undesirable situation. Admittedly, there are factors and scenarios that we may not be able to account for due to the wild nature of fires. However, through this section, we have come together as a group to identify all of the factors that could affect our project not only on a component level basis, but also as Project Athena in its entirety. Thus we believe that while our device test plan will not cover every conceivable factor or threat to the integrity of

our project we will make sure that it demonstrates its capabilities within controlled environments in order to be deployed on the field with confidence in some future.

In the market review we conducted a SWOT Analysis (Strengths, Weaknesses, Opportunities, Threats). This allowed us to view our project from a buyer's perspective considering we are introducing a new product to the market. For strengths, we found our project to be unmanned, fast, and reliable. For weaknesses, we isolated our project's components are not invincible, the terrain when difficult can prove challenging to navigate, and overall system lag. Concerning opportunities, our team determined our systemd would reduce risk of unnecessary entry into hazardous. This opportunity is the heart of our project. By aiding in the firefighting process, our system is both desirable and an aid to society. Finally, for threats our team decided hazardous environments, debris, uneven terrain, connection issues. All in all, our system provides an intriguing opportunity to buyers. This assignment was a fantastic exercise for our team to view our robotic system as a buyable product. This was by far one of the most applicable assignments thus far.

Lastly, the device testing results were a success and verified that our deployable prototype, while ambitious, was ready for the final stages of the build. Our software is ready and can control our motors and servos for locomotion functions while providing the necessary processing power to conduct live feed video object detection. All of our intended features worked individually and now only need to be implemented together. This task will be conducted soon as we have received the fully 3D printed exoskeleton designed from our sponsoring company, Hawk Ridge Systems. Although the test results were positive they did impact our project by allowing us to see how effective the changes to the project throughout the semester were. We noticed performance, reliability, and quality of life improvements that could have otherwise gone unrealized if we had stuck to our original build plan and tested only for those specific cases. Thus revising and updating our test plan resulted in a much more optimized and complete project to showcase for our end of project report.

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GLOSSARY

Define our main terms here.

Climate change - The changes in the Earth's climate due to varying weather patterns for long periods of time.

Graphical User Interface - GUI. A type of user interface that provides graphical elements to make it easier for humans to interact with computers.

API - a set of functions and procedures allowing the creation of applications that access the features or data of an operating system, application, or other service.

TensorFlow - TensorFlow is a free and open-source software library for dataflow and differentiable programming across a range of tasks. It is a symbolic math library, and is also used for machine learning applications such as neural networks

I2C - A serial protocol to connect devices such as microcontrollers to our system and the components it will communicate data to

Pulse Width Modulation - PWM. A means to change the average voltage of a signal by changing the width of the pulse. Used for DC brushed motor speed control and Servo position control.

H-Bridge - A Circuit to control motor direction via transistors

DC Servo Motor - A motor that moves to a specific angle when given a corresponding pulse width

DC Brushed Motor - This is a motor that uses two wires. It's powered by DC current and has wound wires for an armature. This type of motor uses a commutator for rotation of the motor shaft.

Multi-Channel PWM - This is an integrated circuit that has several PWM pins that output pulse signals. It's used to regulate the speed of various motor

Appendix A
User Manual

This is where we will place our user manual once we get a working prototype and can define all of our functions and components accurately. This will serve to assist users, primarily customers in the initial setup of their product along with instructions on how to troubleshoot potential problems.

How to operate our deployable prototype:

Our project uses a custom made GUI that makes our robotic system extremely easy to use. Project Athena can be turned on by pushing the power and AC button for 2 seconds on the external power supply. Once the battery's indicator light comes on, this means that Project Athena is in standby mode and awaiting command. Furthermore, considering that our custom WebService is a multi-browser platform, all one needs to access Athena is the website's URL and the login credentials to access the controls page. Note, you must be on the same network connection as Project Athena to connect to the unit. The motivation behind this is to ensure limited users can access the System, Once configured Athena by default exists on *athena-desktop.local/* where the user is prompted with credentials, these credentials are confirmed and the user is redirected to the Controls UI. The controls page holds an *initialization*, *shutdown,* and *controls d-pad (Directional Pad)* which the user can use to switch the existing state of the System to invoke servos/motors, additionally the livestream footage being captured is analyzed by the machine learning architecture and redirected to the UI using RTP protocols to broadcast the object detection.

