DARPA Drone Triage Project Proposal

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I. Introduction

During a disaster, speed and efficiency are vital to saving lives. The current method of triage begins with the search for all injured people throughout the devastated area; once the injured people are located, triage is performed on the injured victims. The problem with this current triage process is that the time spent searching for injured people can mean the difference between life and death for those victims. Currently, there is no method available that can scan a large area for disaster victims and can also evaluate their medical condition quickly and effectively. That is why DARPA has issued a challenge called the DARPA Triage Challenge, or the DTC.

The purpose of the DTC is to provide another way to assist medical responders in evaluating the condition of victims of a disaster, quickly and efficiently utilizing uncrewed aircraft vehicles, or UAVs, otherwise known as drones. For our capstone project, the goal is to develop the sensing system that will eventually be attached to a drone that DARPA requires for their challenge [1].

The sensing goals for this project will be to measure the presence of heartbeat, measure breathing rate, use a camera as well as a night vision camera to locate victims as well as determine whether they are able to walk, and to use a speaker and microphone to test if a victim can follow commands. All these components will be used to evaluate the medical state of a person that has fallen victim to a disaster to fulfill the challenges that DARPA has issued [1].

II. Background & Constraints

As stated in the introduction, DARPA has issued a challenge called the DARPA Triage Challenge, or DTC. The goal of this challenge is to develop a way to evaluate a person who has fallen victim to a disaster and use this data to assist medical responders in quickly separating victims into several groups indicating if they are in dire need of medical attention, are in a stable condition, or are dead or unable to be saved.

here are two stages that are included in the DTC: the primary triage and the secondary triage. For the primary triage, the main goal is to develop a system that is attached to an uncrewed aircraft vehicle, or UAV or drone, that can quickly and efficiently evaluate the medical condition of victims of a disaster and can transmit that information to medical responders. The goal for secondary triage is to develop non-invasive contact sensors to re-assess and monitor trauma victims after their most urgent injuries have been treated [2].

For this capstone project, the team will be focusing on the primary triage where we will develop a system that can sense the immediate medical condition of a disaster victim. The team will only be focusing on the sensing system and will not attach this system to a drone due to the two-semester time constraint of Capstone projects. DARPA's current problems with the triage system include scaling issues with the sensors on the UAV, they are unable to assess the medical needs of a victim that visually appear stable, and physiological data from the victim. The main goal of the DTC primary triage is to test speed and accuracy for the sensors on the UAV.

During this project, several standards must be abided by. The first standard that must be followed is standard IEEE 1662-2016. Standard IEEE 1662-2016 covers how to safely design and apply power electronics in electrical power systems. Since this project will be composed of many electrical components, all these electrical components must be powered via a power system, so therefore, standard IEEE 1662-2016 must be taken into consideration when designing the project. Standard IEEE 1662-2016 states that the upper limit for power electronics must not exceed 100 kW and 52 kV in land and marine-based power systems [3]. Standard IEEE 1662-2016 also covers that the power electronics must be protected from: overvoltage, overcurrent, short-circuit, fault, stored energy, and reverse current [3]. The power electronic also must be as small as possible, efficient as possible (a minimum efficiency of 95%), have a minimum overload rating of 150% for one minute, and a maximum no-load losses of power electronics should not exceed 2% [3]. All these requirements must be followed when designing the power system necessary for the project's completion.

As stated previously, several different components must be used for this project to ensure its success, one of these components that shall be used is a radar. Since one of the goals of this project is to detect the presence of a heartbeat of a victim using contactless methods, there is a high likelihood that a radar will be used for this project. If a radar is in fact used for this project, the project must abide by the IEEE standard IEEE C95.1-2019. IEEE standard IEEE C95.1-2019 goes over various radio frequencies and their effects on the human body [4]. This standard goes hand in hand with one of DARPA's constraints for the triage challenge where the sensors used must be human skin and eye safe, so when parts for the project are to be chosen, the group must ensure that a radar that abides by standard IEEE C95.1-2019 is chosen to ensure that the radio frequency emitted by the radar does not further injure the victim's skin and eyes.

