Team Fire Scout

Requirements Document

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Sponsor:

Dr. Fatemeh Afghah

Alireza Shamsoshoara

Mentor:

Sambashiva Kethireddy

Team Members:

Nicholas Bollone

Matthew Briody

Jacob Hagan

Kenneth Klawitter

Drew Sansom

Client Signature: Fatemeh Afghah Date: 11/15/2020

Team Signature: Richard A. Sansom Date: 11/15/2020

The purpose of this document is to act as a description of the Fire Scout project's requirements, both functional and non-function, and forms the contractual basis for the expectations to be fulfilled by the development team.

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1.0 INTRODUCTION

Each year wildfires across the globe take lives and cost the economy billions in damages. They burn homes, businesses, national lands, and cannot be fought without risking the lives of first responders. As of November 2020, the California Wildfires have burned down an estimated 4 million acres of land across 9,177 fires. The indirect death alone could total above 1,200 individuals from reduced air quality and has cost dozens of lives directly.

As technology advances, the methods and tools used to fight fires need to as well. One way to revolutionize the way wildfires are fought is with semi-autonomous Unmanned Aerial Vehicles (UAVs), commonly called drones. At one point a novelty, the UAV market is expected to grow to just under $50 billion by 2023, a huge leap from $17.82 billion in 2017. While this is due to a variety of reasons including recreation and filmmaking, it is also because of UAVs practicality in emergencies. UAVs are relatively inexpensive and can be outfitted with sensors and cameras to collect thermal and visual imagery, which can empower artificial intelligence models to analyze fires. These analyses can be performed on the drone or from where the drone was deployed to provide comprehensive and near-real-time information on where fires are located, how they are clustered together, where they are spreading, and if they are threatening bystanders. Most importantly these drones remove humans from the heart of the fire and allow stakeholders to collect data in a way that is safer and more precise than ever before.

The Fires Scout Project aims to harness these advantages that were identified by Dr. Fatemeh Afghah, a member of the School of Informatics, Computing, and Cyber Systems at NAU. Dr. Afghah recognized the need to revolutionize how fires were fought, and with the help of her Ph.D. candidate, Alireza Shamsoshoara, created the “Wildfire Drone: Aerial Imaging, Fire Detection, Classification, and Clustering” project, referred to by the computer science development team as “Fire Scout.” After receiving a $550,000 grant through the National Science Foundation’s Faculty Early Career Development Program, Dr. Afghah brought together a group of Electrical Engineering and Computer Science students to help develop small, inexpensive, and intelligent drone systems that can observe, understand, adapt, and respond to changing environments, like wildfires, on their own.

2.0 Problem Statement

While 2020 was a record year for wildfires, especially in California, fires are a persistent issue year after year. As seen below, even though there are years when United States wildfires are less severe, there is no consistency year to year and no way to predict how many acres will be burnt in any given season.

Year	Acres Burned	Number of Fires
2015	10,125,149	68,151
2016	5,509,995	67,743
2017	10,026,086	71,499
2018	8,767,492	58,083
2019	4,664,364	50,477

Data from the National Interagency Fire Center

Fires are difficult to monitor and their path can be sporadic. Despite this, gathering information in the early stages of a wildfire is crucial in containing it and eliminating its fuel sources. Current ways to do this include satellite imagery and limited use of UAVs. These UAVs can provide an eye-in-the-sky view that shows decision-makers what is happening but do little beyond this. Overall, current fire observation techniques suffer from several issues.

- Information might not be delivered in real-time.
- There is typically a high cost associated with collecting information.
- Some ways of collecting information can risk human life such as manned aircraft.
- The delivery of information is not continuous.

3.0 Solution Vision

Clearly a modern solution needs to be created to help fight wildfires. Fire Scout believes that expanding upon the current use of UAVs is the way forward. Rather than just providing image data, UAVs could be developed to operate semi-autonomously and use artificial intelligence to predict a fire's path and follow the fire accordingly. This provides decision-makers with not only knowledge of where the fire is, but how it will act and allows the UAV to respond appropriately.

