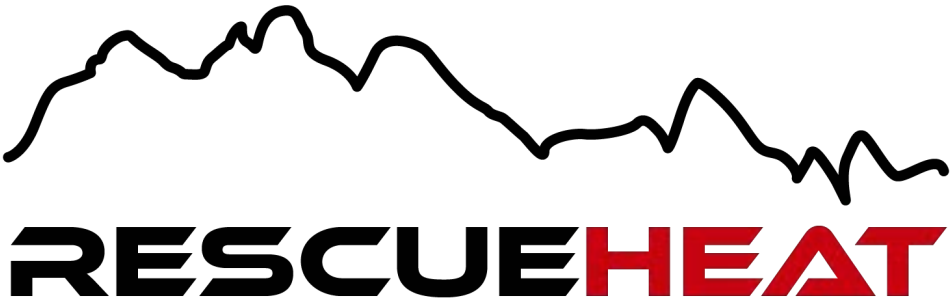

RescueHeat:
HYGER for rescue

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Introduction

RescueHeat, powered by HYGER technology, is a state-of-the-art infrared detection unit embedded in drones and designed to locate humans in mountainous and hard-to-reach regions. HYGER, an advanced infrared detection technology based on high-purity black germanium, offers high sensitivity and low noise characteristics. It is an advanced sensor with a dopant-free inversion layer for efficient signal collection and a nanotextured surface which absorbs 99.99% of the visible light, making it almost pitch black and resulting in an amazing sensitivity.
RescueHeat leverages HYGER's exceptional sensitivity and efficiency in the near-infrared (NIR) and short-wave infrared (SWIR) wavelengths. The typical wavelengths are depicted in **Figure 1:**

Figure 1: Typical Infrared Wavelengths

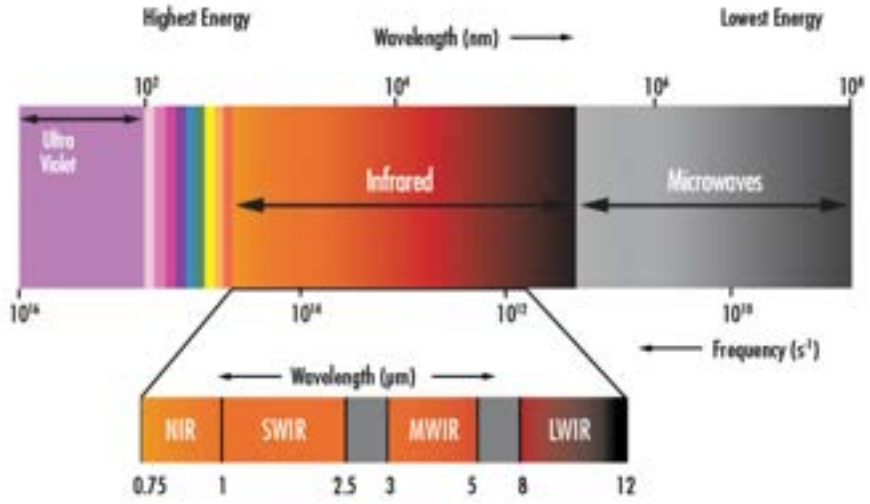
Its communication unit and terrain tracking system can communicate directly with the person in need and guide them or the rescue team through the safest and fastest routes, enabling efficient disaster response and wilderness safety operations. Equipped with spatial microphones, the drone can pick up and transmit sounds from the environment, providing additional context for rescue operations. Built-in speakers allow rescuers to give real-time instructions to those in need.
The drone also features HD cameras that offer high-resolution, real-time video feeds, ensuring that every detail is captured for precise navigation and assessment. Standard drone orientation sensors, including gyroscopes and accelerometers, ensure stable flight and accurate positioning.
This combination of advanced technologies makes it easy to navigate challenging terrains, maintain clear communication, and enhance the overall effectiveness of rescue missions. By leveraging these capabilities, our drones offer a comprehensive solution that enhances both the speed and safety of wilderness rescue operations, providing peace of mind for adventurers and rescuers alike.
With its low manufacturing cost, CMOS compatibility, and rugged adaptability to various terrains, RescueHeat has the potential to transform how search and rescue operations are conducted, bringing efficiency and precision to disaster response, wilderness safety, and security missions.

HYGER Technology

What is it?

HYGER is an advanced infrared detection unit built on high-purity black germanium technology. Instead of using traditional anti-reflection coatings, HYGER employs a nanotextured surface that fully absorbs light across a wide range of wavelengths, from 0.4 to 1.8 µm. This innovative approach provides exceptional sensitivity in the near-infrared (NIR) and short-wave infrared (SWIR[1]) ranges. Developed through a collaboration between Aalto University, Baltic Scientific Instruments, and Umicore, HYGER converts light into electrical signals, making it possible to measure the intensity and wavelength of incoming photons accurately. It offers high sensitivity, low noise, and compatibility with CMOS technology, all while being cost-effective to manufacture.

Figure 2: Electromagnetic Spectrum

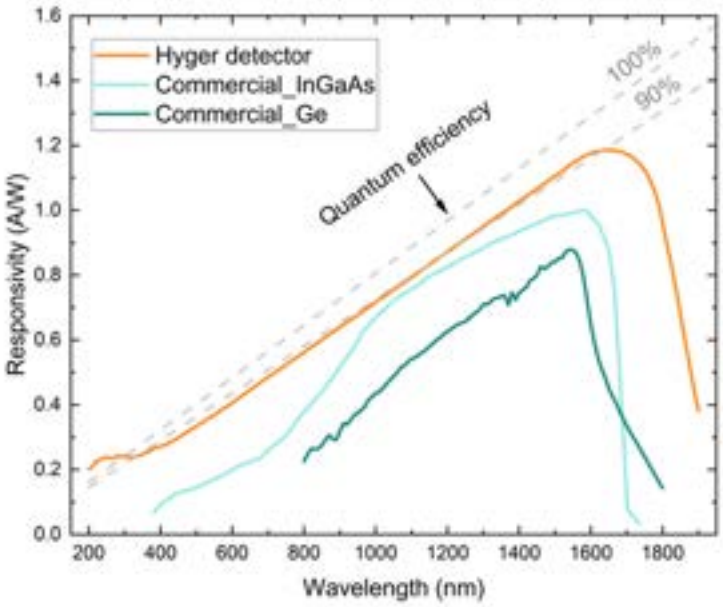


Source: https://www.edmundoptics.es/knowledge-center/application-notes/imaging/what-is-swir/

HYGER technology was initially designed for scientific comparisons between different photosensors. However, researcher Fung John recognized its potential for broader applications, exploring its performance against existing technologies. The sensor demonstrated consistent high sensitivity across a broad wavelength range, positioning it as a competitive alternative to Indium Gallium Arsenide (InGaAs) detectors but at a significantly lower cost. The germanium-based active material is responsible for detecting incoming light, with a scanning electron microscope (SEM) image showing the nanotextured surface that reduces reflectance to less than 1%. This remarkable reduction compared to traditional coatings improves overall performance. HYGER maintains approximately 90% responsivity, making it a strong competitor in the current market.