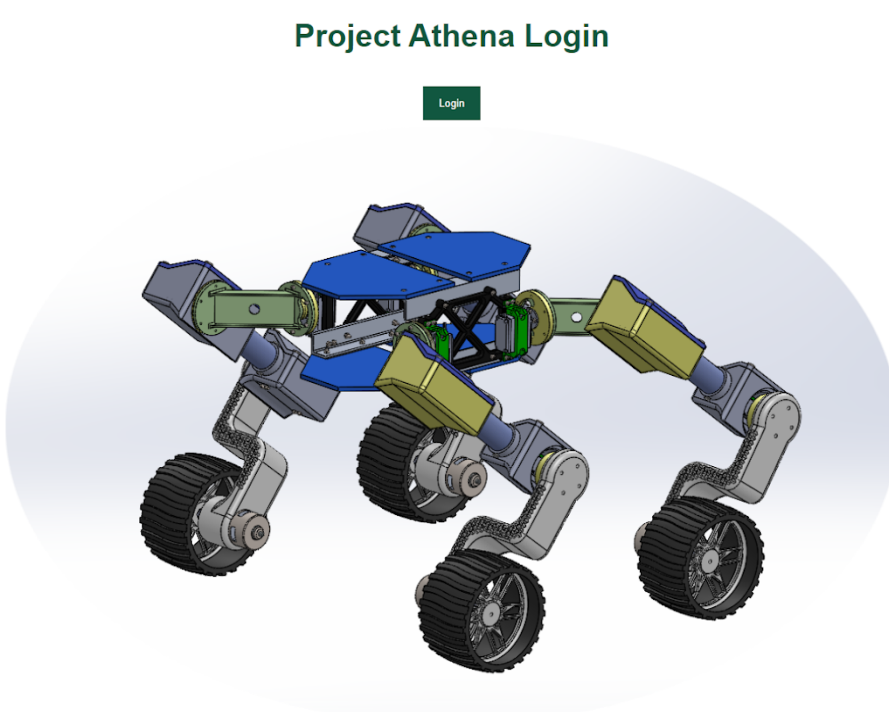


Fig A1. UI Login [27]

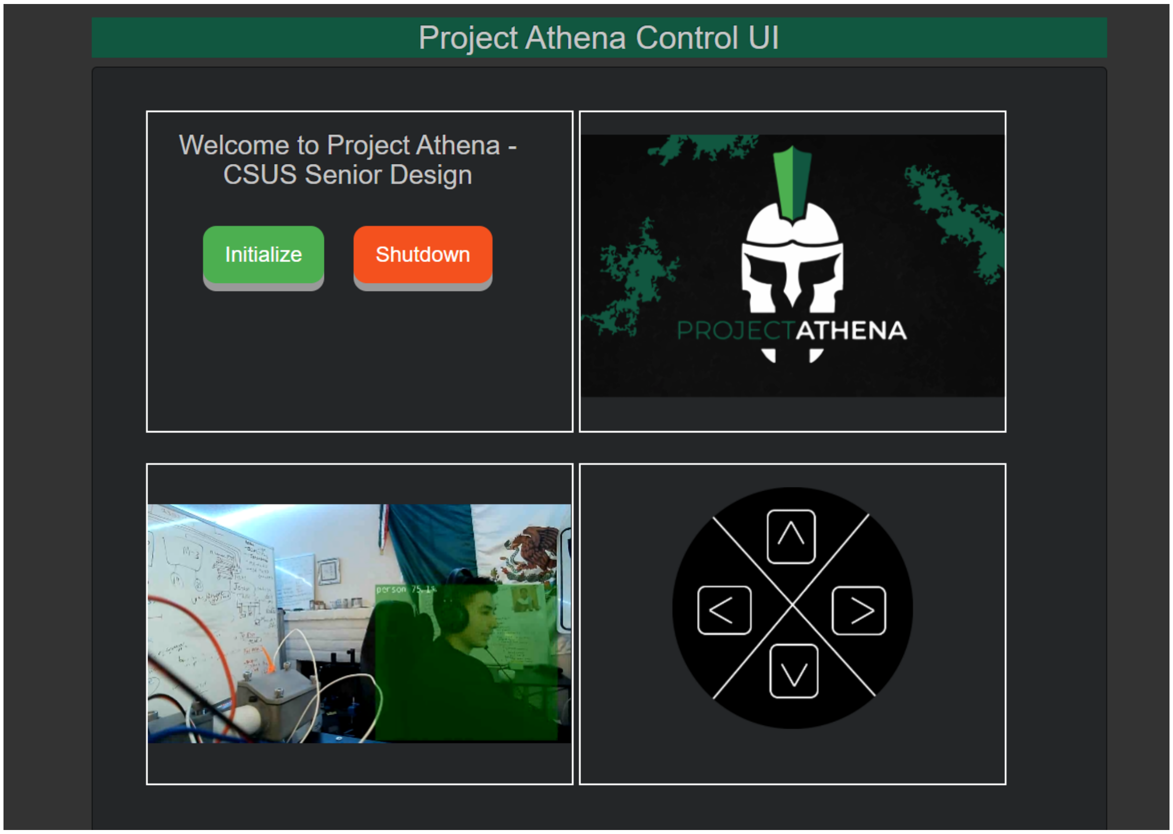


Fig A2. UI Controls [27]

Appendix B
Hardware

Project Athena is a hardware heavy project that incorporates custom manufactured parts along with off the shelf components to build a reliable, sturdy, yet affordable system accessible to our consumers.

The components consist of 3 categories;

Movement:

1. 20kg Servo (8)
2. 60kg Servo (4)
3. DC brushed motors (4)

Control:

1. Nvidia Jetson TX
2. PCA 9685 (2)
3. L298N H Bridge (2)
4. High Definition USB Camera
5. Temperature Sensor

Electrical:

1. 10000mah portable battery pack
2. 5200mah portable battery pack (4)
3. Proto Board (3)
4. 20 AWG wires (many)
5. Jumper Wires (many)

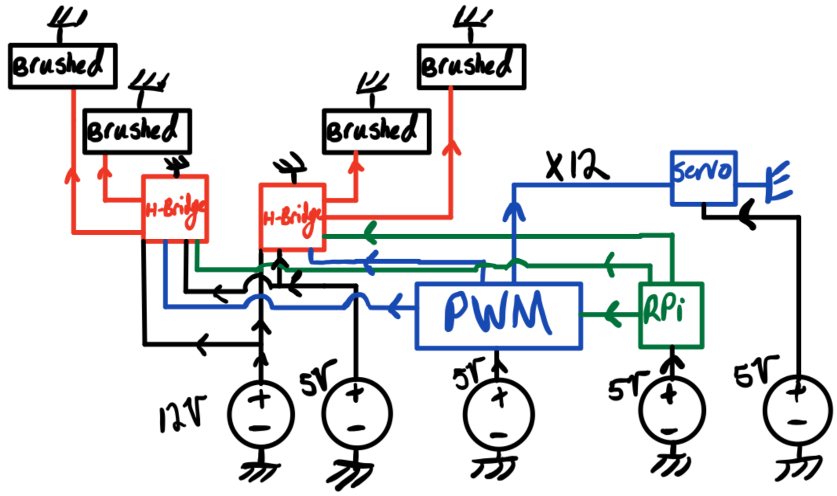


Fig B1. Full Motor Control Circuit Schematic [27]