This solution capitalizes on the well-known benefits of drones and eliminates many of the issues that current fire analysis techniques suffer from. UAVs:

- Can deliver information in real-time.
- Are relatively low cost.
- Do not risk human life.
- Deliver a continuous flow of information as long as they are deployed.
- When flown semi-autonomously, can free decision-makers to focus on other tasks.

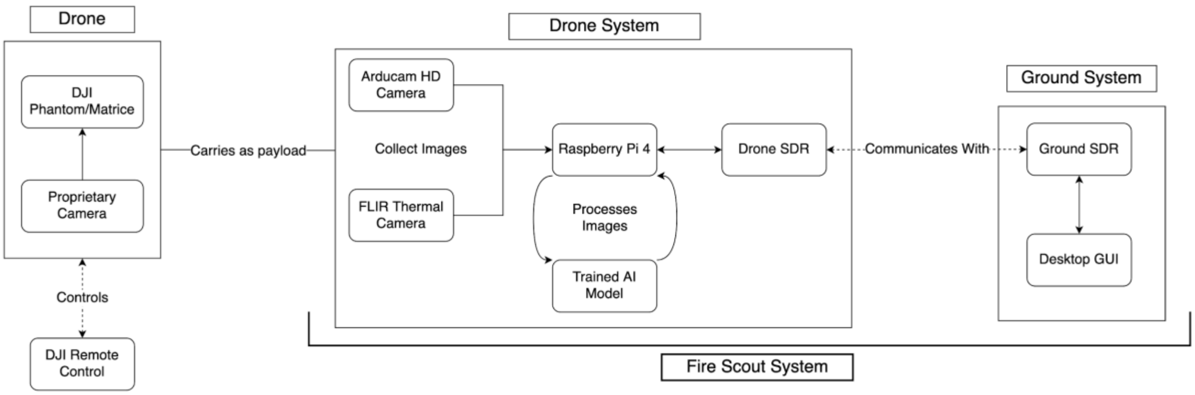
The best way to capitalize on these advantages is to create a custom system for fire analysis. This "Fire Scout System" includes cameras to collect videos, a minicomputer to process those videos, and a software defined radio (SDR) to transmit the processed data back to a laptop. These components make up the "Drone System." At the "Ground System," there will be another SDR attached up to a laptop computer running Fire Scout's GUI that will display the transmitted data and allow users to change the kind of data they see. This set up allows real-time analysis in a safe and reliable manner. An overview of the components follows:

- A drone such as DJI Phantom 3 Pro or Matrice 200
    - The drone is piloted through its native controller
    - Its proprietary hardware is not used for image analysis, that is reserved for the Fire Scout Drone System it carries
    - Instead, its hardware is used for navigation by the pilot

- The Drone System
  - Responsible for image processing
  - The hardware includes:
    - An HD camera
      - Used to capture 1080p video for image analysis and object detection
    - A Thermal Camera
      - Used for image analysis and fire recognition, especially in smokey or dark environments
    - A minicomputer
      - Receives the feed from the cameras
      - Runs AI models and object detection algorithms to process images
    - A software defined radio (SDR)
      - Sends processed images to the ground system
      - Receives signals that control the Fire Scout System from the Ground System
- The Ground System
  - Made up of a GUI running on a laptop and an SDR attached to the laptop
  - The GUI has several responsibilities
    - It interprets the information it receives from the drone's SDR and displays it to the users
    - It lets users select what functions they want the Drone System to perform
    - It can run additional AI and object detection algorithms that are too intense for the minicomputer
  - The Ground System's SDR has several functions
    - It receives images from the Drone System's SDR
    - It sends signals to the Drone System's SDR to control its functions

Setting up Fire Scout in this manner has several advantages. First, by keeping the hardware that processes images separate from the drone, it can be developed independently and deployed on any drone that can carry the hardware's weight. Once the Drone System is proven, in the future, it could be built into custom drones. Second, attaching the hardware to an existing drone allows users to separate responsibilities and improves workflow. One user is responsible for flying the drone through its native camera with a controller that is familiar to them, while the other can focus on controlling Fire Scout through the GUI. This is a more effective setup than only having one camera that is responsible for both navigation and image analysis. Third, by using SDRs Fire Scout can operate in remote locations. Finally, by creating a custom GUI, the user running Fire Scout can control the information being displayed in a non-technical and user-friendly way. This is incredibly important because Fire Scout is not being designed for computer scientists whose aim is to use a command line, but for a wide variety of end-users.

