July 24, 2022

Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
British Columbia, V5A 1S6

RE: ENSC 405W/440 Project Proposal for Ember Trailer

Dear Dr. Scratchley,

The following document is the project proposal for *Ember Trailer*, a wildfire mitigation assistant developed by Nature Coolers. The purpose of this module is to assist wildfire responders in preventing fires from reigniting by managing the remnant embers that rest underground. Currently, the process of dry mopping is messy and ill-equipped, using only basic techniques such as digging trenches and hauling water. The Ember Trailer will use a series of sensors and actuators to identify these subterranean hotspots and extinguish them, alleviating work from the responders.

The following document will provide an outline of the risks and benefits of the module, as well as a high-level system overview. Marketing and competition information will be provided and analyzed along with the budget and cost of a complete product.

Our team at Nature Coolers comprises a team of 6 diligent and experienced senior engineering students: Rachel Djauhari, Kevin Lo, Jake Mix, Richesh Patel, Alfred Rodillo, and Xixuan Song. The combination of Computer and Systems Engineering will bring about the success of this project.

Thank you for taking the time to read and review our project proposal. If you have any further questions, please feel free to contact me at jmix@sfu.ca.

Sincerely,

Jake Mix
Chief Executive Officer
Nature Coolers

Proposal:

Company 3 — Nature Coolers
Ember Trailer

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Submitted To:
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Executive Summary

Wildfires continue to devastate the world, growing increasingly destructive and plentiful as the years pass. These fires threaten everything from industry lands to towns and cities. In 2021, the town of Lytton in British Columbia was engulfed in the flames of a runaway forest fire, something that had not been seen before. Early warning and identification of such wildfires are important for preventing damage, but sometimes finding and containing these fires is not feasible; if they were struck by lightning, far away from a town, for example. In the case of a fire already burning, ensuring that it is fully extinguished becomes equally as important as fighting it. When a fire is partly or fully suppressed, responders must patrol the perimeter of the blaze to check for any embers left underground that could reignite, a process known as dry mopping. This is a crucial role in the overall battle, yet it is also exceptionally time-consuming and exhausting for the workers.

Nature Cooler's prototype, the Ember Trailer, is a drone module that can help relieve the work from responders and increase the efficiency in which dry mopping is accomplished. The Ember Trailer utilizes a series of infrared sensors and actuators to identify and quell any subterranean flames. A build-in drilling arm allows the module to probe underground to detect embers and a parallel nozzle allows for quick suppression all in one movement. This removes the need for responders to actively dig trenches and haul water to perform the same job. Additionally, the low-profile method of finding and suppression embers means the forest floor will not be left with giant hold and trenches, preserving its original state.

The product has a worldwide market that continues to grow as wildfires are a global issue that will not be leaving anytime soon. The cost of suppressing fires has been steadily increasing and shows no signs of slowing down. The longevity of Ember Trailer is a step in the right direction of mitigating the cost of dealing with these inevitable fires. Designed to withstand the rugged terrain of the forests and the heat of the blazes, Ember Trailer will be up to any task and any number of patrols. The water supply is the only component that would need replacing since the rest only require recharging or cleaning after an outing. This minimizes maintenance costs and makes the module very cost efficient to use.

Nature Coolers is proud to be presenting the Ember Trailer as a new tool to help wildfire responders tackle the countless blazes experienced annually. The team of 6 passionate senior engineering students will continue to improve and innovate the field of wildfire fighting with intelligently designed technology. The goal is an effective and efficient form of combating wildfires to be deployed alongside our responders; to help keep them safe and remove some weight off their shoulders.

Ember Trailer will continue to be developed and improved over the next months the skilled engineering team. The hope is to make an impactful difference in the world of fire-fighting with the product's latest designs.

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1. Introduction

Wildfires are considered as one of the most troublesome difficulties which must be settled urgently in North America and around the world. One study has collected information on wildfire activity in Canada from 1959 to 2019, showing that the maximum area burned was over 7 million hectares in 1989. In 2019 alone, there was nearly 2 million hectares of forest destroyed by wildfires nationwide [1]. Unfortunately, this situation is expected to worsen. Environmental research scientists predict that wildfires spread in Western United States could be 1.5 times larger than the current burning area by the middle of the 21st century [2]. Wildfires are both detrimental to the ecological environment of the earth, but also massively threaten the health of all living-beings. A variety of harmful gases and substances are released while fires burn through forests including nitrogen oxide, carbon oxide, and black carbon [3], which directly leads to the global greenhouse effect, thereby increasing the number of wildfires. Additionally, patients who already have lung and heart diseases can be more deteriorated [4].