[1] https://www.edmundoptics.es/knowledge-center/application-notes/imaging/what-is-swir/

Figure 3: Responsivity of Hyger detector across a wide spectrum, compared to commercial detectors made of InGaAs and germanium



Source: John Hang Fung, main researcher

This breakthrough in sensor technology is made possible through three unconventional photodiode manufacturing approaches developed during the ATTRACT Phase 1 pilot action:

- Dopant-Free Inversion Layer: Enables charge collection with minimal electrical losses.
- Atomic Layer Deposited Thin Films: Replaces PECVD dielectric layers with highly charged thin films, improving surface passivation and reducing recombination velocity.
- Nanotexturing Process: Eliminates reflectance by applying a nanotexturing process to germanium surfaces, leading to a fully absorbing surface across a wide range of wavelengths and acceptance angles.

HYGER's performance in the NIR and low-energy X-ray detection ranges offers superior sensitivity and versatility. Currently at Technology Readiness Level (TRL) 4, it has been successfully demonstrated in laboratory settings and is now being explored for real-world applications.

Competitive advantage

We explored HYGER technology by comparing various photo sensor materials and identified the superior characteristics of germanium photosensors compared to other technologies. The table provided showcases the different photodetector technologies and their performance across parameters like gain, useful spectral range, quantum efficiency, response time, and dark current.

Table 1: Comparison of different photodetectors

Characteristic	HYGER	Si PIN	Si APD	Ge APD	InGaAs PIN	InGaAs APD	Photomultiplier
Gain	10-100	1	50-300	10-100	1	10-40	10^5 - 10^7
Useful Spectral Range	800-1750 nm	400-1150 nm	400-1150 nm	800-1750 nm	900-1700 nm	900-1700 nm	160-850 nm
Quantum Efficiency	90%	60-90%	70-80%	50-80%	70-90%	60-90%	30%
Response Time (ns)	0.05-5	0.3-3	0.5-5	0.3-3	0.05-1	0.1-1	0.15-13
Multiplied Dark Current (nA)	5-100	N/A	0.1-1.0	5-100	N/A	0.5-5	10-200
CMOS Compatibility	Yes	Yes	Yes	No	No	No	No
Construction Cost	Low	Low	Moderate	Moderate	High	High	High

Source: Amanor, D. N., Edmonson, W. W., & Anyanhun, A. I. (2016, June). Visible Light Communication System for Inter-Satellite Communication of Small Satellites. Paper presented at the Small Satellites Systems and Services - 4S Symposium 2016, Valletta, Malta.

- **Spectral Range:** HYGER provides a broad spectral range (800-1800 nm), surpassing silicon photodetectors and being comparable to InGaAs APD and Ge APD but with the added benefit of CMOS compatibility.
- **Quantum Efficiency and Responsivity:** HYGER maintains high quantum efficiency (70-90%) in the near-infrared spectrum. Its nanotextured surface reduces energy consumption and enhances detection, with low radiation emission.
- **Construction Cost:** HYGER's compatibility with CMOS processes keeps manufacturing costs low, offering significant advantages over InGaAs and photomultiplier technologies.
- **Response Time**: HYGER's response time (0.05-5 ns) is competitive with other technologies, ensuring accurate and high-speed detection
- **Improved Sustainability:** Germanium is more sustainable than Indium Gallium Arsenide.

- **Reduced Noise compared to Gallium Arsenide:** Higher Signal-to-Noise Ratio provides accurate and reliable data acquisition.

The HYGER sensor's unique blend of quantum efficiency, spectral range, and CMOS compatibility makes it a standout choice among photosensors. These strengths position HYGER as an ideal candidate for applications such as hyperspectral imaging, telecommunications, and fiber optic communications.

Application Selection Process

Research and Analysis

In the early stages of the process, our team set out on a comprehensive research journey to uncover the diverse range of applications that could benefit from HYGER technology. We focused on areas such as pollution monitoring, crop management, and skin detection, aiming to identify where HYGER could make a significant impact.

- Pollution Monitoring:

We explored how HYGER technology could contribute to environmental monitoring by detecting greenhouse gasses like methane and carbon dioxide. Our approach involved reviewing recent scientific papers and existing technologies and services that detect polluted areas, and consulting potential users through surveys to assess interest and understand the specific requirements.

- Crop Management:

In the agricultural sector, we examined the potential of HYGER technology to revolutionize crop scanning and management. This involved researching the latest developments in hyperspectral imaging and disease or pesticides detection to identify practical solutions.

- Skin Detection:

We investigated HYGER's application in the medical field, particularly for non-invasive skin diseases detection. Conversations with dermatologists and experts in biomedical imaging provided valuable insights into current challenges and solutions and the potential improvements HYGER could offer. We also conducted surveys to assess the interest of potential users in a skin detection device.

Applications Considered

HYGER technology has the potential to revolutionize multiple industries with its advanced infrared sensing capabilities combined with the robustness of germanium-based sensors. This technology offers a myriad of applications that promise to enhance efficiency and safety across fields ranging from aerospace to agriculture and beyond. Let’s delve into the possible impacts and integrations of HYGER technology that we considered during our design process.

- **Aerospace Applications**

In the high-stakes realm of aerospace, precision and reliability are essential. HYGER technology’s exceptional sensitivity to infrared variations could be a game-changer for monitoring critical substances like fuel, water, and oxygen. The ability to detect even the smallest leaks that are invisible in the visible spectrum can significantly enhance the safety of astronauts and the reliability of space missions. This early detection capability could prevent potential disasters, making space travel safer and more sustainable.

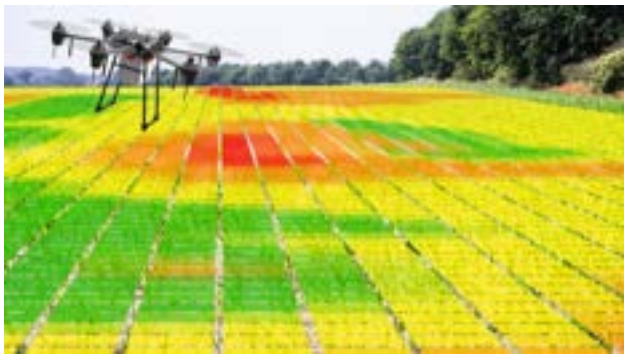
Figure 4: Example of leak detection

https://www.flir.com/

- **Agricultural Enhancements**

The agricultural sector stands to benefit greatly from HYGER technology. Its ability to perceive subtle differences in infrared radiation can help farmers detect early signs of stress in crops, such as disease or water shortage. This precise detection enables targeted treatments, which conserves resources and increases crop yields. Imagine farmers being able to apply water or pesticides only where needed, leading to healthier crops and a reduced environmental footprint. This kind of smart farming is a step towards more sustainable agricultural practices.