Another one of the sensing goals that the project wants to accomplish is looking for visible injuries and body detection using an optical sensor, and another goal is testing the cognition of a victim using a call and response action using an audio sensor. To accomplish these tasks, the project will most likely have a camera acting as the optical sensor, and a microphone and speaker system to act as the audio sensor. Due to the high likelihood that a camera, speaker, and microphone shall be implemented into this project, concerns of recording audio and video from victims or other parties present at a disaster location has arisen. In Tennessee where this project is being developed, Tennessee follows a one- party consent rule meaning that the consent of at least one party to a conversation is required to record [5]. This also means that consent is not required to record conversations in public where there is no reasonable expectation of privacy according to Tennessee Code Ann. §§ 39-13-601, 40-6-303 [5]. However, since the sensing system of this project is expected to go past the state bounds of Tennessee, other states, and potentially other countries, the consent laws of these locations must be considered as well where some of these locations, such as California follow a two-party consent law where both parties must give permission for a conversation to be recorded [6]. The easiest solution to this problem is ensuring that our system will not record visual and audio data but will only analyze this data for the project.

The team must comply with DARPA's guidelines and expectations. The following are the specifications and constraints given by DARPA for their challenge: The sensors must be contactless (operate at a minimum distance of 1 m from the human subjects) and be skin- and eye-safe. The maximum distance the sensing system may be from the ground is 30 m. The entire system (drone, sensing system, and any additional payload) is expected to be no heavier than 9 kg (just under 20 lbs.). The sensing system must operate in austere and complex environments. This implies that the system must perform within a range when introduced to elements relating to a catastrophic event such as dust, wind, inclement weather, smoke, loud noises, etc. The sensing system must fit on a single vehicle. Algorithms must run off either the user interface, autonomous platform, or an additional workstation that does not enter the field (the field being the catastrophe zone). DARPA expects the data retrieved from the sensing system to be utilized by a medic via a user interface that could include a cellular device or tablet. The autonomous platform is the case or unit where the sensing system resides. The additional workstation may be a separate computer system or server. The system must classify injury patterns close to real time which means the digital signal processing applications the team implements must operate in real-time; the system must be processing data as it is happening in real-time and not as recorded data. The endurance limitation on the system is that it must operate continuously for 15 to 60 minutes. The only visible light allowed on the UAV and sensing system is the legally required amount of visible light issued by the FAA [1].

The lights that are legally required to be on the drone are specified in the FAA standard FAA 14 CFR Part 107. This standard issued by the FAA states that for a drone to fly during twilight, the drone must be equipped with anti-collision lights [7]. These anti-collision lights are white and blinking and must be visible from three statute miles away from the drone [7]. Some drones also come equipped with navigation lights which are red and green unblinking lights that help the drone pilot determine which direction the pilot is facing; however, these lights are not enforced by the FAA [8].

There is a defined process called the START model (Simple – Triage - And - Rapid - Treatment) by which triage should be conducted. START has four categories that define the status of a person, these categories include: minor, delayed, immediate and expectant. The minor category signifies the person has relatively minor injuries and is expected to be in a stable state that does not require immediate medical attention. The START model would consider a person to be minor if they are able to move on their own and can respond to audible commands. The delayed category signifies that the person has potentially suffered life threatening injuries but is in a somewhat stable state that can receive medical attention at a later date. The START model will consider a person to be delayed if they pass all the following conditions: if they cannot move under their power, if they have a breathing rate of fewer than thirty breaths per minute, if they have capillary refill in less than two seconds or a radial pulse present, and if they are responsive to audible commands. The immediate category signifies that the person has suffered life threatening injuries and requires immediate medical attention in less than sixty seconds. The START model will consider a person to be immediate if they fall into any of the following categories: if they are unable to move under their power, if they have a breathing rate of greater than thirty breaths per minute, if the radial pulse is absent, or if they have capillary refill greater than every two seconds or unresponsive to audible commands. The expectant category signifies that the person has suffered life threatening injuries and is not expected to survive given immediate medical attention. The START model would consider a person to be expectant if they are unable to move and all breathing has ceased. For this project, we will follow the guidelines set by the START model to evaluate the medical conditions of disaster victims [9].

