ElectroCap Project Proposal

IGNIS

Intelligent Ground Network for Independent Surveillance

Team 2

TÉCNICO UNIVERSIDADE DE LISBOA

Team

Bárbara Trigueirão
LEEC 109590

Gonçalo Caetano
LEEC 109925

Salvador Carvalho
LEEC 109394

Carolina Rodrigues
LEEC 109562

Marco Mendonça
LEEC 109977

Diogo Vicente
LEEC 110736

Advisor & Co-advisor

Prof. Ayman Radwan

Advisor

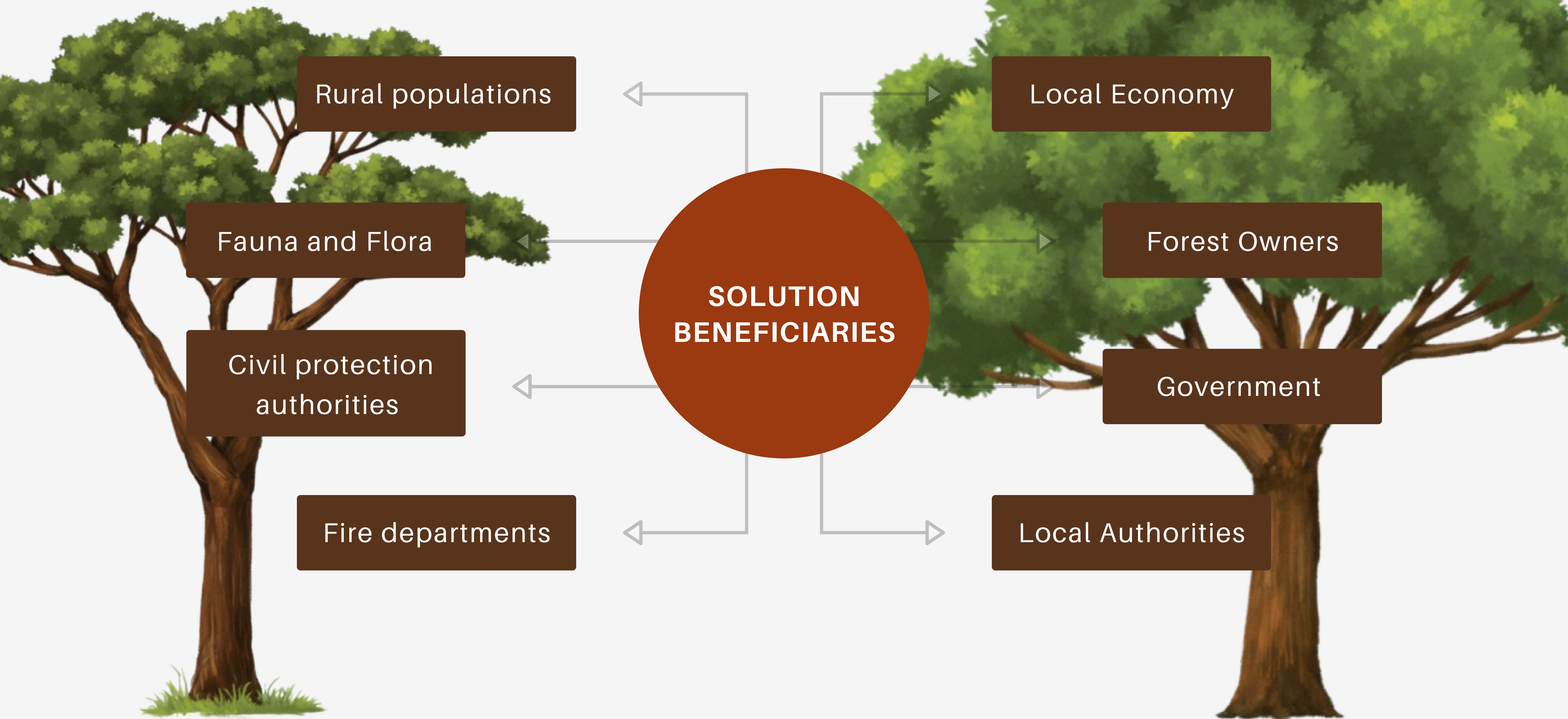
Mariana Santana

Co-advisor