Figure 5: Example of crop health monitoring



https://avirtech.co/

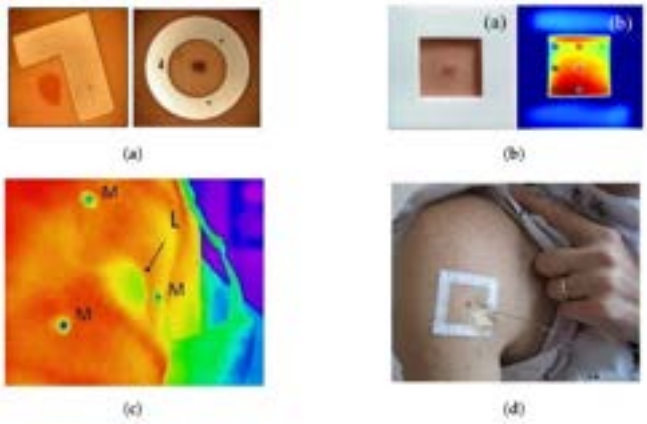
- **Environmental Monitoring**

As environmental concerns grow, monitoring pollutants becomes increasingly critical. HYGER technology could significantly improve our ability to track air quality by accurately detecting pollutants at the molecular level. This could empower local governments and environmental agencies to take timely actions to protect public health and the environment. Whether it's keeping an eye on industrial emissions or checking the air quality in urban areas, HYGER sensors could provide the data needed to make informed decisions.

- **Healthcare Innovations**

In healthcare, HYGER technology could introduce groundbreaking tools for diagnosing and monitoring various conditions. Its ability to analyze changes in skin temperature can help in the early detection of medical conditions that manifest as thermal anomalies. For the cosmetic industry, HYGER sensors could evaluate the effectiveness of skin treatments, offering insights that help tailor personalized skincare routines.

Figure 6: Thermal skin monitoring



Verstockt, J., Verspeek, S., Thiessen, F., Tjalma, W. A., Brochez, L., & Steenackers, G. (2022). Skin Cancer Detection Using Infrared Thermography: Measurement Setup, Procedure and Equipment. Sensors, 22(9), 3327. https://doi.org/10.3390/s22093327

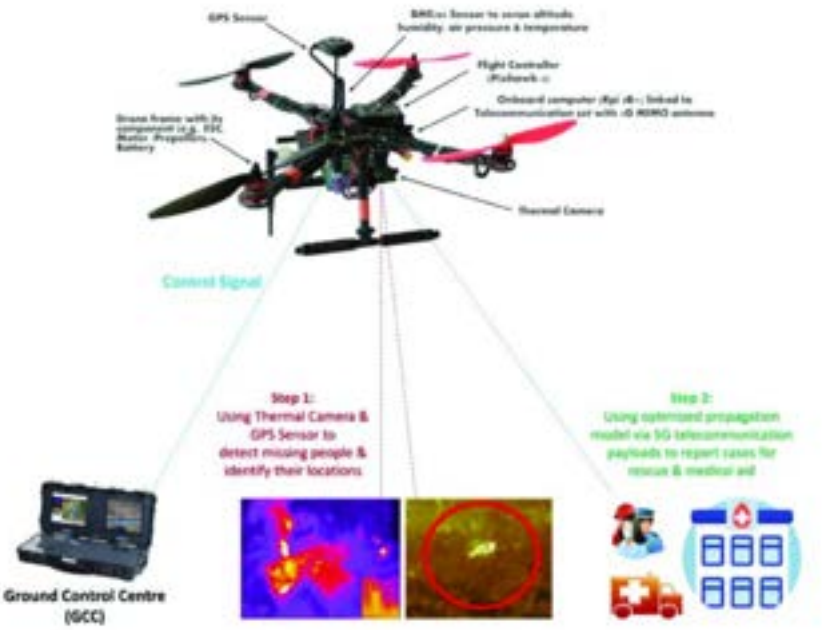
- **Disaster Response**

Perhaps one of the most impactful applications of HYGER technology is in disaster response. Attached to drones, HYGER sensors can quickly identify the heat signatures of people trapped in disaster-stricken areas. This technology can drastically cut down the time it takes to locate and rescue survivors, saving lives and making rescue missions safer and more efficient. In the chaos following a natural disaster, every second counts, and HYGER technology could be a critical factor in improving outcomes.

- **Outdoor Recreation Safety**

For enthusiasts exploring the great outdoors, HYGER technology can enhance safety. Drones equipped with HYGER sensors could patrol popular hiking or climbing spots, quickly locating distressed adventurers by their heat signatures. This would not only speed up rescue operations but also ensure that vast, remote areas are monitored effectively, keeping thrill-seekers safer as they indulge in their adventures.

Figure 7: Proposed structure of a drone for use in search-and-rescue operations



Almalki, F. A., & Ben Othman, S. (2022). Modifying Hata-Davidson Propagation Model for Remote Sensing in Complex Environments Using a Multifactional Drone. Sensors, 22(5). https://doi.org/10.3390/s22051786

Final Selection

After evaluating various potential applications of HYGER technology, our team decided to focus on integrating it into drones specifically designed for wilderness search and rescue operations. This decision was driven by several key factors that highlighted the unique benefits and urgent need for advanced technological solutions in this area.

1. **Critical need:** Every year, thousands of individuals find themselves lost or injured in remote areas, often with fatal outcomes. The existing methods for locating these individuals—ranging from ground search parties to standard aerial surveillance—are not only time-consuming and labor-intensive but also often ineffective in complex terrains or adverse weather conditions.
2. **Improving reach and safety of operations:** Our drones can access rugged and hard-to-reach areas that are challenging, if not impossible, for ground teams to navigate safely. By deploying RescueHeat drones, search teams can cover vast areas quickly, minimizing the physical risk to rescuers and maximizing the area scanned within crucial time limits.
3. **Cost-effectiveness:** Incorporating HYGER technology into search and rescue drones also presents a cost-effective solution compared to the high operational costs associated with manned helicopter searches. Drones require less manpower and can be deployed quickly and repeatedly without the need for extensive logistical support. This efficient use of resources not only saves costs but also allows rescue teams to allocate their limited resources more effectively, potentially increasing the number of lives saved.

4. **Scalability and versatility:** Another compelling reason for choosing RescueHeat drones is their scalability and versatility. The technology can be adapted and scaled to different types of terrain and search conditions, from mountainous regions and dense forests to desert landscapes. Furthermore, the data collected by these drones can be used not only for immediate rescue operations but also for planning and improving safety measures in frequently visited wilderness areas.

RescueHeat

Problem Definition

The challenge of locating and rescuing individuals lost or injured in wilderness areas is a global issue, with alarming statistics that highlight its severity. While we will cite US data due to its better availability, it is important to understand that this significant problem persists worldwide, especially in mountainous regions where the terrain complicates search and rescue efforts.

Each year, approximately 4,661 people are reported lost in the wilderness in the US, necessitating urgent search and rescue operations. These operations, which number around 50,000 annually across the U.S., are often hampered by the vast and challenging terrains that make traditional search methods inefficient and sometimes ineffective. Notably, most incidents occur in the late afternoon and during weekend explorations, complicating rescue efforts as daylight fades.