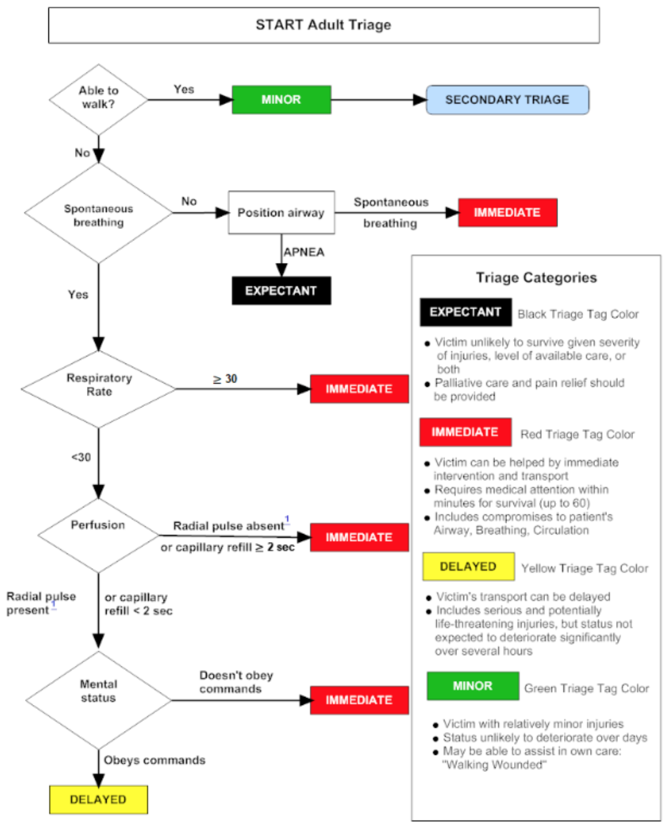

Fig. 1. The above chart displays all categories of the START Method [9]

III. FEASABILITY

Various sensors must be implemented into our project in order to fulfill the goal that has been set for capstone, and to fulfill the goal that has been assigned by the DARPA Triage Challenge. As stated previously, our goal is to develop a system that can detect the presence of a person's heartbeat, breath rate, movement/body detection, and cognitive abilities. Four sensing systems will be implemented in total allowing each one of these tasks to be accomplished. Contactless measuring of an individual's heart beat has become a growing area of research in the past years and has been successfully achieved as evidenced by Riccuiti [10].

This paper looks at two successful methods of contactless measuring of an individual's heart rate using radar technology and video processing using an RGB camera. The radar technology works by sending out "chirps" which can precisely measure the position of the subject which then calculate the rate of heart movement. The RGB camera method functions by detecting slight variation in skin color caused by blood flow movement through tissue. This project will focus on using radar technology techniques similar to the one used by Riccuiti. The project must also function in night conditions meaning any sort of RGB camera use is not possible. Similar to heart rate monitoring, contactless respiratory monitoring has also received a growing amount of interest and success in the research field with positive results. Massoroni reviews four such contactless methods used to detect breathing rate [11]. The first method uses environmental respiratory sounds to detect inhalation and exhalation sound changes. This method uses a microphone placed near the trachea and an amplifier to calculate a breathing rate.

The second method uses air temperature differences to detect heat flow from nostrils due to breathing. A thermal camera is used to reflect the air temperature difference on an individual's face. The third method uses depth sensors to detect chest wall movements. Similar to heart rate monitoring, position sensors such as radar or lasers can be used to detect change in an individual's chest movement. The final method uses RGB cameras and visual sensors to detect changes due to breathing on the visual spectrum. Due to harsh unknown mass causality environments, RGB camera and thermal camera won't be able to function.

This project will focus on the other two methods: sound and depth sensors, primarily utilizing radar technology for depth sensors as DARPA does not allow lasers or visible light to be used in the system [2]. The presence of an individual along with mobility detection can be achieved using image processing algorithms and visible and infrared cameras. Once again this has already been achieved as seen by Pokee Et Al's research [12]. The group successfully implemented depth learning and image processing algorithms in both visible and infrared video data to obtain data on if an individual was moving or not [12]. The algorithm was implemented using python and went through a series of steps to pick out which part consists of humans and if they moved or not [12].

This project's budget cannot fit the expensive cameras in this experiment, but a similar approach using cheaper visible and infrared cameras and python image processing algorithms will be used for this project to achieve the visual sensing goal needs. To determine an individual's cognitive ability and responsiveness human voice detection can be used by implementing a microphone and signal processing system to detect if a human voice is present. This has also been achieved before as evident by Giao Et Al [13] and is coined as voice activity detection or VAD. This paper looks at using probability distribution functions as algorithms to achieve a more accurate VAD method. This project will utilize a similar method of VAD by taking raw data from a microphone signal and running through a VAD algorithm to extract if the noise came from a human voice. Although it is a challenge to implement everything together, each sensing system has been implemented before in some shape or form proving strong feasibility for this project.