Although expenditures on both wildfire prevention and mitigation continuously increase in Canada, there is no indication that the growth of wildfires are effectively restrained. More than $600 million have been spent on suppression wildfires in British Columbia in 2017 [5] and over $1 billion is used every year on wildfire protection in Canada over the last decade [6]. The main contributor to the long-burning-life of wildfires are underground embers which are hard to find, difficult to manage, and commonly exist in areas with flammable materials such as litter, root, and buried logs [7].

Nature Coolers is dedicated to producing a competent and loyal assistant to help firefighters and responders and have developed the Ember Trailer module. This is a serviceable module able to reach most terrains that are dangerous to firefighters, so they no longer spend as much effort and time to dig through the ground to reach subterranean embers and suppress them. In addition, a simple, easy-to-understand user interface will enable firefighters to remotely control Ember Trailer from hundreds of meters away from the field. Furthermore, the user application will store records of past alerts and provide status data collected by Ember Trailer.

1.1 Background

The aftermath of a wildfire requires tedious, yet critical tasks to be carried out by responders to ensure the fire does not reignite. This process is known as “dry mopping” and involves a large amount of manpower and time to complete. Responders will patrol the perimeter of a partially or fully extinguished fire to check for remnant embers or flames that could pose a threat. Many embers are buried underground where they smolder and threaten to unpredictably spread, causing the reignition of a surface fire, or the start of a ground fire [8].

The job of responders is to ensure that any remaining embers are identified and extinguished immediately. This task leads to many hours of careful searching, where responders will typically use their hands to check if the ground is unusually hot, which many indicate a subterranean fire. Once a fire is found, responders dig a trench to reach the embers and pump water over the hotspot to fully extinguish it.

1.2 Scope

The scope of Ember Trailer will be viewed through several topics: the project objective, deliverables, technical requirements, and limits and exclusions.

Project Objective

To construct a high-quality, and remotely detected and controlled module within 5 months and for cost be below C$3380.

Deliverables

- An easy-to-use, aesthetic user interface that supports Windows 10
- A flexible, multi-functional unmanned ground vehicle with a maximum dimension of approximately 1100×500×500mm

Technical Requirements

- The module must obey all related engineering standards
- The module must periodically receive instructions and send the current status of the UGV to responders
- Font and color settings are provided in the user interface to make it accessible for users with vision impairment
- The module must be able to communicate with HQ when within a 2km range
- The thermal camera must detect hotspots at least 10m away from the module
- The thermocouple must be able to operate under an environment of 800°C
- The drill can reach 20cm in depth underground
- The module must be installed with a protective shell to guard it from the surrounding heat and external damage
- The module should weigh up to 30lbs

Limits and Exclusions

- Misinformation of hotspot detection
- Working temperature of the UGV is under 90°C
- WLAN is required to manipulate the operations of the UGV
- Simulated test environment and amateur participants may be involved in the beta testing phase
- Drill may not reach underground embers
- User confirmation is needed if there has been no operation for over 10 minutes
- Manual manipulation is mandatory to reach the location of the hotspot

2. Potential Risks and Benefits

2.1 Risks

While the Ember Trailer is designed to be as accurate and accessible as possible while keeping within the budget, there are still some minor risks involved. Hearing of the drill system can give inaccurate readings to the temperature probe while measuring. When a drill penetrates any material, it heats up because of the friction, and this is what will cause the probe to measure a higher ground temperature than what it truly is. This can cause false positives when searching for embers, and may lead to wasted time and resources, such as water or battery charge. However, due to the manual remote control of the system, operators can wait for a short time for the auger bit to cool sufficiently before analyzing the probe’s measurement. Additionally, water

used for suppression will also help the system cool itself while also accomplishing its primary task.

One of the biggest risks is not accomplishing the primary objective of finding hotspots. Failure to find hotspots could pose a risk to other firefighters and responders who may rely on this product. Because of the varying environment and terrain, Ember Trailer may sometimes struggle to determine accurate, consistent readings even with a wide array of sensors therefore it is recommended to have a responder check the site in-person after Ember Trailer has dealt with the hotspot.

There are also potential risks with data flow and storage. Since radio is used to communicate between Ember Trailer and HQ, it is possible that an attacked could access and send messages. To minimize the risk, an encryption scheme will be used so only HQ should be able to read and understand messages. Inputs and messages will also be sanitized to prevent any unwanted behaviour. Logs will be stored locally at HQ in password protected files, accessing through the user application. Data flow may encounter risks natural with radio interference or weak signal strength. However, the Ember Trailer module will most likely be deployed in remote areas so not much radio interference is anticipated. Advanced antennas and radio transceivers are also available to upgrade after the proof-of-concept prototype if dropped signals are a problem.