Problem Definition

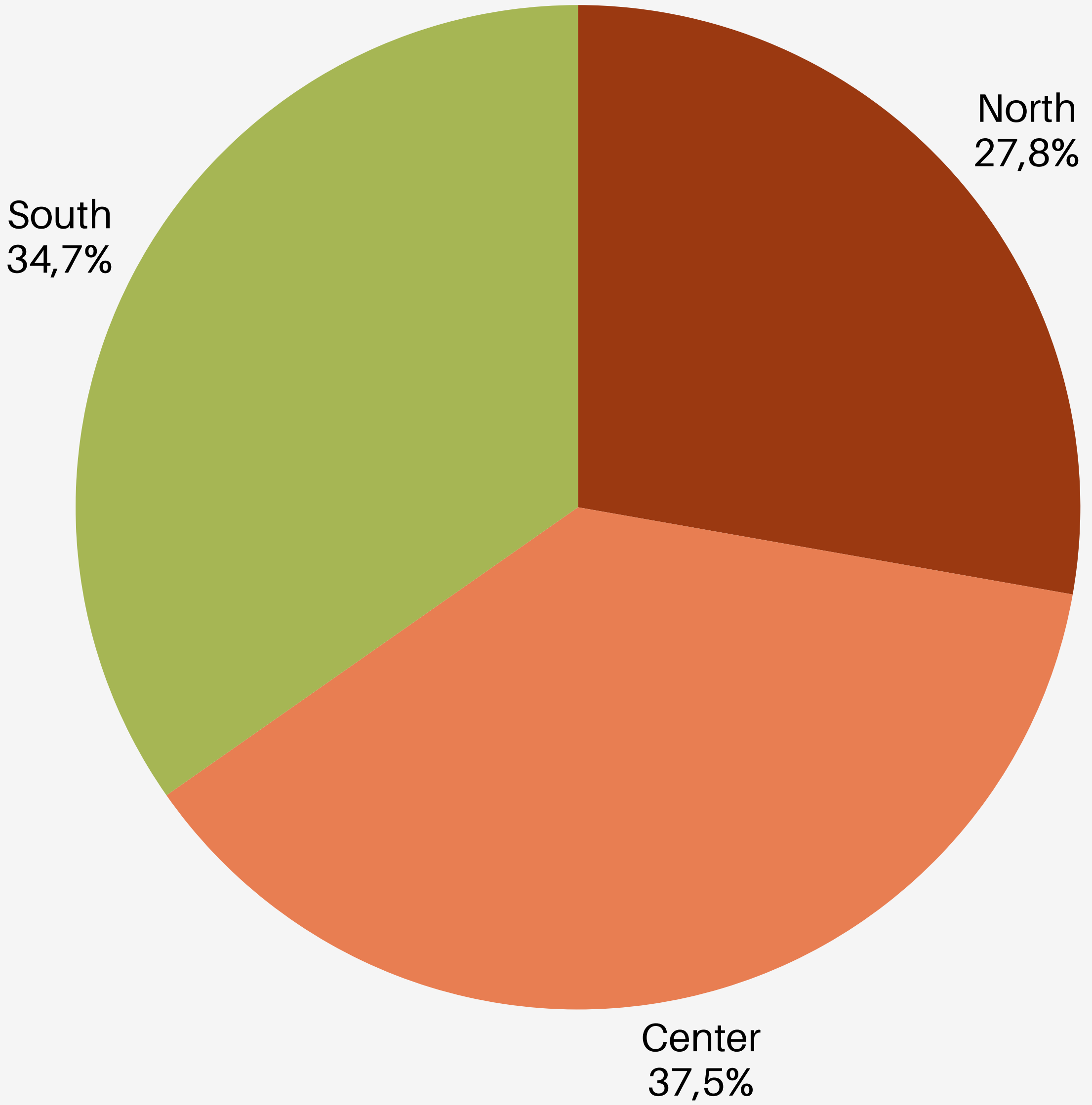
Currently, the core problem lies in the fact that forest fire detection is predominantly carried out by humans through visual inspection. This exclusive reliance on manual surveillance often proves inefficient, leading to several negative consequences for the effectiveness of firefighting, such as delayed detection, physical and geographical limitations and lack of precision in localization.