IV. Required Resources

Due to the success achieved with Riccuiti's research, an automotive radar sensor (such as the TI AWR1843 used in the experiment) will be used to precisely detect the presence of heart rate. Such devices range from $300-$350. The figure below shows a TI AWR1843 [14]. The use of radar technology requires some skill in signal processing as the data retrieved by the sensor needs to be processed in such a way to retrieve the presence of a heartbeat. The team's course work in DSP and Signals and Systems will be used as a starting point in achieving this task.

There is potential in using the same radar device for both heart rate and respiratory rate monitoring due to multiple transmitters and receivers on radar sensor devices such as the AWR1843 making radar technology the main resource for respiratory detection. To be clear, this project will primarily utilize a depth sensor with respiratory sound detection as an alternative for respiratory rate detection. A microphone such as the Sony ECM-77B mentioned can cost between $200-$300 while the UWB depth sensor can cost between $100-200 [15].

Once again with the use of radar technology there will be a need for skills in digital processing, but due to heartbeat sensor and course work done by the team, some knowledge will already be present. The visual system will require a visible and infrared camera. An example of such cameras is the Charmed Lab Pixy2 and the Speed MLK90641 and cost between $150-$170. This sensing unit will require the knowledge of programming algorithms in a language such as python as well as an understanding into image processing of video data.

The team's knowledge and skill set in coding will give a helpful introduction into the knowledge necessary to complete this task. The VAD system will use a simple microphone to retrieve raw data such as the ETS ML1 which costs between $30-$50. The processing of this data will require coding algorithms to detect if a voice is present. The skills needed are similar to the previous sensing systems in that knowledge in programing and signal processing are needed. The team's knowledge in courses such as DSP and other programming classes will be useful for this task.

This system must tie in all the information from each sensing module and combined with the triage information mentioned before to give an accurate reading on an individual's triage status. Many such computing devices exist, but this project will focus on the use of a raspberry pi or a NVIDIA Jetson. These devices not only have the capability to integrate with some of the sensing modules, but also have the computing power to handle this system's workload. Such computing devices cost between $150-$200. This computing system will require knowledge on the software used to run the microcontroller and programming all the necessary items to output a level of triage needed. As stated above the team does have some minor skills necessary for each task, but there will be a need to spend more time in the experiment and testing to gain the skills necessary to complete each task. Table I below shows a breakdown of the anticipated budget more clearly.

TABLE I. Anticipated Budget

Anticipated Budget		
Sensor/ Component	**Anticipated Components**	**Price**
Heartbeat Sensing	Radar Sensor	$300-$350
Breathing Sensing	Radar Depth Sensor	$100-$200
Visual Sensing	Standard Camera + IR Camera	$150-$170
VAD Sensing	Microphone	$30-$50
Computing System	Microcontroller	$100-$200
	Miscellanous Expenses (Power Supply, Wires, Etc.)	$120-$230
	Total Budget	$800-$1200

V. Measure of Success

The goal for this project is to develop a system that can sense and evaluate the medical condition of a disaster victim that can be used in a triage for disaster relief that also adheres to the constraints stated above. For this project, we shall develop a system that has the ability to detect the presence of a victim's heartbeat using a contactless method from a minimum distance of 1 m, and potentially retrieve a specific quantified value of the individual's heart rate. To test this subsystem, a live human test subject with a beating heart and an object which is known to not have any pulse will be placed under the sensor at a distance of 1 m. The output of the system will be recorded for accuracy whether the output is yes for the live human and no for the object. This process will be repeated for multiple trials so a percent error of false positives and false negatives can be calculated. This test is appropriate as it outputs a quantified value of accuracy that will directly relate to DARPAs need for an accurate system. If the potential goal of achieving a specific beats per minute value is accomplished the system can also be tested by comparing the value with a contact heart sensor value and determining the accuracy rate as before. To adhere to the austere and complex weather constraint this same test will be done in night (darkness), windy (shaking system), and dusty(victims covered in dirt) conditions to also get an accuracy value of more complex conditions.

The system shall also detect the presence of an individual's breathing through contactless sensing at a minimum of 1 m. This system will be able to check if a victim is breathing or not. Once again there is the potential for the breath sensor to potentially be able to derive a specific breath rate value and act similarly to the heart beat sensor where the sensor determines if the victim can be saved, or if it would be the better option to move onto the next victim. Similarly to the heart beat subsystem, the respiratory subsystem will be tested by taking two subjects, a live human that is breathing and an object that has no breath, and place each under the sensor at 1 m distance. The accuracy of whether the system outputs yes for live humans and no for non-breathing objects can then be recorded. This test can appropriately tell if the presence of breathing is being detected as well as the accuracy of the overall system. The same test will also be recorded for more complex weather conditions of night, windy, and dusty and an accuracy reading will be taken.