2.2 Benefits

The Ember Trailer module will provide wildfire responders with assistance during their most tedious task when battling a fire. Although the module was created with British Columbian wildfires in mind, since the last summers have been exceptionally difficult with mass fires, Ember Trailer can be applied worldwide to any person or group that wants assistance when dry mopping.

The major benefit of this module is the time and manpower saved from its implementation. Reducing the need to dig trenches to reach fires saves responders energy and time, since the module is capable of quelling embers without digging up large patches of rough land. Usage of the Ember Trailer module will be very intuitive for responders to operate. The operator can control all the module's functions from a desktop application. There will be periodic status updates which will be automatically displayed. All logs will also be saved and viewable in the application in the event responders wish to review what happened.

Ember Trailer will help improve the environment by reducing the risk of re-ignition and preventing further lost of vegetation and habitats for animals. By helping responders neutralize fires faster, less smoke and ash will drift to nearby cities and will improve the air quality for the residents. Since water will be used as a suppressant, there will be no negative impact to the area Ember Trailer is deployed in.

3. The Market and Competition

3.1 Market

Reports published by the Canadian Interagency Forest Fire Centre (CIFFC) provide yearly statistics on wildfires that have occurred in Canada. The number of wildfires and the area burned is shown in Fig. 1. and Fig. 2. below [9].

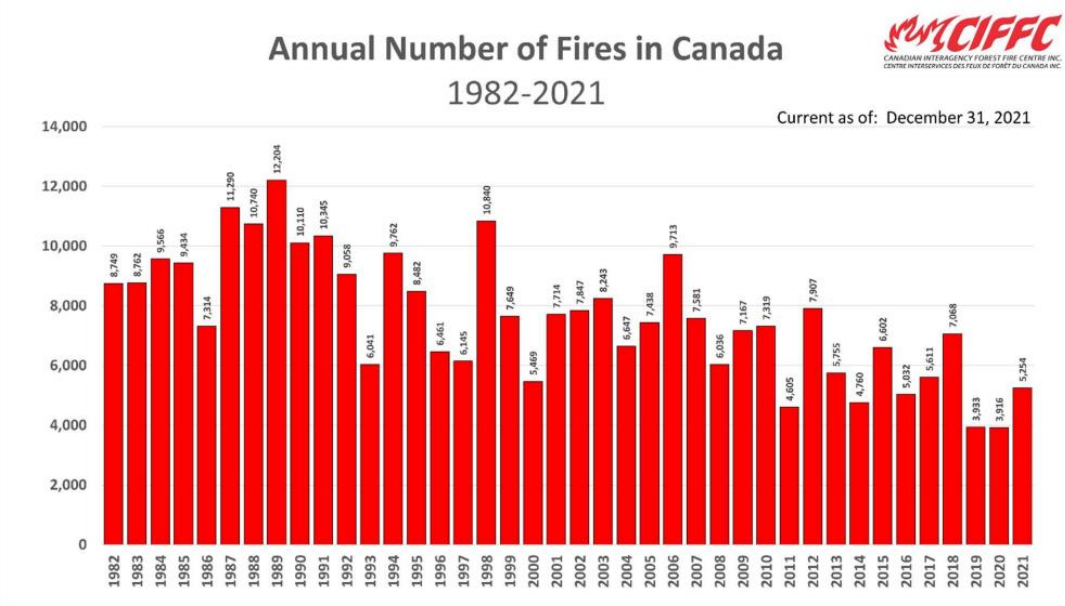

Fig. 1. Annual Number of Fires in Canada from 1982-2021 [9]