The stakes are incredibly high, as the survival of those lost or injured often hinges on the critical "golden hour"—the brief window after an incident during which medical intervention is most likely to be successful. Unfortunately, the average search duration extends well beyond this, with search and rescue teams typically locating individuals after about 10 hours, during which the chances of survival diminish significantly. Moreover, these operations are not only time-intensive but also expensive, costing approximately $32,000 per mission.

Compounding the problem, the data reveals that those who go missing are often alarmingly close to safety, with the average person found just 1.8 km from their starting point and only 58 meters from the nearest trail or road. This proximity highlights the dire need for more effective detection and localization technologies that can significantly shorten search times and improve outcomes.

The integration of advanced technologies like HYGER into search and rescue operations, particularly through our RescueHeat drones, addresses these challenges head-on, offering a faster, safer, more efficient, and potentially life-saving response to a grave and ongoing problem.

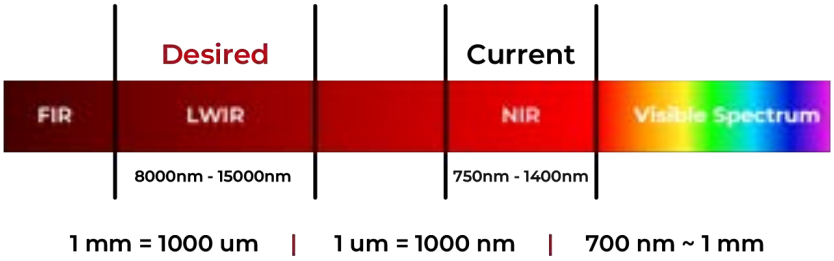
Technology

Essential idea to use HYGER sensors for thermal imaging and, hence, scanning the environment lies with two simple concepts.

Initially, the application area is often overlooked, leading to a high incidence of missing or deceased hikers, trail runners, mountaineers, and so forth. This happens due to the large scale of search areas and limited rescue resources. In most cases related to this type of emergencies, time plays a vital role in locating injured humans, who seek for immediate hospitalization or medical assistance.

Current HYGER availability doesn't provide a significant advantage in thermal detection, due to the primary region of operation – NIR and SWIR. Our vision is to use Hyger Approach and push it forward to the LWIR region by using nanotexturisation process for different types of materials such as GaAs (gallium arsenide) a-Si (amorphous silicon), Ti (titanium) or ZnSe (zinc selenide). This implementation allows us to achieve desired wavelength and, therefore, we can use HYGER as a thermal camera with exceptional sensitivity. The desired wavelength is shown in **Figure 8**:

Figure 8: Desired Wavelength for thermal camera application



Functioning

The core principle behind our solution is the use of an infrared spectrum receiver. In mountainous environments, the ambient temperature is typically lower than the human body temperature. This allows the infrared receiver to detect temperature variations and identify the presence of humans by scanning for these differences.
The drones, controlled by operatives using RC controllers, are equipped with advanced computer vision algorithms that enable the tracking and identification of objects, particularly humans.

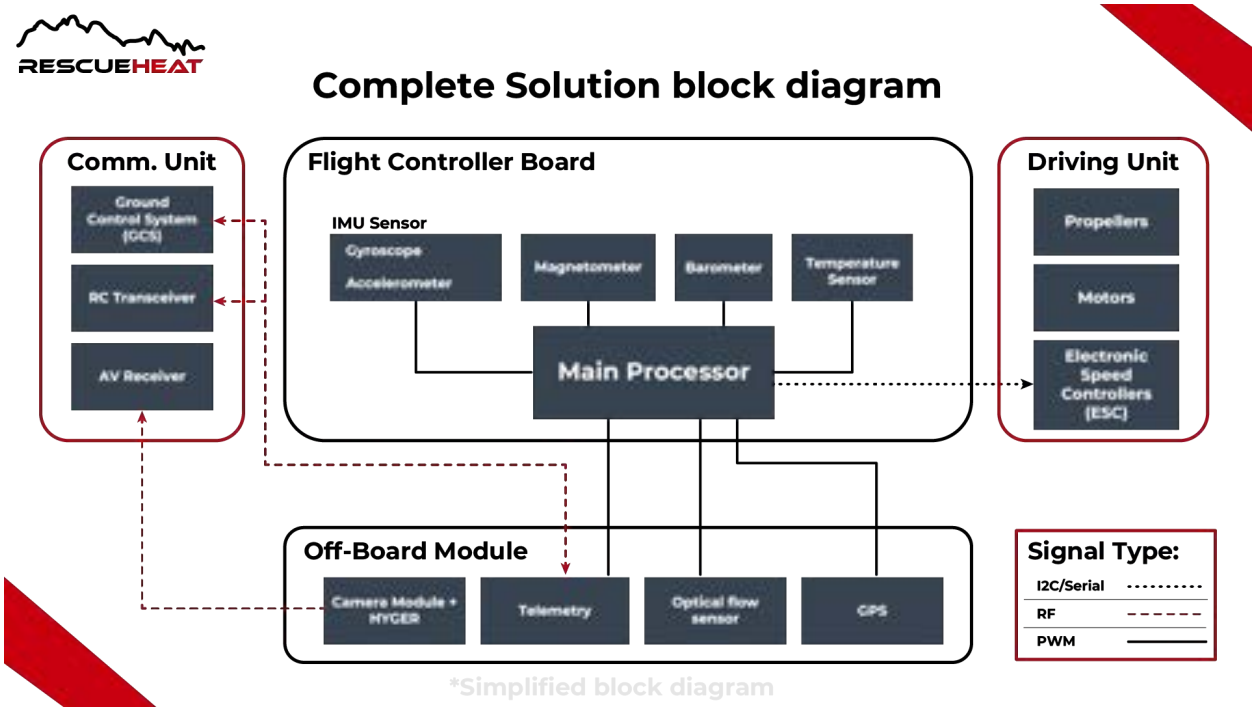
Figure 9: Possible concepts for applications

These algorithms process the visual and thermal data to accurately recognize and follow targets.
Additionally, the system incorporates 3D mapping of the terrain, allowing it to create detailed topographical maps. This enhances the drone's ability to navigate complex environments and improves the accuracy of search and rescue operations.
The portability of our system enables frequent and flexible scanning sessions, ensuring consistent and reliable detection in various locations. Thus our key advantage is portability, compared to the existing alternatives such as helicopters.

Architecture

To implement our solution it is necessary to integrate it to the existing drone technology. Therefore our engineering team designed the actual drone block diagram, which shows how the independent drone modules interact with each other. This allows us to understand how modern drones operate and further integrate additional sensors (HYGER) into the system. The diagram is depicted in Figure 10:

Figure 10. Solution block diagram



To specify, each module does its unique tasks, starting with a communication unit.
Comm. Unit (Communication Unit):

- **Ground Control System (GCS)**: The interface for controlling and monitoring the drone from the ground.
- **RC Transceiver (Radio Control Transceiver)**: Enables two-way communication between the drone and the remote controller.