The system shall also have a visible and IR camera that can act as a visual sensor that will autonomously detect if an individual is moving at a minimum distance of 1 m. To appropriately test this system a live human will be placed under the sensor completely still. The output of the system should say there is no movement present. The individual will then move different parts of their body before returning still and see if the output of the system detects that movement when the subject is moving and no movement when the individual returns back to stillness. The error of false positives and false negatives can then be taken to achieve a value of accuracy to the system. As before, this same test will be done in night, windy, and dusty conditions and an accuracy will be recorded. Finally the system using a microphone shall be able to detect the presence of a human voice at a minimum of 1 m. This system will relay back an individual's cognitive ability and responsiveness. To appropriately test this system a series of sound bites will be played in front of the sensor at a distance of 1 m that will include a segment of human voice. The system output will then be recorded with how many times it is able to detect the human voice bite correctly and how many times it wrongly detects a human voice or overlooked the human voice. This error value can be used to get an accurate reading of the system. It is also important to repeat this test with constant sounds layered on top of the human voice to get a more accurate condition of where this sensing system will be placed. Another error reading can be taken to get an accuracy reading of the overall system.

VI. Obstacles

Most obstacles that will need to be overcome are related to a lack of experience. Many team members have never worked on the field before, only working in a classroom or pre-designed lab setting. To combat this obstacle, team members will be expected to do extensive research to gain knowledge that can assist in solving any unknowns that will be encountered during the development of this project.

One obstacle that the team will encounter during this project, is simulating the movements of a drone since the final goal of this project assigned by DARPA is to have the sensing system, that the Capstone group is developing, attached to a drone. To overcome this obstacle, extensive research on drones and how they move will have to be conducted. Once this research is completed, the data gathered from this research will be applied to the testing phase of the project where one of the group members will most likely hold the sensing system and move it in an erratic motion like how a drone moves and hovers. Once testing is completed, data gathered during the testing phase will be taken and used to make our sensors used in the sensing system be able to focus on a victim more clearly while there is erratic movement present. The data from this test may influence new designs that must be implemented into the design of the sensing system. The possibility of a stabilizing case may have to be implemented, or some program that enables the sensors to gain more stability as they are sensing.

Another obstacle that must be overcome, is simulating austere environments where the sensing system and drone could be present in. During the testing and experimentation of the project, the opportunity to go outside during severe weather and test the system that the group has developed might not always be present; therefore, the group must find a more efficient way of testing the sensing system against severe weather. The best way to test severe weather against the sensing system, is to simulate it using man made devices. An example of this is using a hose to simulate how rain would affect the sensing system. Another example is to throw dust at the sensing system to see how the system operates in dusty weather conditions, and a final example of how to test the sensing system during severe weather conditions is using a leaf blower or some wind generating device to simulate high speed winds. Results from this test may influence how the case housing all the components must be constructed to protect the components from these environmental hazards.

Another obstacle that the team could face is exceeding the weight limit of approximately twenty pounds constraint issued by DARPA. As of now, the group is unsure of what exact components will be ordered for this project, and due to this unknown, there is potential for the components that the group orders could exceed the weight limit. To overcome this obstacle, extensive research on the exact components to be used and their weight must be done to ensure the weight limit is not exceeded. Once this research is complete and the parts are ordered and the construction of the prototype is complete, all components including the case housing the components must be weighed to ensure the weight limit is not exceeded. This unknown may influence what components will be used in the project, and this may also influence how the group will go about constructing the case that the components will be housed in.

Another obstacle that must be overcome is the potential that some components may give off excess light. As DARPA has specified, there should be no lighter on the drone with the sensing system other than the legally required amount issued by the FAA which has been mentioned in previous sections of the project proposal. To overcome this obstacle, extensive research on specific components that shall be used for the project must be done to ensure that they do not produce any additional light. If there is a component that does produce an additional light, but that light is not needed for the function of the component, an example is a camera with a light to indicate it is on, the unneeded light source will need to covered using tape or another light blocking method. This unknown may influence what components will be used for this project.

Another obstacle that must be overcome is solving how to ensure that all the components used in the sensing system can communicate with one another and provide a readable output to be viewed by first responders or other medical professionals at a disaster site. This obstacle was brought to light as Andrei was doing his research on components. While doing research on the radar, his concern was that the radar might not be able to communicate with the other sensors present in the sensing system. To overcome this obstacle, extensive research on the sensors and components used must be done to ensure they can all communicate with each other and produce a readable output using a computing system of some kind. This obstacle may influence what components and sensors we can use for the project.