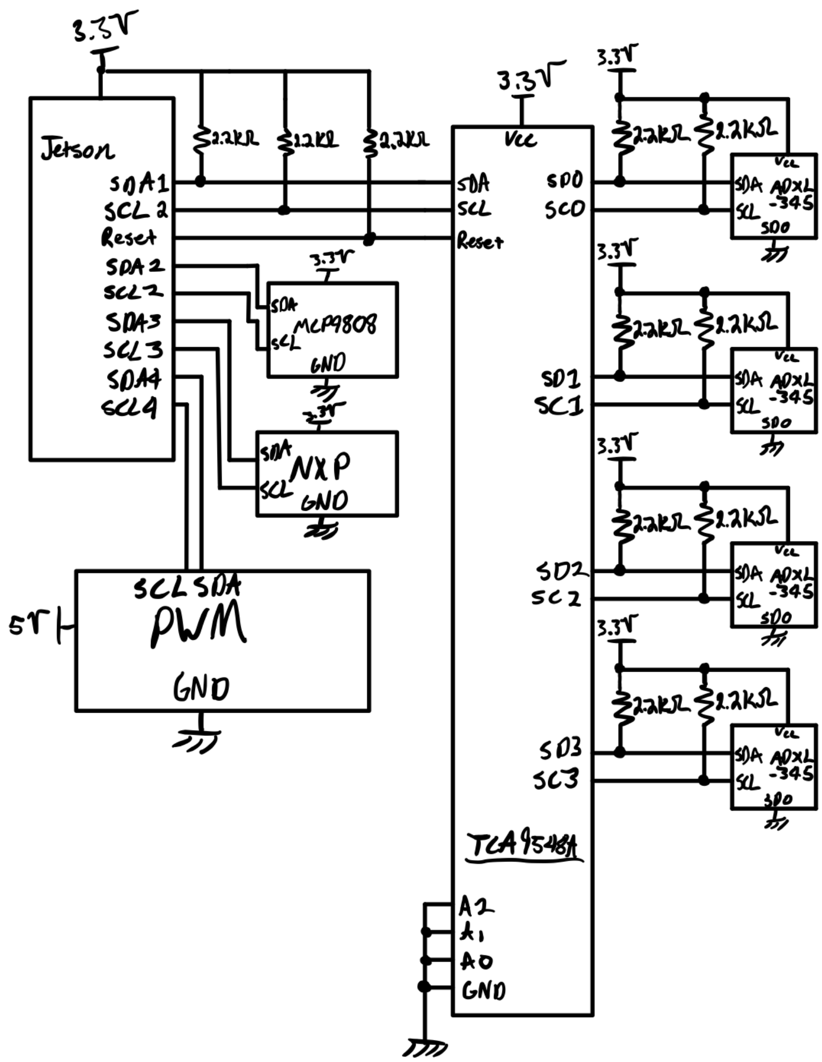


Fig B2. I2C Circuit Schematic [27]

Appendix C
Software

Project Athena relies on a multitude of software and coding algorithms to operate and produce some of the key features to the project. This includes a remotely controlled user interface hosted on the web, machine learning technology to detect objects, and servo and motor control to work in conjunction for locomotion.

The user interface is hosted on a web server provided by Apache which is an open-source HTTP server for modern operating systems including UNIX and Windows

The object detection is based upon the ImageDetect Nvidia library which is a free and open-source software library for machine learning.

The servo and motor control come from I2C libraries that allow the microcontroller to interact with the PCA that decifiers the pulse width signals coming out of the microcontroller to set and activate each and every servo and motor depending on the channel being invoked.

Appendix D
Mechanical Aspects

Project Athena was a joint discipline project between the CPE and ME departments at Sacramento State. Thus, the mechanical aspects were handled and designed by the mechanical team while complying and collaborating with our electrical team to achieve the rated specifications necessary to deploy project athena. The mechanical team designed project athena from scratch in autoCAD and created a 3D file that was printed and manufactured by our sponsoring company Hawk Ridge Systems.