- **AV Receiver (Audio/Visual Receiver)**: Receives video and audio signals from the drone for real-time monitoring.

Followed by the flight controller board.
Flight Controller Board:

- **IMU Sensor (Inertial Measurement Unit Sensor)**: Measures the drone's orientation and movement.
- **Gyroscope**: Measures angular velocity.
- **Accelerometer**: Measures linear acceleration.
- **Magnetometer**: Measures the magnetic field to help determine the drone's orientation.
- **Barometer**: Measures atmospheric pressure to determine altitude.
- **Temperature Sensor**: Monitors temperature to ensure optimal operating conditions.
- **Main Processor**: Central processing unit that controls drone operations and processes data from sensors.

Then goes the Driving unit of the drone.
Driving Unit:

- **Propellers**: Generate lift and thrust for flight.
- **Motors**: Drive the propellers to create necessary thrust.
- **Electronic Speed Controllers** (**ESC**): Regulate motor speed based on flight controller commands.

Followed by an off-board module.
Off-Board Module:

- **Camera Module + HYGER**: Captures images and videos, potentially including thermal imaging.
- **Telemetry**: Transmits drone status and environmental data to the ground control system.
- **Optical Flow Sensor**: Detects ground movement to assist in stable flight.
- **GPS (Global Positioning System)**: Provides location data for navigation and positioning.

To communicate within the complex system several types of communication signals are used:
Signal Types:

- **I2C/Serial (Inter-Integrated Circuit/Serial Communication)**: Communication protocols for data transmission between modules.
- **RF (Radio Frequency)**: Wireless communication for remote control and telemetry.
- **PWM (Pulse Width Modulation)**: Signal type used to control motor speeds via ESCs.

Team 5 (Hyger):
Evripidis Avraam, Federica Tornaghi, Nicolay Garcia, Richard Malpartida, Vicky Mercado Luna

Business Model Canvas

Key Partners

- **Manufacturers of infrared sensors:** Baltic Scientific Instruments and other sensor manufacturers play a crucial role in supplying essential components.
- **Drone manufacturers:** Partnerships with drone manufacturers allow for seamless integration.
- **Universities and research institutions:** Aalto University and CERN, among others, provides research support and technical expertise for product development.
- **Emergency Management Agencies:** Collaboration ensures the product meets field requirements.
- **NGOs:** Help in reaching out to vulnerable areas where humanitarian aid is needed.

Key Activities

- **Development of RescueHeat Hardware and Software:** Continuous improvement of the sensor and integration with other systems.
- **Integration with drones:** Customization and testing to ensure smooth operation.
- **Field testing:** Collaboration with emergency services for real-world validation.
- **Marketing and awareness campaigns:** Promote awareness among potential customers and end-users.

Key Resources

Tangible resources:

- Advanced drones and infrared Sensors
- Manufacturing and testing facilities for assembly and quality control.
- Distribution Network

Intangible Resources:

- Software and algorithms for image processing and navigation integration.
- Expertise in aerospace, robotics, and thermal imaging skills.

Value Proposition

- Rapid and accurate detection of humans in mountainous and hard-to-reach regions to **enable swift and efficient search and rescue operations.**
- Real-time, high-resolution thermal mapping that **provides rescue teams with accurate data for informed decision-making and effective resource allocation.**
- Cost-effective, scalable design to allow integration with drones **to cover wide areas quickly.**
- More precise identification of human heat signatures, thanks to HYGER technology, which offers **superior sensitivity and affordability** compared to existing infrared sensors on the market.

Customer Relationships

- **Dedicated support and training:** Direct assistance and field training for rescue teams to learn the perfect use of RescueHeat.
- **Online resources:** Tutorials, guides, and troubleshooting resources.

Channels

- **Direct sales:** reaching government agencies and rescue organizations directly.
- **Partnerships:** collaborating with manufacturers and NGOs for broader reach.
- **Fairs and conferences**

Customer Segments

- **Search and rescue organizations:** Need accurate data for quick and smooth operations in challenging terrains.
- **Government emergency management agencies** responsible for disaster management and response.
- **Humanitarian NGOs:** Conduct rescue missions in difficult areas.
- **Drone manufacturers:** for seamless integration of sensors.
- **Border security agencies:** Need effective monitoring of remote border regions

Cost Structure

- **Research and Development costs**: Continuous improvement and innovation.
- **Manufacturing costs**: For sensor and device production.
- **Marketing and sales costs:** To build awareness and generate leads.
- **Training and support expenses**: Customer support and training programs.
- **Software development costs:** Maintaining and updating the software.

Revenue Streams

- **Direct sales**: One-time payment for purchasing the device.
- **Licensing fees:** Licensing the technology to third-party drone manufacturers.

Impact Assessment

Implementing RescueHeat technology in search and rescue operations offers not only a technologically superior solution but also one that is cost-effective and potentially life-saving. With approximately 50,000 missions conducted annually across the U.S., the integration of RescueHeat could lead to a 25-30% reduction in casualties, effectively saving more lives by enhancing the speed and accuracy of these missions. According to the US Rangers Dept reports for 2023 around 50.000 SAR operations were conducted, which resulted in a dramatic number of 140 per day and, in addition to that, resulted in a huge budget increase.
Financially, the adoption of our drones would decrease the cost per mission by 20%, leading to considerable annual savings given the current expenditure of over $160 million on these operations, and making the technology more accessible even for resource-constrained regions. This innovative approach not only ensures quicker and more effective rescues but also represents a significant advancement in resource management and operational efficiency in the critical first hours of search and rescue missions.

Assumptions:
Total Search and Rescue operations per year: **50,000**
Cost of each SAR mission: **$32,000**
Casualty rate in SAR Missions: 6.5%
Improvement in casualty rate due to RescueHeat technology: Assuming a 30% reduction in casualties due to more efficient searches.
Cost reduction per mission with RescueHeat: Assuming 20% cost reduction.

Lives saved:
New Casualty Rate with RescueHeat: 0.065 × (1-0.30) = 0.0455 = **4.55%**
Lives saved: 50,000 x (0.065-0.0455) = 975 lives saved per year only in the US

Cost optimization:
Annual cost of SAR missions: 50,000 x $32,000 = **$1,600,000,000**
New cost per mission with RescueHeat: $32,000 x 0.80 = **$25,600**

Annual cost savings: $1,600,000,000 - ($25,600 x 50,000) = $320,000,000

This significant improvement in both social and financial terms underscores the potential transformative impact of implementing the RescueHeat technology in wilderness search and rescue operations.