A major obstacle that was found is a lack of knowledge on if the radar used in this project will be able to detect a person's heartbeat if the person is wearing a large amount of clothing.

The solution to this problem will either be found through research or in the testing and experimentation phase of this project.

VII. Anticipated Timeline

The anticipated timeline for this project will span over two Tennessee Technological University semesters, or approximately thirty to thirty-two weeks in total. The project initially started in January, where the first several weeks were focused on choosing a project assignment as well as forming a teamwork contract with the project's group members. These two tasks required participation from all team members to complete. Once the teamwork contract was finished and the project to develop a system that senses a person's vital signs and medical condition using contactless methods was chosen, the next step was writing the project proposal. To complete the project proposal, several sections were split among the group members to ensure efficient completion of the project proposal. The introduction of the proposal was overseen by Raymond. The background and constraints were overseen by Logan and Raymond, the anticipated budget/literature review was overseen by Andrei. The obstacles were overseen by Michael. The anticipated timeline was overseen by Russel and Raymond. The broader impacts were overseen by Michael, and the anticipated timeline was overseen by Raymond. Since much research is needed to complete this project, more time will be spent researching the background, constraints, and standards sections of the project proposal to ensure that the project proposal is high in the quality of research provided. As noted, multiple members worked on multiple sections simultaneously. To make the process of writing the project proposal more efficient, group members would first work independently on their own part, and then once they have finished their own part, they were to work with another group member to complete and additional section of the project proposal. Once all sections were completed, all group members reviewed the project proposal with all sections included, and afterword, Michael compiled the project proposal into an IEEE Conference Paper format.

Once the project proposal is done as well as rectifying any errors found in the project proposal, the next step is to create a presentation to display the project proposal to other Capstone I members as well as starting to develop a conceptual design for the project. For the project proposal presentation PowerPoint, Raymond was tasked with creating a power point for the presentation using the data from the project proposal. Once the power point is completed, the conceptual design must be started. Sections of the conceptual design are to be split among the group to ensure efficiency. The introduction of the conceptual design is to be overseen by Michael. The background is to be overseen by Logan and Raymond. The standards and constraints are to be overseen by Russel and Raymond. The block diagram is to be overseen by Andrei, and the system and subsystem descriptions are to be overseen by Andrei and Michael. Since most of the information of the conceptual design can just be taken from the project proposal, the main priority and bulk of time will be spent completing the system and subsystem description of the conceptual design. To ensure the conceptual design is completed with high quality, more time will be allotted for and spent on the block diagram, system description, and subsystem description of the conceptual design. The project proposal, project proposal presentation, and conceptual design will be within the months of February as well as the beginning of March. During the month of March, the conceptual design should be completed, and work on the conceptual design presentation, which presents the conceptual design of the project to another Capstone I group, will begin. During this time, Raymond will again be assigned with creating the power point slide used to present the conceptual design to fellow team members. Once the conceptual design and conceptual design presentation have been completed, Capstone I will be put on hold due to Tennessee Technological University's Spring Break. After spring break has concluded around the middle of March, work on the detail design of this project shall begin. The detail design will be worked on throughout the remaining time in March and go into around the halfway point of April. During this time, sections of the detail design shall be split among group members to ensure its completion and efficiency. The introduction of the detail design shall be overseen by Michael. The background shall be overseen by Logan and Raymond. The standards and constraints will be overseen by Russel and Raymond. The detailed block diagram shall be overseen by Andrei, and the detailed system and subsystem description shall be overseen by Andrei and Michael. Much of the time spent on the detail design will be focused on the detailed block diagram, system, and subsystem descriptions, so more time will be allotted to sure those sections can be complete since the remaining sections can use data from previous written reports such as the project proposal and the conceptual design. Once the detail design of the project is completed and signed off, components needed for the project are to be ordered by Andrei. Once all components are ordered, the group must prepare a final presentation displaying all the work that has been completed in Capstone I. During this time, sections of the final presentation will be split among group members to ensure its completion and efficiency. The introduction of the final presentation will be overseen by Raymond. The literature review will be overseen by Andrei. The methodology will be overseen by Andrei. The results and discussion will be overseen by Logan. The timeline and cost estimates of the project shall be overseen by Raymond. The ethical and professional responsibilities shall be overseen by Russel. The lessons learned shall be overseen by Michael. The conclusion and appendix shall be overseen by Michael and Russel, and the power point used to show the final presentation shall be overseen by Raymond. The final presentation shall be completed by late April or early May. More time will be allotted for the methodology section of the final presentation due to all other sections of the final presentation being referenced from previous completed works such as the project proposal, conceptual design, and detail design. Once all tasks stated previously have been completed, Capstone I will be over and Tennessee Technological University's summer break will begin and last from the first week of May through the middle of the month of August. During this time, progress on the project will be put on hold due to the break.