Below is a graph that shows how all the components fit together. The Drone section on the left shows that the drone will be flown through its native controller and carries the Drone System. In the middle, the Drone System displays how information is gathered and processed before being sent to the Ground System on the right side of the graph. The two-way arrows that run from the Raspberry Pi 4 and Desktop GUI show the flow of information from the drone to the user and vice-versa. This setup composed of the Drone System and Ground System is the Fire Scout System that can be deployed on almost any drone or laptop providing extensive reusability, and more capability than ever before for fighting wildfires.



A graphic overview of Fire Scout's Solution and flows of data between components.

4.0 Project Requirements

Of course, to successfully build a complex and meaningful system, detailed requirements must be understood and laid out for development. These requirements will help Fire Scout fight fires effectively, and provide the real-world value the Team seeks to deliver. There are 3 groups of domain-level requirements:

1. Fire analysis
2. Object detection
3. Data communication

Fire Analysis

In real-time, Fire Scout System needs to accomplish several things.

1. The system must classify images from its cameras into one of two categories: images that have fire in them, and images that do not.
2. The system must be able to segment images with fire into specific regions of fire and no fire.
3. The system must be able to plan the fire's path.

These requirements relate to and play off one another. Fires have been classified and segmented by members of Dr. Afghah's lab, however, Fire Scout seeks to do so more accurately than before and use this information to plan the path of fires, something that is novel to all members of the lab and Team Fire Scout. This path planning can only be done after a fire has been classified and segmented though since these analyses provide the data needed, such as fire shape and size, that allow for path planning.

Object Detection

In real-time, Fire Scout must also accomplish another task.

4. The Fire Scout System will implement object detection to identify humans, trees, or other objects as needed.

Since the overall goal of Fire Scout is to prevent loss of life and minimize wildfire's damages, it makes little sense to build a drone that cannot distinguish if some firefighters or pedestrians are too close to a fire. By adding object detection, decision-makers can stay informed of not just the fire, but who is at immediate risk and act accordingly. Additionally, the detection of certain objects such as trees and other fuel sources could aid in path planning for the fire.

Data Communication

Finally, to communicate the Drone System's findings in a meaningful way, a final set of requirements must be met.

5. Fire Scout must relay its analyzed images to a desktop GUI so users can see them.
6. The GUI must be able to send signals to the Drone System selecting what images and information it wants to receive.

This two-way communication between the Drone System and GUI allows for specific information to be selected and delivered. Since information delivery is limited over an SDR, this allows decision-makers to focus on the information they feel is most relevant at any given time.

4.1 Hardware Requirements

To better understand how the software will be implemented, a detailed understanding of Fire Scout's hardware is needed. When starting the Fire Scout project, the software and solution were instantly limited by the hardware the team had to work with. Additionally, some functionality of the Fire Scout System is being implemented by an Electrical Engineering team, so distinguishing between what is the responsibility of the software engineers and electrical engineers is crucial. In many ways, these requirements could be considered Environmental Requirements since they are outside the control of the software engineers; however, they are also unique enough to warrant their own category.

Starting with the drones which were provided to Team Fire Scout by Dr. Afghah and Ali directly:

- All the onboard hardware will fit onto either a DJI Phantom 4 or a DJI Matrice 200.

This hardware includes the minicomputer that Fire Scout's AI Systems will run on, the cameras hooked into this minicomputer, and the software-defined radio (SDR) that will communicate with the desktop GUI on the ground. All of these will be powered by a battery carried by the drone.