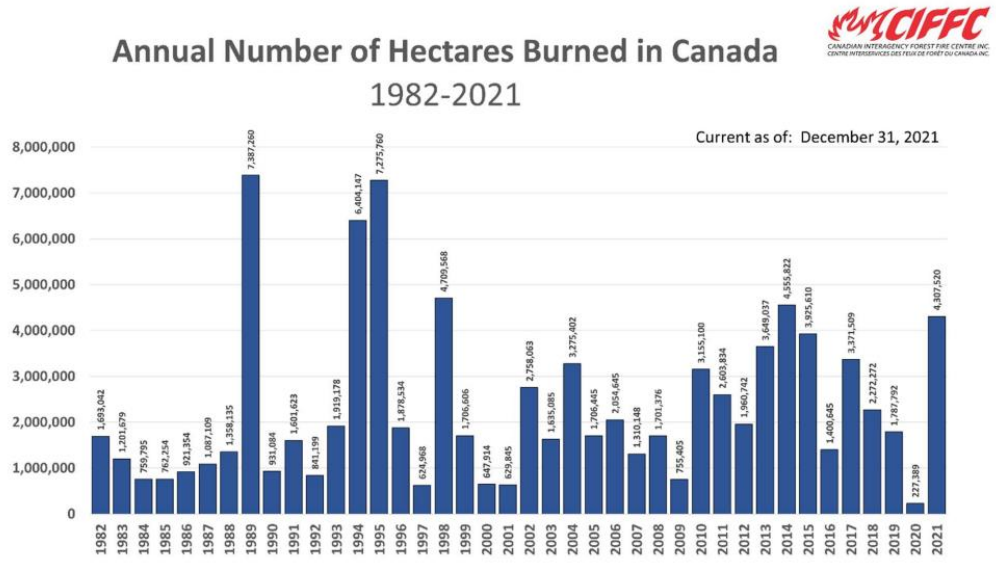

Fig. 2. Annual Number of Hectares Burned in Canada from 1982-2021 [9]

Similar trends can be seen in the United States; a slight decrease in the number of fires per year but growth being observed in burned areas [10]. However, recent studies, including a report published by the UN Environment Programme [11], predict an increase in both frequency and severity of wildfires due to climate change.

The cost of dealing with wildfires can also be observed to have steadily increased over the years. In Canada, this annual cost has exceeded $1 billion multiple times in the past 2 decades, as show in Fig. 3. below [6]. These costs consider the mitigation, response, and recovery of wildfire management agencies. Once again, similar results are observed in the United States, where the wildland fire suppression costs exceeded $2 billion [12].

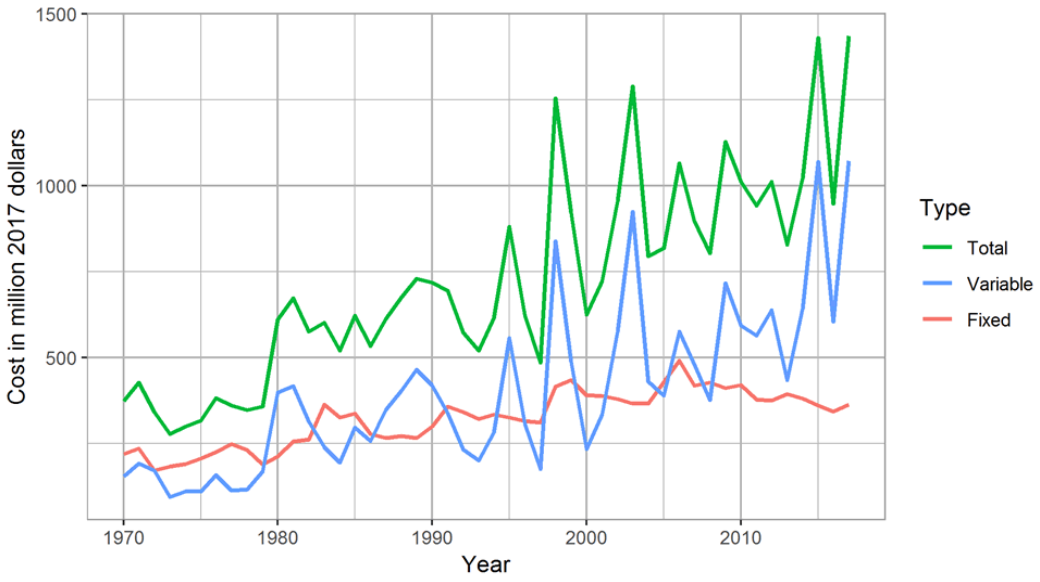

Fig. 3. Cost of wildland fire protection in Canada from 1970-2017 [6]

By assisting the dry mopping process, Ember Trailer can allow other wildfire responders to be deployed elsewhere as needed. In doing so, the module can contribute to potentially lowering costs, and encourage more efficient use and allocation of resources. Given the presented statistics, it will be important to be prepared for dealing with wildfires, and to have effective and efficient solutions in the future. The Ember Trailer module can capture a large market as a tool for reinforcing wildfire response efforts, which has become a growing worldwide issue.

3.2 Competition

Currently, there are robots in the market that are fully equipped to directly fight fires. One such robot is the Thermite RS3 manufacture by Howe and Howe shown in Fig. 4. below [13].