Once Tennessee Technological University's Fall semester begins, the project will be picked back up once all group members have progressed to the Capstone II course. During the beginning of August, components ordered from the previous semester should arrive to the school. Once the components are confirmed to be in the group's possession, construction of the prototype shall begin. The prototype construction process will last several weeks into September and leak into the month of October. During this time, several tasks required to fully construct the prototype will be split among group members based on the specialties of each individual member. The mechanical portions of the prototype shall be overseen by Michael and Andrei. The electrical portions of the prototype will be overseen by Raymond. The power portion of the prototype shall be overseen by Russel, and the programming portion of the prototype shall be overseen by Logan. Due to an overall lack of experience of programming, more time will be allotted for the programming portion of the project, and if more members of the team will be required to fully program the project, more members will assist Logan in completing the programming portion. The power portion of the project is also a concern, so more time will be allotted for this portion as well but not as much time as the programming portion of the prototype.

Once the prototype has been constructed, testing and experimentation will occur to ensure that the project functions as intended, and if not, will leave time to rectify errors that have been found during this testing phase. Prototype testing will last from the middle of September to the middle of October. During this time, all group members will participate in the experimentation and testing of the prototype, but Michael will be placed in charge of all recorded materials gathered from the experimentation and testing phases. In the middle of this phase of the project, a short break on October ninth and tenth will occur due to Tennessee Technological University's Fall Break. Once experimentation and testing have been completed, work on the final presentation practice of the project shall begin which will last from the middle of October to the end of October or beginning of November. During this time, tasks for the preparation of the Final Presentation shall be split among group members. Final poster construction will be overseen by Logan, Michael, and Andrei, and the power point used in the final presentation will be overseen by Raymond and Russel. More time will be allotted for the power point presentation, so once the other three members have completed the poster for the final presentation, they will be expected to assist the other two members who are working on the power point to ensure its completion.

Once final presentations practice has concluded, any extra errors that have been found during the testing and experimentation phase of the project will be rectified or improved. The improvement and rectification of the prototype shall last from the end of October to the middle of November. During this time, the same tasks that were performed in the prototype construction phase of the project will be repeated, so the mechanical portion of the prototype revisions/ improvements will be overseen by Michael and Andrei. The electrical portion shall be overseen by Raymond. The power portion shall be overseen by Russel, and the programming portion shall be overseen by Logan. Like the prototype construction phase, more time will be allotted for the programming and power portions of the prototype revisions to ensure its completion. Also, during this time, work on the final documentation shall begin which last from the beginning of November to the beginning of December. During this time, sections of the final documentation will be split among group members to ensure its efficiency and completion. The introduction of the final documentation will be overseen by Raymond. The literature review will be overseen by Andrei. The methodology will be overseen by Andrei. The results and discussion will be overseen by Logan. The timeline and cost estimates of the project shall be overseen by Raymond. The ethical and professional responsibilities shall be overseen by Russel. The lessons learned shall be overseen by Michael. The conclusion and appendix shall be overseen by Michael and Russel. Due to most of the information within the final documentation can be found within past reports such as the project proposal, conceptual design, detail design, and final presentation from Capstone I, more time will be allotted for the revisions and improvements of the prototype to ensure its completion. Once the revisions and improvements of the prototype are over, the group shall go on a short break due to Tennessee technological University's Thanksgiving Break which will last November twenty-second through November twenty-fourth. After group members return from Thanksgiving Break, the final documentation must be completed. Once the final documentation is completed which should be around the beginning of December, the entire group must present the final presentation to a group of judges in early December. Materials used for the final project should have been completed in the middle of November. Once all members have concluded the final presentation, it will mark the end of the semester, project, and Capstone II course. A detailed representation utilizing a Gantt chart is shown in Figure 2 below.