- The minicomputer will be a Raspberry Pi 4 or NVIDIA Jetson Nano.
    - The Raspberry Pi will be used for preliminary development due to its larger user base which eases initial development.
    - The Raspberry Pi may be switched for the Nano if the Nano proves to be faster and capable of capturing feed from the thermal camera (which is unknown at this point).
- The HD Camera attached to the Raspberry Pi will be the Arducam HD Camera.
    - It will capture HD video feed in 1080p for the AI model on the Raspberry Pi.
- The Thermal camera attached to the Raspberry Pi will be the FLIR Vue Pro R.
    - It will capture thermal video feed for the AI model on the Raspberry Pi.
- The SDR will be attached and programmed by the electrical engineering team.
    - An interface document specifying how data is passed between the SDR and Raspberry Pi by the CS and EE teams is in the Appendix (Section 8.0).
- A battery will be used to power the on-board hardware.
    - This is separate from the drone's battery and is just for the aforementioned components

This hardware is responsible for running Fire Scout's software and helping the team meet the rest of the functional, performance, and environmental requirements.

4.2 Functional Requirements

These functional requirements will provide a road map for development that can be referred to by the development team and client for the duration of the project. They detail what the Fire Scout System will accomplish.

4.2.1 Fire Analysis

Much of the real-world value Fire Scout provides comes from its ability to analyze fires. The cumulative goal of the Team's fire analysis is for the drone to predict the path of fires and follow this path, so these next requirements will aid in accomplishing that goal.

Classification

The first step in this pipeline is classification, the ability to distinguish between two things. Namely, video frames with and without fire in them. This sets the stage for segmentation, which can only be performed once a frame with fire in it is identified. This leads to the following requirements:

- Fire Scout will be able to distinguish between video frames with and without fire in them.
- Fire Scout will display classified images on the GUI.
- Fire Scout will perform classification on the Drone System.

Keeping classification onboard the drone gives future developers the ability to use classification to help with autonomous flight. So if Fire Scout is ever built directly into a drone, the drone itself could classify fires and then fly towards them autonomously. However:

- Programming drones to fly themselves is outside of the scope of the current Fire Scout team.

Segmentation

After the video-frames have been classified segmentation begins. The goal is to identify the shape of the fire and where it is within the video frame.

- Fire Scout will segment frames that have been determined to contain fires.
- Fire Scout will separate the fire from the image pixel-by-pixel.
- Fire Scout will perform segmentation on the minicomputer if possible, or the ground station otherwise.
  - Segmentation will be performed on the minicomputer if it does not affect the minicomputer's ability to perform image classification.

  - Segmentation will be performed on the Ground System otherwise.
  - How much image segmentation affects the minicomputer will be determined by the client and Fire Scout Team through the course of development.

While the Fire Scout team is planning on using image segmentation primarily for wildfire detection, it can also be used for identifying other objects as well working hand in hand with the Object Detection (4.2.2).

Path Planning

Once classification and segmentation have occurred, Fire Scout will have enough information to start planning the path of the fire. This will allow the drone to stay ahead of the fire and provide valuable information to stakeholders.

- Fire Scout will be able to predict the path of a fire.
  - Fire Scout will predict the path after classifying and segmenting images with fire in them.
- It will predict the path either on the Drone System or the Ground System.
  - Prediction will take place on the Drone System if it does not affect the minicomputer's ability to perform image classification and/or segmentation.
  - Prediction will take place on the Ground System otherwise.
- The fire's path will be displayed on the GUI.

Worth noting is that this is the end goal of Fire Scout and is largely dependent on whether or not real wildfire data can be collected. Wildfire path planning may not be possible or simply not accurate unless the proper data for training models are gathered. Ways to develop path planning without data are elaborated upon in Section 4.3 below.

4.2.2 Object Detection

While the drone is flying the Fire Scout System will detect objects such as people and trees near the fire. Object Detection provides valuable information that decision-makers can use to keep others safe.

- The main objects Fire Scout will detect are humans, trees, and fires.
- Fire Scout may detect more objects as needed.
- Fire Scout may use segmentation (section 4.2.1) for object detection.
- Fire Scout will perform object detection on the Drone System, Ground System, or both if possible.
    - Object detection will originally be implemented on the Ground System
    - If fire classification, segmentation, and path planning are implemented on the Drone System without excess overhead, then some detection models will be moved to the minicomputer if desired by the client.