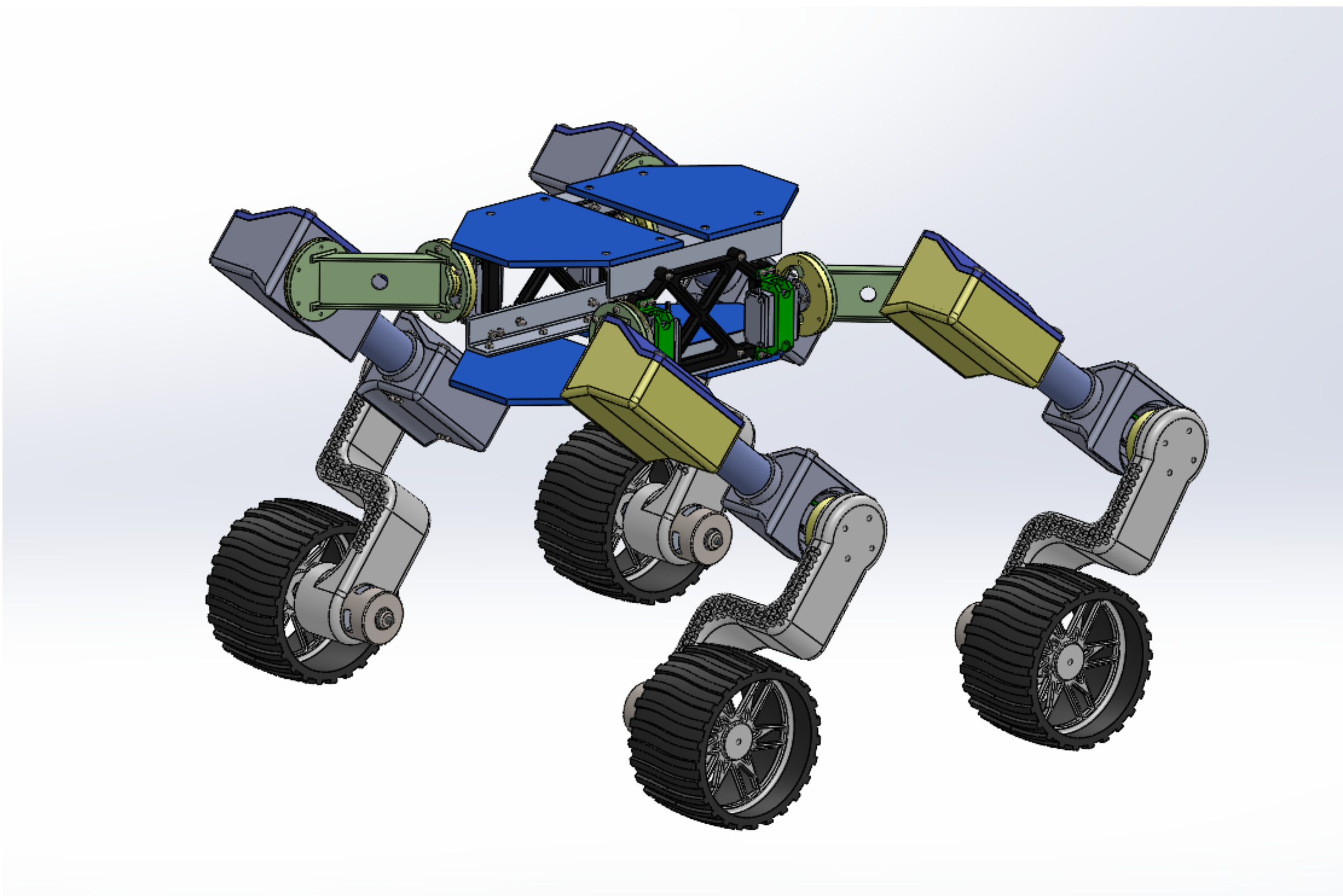


Fig D1. Project Athena CAD render [27]

Appendix E
Vendor Contacts

Table E1.
Company Funding

Project Athena Funding	Source	Amount
	Hawk Ridge Systems	3D printed parts manufacturing
	Swinerton Builders	$1000
	Lee Education & Heritage Foundation	$200
	Private Donors	$250
	Motogloss	Vinyl Stickers

We have received funding from Hawk Ridge Systems and Swinerton builders. To do so we have created presentation material and a website where we can promote our product and showcase it to interested parties so that we may continue building and potentially fund our project enough to obtain components that allow us to create a reliable and efficient project.

We have also enrolled our teams project into the Sac State Carlsen Center university wide entrepreneur pitch competition in which we showcase and convey our ideas and project in a way that shows we are motivated to create and market a product in a competitive and highly detailed business sector. We have advanced to the final round and will continue to work towards receiving the top prize in this competition as we believe our project is capable of winning and becoming marketable.

Ultimately we ended up receiving support from educational foundations and private donors who wanted to see our project come to life. Now that we have completed our project we have a list of the support given by each of these individual companies/sponsors. While we did not get a dollar amount from Hawk Ridge Systems they comprise a large part of our project for taking on the manufacturing of our designed model by taking the time and resources to create Project Athena’s exoskeleton.

Appendix F
Resumes

Daniel Gonzalez

gonzalez.daniel841@gmail.com | www.linkedin.com/in/DanielGonzalez19

Education:
California State University, Sacramento
Bachelor of Science in Computer Engineering & Minor in Mathematics Expected: Spring 2021

Knowledge and Skills:
- Languages: Java, C++, Python, PowerShell, C, Verilog, VHDL, x86 Assembly
- Software and OS: GDB, Git, Linux, JIRA, Confluence, SharePoint, PowerBi, Office 365, Packer, Windows, macOS

Work Experience:
Lockheed Martin, New Jersey - *Systems Engineering Intern* **June 2020 – August 2020**
- Supported AEGIS weapon combat system Baseline 10 missile team, emphasis on C++/GIT/GDB/Linux/Python
- Refactored geometry outputs for AAW/BMD missile threats, utilizing a new output manager, removing 200+ lines
- Implemented change requests to add accuracy in probability matrix during missile acquisitions in simulation
- Debugged and troubleshot discrepancies in tactical vs simulated data by using GDB in C++ code base

SMUD, Sacramento - *API Development Intern* **April 2020 – June 2020**
- Engineered RESTful API for GIS (Geographical Information System) to SAP using software AG designer(Eclipse IDE)
- Dev work emphasized GIT, JDBC, SQL, Postmates for API testing, SCRUM framework and weekly sprints