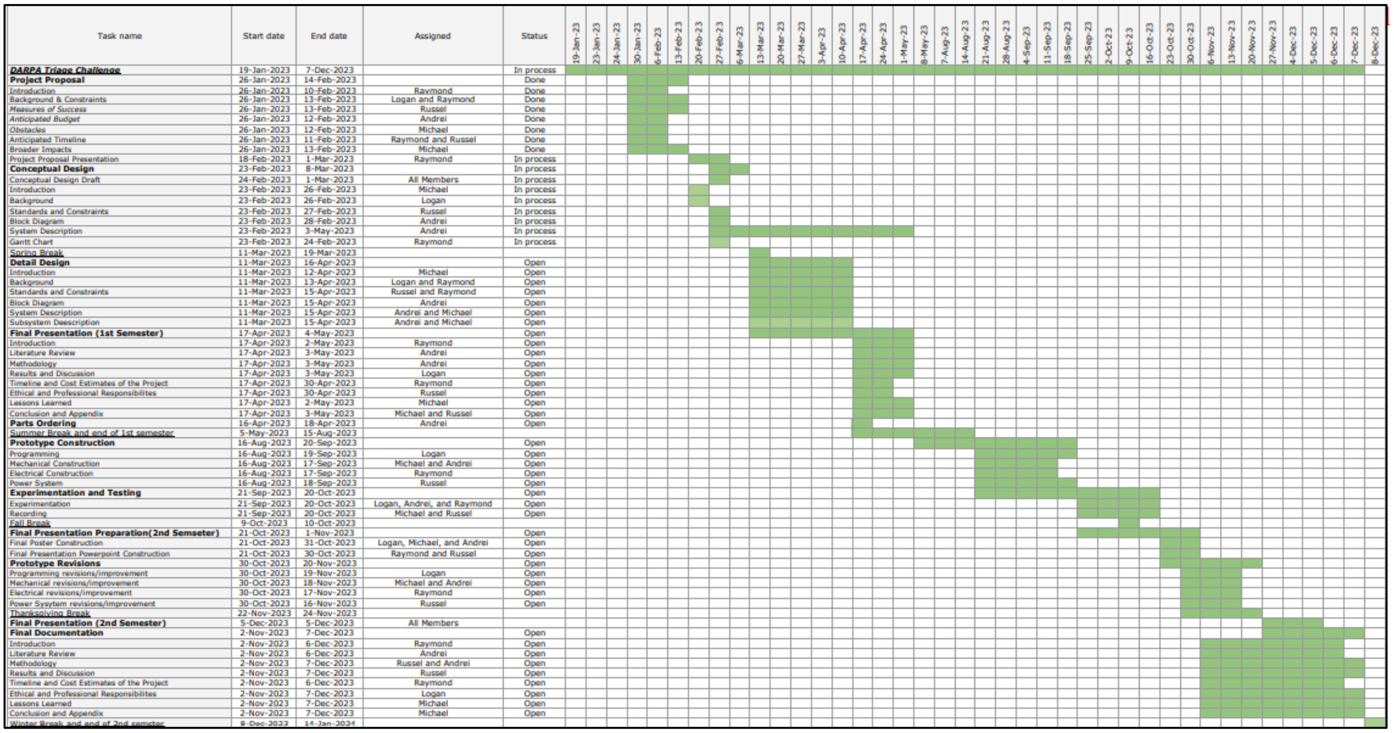

Fig. 2. Pictured is a Gantt Chart of the Anticipated Timeline for this Project

VIII. Broader Impacts

The impacts that this project could have on society is an early-stage development of a sensory system that can be attached to a UAV to determine the medical condition of a victim during a disaster. The development of this project could potentially save the lives of many victims during a disaster. In a perfect future where all objectives are clearly met and even some extra functionalities are applied, this project could potentially be picked up by a future team to become a system that saves multiple lives quickly and efficiently. Whoever picks this project up in future Capstone groups and adds to it will ideally already have a working camera and microphone system to communicate with victims as well as breath detection, and heartbeat detection after our part of this project is complete. They will also ideally find it easy to attach to a drone to fulfill the primary triage goal that DARPA has issued [1].

Ethically and globally speaking, this technology may also be utilized by the United States military to potentially spy on foreign militaries with whom they are at war. This is not an intended use for this technology. To prevent such spying and/or sabotage, the project will not have the capability to save the images taken by the camera as is required by the one-party/two-party consent laws [16]. As required by such consent laws, these images will simply be processed, never saved.

There is also the worry for any power system that it could potentially have a negative effect on the environment. As the power system is designed, each individual plans to take the environmental impact of each component into account to minimize our negative footprint. If a similarly priced sensor or power component is found that also has a lower environmental

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