4.2.3 Data Communication

The data that the Drone System collects must be accessible to an end-user through a GUI. This presents the following requirements:

- The Drone System's SDR will send its data to the Ground System's SDR.
- The Drone System will send images from its cameras to the Ground System.
- The Drone System will send its coordinates from its GPS to the Ground System.
- The GUI will be able to display photos collected from the Drone System's cameras.
    - It will be able to display photos from the HD camera.
    - It will be able to display photos from the thermal camera.
    - It will be able to display both HD and thermal photos side-by-side.

Next, the ground station GUI needs to communicate with the Fire Scout drone to select the information it wants to receive.

- The Ground Station will communicate back to the Drone System with its own SDR
- The GUI will present options that control the information the Drone System sends back.
    - These include the options that will send back the HD and thermal cameras frames.
- The GUI will present options that control the image processing taking place on the laptop.

  - These include what kinds of objects to detect.
  - These options also include segmentation and path planning if they take place on the Ground System.

4.3 Performance Requirements

While the above requirements set the goals of Fire Scout, there needs to be a way to measure if the team successfully met these goals. The following are requirements that serve as a way to measure the team's success and provide tangible ways of measuring that success.

Worth noting is that the challenge with measuring AI performance is that human bias can work its way into datasets and code. A programmer must make sure the neural network is neutral. For example, if the same images are used for testing and training sets, then the neural networks will know what to classify because they are examining data they have already seen. So, it can be beneficial to specify the processes and ways AI algorithms will act when defining their performance.

Finally, all accuracy and measurement ratings are given as *minimums*. This is not to say that Team Fire Scout will not try to achieve levels of accuracy greater than the ones specified, only that the listed ones are what are needed for project completion.

Classification

- Fire Scout will label images with "fire or "no fire" labels.
- Fire Scout will have an unbiased accuracy (probability score) based on training datasets in a neutral model.
- For every input image, algorithms will output one "fire" or "no fire" label with its associated probability score.
- Fire Scout will measure classification results using sensitivity and specificity.
  - *Sensitivity* measures the percentage of positive values that are correctly identified.
    - Sensitivity will have a minimum rating of 80% with a variance of 5%.

- *Specificity* measures the percentage of negative values that are correctly identified.
  - Specificity will have a minimum rating of 80% with a variance of 5%.

- Fire Scout will use Area Under the Curve to measure the performance of classification models and make sure that classes are not being mislabeled.
  - Fire Scout will achieve a minimum score of 80% for Area Under the Curve.
- Fire Scout will use True Positives, False Positives, True Negatives, and False Negatives to check for accuracy.
  - This metric will achieve a minimum of 90% accuracy.
- Fire Scout will use Tensorflow, Keras, and OpenCV as necessary to accomplish this.

Segmentation

- Fire Scout will check that pixels are labeled accurately.
- Each object segmented will have a color associated with its label.
- Fire Scout will have an Intersection over Union (Ratio) to measure overlap between pixels.
  - This metric will achieve a minimum of 80% accuracy.
- Fire Scout will use True Positives, False Positives, True Negatives, and False Negatives to check for accuracy.
  - This metric will achieve a minimum of 85% accuracy.
- Fire Scout will use Tensorflow, Keras, and OpenCV as necessary to accomplish this.

Object Detection

- A single input image will produce multiple boxes and labels as output.

- Fire Scout will have one bounding box for each label/item.
  - Not multiple boxes per label/item.
- The bounding boxes will contain all pixels associated with a particular label/item within them.
- The bounding boxes will display accuracy ratings.

- The bounding boxes will not display incorrect labels/items.
    - I.e. a person will not be labeled as a fire.
- Object Detection can use CNNs and other algorithms such as image pyramids, sliding windows, and non-maxima suppression.
- Fire Scout will use True Positives, False Positives, True Negatives, and False Negatives to check for accuracy.
    - This metric will achieve a minimum of 85% accuracy.
- Fire Scout will have an Intersection over Union (Ratio) to measure overlap between bounding boxes.
    - This metric will achieve a minimum of 80% accuracy.
- Fire Scout will use Tensorflow, Keras, and OpenCV as necessary to accomplish this.