SMUD, Sacramento - *Information Technology Applications Intern* **May 2019 – April 2020**
- Developed PS scripts in order to automate tasks which involved SharePoint/Security Tools/Excel/Outlook Mail
- Used PS to assist on SharePoint migration by automating metalogix tools for 900+ sites, wrote HTML/JS Snippets
- Worked on PowerBi Analytic report for storage team clusters and rewrote PS script writing to SQL database
- Researched alternative windows security patching policies for specific application servers

CounterTack Inc, Rancho Cordova - *CounterTack DevOps Intern* **May 2019 – Aug 2019**
- Worked alongside DevOps engineer in order to automate and test processes through Packer and VirtualBox
- Grew and developed familiarity with VM provisioning by writing installation preset software through JSON
- Internship resulted in daily use of Atlassian software such as JIRA, Confluence, Stash, Bamboo, and Jenkins

California State University, Sacramento - *Mathematics Tutoring Lab Facilitator* **Aug 2018 – May 2019**
- Facilitated and mentored the learning of students enrolled in a wide range of mathematics courses
- Maintained an appropriate learning environment and proctored students who scheduled exams in the lab

Poke Moana, Livermore - *Manager* **May 2018 – Dec 2018**

Projects:
IEEE Visual Analytic Challenge **May - June 2019**
- Annual challenge presented by IEEE which required the sorting and organization of 80,000+ earthquake seismic readings in order to extract valuable statistics used to prioritize locations where dispatch may proceed
- Wrote backend end software using an object-oriented approach and personalized sorting algorithms
- Project used Tableau in order to give significant information to support our analysis accordingly to present data

Project Homestead **Feb 2019 - May 2019**
- Team-based project-oriented to automate home appliances on mobile application using a Bootstrap framework
- Application utilizes lights, fan, temperature, through a Raspberry Pi that communicates with various hardware
- Project emphasizes a mixture of hardware sensors/modules and JavaScript/Python/PHP software engineering

UNIX Mini Shell **Oct 2018 - Dec 2018**
- Learned a user Interface aspect of a UNIX shell with process management and basic system calls
- Utilized the built-in functions executed by the shell rather than forked by executing an executable through C

2048 Emulator **Dec 2018**
- Personal project that emulates the popular 2048 app game through a Java Algorithm which emphasizes OOP
- Randomly generates integers on the UI and runs accordingly through logic to update the existing environment

Clubs and Activities:
- Member, Mesa Engineering Program (MEP) **Fall 2017 – Present**

Justin Bolles

jtbonlybro@yahoo.com | www.linkedin.com/in/justin-bolles

Education:

California State University, Sacramento
Bachelor of Science in Electrical & Electronics Engineering Expected: Spring 2021

Los Medanos College, Pittsburg, CA
Transfer in Engineering August 2017 – May 2019

Knowledge and Skills:

- Theory: Circuit Analysis, Circuit Design, Logic Design, Electromagnetics, Mathematics, Physics
- Hardware: Oscilloscope, Raspberry Pi, STM32 Nucleo-144, Parallax Propeller,
- Software: PSPICE, STM32Cube, AutoCAD, Microsoft Office Suite
- Languages: x86 Assembly, C++, C, Python, Verilog HDL, MATLAB, Wolfram Language

Work Experience:

Los Medanos College - *Math Tutor* **January 2018 – May 2019**

- Assisting students in multiple levels of math classes
- Help the professor during lecture answer any questions that arise
- Developing leadership skills through guiding students through challenging assignments

Projects:

Project Athena **May 2020 - Present**

- Senior Project Design robot focusing on:
- DC Brushed and Servo Motor control
- GUI wireless control
- Sensors and Microcontroller programming

Guitar Tuner **May 2020**

- Raspberry Pi which receives input from Parallax Propeller which controls a microphone sensor
- State function built in C to choose guitar string being tuned
- Deployed web page that displays if string is tuned

Heartbeat Sensor **May 2019**

- An analog circuit able to read heartbeat when finger is applied to does
- Circuit consists of Diodes for pulse detection, LED Diodes to display pulse, op amps, resistors and capacitors

Organizations:

- Member, Mathematics, Engineering, Science Achievement (MESA) **August 2018 – May 2019**
- Member, Institute of Electrical and Electronics Engineers (IEEE) **October 2019 – Present**

Relevant Coursework:

Electronics I, Intro to Microprocessors, Electromechanical Conversion, Communication Systems, Probability of Random Signals, Circuit Analysis I & II, Applied Electromagnetics, Signals & Systems, Intro to Logic Design, Engineering Economics, Introduction to C++, Differential Equations, Single and Multivariable Calculus, Physics – Mechanics & Electromagnetism, Introduction to Engineering, and General Chemistry 1.