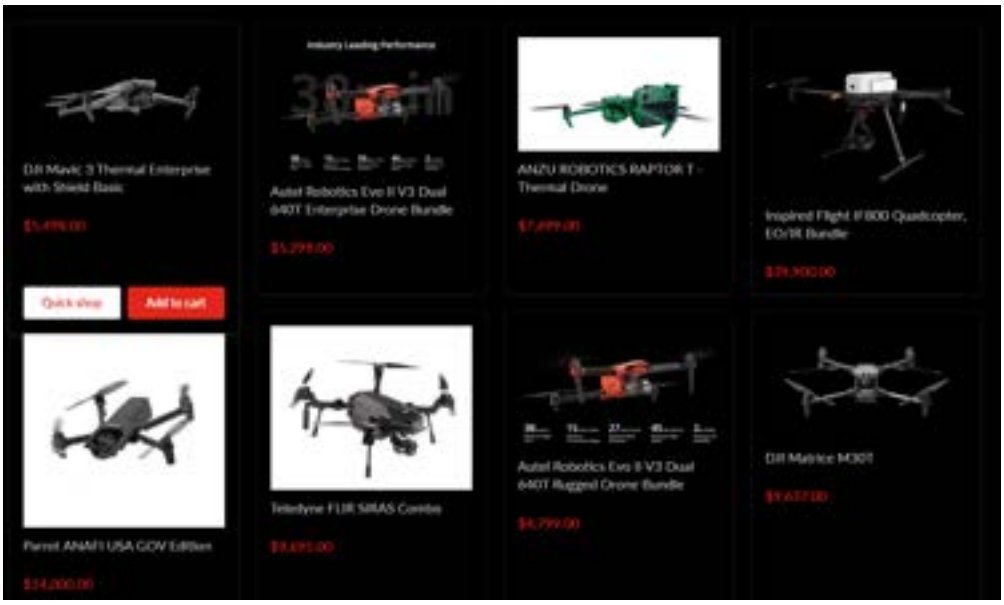
Market Analysis

Competitors and Alternatives

The search and rescue (SAR) equipment market is increasingly vital due to growing demands for efficient emergency response solutions across various environments, including wilderness areas and disaster sites. This market includes diverse technologies such as thermal drones, GPS devices, and traditional helicopter rescue services.

- Thermal Imaging drones: Companies like DJI and FLIR offer drones with thermal cameras for search operations. These units can spot heat signatures from the air but often at higher price points. Figure 11 and Figure 12 show the very high prices of both drones and thermal cameras. Moreover, these drones do not come with built-in tracking and communication units, making them effective only in locating people, not in rescuing them.

Figure 11: Main thermal drones prices



https://www.tracerdrone.com/collections/thermal-drones?view=view-24&grid_list=grid-vieW

Figure 12: Thermal cameras prices

https://www.heliguy.com/collections/thermal-drones-cameras

- GPS trackers and satellite messengers: Devices from brands like Garmin and SPOT provide crucial location tracking and communication in remote areas, enhancing the safety of adventurers and rescuers alike.
- Helicopter search: Despite having good range and speed, especially in severe terrains, helicopters are costly and limited by weather conditions and visibility issues. Also, a pilot is needed to fly them and operate them, which brings additional costs.

Competitive Advantages

RescueHeat incorporates HYGER technology to enhance traditional SAR approaches with several distinctive advantages:

- Superior detection capabilities: Utilizing high-purity black germanium, RescueHeat drones detect minute temperature differences more effectively and from greater distances than typical thermal imaging devices. This feature is crucial in locating individuals hidden by natural cover or obscured by harsh weather.
- Communication capabilities: RescueHeat's communication unit would allow direct verbal communication with the person in need to assess their state and, as a consequence, the best rescue approach.
- Smart terrain navigation: The integration of advanced navigation algorithms allows RescueHeat drones to map and traverse challenging landscapes autonomously, providing rescuers with invaluable insights and optimal paths to stranded individuals.
- Cost efficiency: Despite its advanced capabilities, RescueHeat offers a more economical solution due to the lower production costs of HYGER sensors, which are compatible with standard semiconductor manufacturing techniques.

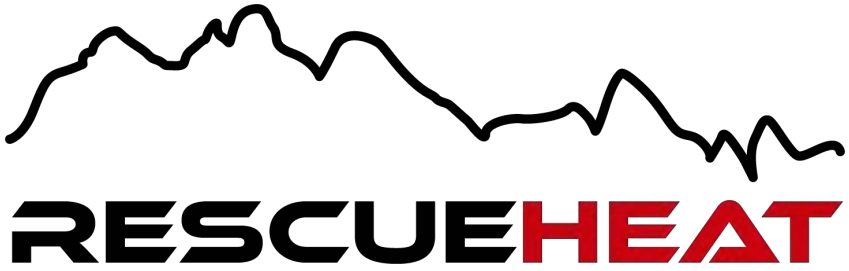
Market Positioning

RescueHeat is set to revolutionize the SAR market by providing a solution that not only exceeds the performance of current offerings in sensitivity, user interaction and operational range, but also offers these advancements at a more accessible price point. This positions RescueHeat as an attractive option for a broad spectrum of SAR teams, including those with limited financial resources.

Branding

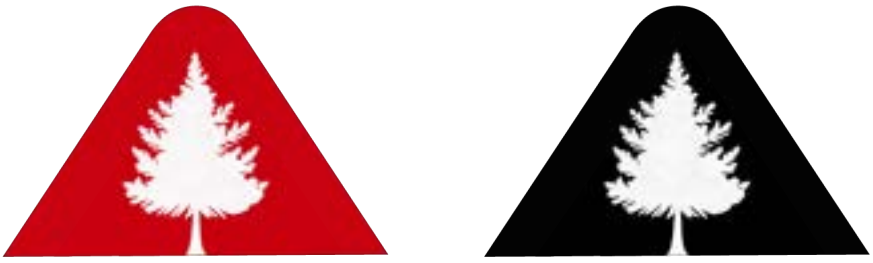
For Visual Communication, and further representation in Social media, we have designed our logotype. Since the main concept of our application is Rescuing people in harsh environments, such as forests, mountains etc., and as primary source for detection of human beings is heat. The name was selected accordingly – **RescueHeat**. Furthermore, our essential idea is to use it in the mountainous areas, therefore, the mountain shaped silhouette was selected. Combined with Black / Red color palette we created the main logo:

Figure 13: Main Logo for RescueHeat Project



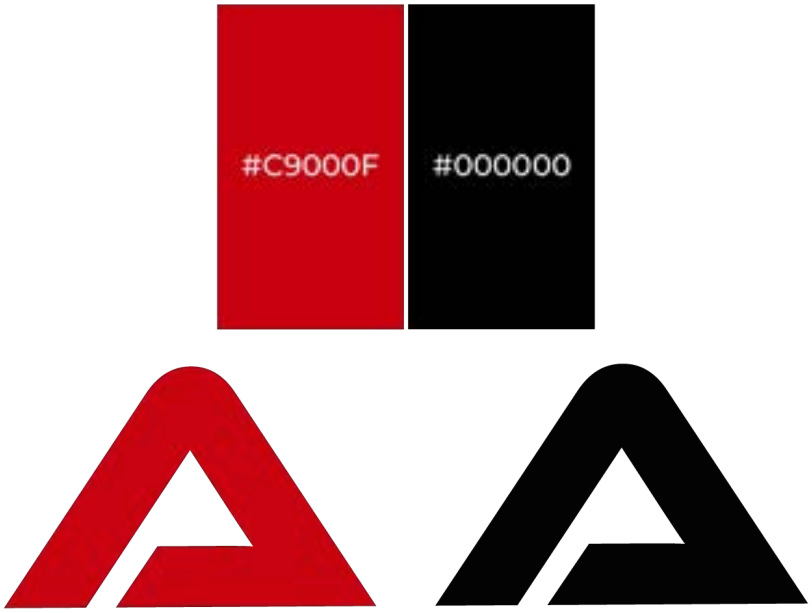
Then, to create a simpler way to display our product we thought about symbols, following the analogy with Nike and their Swoosh symbol. Using the same font as in the Main Logo depicted in the figure above we pushed the idea of “wilderness” a little bit further, pointing out the main region of operation: Mountains and Forests. Hence, we got 2 versions of Symbols, which represent the essential concept of our project.