Path Planning

While predicting the path of a fire is the cumulative goal of Fire Scout's AI models, it may be hard to implement due to the lack of data. There is no way to train a model to predict the path of a wildfire if the Team cannot legally obtain footage of wildfires. However, general path planning that follows objects can be created, setting the stage for future teams to adapt these algorithms to follow fires instead. If footage of wildfires can be collected, then Team Fire Scout will divert its efforts to planning the path of fires.

- Fire Scout will train its AI models to track and predict the path of objects instead of fires unless footage of fires can be obtained.
- Fire Scout will work with Dr. Afghah in the spring to make an addendum to the project requirements specifying what objects will be tracked, and how tracking will be tested.
- If footage of wildfires can be collected, Fire Scout will make an addendum with Dr. Afghah detailing how wildfire's paths will be predicted and displayed to the user.

DATA COMMUNICATION

SDR performance will be dependent on the Electrical Engineering team. However, there are a few requirements the computer science team can strive to meet with the assumption that the SDRs will be fully functional.

- The GUI will give the user the options to:
  - View only the HD camera's frames
  - View only the thermal camera's frame
  - View both the HD camera and thermal camera's frames
  - Show no camera display
- The GUI will always display:
  - The predicted direction of the fire in decimal degrees from 0-360 (if path prediction is implemented).
  - The coordinates of the Fire Scout drone.
- The GUI will be created with TkInter.

USE CASE

With these requirements in mind, an elaborate use case can be constructed to illustrate how Fire Scout may function. This scenario assumes that the user knows there is a wildfire, the Fire Scout drone has been launched, and image classification, segmentation, and path planning all take place on the drone.

1. The Drone System will classify what it sees into "fire" and "no fire" categories.
2. The user on the GUI will see the classified images the drone sends.
3. When the user on the GUI sees an image labeled as "fire," they tell the pilot which direction to fly.
4. When the drone is close enough, the minicomputer will start to segment fires.
5. It will transmit the segmented fires to the user on the GUI.
6. The user on GUI will be able to see the segmented fire.
7. The user on the GUI will select a button telling the drone to start displaying thermal images as well as HD images.

8. The Drone System will receive a signal from the Ground Station asking for thermal images.
9. The Drone System will start to transmit thermal images and HD images.
10. The user will see both thermal and HD images side by side.

When path planning is implemented:

11. The minicomputer will calculate the fire's path.
12. The Drone System will send the fire's predicted path back to the GUI.
13. The GUI will display which direction the fire is heading.

On-board the Ground System:

14. The user will be able to select the objects they want the Ground System to detect.
15. Elements of the live feed will then have bounding boxes around them showing what they are and the accuracy rating.

Not only are humans removed from the fire across the entire process, but they are kept continuously informed of the fire and its movements. The user on the GUI can select the information that is relevant to them at the time, such as objects to detect and what camera feeds to view. While they focus on analyzing the fire, the pilot stays in complete control of the drone and can work with the GUI's user to gather information in a manner that is meaningful and safe.

4.4 Environmental Requirements

These are constraints that are beyond the control of Team Fire Scout. They include the hardware requirements mentioned above (Section 4.1), and additional requirements that the team needs to follow.

- The project has a $500 budget allotted to the EE team.
- It is the EE team's responsibility to get the SDR communication between the Drone System and Ground System functional. The CS team is reliant upon them for this.
- There are laws that limit when, where, and how drones can be flown over fires to gather data. It is up to Dr. Afghah to obtain legal permissions for further flight and data collection.

- Semi-autonomous drone capabilities will be the result of a drone Alireza Shamsoshoara is developing, and as such Fire Scout cannot plan for when, or how integration with this new drone will function.

5.0 Potential Risks

While the technologies Fire Scout is using are well developed and proven, the combination of them is fairly novel. Additionally, some of these technologies are new to the computer science team working on Fire Scout. Combined with outside factors, these present potential risks for development that should be acknowledged by both the client and the development team since Fire Scout's success hinges on overcoming them.