Nestor Garcia

nestorabrahamgarcia@gmail.com

Education:

California State University, Sacramento
Bachelor of Science in Electrical and Electronics Engineering Expected: Spring 2021

Knowledge and Skills:

- Languages: Java, and C
- Software and OS: Office 365, Windows, and macOS
- Hardware: Circuit Analysis, DMM, Oscilloscope, AD2, PSpice, and MATLAB

Work Experience:

Pegatron **May 2020 – August 2020**
Operator

- iPhone Repair
- Disassembly
- Various Troubleshooting Tests

Kovar's Satori Academy **Dec 2014 – Jun 2015**
Teacher's Assistant

- Led a few workshops
- Taught students self-defense techniques

Projects:

BJT Light Switch **Sep 2020**

- This is an analog circuit used to simulate the operation of an H-bridge circuit
- Designed a circuit that used two BJTs. I biased this circuit in a way that turned on and off an LED

Heartbeat Detector Circuit **May 2019**

- This is an analog circuit used to detect heartbeats
- Wired the entire circuit network
- Troubleshooted the entire circuit

Micromouse **June 2018**

- This is an autonomous robot that moves from a starting point in a maze to the center of the same maze

Clubs and Activities

Officer, IEEE **June 2018 – Jan 2019**

- My role was to assist the webmaster with a few HTML assignments

Unofficial Officer, ACM **June 2018 – Jan 2019**

- Assisted with fundraising tasks

Gabriel Rodriguez

gerodrig97@gmail.com | https://www.linkedin.com/in/gerodrig97/

Education:

California State University, Sacramento

Bachelor of Science in Computer Engineering Expected: Spring 2021

Knowledge and Skills:

- Languages: Java, C++, Python, PowerShell, C, Verilog, VHDL, x86 Assembly
- Software and OS: GDB, Git, Linux, SharePoint, Office 365, Packer, Windows, macOS

Work Experience:

California State University Sacramento, Sacramento - IT Student Assistant **Feb 2020 – Present**

- Administrative support in requests for IT assistance, repair, and setup
- Familiarity with computers and other IT devices as well as Microsoft Office and Adobe programs

Rayley's, Sacramento - *System Technician I* **Jan 2018 – Jan 2019**

- Monitors mainframe computer systems and peripherals
- Pushes software updates to users as released by vendor
- Dev work in GIT, SQL, SCRUM framework and weekly sprints
- Oversee and modify scheduled production jobs
- POS Server Image and Configuration
- Level 2/3 Engagement to Resolve Common Issues

Bel Air, Sacramento - *Deli Clerk* **Apr 2017 – Dec 2017**

- Cross trained position with a very steep learning curve
- Responsibilities including handling of money, and following food preparedness and sanitation guidelines
- Customer service is essential in this position where customers may be in a hurry, or in need of assistance

Sacramento Food Bank and Family Services, Sacramento - *Intel Clubhouse Mentor* **Aug 2015 – Mar 2016**

- Intel Sponsored after school technology discovery program for students from underserved communities
- Mentor to a group of 10 students ranging in ages from 5-15 years old
- Planned daily projects and activities to advise, nurture, and create interests in technology for young students

Projects:

Mini Smart Home Security System **Jan 2019 - May 2019**

- Working prototype
- Wrote project in C code to allow microcontroller used for sensors and motors
- Project was self arming and disabling depending on certain conditions

Pipelined Processor **Jan 2020 - May 2020**

- Replicated a pipelined processor CPU in Verilog
- Allowed for tasks to be run in multiple threads at the same time (hyperthreading)
- Contained CRC recursive error checking

TensorFlow AI Algorithms **Aug 2020 - Dec 2020**

- Tested and deployed a custom machine learning model that identifies specific objects through AI
- Will be converting data from models into information for a quadrupedal robot that assists in fire recovery efforts

Clubs and Activities:

- Member, Society of Hispanic Professional Engineers(SHPE) **Fall 2017 – Present**

Appendix G
Task List

Table G1.

Work Breakdown Structure Overview

Level 1	Level 2	Level 3
Locomotion		
	Motor movement	System Stabilization
		Forwards
		Backwards
User Interface		
	Web server	
		Video feed
		Digital controls
		Network connectivity
Artificial Intelligence		
	Object detection	
		Video analysis
		Humanoid detection model
		Detection results output

Appendix H
Gantt Overview

Table H1.

