Ember Trailer

Company 3

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Meet the Nature Coolers Team

NATURE COOLERS

CEO - Systems Engineer
Jake Mix

CCO - Computer Engineer
Rachel Djauhari

Systems Engineer
Richesh Patel

Computer Engineer
Xixuan Song

Computer Engineer
Kevin Lo

Computer Engineer
Alfred Rodillo

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Average of **1,600** wildfires in BC per year [1]

Our Purpose

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Contribute to the efforts to prevent and mitigate the growing rate of wildfires each year.

Our Focus

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Increasing the efficiency of the ***mopping up process*** using a handheld device that rolls on the ground

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“Mop Up” (v.)

Extinguishing or removing burning material near control lines, felling snags, and trenching logs to prevent rolling after an area has burned to make a fire safe, or to reduce residual smoke [2].

The act of extinguishing a fire after it has been brought under control [3].

Rescoped Work

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- Original design used a UGV to carry the module
  - Many complications found with this method
    - Battery life
    - We could not work directly with UGV as we couldn’t physically acquire it
    - Traversing terrain
- New design created and modules simplified
  - Handheld rolling device
    - Solved all problems stated above
    - Achieved original goal in a more efficient manner
  - Less modules
    - Reduced to 3 simpler, main modules

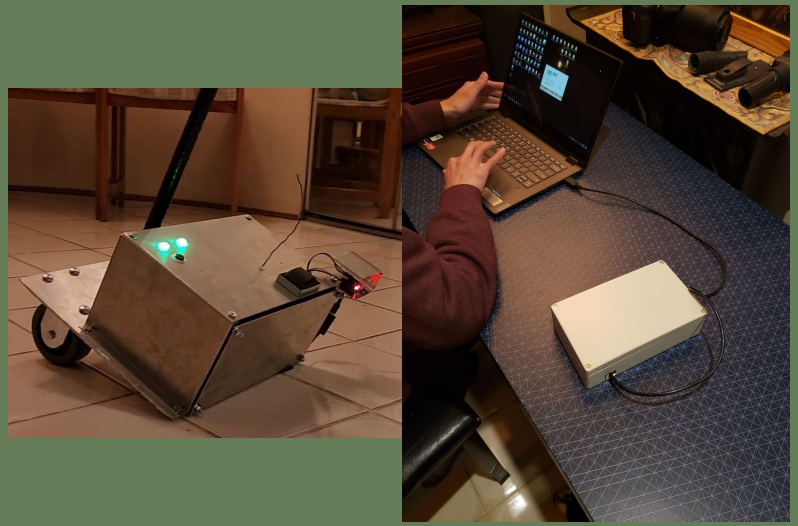

Fig. 1. Rescoped Ember Trailer Module

System Overview

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- Primary function is to detect and alert responders to hotspots on and under the ground

- Main components:
  - Detection + Visual feedback alert system
  - Communication system

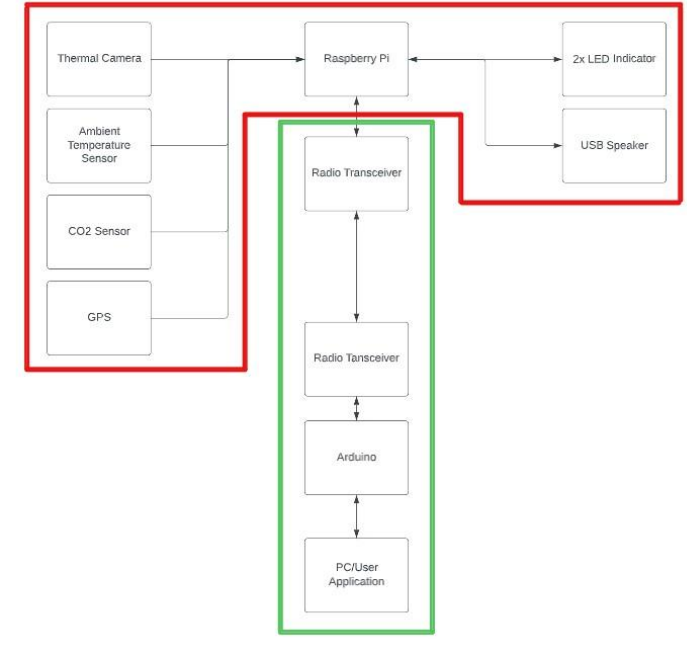

Fig. 2. System Diagram of Module

Design of Systems

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- Detection system
  - Uses thermal camera for visual spotting
  - Gas sensor to detect smoke particles
- Feedback Alert System
  - Uses 1 LED to show status of module
  - Another LED to show hotspot detection (changes color depending on severity)
  - Buzzer to provide extra layer of alerting the responder for hotspot detection
- Communication System
  - Transmits GPS coordinates to HQ computer
  - Displays a map of the area to show current location of module and detected hotspots

Design of Systems cont.