1. The AI model may not be as accurate as desired due to limited data. Currently, there are laws and restrictions that limit the flight of UAVs above wildfires, and special permissions are needed to pilot them. This makes it difficult to obtain data in a legal manner that could be used to train an AI model, especially for a model that plans fire's paths. Fire Scout currently has some data from controlled burns, but these do not accurately mimic wildfires. Additionally, wildfires are unpredictable and the team does not know if there will be any over the winter and spring that could be filmed for further data collection. Therefore all requirements in this document are for data gathered by the signing date of this document. Addendums can be made if new data sets are collected.
2. The Raspberry Pi and/or the NVIDIA Jetson Nano may not be able to handle all the processing they need to. While preliminary testing and testimony from the Aireza inspires confidence in both minicomputers, there is no way to tell how they will handle the fully trained and developed Fire Scout AI models until they have been deployed on the minicomputer. This is something that cannot happen until development is progressing next semester.
3. While using image processing to detect fires has been successful in the past, it is still a newer and growing technology. This means that Fire Scouts resources for

development are limited in scope, which could hinder development since some technologies are being performed from the ground up.

4. Even if the CS team completes all the above requirements, if the EE team cannot get the SDRs working and able to send data, the project will fail (although this is unlikely).
5. Finally, there is a small risk that the CS team will not reach complete competency with the technologies being used such as TensorFlow, Keras, and OpenCV, or their underlying concepts such as CNNs. Though the team members have already started online courses and tutorials to master these technologies, they are still complicated in scope and new to members of the CS team. However, it is unlikely that Team Fire Scout will not be able to understand these frameworks and concepts.