Fig. 4. Thermite RS3

The Thermite RS3 is a large, heavy vehicle equipped with treads, and can pull up to 800 pounds. It has been used in Los Angeles to help with a building fire, and it could see use fighting wildfires in the future due to its capabilities [14].

Drones may not be as capable, but they are still commonly used for the aerial view they provide which is useful for gathering information quickly. DJI is a well-known company that manufactures unmanned aerial vehicles. In China, a DJI drone was used by the crew to help fight a forest fire, assisting with identifying secondary fires to put out to avoid reignition [15].

The Ember Trailer is designed as a module that can be attached to an unmanned ground vehicle that will be deployed to help with dry mopping. Additionally, unlike drones, the Ember Trailer module will provide both detection and suppression to deal with remaining hotspots during this process. The focus on the dry mopping process is unique and will help it stand out against other current products for fighting wildfires.

4. Company Details

4.1 Jake Mix – CEO

Jake is a fifth year System Engineering student. He has experience in mechanical and electronics design and implementation. Previous co-op terms include PCB manufacturing with Canadian Circuits and audio circuit design with Radial Engineering. Jake's knowledge of circuit design and previous experience with mechanical devices will help Nature Cooler's when working with the motorized systems of the Ember Trailer module.

4.2 Rachel Djauhari – CCO

Rachel is a fifth year Computer Engineering student with experience in Python, C/C++, and C#. She previously worked as a Control System Engineer at Cellula Robotics working on both electrical and software tasks including communication between Arduino and WPF UI Interface in Visual Studio. Additionally, she recently finished a co-op placement at Offworld Industries as a Software Engineer in game development working with C# in Unreal Engine. Rachel's experience with communicating data using the Arduino and transferring it to be visible in the UI will be most valuable to Nature Coolers in the development of the Ember Trailer module.

4.3 Alfred Rodillo

Alfred is a fifth year Computer Engineering student. His previous co-op terms include working as a software tester at OSI Maritime Systems, and most recently as an Application Engineer at LMI Technologies where he contributed to the development of internal and customer-facing applications. With his experience, Alfred will focus on the development of the user application and software components of the Ember Trailer module.

4.4 Richesh Patel

Richesh is a fifth year Systems Engineering student with experience in mechanical and electronic design. He has previously worked at Stryker as a System Engineer Co-op student. This included mechanical, electrical, and some software tasks in the development and testing of Stryker's new products. Richesh's experiences will be used to develop the mechanical and electrical designs of the Ember Trailer module.

4.5 Kevin Lo

Kevin is a fourth year Computer Engineering student with an interest in software. In his previous co-op position at Tantalus System, he worked on developing infrastructure for utilities. He gained experience in wireless communication networks which will be useful in designing the software components for Ember Trailer.

4.6 Xixuan Song

Xixuan is a fifth year Computer Engineering student with interest in software and image analysis. His major responsibilities of the previous co-op position were to acquire medical images from the patients using MATLAB and implementing segmentation operations using machine learning (Tensorflow) based on Python. He has drawn plenty of experience in image analysis both in MATLAB and Python. He is confident that he can contribute all his efforts on thermal analysis and UI design for the Ember Trailer module.

5. Project Planning

The development of the Ember Trailer module will proceed over 3 phases: alpha phase, beta phase, and production phase.

The alpha phase is the first phase. It will be completed by the end of ENSC 405W in August 2022. This phase will include the functionality of the major systems of the module, detection, suppression, communication, and a rough UI displaying the communicated data. At the end of this phase, a presentation and demonstration will be given for the proof-of-concept prototype, providing a visualization of how the system works together. Most of the sensors for detection should be working to identify a hotspot while the suppression system should at least be able to drill into the ground. In the meantime, communication will occur between HQ and the module with the data obtained. The figures below show a GANTT chart of the alpha phase thus far.