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Fig. 3. Portable Battery Pack used as PSU

- Power Supply
  - Using a rechargeable 5V 3A power pack to run the systems (150W Capacity)
  - Displays the battery level for user
  - Easy charging
  - 9-10 hour battery life
- Processing
  - Raspberry Pi 4 to process data from sensors and drive feedback systems
  - Also drives the transceiver for communication
  - Arduino Uno used has a receiver for HQ communication

System Overview

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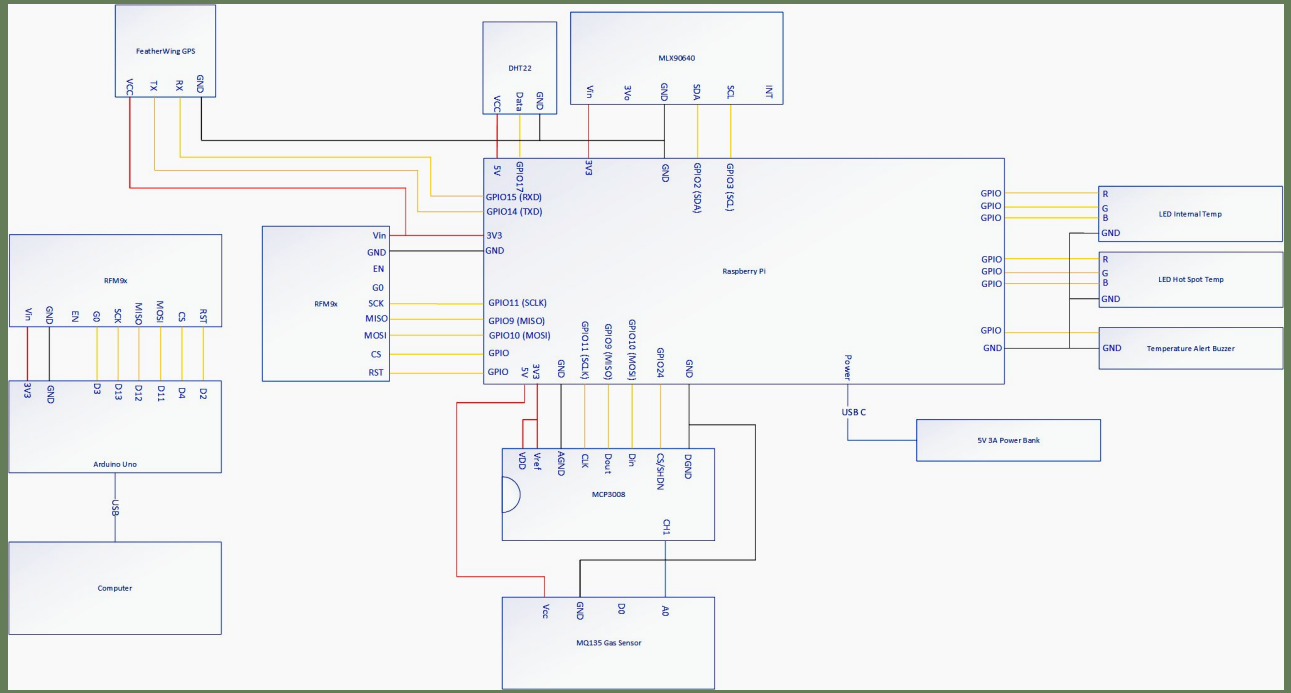

Fig. 4. System Wiring Diagram of Module

Materials

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- Sensors/Electronics
  - DHT22 Temp Sensor
  - MLX90640 IR Camera
  - RFM9x Transceiver
  - Featherwing GPS
  - MQ135 Gas Sensor
    - Can all be repurposed if whole device fails and they are not damaged
  - 5V 3A Power Bank (150W Capacity = about 10 hours of battery life)
- Raspberry Pi / Arduino Uno
  - Were excellent for testing and producing a prototype
  - Both can be easily reused for other projects if an Ember Trailer unit is unusable