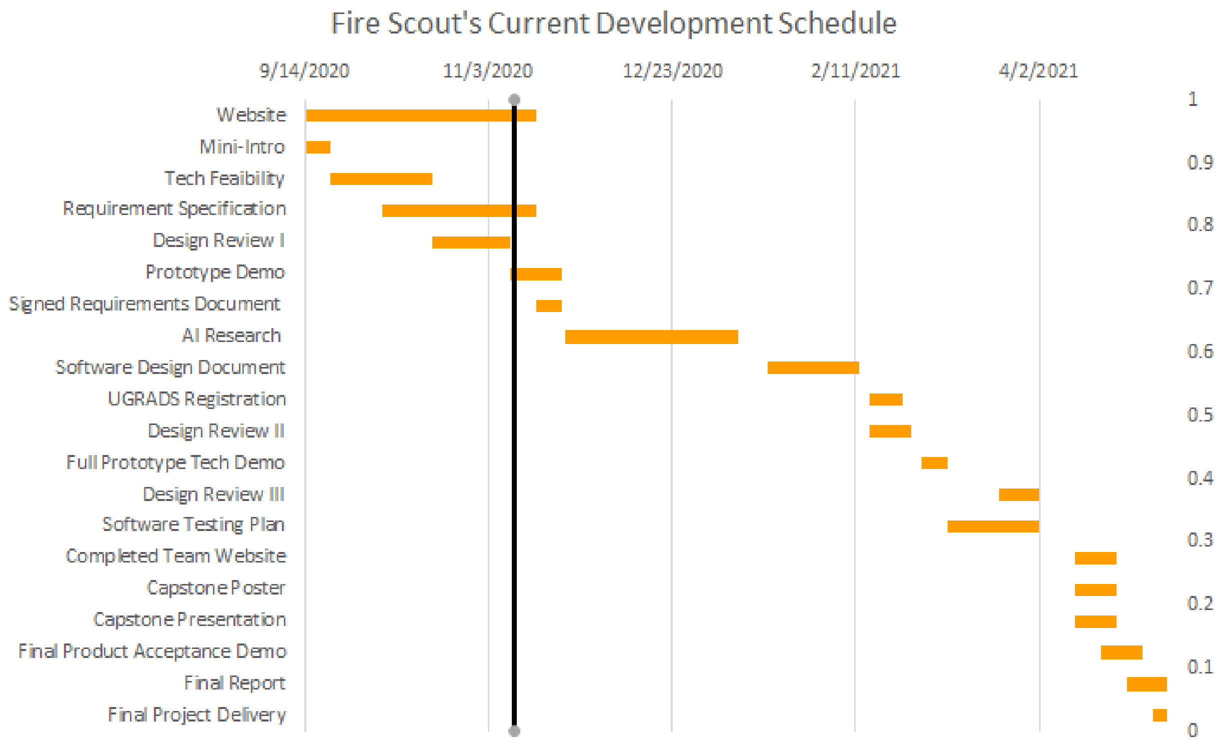
6.0 Project Plan

For the rest of the semester, Team Fire Scout's goal is to finish gathering requirements, present a design review, and develop a prototype. Upon getting the client's signature on this document, Fire Scout will move into the development phase which will last until graduation in May of 2021. This starts with team members researching and learning more about artificial intelligence, ANNs, image analysis, and the technologies needed for successful development. This research will go through early January. From January through May, the team will work in an agile manner to meet the requirements laid out in this document. An overview of the main development phases and a more detailed Gantt chart follows.

- November
  - Finish the Requirements Specification
  - Present the Design Review
  - Present the prototype
- December - January
  - Research and learn about relevant technologies
- January - May

- Agile development of the Fire Scout product
- Successfully meet the requirements of the project

- As needed
  - Obtain more fire data whenever legally and practically permissible



Gantt chart outlining estimated development timeline

7.0 CONCLUSION

With how devastating wildfires are and how quickly technology is evolving, the opportunity to change how they are fought is more feasible than ever. A novel solution that prevents the loss of life, billions in economic damages, and keeps responders safe becomes not just an ideal possibility, but a feasible solution.

Fire Scout is the path forward for fighting wildfires. When using Unmanned Aerial Vehicles responders are kept out of harm's way. By providing real-time information and aerial images of the fire, stakeholders are kept informed of the fire’s status in an unprecedented manner. Coupled with artificial intelligence and deep learning, the information provided is more meaningful than traditional image collection. The AI model can quickly and accurately show where fires are, how they are clustered together, predict their path, and alert responders of humans in proximity to the fires.

Additionally, by creating a modular system based on third-party components such as the Raspberry Pi and its accessories, Fire Scout can be deployed on any drone that can carry the necessary hardware, and on any processor powerful enough to run the ANN models. This allows the system to be applied to a wide range of situations by many kinds of users and developers. It is the perfect blend of technology and inspiration relying on proven methods like AI and UAVs, yet using them in new ways.

Up to this point in development, Fire Scout has completed several key documents and milestones including:

- A Team Inventory that highlights the members' skills and interests.
- A Team Standards document that set the guidelines for team members' behavior, professionalism, responsibilities, and team disciplinary actions.
- Multiple peer evaluations ensuring fair cooperation and effort among team members.
- A Miniature Introduction of our project that served as an overview of the importance of Fire Scout.

By completing this requirement document and obtaining a signature, Fire Scout is now able to begin development following the aforementioned requirements. The team now knows and has come to an agreement with Dr. Afghah and Alireza Shamsoshoara on what Fire Scout needs to do, how well it should perform, what the development restrictions are, and what the expected outcome is. Going forward, the team feels confident that this document will serve as a guide for development and that the research, time, and energy put into gathering requirements will be key in the successful deployment of Fire Scout in real-world applications.

8.0 Appendix A: Hardware Interfacing

The Software Defined Radio (SDR) is the main form of communication between the Drone System and Ground System. It is connected directly to the minicomputer on the drone and to the laptop on the ground which allows these devices to communicate in remote settings.

While the computer science team is responsible for creating the software that runs on the drone and the GUI, it is the responsibility of the electrical engineering team to implement the SDRs so the Drone System can communicate with the Ground System. Because of this, a basic understanding of how the teams will work together and how data will be transmitted is needed.

- The SDR on the drone will be the USRP 205mini-i.
- The SDR plugged into the laptop will be the USRP 210.
- Attached to each SDR, there will be an analog to digital converter (ADC) so that any code written by the computer science team will be translatable to a radio signal on the sending end, and translatable to a digital signal on the receiving end.
- The EE team will send signals between 2.4 GHz and 2.5 GHz.
- The EE team will implement the communication protocol between the drone's SDR and the SDR on the Ground System.
- Any other developments made by the EE team will be communicated to the CS team and appended to this document.

9.0 SOURCES

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