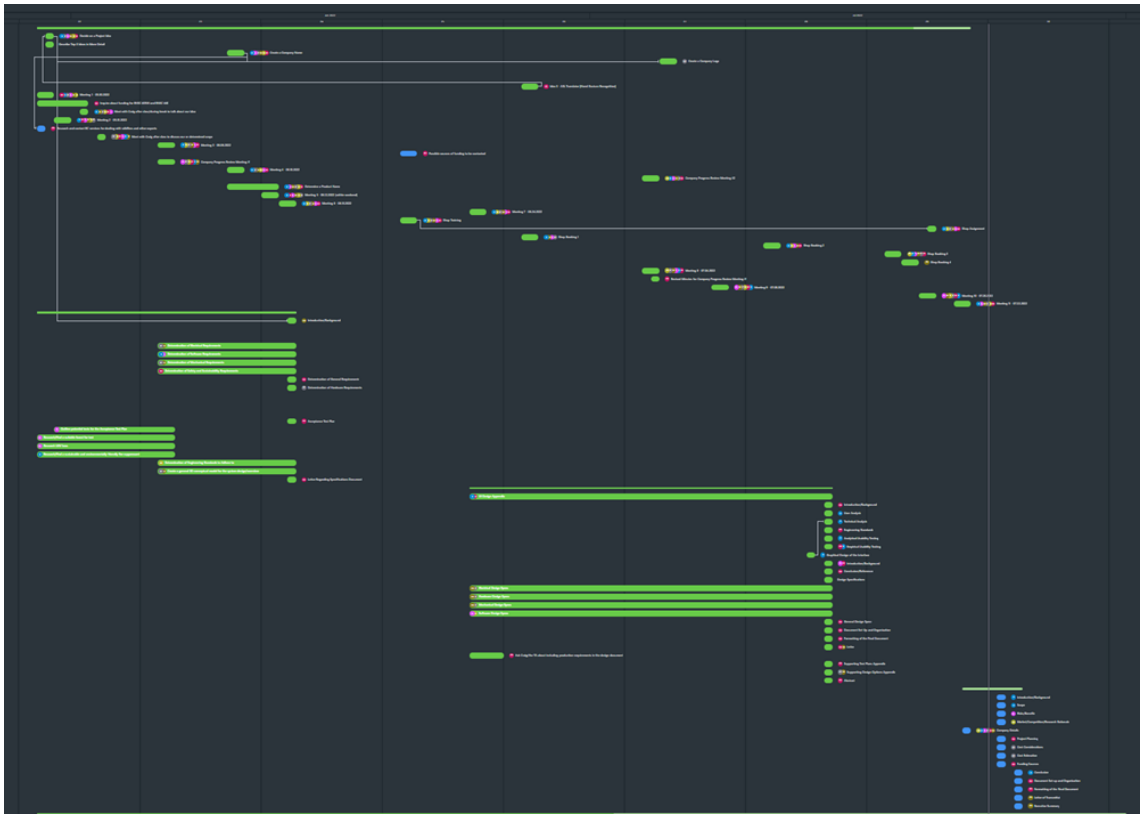

Fig. 5. Alpha Phase GANTT Chart

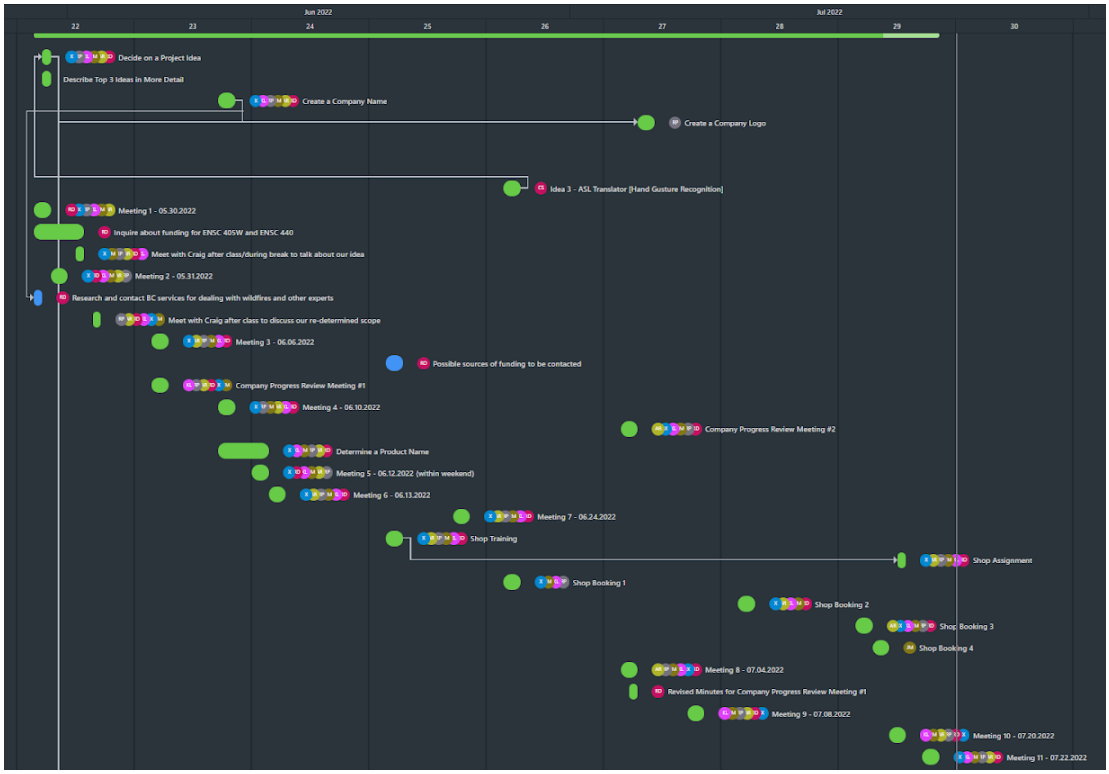

Fig. 6. Alpha Phase - Project Overhead GANTT Chart

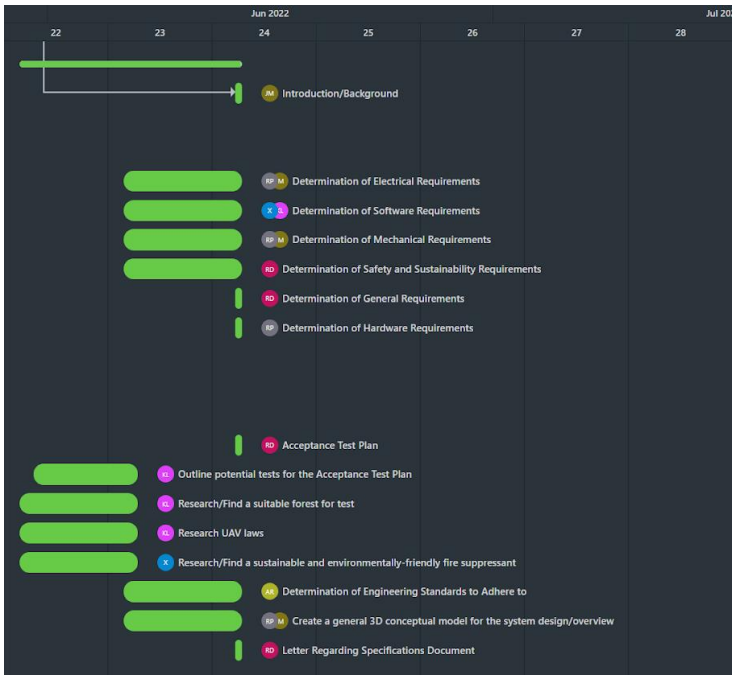

Fig. 7. Alpha Phase - Requirements Specifications Document GANTT Chart

Fig. 8. Alpha Phase - Design Specifications Document GANTT Chart

Fig. 9. Alpha Phase - Proposal Document GANTT Chart

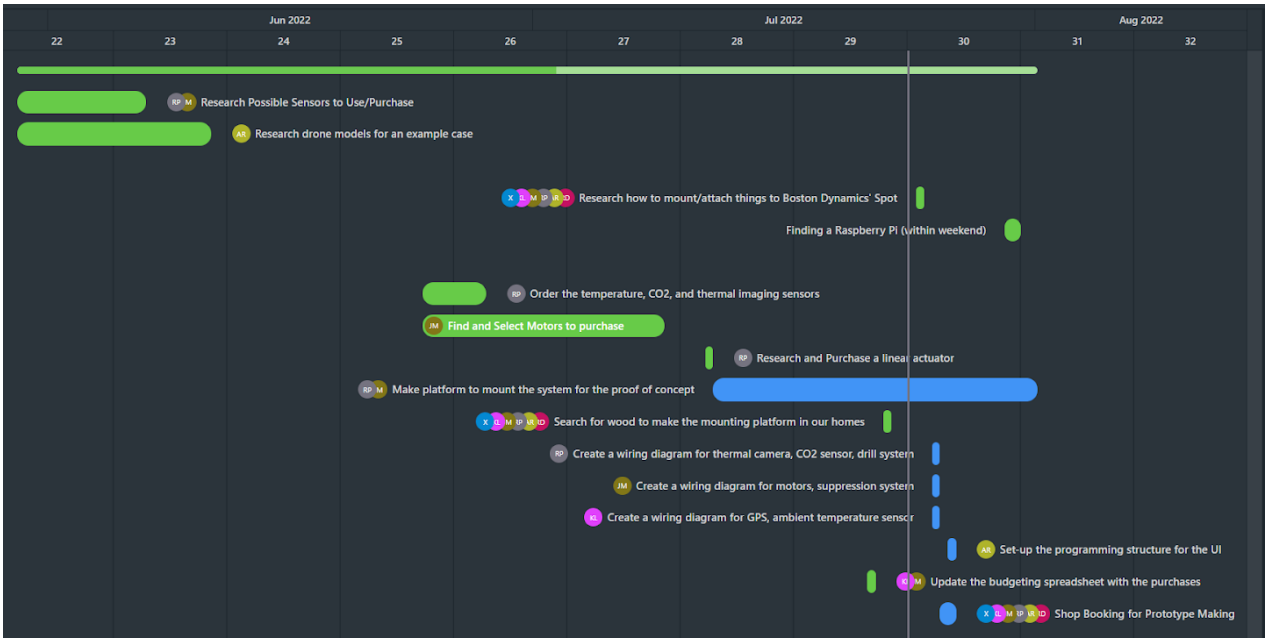

Fig. 10. Alpha Phase - Proof-of-Concept Prototype GANTT Chart

The beta phase for Ember Trailer will be during ENSC 440 starting September 2022 through to December 2022. An engineering prototype will be completed by the end of this phase and will include more functionality for the system and smoother communication between the module and the user application. Improvements will be made to the accuracy of the detection subsystem and the design of the user application to better showcase the data obtained by Ember Trailer.

The production phase will be post-ENSC 440 where an iterative process will refine the module to better suit the needs of the target market. There will also be a focus on increasing the effectiveness and efficiency of the Ember Trailer module.

6. Cost Considerations

6.1 Cost Estimation

The following tables outline the approximate cost for constructing the proof-of-concept prototype of the Ember Trailer module and the cost for constructing the functional product of Ember Trailer. The cost chart for the functional module will not include items already bought for the proof-of-concept prototype.

Table 1. Cost Chart for Proof-of-Concept Module

Component	Cost (CAD)
Water Pump	$30