Figure 14: Secondary Logos



As already mentioned, the color palette represents the harsh conditions where people are being detected in addition to the main method of detection – infrared detection. To highlight the Infrared red spectrum the primary color we use is Red and Black, to point the contrast between Mountains and Body Heat:

Figure 15: Color Palette



It is also important to note that to arrive at this final version of the logo for our project the whole ideation process was considered, creating numerous different versions of logotypes, using different fonts and techniques. The concepts, designed during the ideation process are presented in the following Figures:

Figure 16: Possible Logo Concepts

Prototypes

Poster

Figure 17: Main RescueHeat poster

Storyboard

A storyboard was crafted to illustrate and clarify the functioning and use case scenarios of RescueHeat. This visual narrative delineates six key steps that outline how RescueHeat operates in diverse environments.

Figure 18: Storyboard of RescueHeat

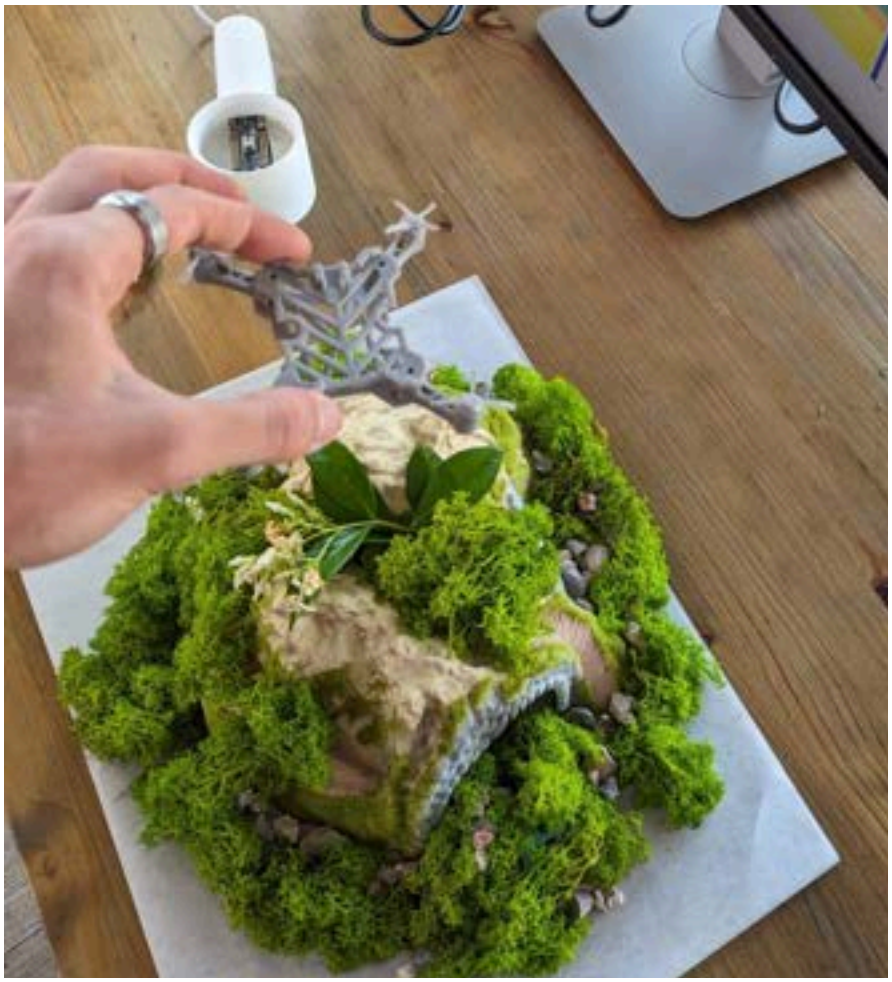
3D - Model

To showcase a concrete example of what the drone with the integrated sensor would look like, we designed and printed a 3D model of a small, compact drone and the sensor attached to it.

Figure 19: 3D printed drone model

During the prototype display we have demonstrated the type of environment that the drone would scan and how we envisioned its functioning.

Figure 20: Demonstration of the 3D printed drone



Thermal Camera

To illustrate the possible uses of our idea, we propose to create a thermal camera that is improved with hyper-spectral technology. This initiative's main goal is to make it easier for those who are lost in steep terrain to be found. With its ability to identify heat signatures at a distance, this advanced imaging device will significantly improve the effectiveness and efficacy of search and rescue missions in difficult-to-reach areas. Furthermore, compared to conventional infrared light cameras, our method ought to be less costly and have better detection capabilities in a variety of environmental settings.

To make the prototype of the thermal camera we used matlab to program the sensor and arduino like board. The manufacturer of the controller provided the code to interpret the data from the censor. At the end our ultimate objective was to program the sensor to read the environment, differentiate the highest and lowest values of temperatures. The final code we designed is presented in **Figure 21**.