Gannt Chart

Gantt Chart

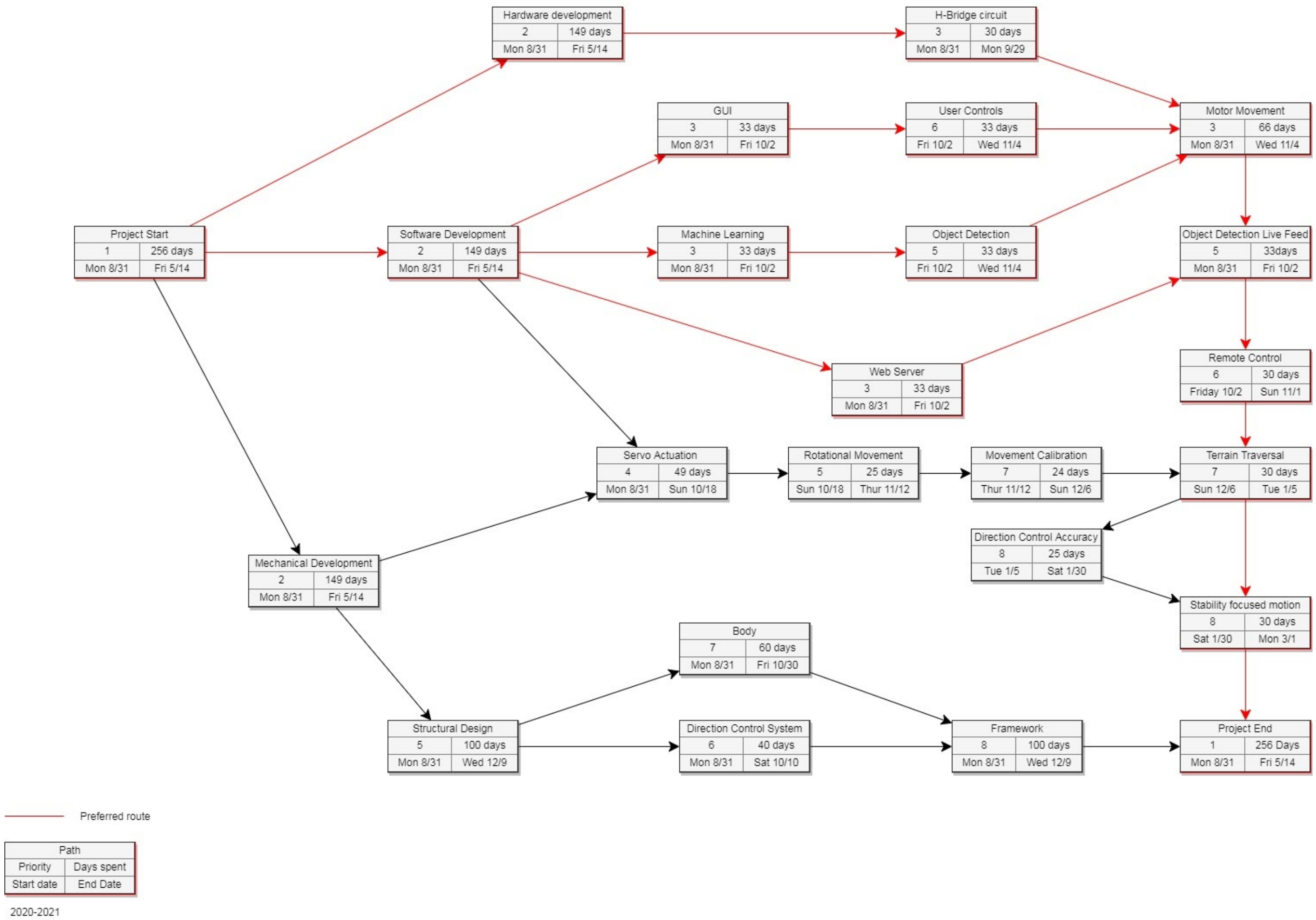
Task Family	Milestones	Task	Status	Priority	Start Date	Due Date	Assignee	Team Leader	Notes/Updates	
		Select electrical components	Completed	High	5/25/2020	11/2/2020	Justin/Nestor	Gabe/Justin	IR sensors required	
		Motor Control Research	Completed	Medium	5/25/2020	8/31/2020	Justin/Nestor	Gabe		
		Motor Control System Proof of Concept	Completed	Medium	7/1/2020	10/31/2020	Justin/Nestor	Gabe/Justin		
	Motor Control System Demo Build		Completed	High	10/31/2020	10/31/2020	Justin	Gabe/Justin		
		Sensors approval by team	Completed	High	10/27/2020	11/9/2020	Justin/Nestor	Justin		
		Full Wiring Concept Schematic	Currently discussing	Low	11/9/2020	11/15/2020	Justin/Nestor	Justin		
		ADXL 345 Accelerometer Implementation	Initial stages	Low	11/9/2020	5/3/2021	Justin/Nestor	Justin/TBD		
		Physical I2C bus wiring	Planning stage	Low	11/9/2020	11/15/2020	Justin/Nestor	Justin		
		Soldering pins onto board	Completed	Low	11/9/2020	11/15/2020	Justin/Nestor	Justin		Discord voice and text
Hardware		H-Bridge Implementation	Completed	High	7/1/2020	10/31/2020	Justin/Nestor	Gabe/Justin		
		Multi-Channel PWM Implementation	Completed	High	8/1/2020	10/31/2020	Justin/Nestor	Gabe/Justin		
		IMU sensor implementation	Initial stages	Low	11/9/2020	5/3/2021	Justin/Nestor	Justin/Nestor/Daniel		
		Physical I2C bus wiring	Initial stages	Low	11/9/2020	11/15/2020	Justin/Nestor	Justin		
		Soldering pins onto board	To be completed	Low	11/9/2020	11/15/2020	Justin/Nestor	Justin		
		IR sensor implementation	Initial stages	Low	11/9/2020	5/3/2021	Justin/Nestor	Justin/Nestor/Daniel		
	Sensor Reliability Demo		To be completed	Low	5/3/2021	5/3/2021	Justin/Nestor	Justin/Nestor/Daniel		
	Prototype Electronics Build		To be completed	High	12/11/2020	12/11/2020	Justin/Nestor	Justin		
	Final Electronics Build		To be completed	High	5/14/2021	5/14/2021	Justin/Nestor	Daniel		

Task Family	Semester	Task	Status	Priority	Start Date	Due Date	Assignee	Team Leader	Notes/Updates	Method of Coordination
		Assignment 1a - Individual Problem Statement		Very Low	5/20/2020	9/24/2020	Team	Gabe		
		Assignement 1b - Team Societal Problem		Very Low	9/21/2020	9/28/2020	Team	Gabe		
		Assignement 2 - Design Idea Contract		Very Low	9/28/2020	10/5/2020	Team	Gabe		
	Fall 2020	Assignment 3 - Work Breakdown Structure		Very Low	10/15/2020	10/26/2020	Team	Gabe		
		Assigment 4 - Project Timeline		Very Low	10/26/2020	11/2/2020	Team	Gabe/Justin		
		Assignment 5 - Risk Assessment		Very Low	11/2/2020	11/9/2020	Team	Justin		
		Assignment 6 - Project Technical Evaluation		Very Low	11/9/2020	12/7/2020	Team	Justin		
		Assignment 7 - Laboratory Prototype Presentation		Very Low	11/9/2020	12/11/2020	Team	Justin		
Class Assignments		Assignment 1 - Revised Problem Statement		Very Low	1/27/2021	02/01/2021	Team	Nestor		Discord voice and text
		Assignment 2 - Device Test Plan Report		Very Low		02/08/2021	Team	Nestor		
		Assignment 3 - Market Review		Very Low		03/01/2021	Team	Nestor		
	Spring 2021	Assignment 4- Feature Report		Very Low		03/08/2021	Team	Nestor		
		Assignment 5- Testing Results Report		Very Low		04/05/2021	Team	Daniel		
		Assignment 6 - Ethics Quiz		Very Low		04/19/2021	Team	Daniel		
		Assignment 7- Deployable Prototype		Very Low		4/26/2021	Team	Daniel		
		Assignment 8- Final Documentation Report		Very Low		05/03/2021	Team	Daniel		