Materials

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- Aluminum Frame
  - Aluminum is sturdy and lightweight enough to survive usage in wildfires
  - Melting point is 660C
  - Frame can be recycled if internal components fail
- Caster Wheels
  - Originally used for oven racks
  - Operating temperature of upto 250 degrees celsius
- Silicon Grip and Insulation
  - Operating temperature of upto 260 degrees celsius

Demonstration

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Demonstration

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- Temperature readings found:
  - Exposed ember is at least 350 degrees
  - Embers just below the surface is 100 degrees
  - Embers deeper underground is 50 degrees
  - Embers when cooling down and deep underground is 30-50 degrees
- LED Indicators
  - Changes colour depending on severity
  - 0 degrees is pure green and 50 degrees is pure red. Orange and yellow colours are used to indicate the temperatures between the green and red severities.

Estimated Schedule Timeline

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- September 2022
- Initial product design from the proof-of-concept

Fig. 5. Estimated GANTT Chart

Actual Schedule Timeline

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- Narrowed down the scope
- Simplified the project to focus mainly on detection and communication
- Changes made in the last month before demonstration
- Testing postponed multiple times due to poor weather conditions

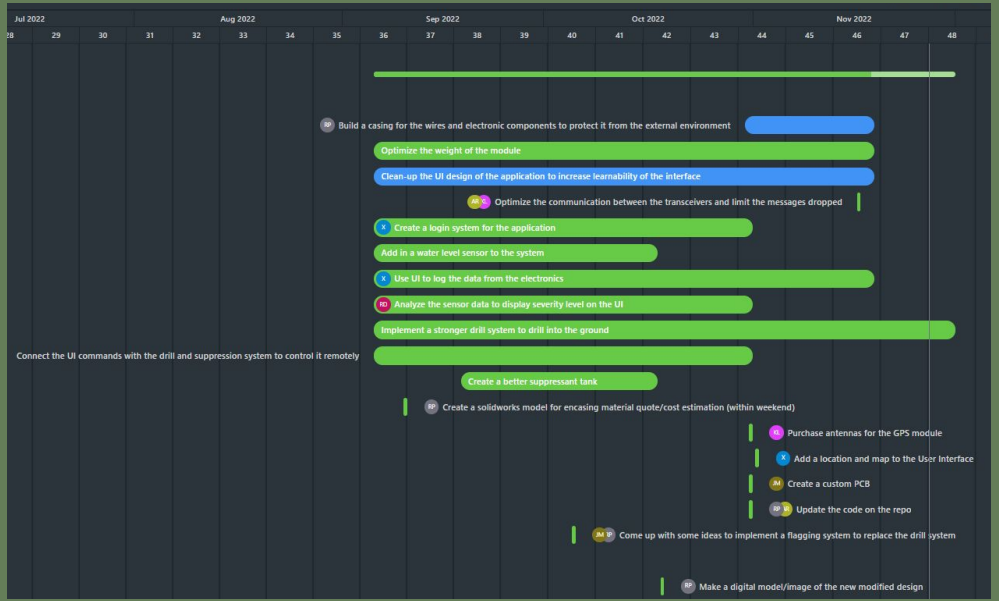

Fig. 6. Actual GANTT Chart

Breakeven Point Calculation

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Mass Production (25 Units)

Item	Total Cost
Raspberry Pi 4	$1886.25
Arduino Uno	$690
Ultimate GPS Featherwing*	$561.5
IR Camera MLX90640*	$1686.5
Gas Sensor MQ-135*	$175.75
MCP3008 ADC*	$101.25
RFM96W LoRa Radio Transceiver*	$449
DHT22 Temperature Sensor*	$213.75
Aluminum Case*	$3900
Wheel x2*	$1264
Handle (Flange and Pole)	$314.75
Portable Charging Power Supply	$1174.75
Custom PCB* (need to order 30 pcs)	$162
LED x2*	$34
Buzzer*	$40
Total Cost of Parts	**$12653.5**