Figure 21. Matlab code for thermal sensor

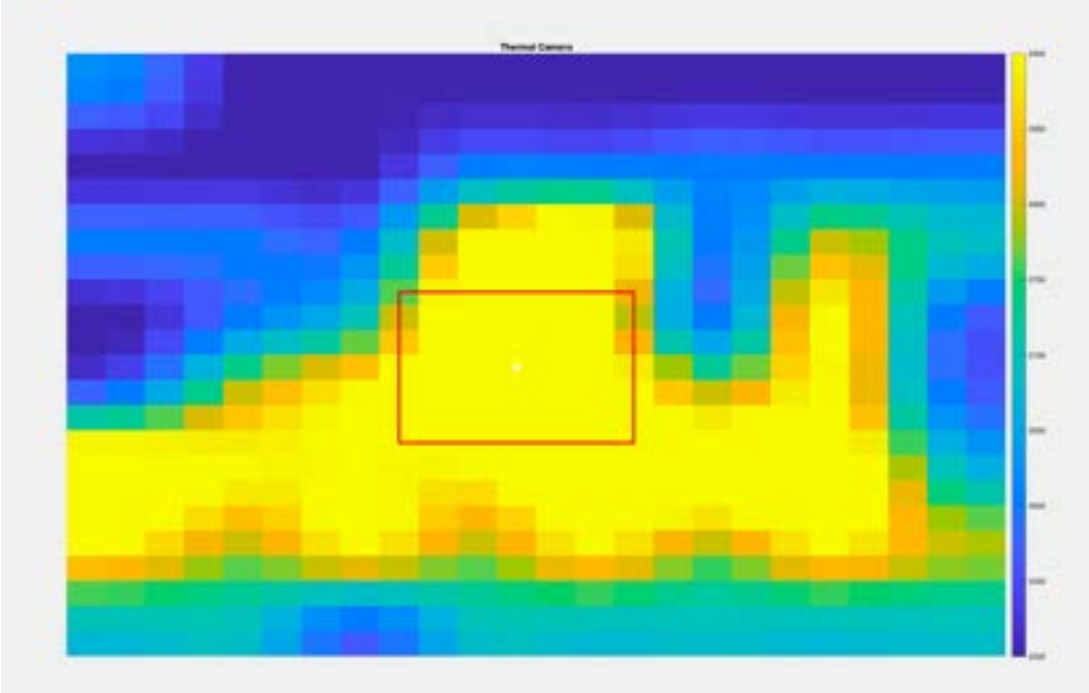
To describe the final code shortly we firstly have to connect to a thermal camera via a serial port, continuously read temperature data, process it to create thermal images, and highlight the hottest spots.

Initially, it clears previous serial connections and establishes a new one, to get rid of excessive/irrelevant data. The main loop repeatedly reads temperature data, reshapes it into an 8-column matrix, interpolates to enhance resolution, and rotates the image according to sensor orientation in the environment.

It then applies a convolution filter to detect hot zones and identifies their locations. The thermal image is displayed with a color map, highlighting the hottest spot with a rectangle for better visualization. The code also averages the column indices of hot spots over several iterations to reduce noise and stabilize the display. Our sensor has relatively low resolution, since it only has to show the workability. The resolution of the sensor is 8x8 pixel, therefore the output image is more abstract than defined.

The output of the working code is presented in **Figure 22**:

Figure 22. The output of the code



Next Steps

As we conclude our research on the potential application of HYGER technology in the development of RescueHeat, we suggest the following steps for further researchers and development teams looking to bring this concept to fruition:

- Prototype development: The initial step should involve the construction of prototypes that integrate HYGER's infrared sensors with drone technology. This phase is critical for validating the basic functionality and integration capabilities of the system.
- Field testing: It is essential to conduct extensive field testing in a variety of environmental conditions to assess the system's real-world performance. These tests will help identify any necessary modifications to optimize functionality and durability.
- Feedback: Feedback from potential end-users, such as search and rescue teams, can be integrated into the development process to ensure the solution meets practical operational needs.
- Regulatory compliance: Ensuring compliance with all relevant safety and operational regulations is crucial. This step will facilitate smoother adoption and deployment, particularly in global markets with varying regulatory landscapes.
- Pilot programs: Collaborating with search and rescue organizations to implement pilot programs could validate the effectiveness of RescueHeat in live rescue scenarios.
- Scalability research: Research should be conducted to explore the scalability of the technology to various drone sizes and types, assessing the feasibility for broader application and potential mass production.
- Marketing and deployment strategy: Developing a strategic marketing and deployment plan is essential for promoting the technology to potential stakeholders and ensuring it reaches regions most in need of innovative search and rescue solutions.

Team Reflections

As our project comes to a close, our team has gained valuable insights into the complexities and challenges of integrating HYGER technology into the RescueHeat application. While we are optimistic about the potential of this technology to enhance search and rescue operations, we've also recognized the limitations that need to be addressed.

The idea of using HYGER-equipped drones for real-time communication and navigation in rescue scenarios is promising, but currently faces significant technological and practical challenges. The development of route tracking and effective communication modules that function seamlessly in harsh environments is not yet fully realized. Additionally, the sensitivity and deployment costs of HYGER technology, while potentially more efficient, still require optimization to truly compete with existing solutions.

This project has sharpened our understanding of the technological advancements needed and the realistic scope of applying such innovations. It has grounded our expectations, teaching us the value of iterative development in bringing such ambitious technologies to fruition. Our journey with RescueHeat has been as much about learning the limits of current technology as envisioning its future possibilities.

Bibliography

Adams, A. L., Schmidt, T. A., Newgard, C. D., DeFreest, M., & [additional authors as necessary]. (2007). Search Is a Time-Critical Event: When Search and Rescue Missions May Become Futile. Wilderness and Environmental Medicine, 18(2), 95-101. https://doi.org/10.1580/06-WEME-OR-035R1.1

Almalki, F. A., & Ben Othman, S. (2022). Modifying Hata-Davidson Propagation Model for Remote Sensing in Complex Environments Using a Multifactional Drone. Sensors, 22(5). https://doi.org/10.3390/s22051786

Hashimoto, A., Heintzman, L., Koester, R., et al. (2022). An agent-based model reveals lost person behavior based on data from wilderness search and rescue. Scientific Reports, 12, 5873. https://doi.org/10.1038/s41598-022-09502-4

Heggie, T. W., & Amundson, M. E. (2009). Dead men walking: search and rescue in US National Parks. Wilderness & Environmental Medicine, 20(3), 244-249. https://doi.org/10.1580/08-WEME-OR-299R.1

Macwan, A. (2013). A Multi-Robot Coordination Methodology for Wilderness Search and Rescue [Doctoral dissertation, University of Toronto]. Department of Mechanical and Industrial Engineering, University of Toronto.

Verstockt, J., Verspeek, S., Thiessen, F., Tjalma, W. A., Brochez, L., & Steenackers, G. (2022). Skin Cancer Detection Using Infrared Thermography: Measurement Setup, Procedure and Equipment. Sensors, 22(9), 3327. https://doi.org/10.3390/s22093327

https://medium.com/@taosoba/navigating-the-mystery-of-missing-trail-runners-and-hikers-aed94e18dec1

https://nypost.com/2020/07/04/why-hundreds-of-people-vanish-into-the-american-wilderness/

https://www.greenmatters.com/news/how-many-people-go-missing-in-national-parks
https://locationsunknown.org/the-missing-list

https://www.bostonherald.com/2023/09/05/investigator-and-author-says-people-are-mysteriously-missing-in-national-parks/

https://survivaldispatch.com/statistics-of-getting-lost-and-found/
https://www.travelawaits.com/2721645/national-parks-missing-people-search

https://www.icmp.int/wp-content/uploads/2021/08/ICMP_Global-Report_April_Digital.pdf

https://missingnpf.com/

https://www.heliguy.com/collections/thermal-drones-cameras

https://www.tracerdrone.com/collections/thermal-drones?view=view-24&grid_list=grid-view

https://avirtech.co/

https://www.edmundoptics.es/knowledge-center/application-notes/imaging/what-is-swir/