Task Family	Semester	Task	Status	Priority	Start Date	Due Date	Assignee	Team Leader	Notes/Updates	Method of Coordination
		Select Visual Components	Completed	High	5/25/2020	11/2/2020	Daniel/Gabriel	Gabe/Justin	Camera sensor requi	
		Machine learning research	Completed	Medium	5/25/2020	8/31/2020	Daniel/Gabriel	Gabe		
		Web server choice	Completed	Medium	7/1/2020	10/31/2020	Daniel/Gabriel	Gabe/Justin		
	Web server build									
		Apache web server deployment	Completed	High	10/27/2020	10/13/2020	Daniel	Justin		
		Graphical User interface build	In progress	High	11/9/2020	11/15/2020	Daniel	Justin		
		Port forwarding of web server	Completed	Low	11/9/2020	5/3/2021	Daniel	Justin/Nestor/Daniel		
		PHP code handling	In progress	Low	11/9/2020	11/15/2020	Daniel	Justin		
		Security implementation through user login	Completed	Medium	11/9/2020	11/15/2020	Daniel	Justin		
Software	Machine Vision Demo Build									Discord voice and text
		Object detection sample tests	Completed	High	8/1/2020	10/31/2020	Gabriel	Gabe/Justin		
		Visual sensor demo for team	Completed	Low	11/9/2020	5/3/2021	Gabriel	Justin/Nestor/Daniel		
		Live stream video implementation	Completed	Medium	11/9/2020	11/15/2020	Gabriel	Justin		
		Tensorflow architechture implementation	Completed	High	11/9/2020	11/15/2020	Gabriel	Justin		
		Data log confidence levels of object detection	In progress	Low	11/9/2020	5/3/2021	Gabriel	Justin/Nestor/Daniel		
		Camera input settings	In progress	Low	11/9/2020	5/3/2021	Gabriel	Justin/Nestor/Daniel		
	Server and object detection demo		Initial stages	High	5/3/2021	5/3/2021	Daniel/Gabriel	Daniel		
	Prototype software and GUI build		Initial stages	High	12/11/2020	12/11/2020	Daniel/Gabriel	Justin		
	Final end user experience		Initial stages	High	5/14/2021	5/14/2021	Daniel/Gabriel	Daniel		

Appendix I
PERT Overview
Table I1.

PERT Diagram



Appendix J
Table J1.

Test Plan

Team Member	Task	Description
Justin Bolles	Test to ensure the output current of our H-bridges do not exceed 2A UPDATES: Testing is complete. The H-bridges cannot exceed 2A of output.	The current supplies for our motors come directly from our H-Bridges, and 2A is the max we want our motors to receive. UPDATES: The maximum PWM sent to the motors did not cause the H-bridges to output a max over 0.85A. This means the H-bridges cannot output more than this since it is the maximum current. This is well under the 2A requirement to protect the motors and circuit.
Nestor Garcia	Test to make sure the TCA9548A voltage output is behaving properly UPDATES: Testing is complete. The problem was that I was using the wrong MCU. I swapped this MCU for a better one that regulated the voltage to 3.3V when applied to the SDA/SCL pins of the TCA9548A.	Make sure the input and output voltages aren't improperly creating a voltage gain. UPDATES: There is no voltage gain at all and there never was. The voltage supplied by the MCU I was using was regulating the voltage to 5V which is something I did not want. Now, however, the voltage supplied to the SDA/SCL pins of the TCA9548A is 3.3V. This was accomplished by using an NVIDIA jetson.

Daniel Gonzalez	Test to ensure proper values throughout the entire software execution stack from. UPDATES: Added additional code revisions to minimize delays and mitigate potential critical errors. Successfully integrated communicates for all sensors/components.	Run GDB throughout the driver file to validate logical blocks in the executable. UPDATES: While examining for potential edge cases we found the possibility of reading/writing being invoked at the same time leading to a critical error. Code Execution during full System deployment was found to be 350ms from the user.
Gabriel Rodriguez	Document and stress Machine Learning Capabilities to ensure OS is stable. UPDATES: In order to test the Object Detection feature we will include statistical figures within our implementation to showcase frame rates per second along with confidence intervals of the object in frame.	Machine Learning solutions are resource heavy and require multiple threads. We need to ensure this process won't interfere with our controls system and WebService. UPDATES: While testing we were able to implement an fps counter that showed us how many frames were being processed by the object detection framework per second. In our testing results we saw an increase 10 fold in average. Jumping from around 7fps to about 100fps after the change in microcontrollers. This also led to an increase in confidence levels of objects detected as the microprocessor could keep up with the video input and more accurately analyze it.