*Materials can be bought at discount in bulk

$508.57 per unit

Breakeven Point Calculation

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Payroll and Utilities

- 5000 square feet warehouse is $5500
- BC Hydro utilities $97.53 for a year

Position	Average Salary*	# of Employees	Total Cost (bi-weekly)
Shipping/Receiving	$21.32/hr	2	$3411
Production Worker	$18.73/hr	3	$4495
Sales Representative	$24.28/hr	2	$4364
Systems Engineer	$42/hr	1	$3360
Computer Engineer	$41.18/hr	1	$3294

Total Payroll Costs:

Biweekly: $18924

Monthly: $37848

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$508.57 / unit

- Expenses for a month with 25 units built: $56009.63
- Product selling price to breakeven: $2240.39 per unit
- If the work is done on our own, the breakeven point becomes: $508.57

Cost Plus Pricing Strategy

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— Add percentage to cost for profit margin to determine final selling price —

- 50% profit margin from the breakeven point price per month…
- $508.57 => breakeven point per unit, assuming 25 build per month
- $508.57 * 1.50 = $761.99 per unit selling price

Since we sell less units to a niche market, 50% profit margin increases the profit more due to the lower volume of expected sales.

Budget and Financing

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- Willing budget: $100 per team member
- Financing received from ESSEF ($1000)
- Due to large changes in the project, resulted in a lot of sunk costs
    - Costs exceeded $1000 fund amount

The Market

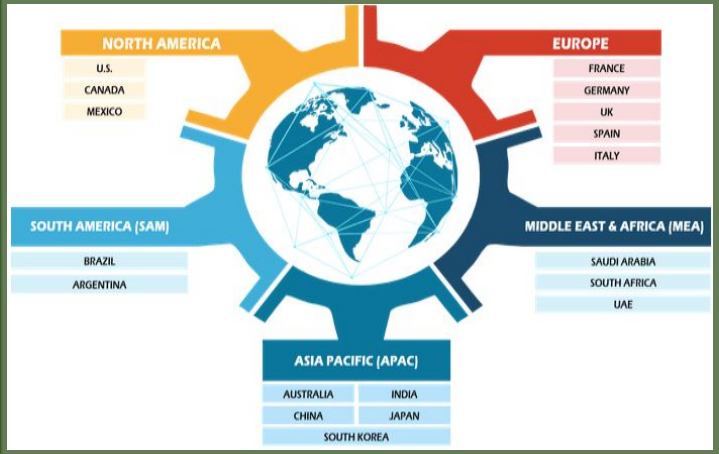

Fig. 7. Countries analyzed by market report [4]

- The current market for wildfire detection services is expected to grow at a rate of 6.5% from 2022 to 2030 [5]
- With a total market value of USD 60.51 billion [5]
- Market is worldwide as wildfires are a global threat and only getting more common

- Currently few IR technology used for cold trailing and mop-up
- Our product will fit into this market area and is an interesting prospect to BCWS

Customer Base

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- Primary target market:
  - Wildfire responders
  - Licensees of forested land
  - Private owners of forested land
- Risks:
  - Already formed partnerships by responders with other tech companies/organizations
  - Threshold needs to be adjusted depending on location and season
  - Potential job loss

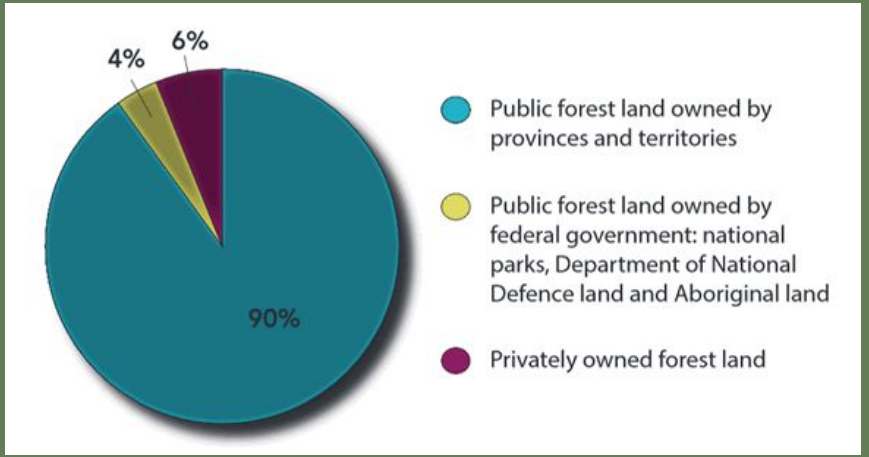

Fig. 8. Pie Chart of Forested Land Ownership in Canada [6]