Vinyl Tubing	$6
DC Motor Driver	$12
Linear Actuator	$180
Arduino	$28
Raspberry Pi	$80
Thermocouple + Amplifier	$20
Thermal Camera	$80
Air Quality Sensor	$8
Stepper Motor Controller	$20
Drill Motor	$40
Auger Drill Bit	$25
Drill Chuck	$40
Radio Transceiver	$40
GPS	$25
Analog to Digital Converter	$13
Shaft Coupler	$14
Breadboard x3	$30
Wooden Platform	$50
Screws/Nails	$30

Buck Converter	$20
Power Supply	$50
Total Cost	**$841**

Table 2. Cost Chart for Functional Module

Component	Cost (CAD)
FLIR Thermal Camera	$3000
Custom PCB	$40
Aramid Fibers	$40
Custom Structure	$300
Total Cost of new additions and replacements	**$3380**

Most items can stay the same from the proof-of-concept to the functional model, however, there are a few additions and changes. The thermal camera from the proof-of-concept would need to be changed with a higher quality thermal camera. FLIR has a few that are used for monitoring fires [16]. The breadboards used for the proof-of-concept prototype would also be changed for custom made PCB to better fit the structure of the module. The customer structure will have parts made from carbo fiber, due to its heat resistance and weight [17], and metals with a high melting point, such as steel [18]. It would also have a mounting rig at the bottom, so that the module can be mounted to the UGV. The price tag for the structure is approximated based on the material that would be used to construct it however the price may change depending on the quote given by the manufacturer used to construct it.

6.2 Funding Sources

There are 3 sources of possible funding being considered for this project:

1. Engineering Science Student Endowment Fund (ESSEF) [19]
2. Wighton Development Engineering Fund [20]
3. Forest Enhancement Society of British Columbia (FESBC) Funding [21]

The ESSEF is specifically designed by Engineering Science Student Society (ESSS) for Engineering Science students at SFU and will be applicable for this project in the beta phase at the start of ENSC 440 in September 2022.

The Wighton Fund is based on a competitive evaluation by an ad hoc committee of the project proposal. Applications for this fund will begin in the beta phase (ENSC 440). If successful, funding will be received according to a fixed budget, which will be negotiated.

The FESBC funds projects to assist BC in reducing the risk of wildfires and to promote awareness to communities about wildfires. Applications commenced on July 11, 2022, and will continue throughout the next year until March 15, 2024, when applications must be completed to be evaluated.

7. Conclusion

In conclusion, the increasing trend of wildfires has become one of the most urgent problems needing to be solved. Protecting the forest resources is an incumbent duty for every person to better the planet and all living-beings. The engineers at Nature Coolers thrive on developing an excellent product for the end users to achieve a common goal of saving the forests as much as possible and mitigating damage done. Also, safety and usability are key values in building Ember Trailer. Although it is unavoidable to encounter many risks and challenges during the development process, the expertise of the team will lead to the success of the product's development.

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