Competitors

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- FLIR Thermal Imaging Cameras
  - Provides a handheld model recommended for mop-ups
- Cold Trailing Solutions
  - Conduction-based heat sensing probe
  - Release physical strain during mop-up process
- DJI UAVs (Unmanned Aerial Vehicles)
  - Provide bird’s eye view of large areas when equipped with thermal cameras

Risk Analysis

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- Risk of functional failure in the field
  - Could miss hotspots if internal components fail
    - Mitigated by status LED to warn user if there's an issue
    - General casing design helps to prevent physical damage
- Electrical safety risk
  - With all electronics, there's risk of electrocution
    - Casing is grounded, so user not at risk
    - Max voltage used is 5VDC from PSU
- Aluminum Heat Risk
  - After a sweep, metal casing could be hot from being near embers
    - Warning in product manual
    - Handle is insulated

Plan B

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If commercialization fails…

- Reconnect with BC Wildfire Services and determine what they would like to see with the product
- Reach out to other wildfire services that may be interested in the product
  - Likely reaching out to the U.S. NFPA (National Fire Protection Association)
- Can rescope project for a different detection task
  - Our hardware is based around detection

Engineering Standards

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Table. 1. Relevant Standards for Electrical Components

CSA C22.2 NO. 0.23:15, General requirements for battery-powered appliances [7]
CSA C22.2 NO 61508-1:17, Functional safety of electrical/electronic/programmable electronic safety related systems - Part 1: General requirements [8]
CAN/CSA-C22.2 No. 60529:05, Degrees of protection provided by enclosures [9]
CAN/CSA-C22.2 No. 94.2-07, Enclosures for Electrical Equipment, Environmental Considerations [10]

Table. 2. Relevant Standards for Hardware Components

Canadian Table of Frequency Allocations [11]

Engineering Standards

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Table. 3. Relevant Standards for the User Application and Interface

ISO 9241-125:2017, Ergonomics of human-system interaction - Part 125: Guidance on visual presentation of information [12]
ISO/IEC/IEEE 26514:2022, Systems and software engineering — Design and development of information for users [13]
ISO/IEC 29138-1:2018, Information technology - User interface accessibility - Part 1: User accessibility needs [14]

Table. 4. Relevant Environmental Standards and Guidelines

ISO TS 19677, Guidelines for assessing the adverse impact of wildland fires on the environment and to people through environmental exposure [15]
IEC TR 62824:2016, Guidance on material efficiency considerations in environmentally conscious design of electrical and electronic products [16]
IEC 62430:2019, Environmentally conscious design (ECD) - Principles, requirements, and guidance [17]

Engineering Standards

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- How they influenced the design process
  - Enclosures for Electrical Equipment [9]
    - We ensured our casing was grounded
    - For final design, casing would be fully sealed
  - Environmentally conscious design [17]
    - Originally we were going to use spray paint and other marking products
    - In the simplification of design, we eliminated the need to use these
    - Product now leaves nothing behind to damage environment
  - User interface accessibility
    - Labels are clear and readable, with units included
  - Using license-free radio frequency for communication

Reflection

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- Feedback incorporated from presentations and meetings
  - Rescoping of the initial project to what it currently is
- What changes did we make
  - Removed the suppression and drilling subsystems
  - Discarded the flagging system idea and opted for a simpler module focusing on efficient detection
- What did we learn
  - Don’t try to tackle too many components of a targeted process (narrow down the scope)

Conclusion

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- Ember Trailer device to increase efficiency and mitigate strain on wildfire responders during mop up.
  - Uses IR technology to detect hotspots
  - Physical feedback to operator about status of area

- Learnt the importance of keeping a design simple rather than complex and understanding the target customer’s needs
  - Feature management
  - Communication with customers

Acknowledgements

ENSC 405W

Dr. Craig Scratchley

Mohammad Soltanshah

ENSC 440

Dr. Andrew Rawicz

Eric Brace

BC Wildfire Services

Justin Nicholas

Kara Froese

Michael McCulley

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