Solution beneficiaries:

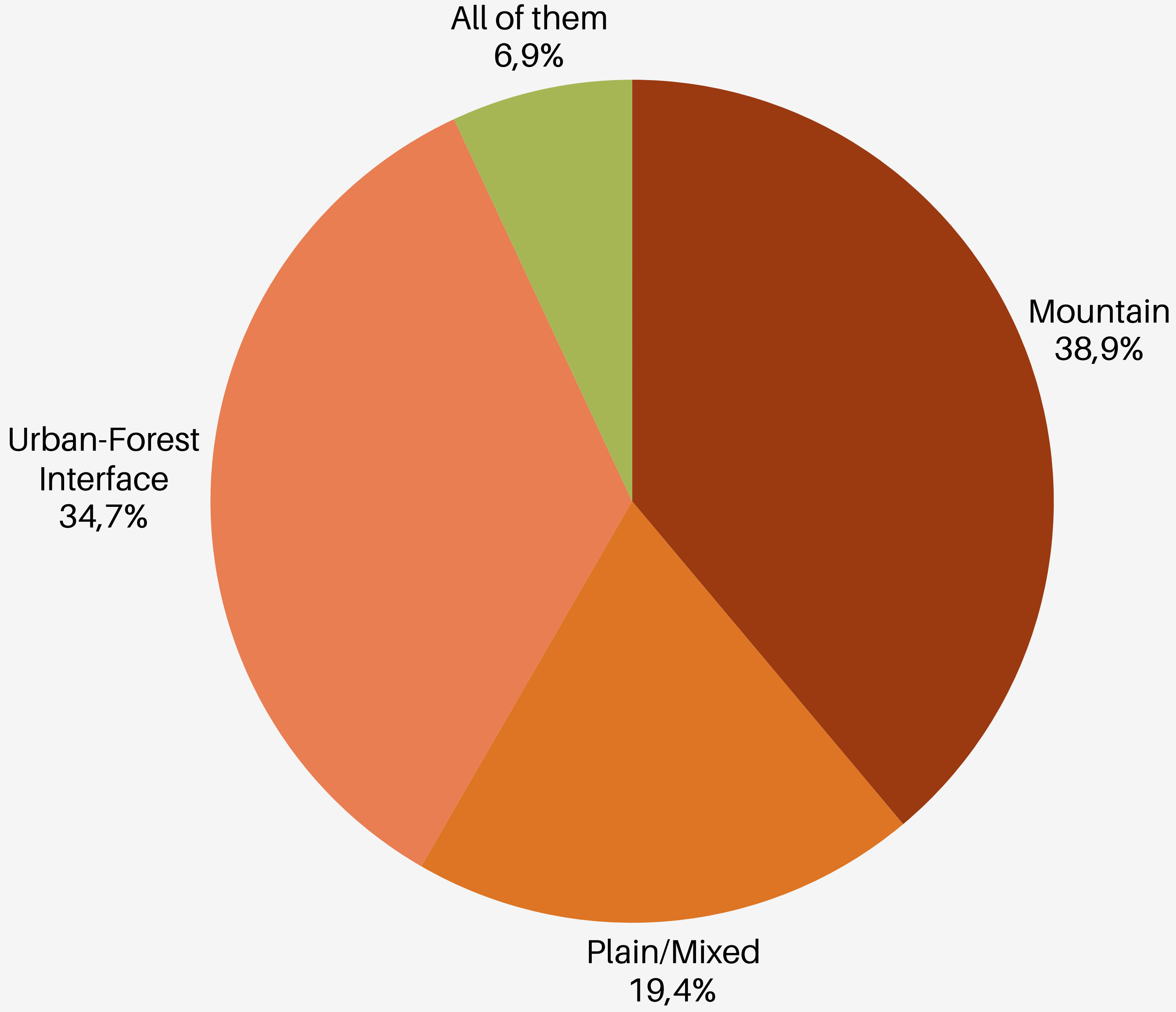


Validation & Study Sample

1. What region is the Fire Station in?



2. What type of ground do they work on?



References:

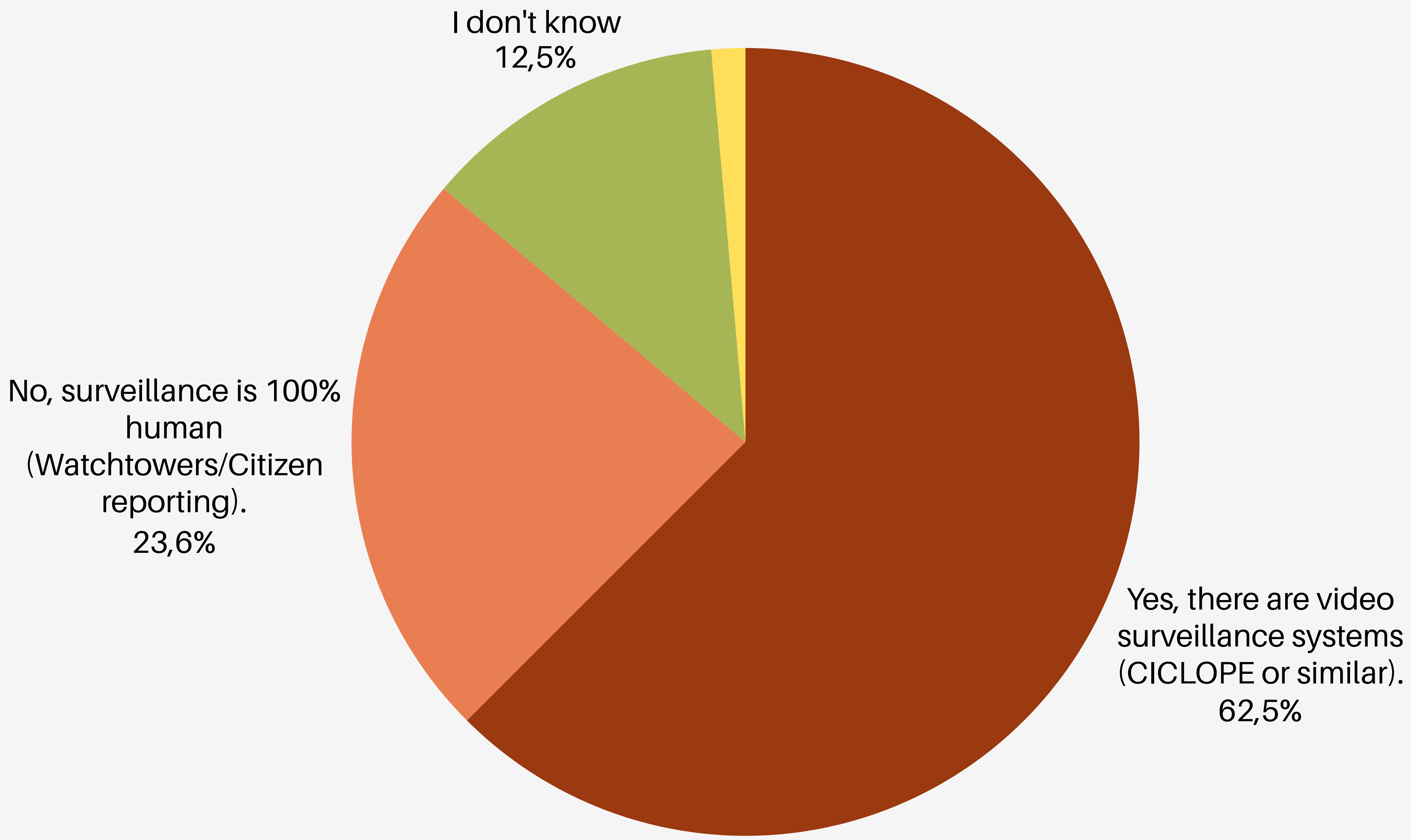
Data compiled from feedback provided by Fire Departments across Portugal via email survey.

Forms sent to Fire Departments here You can see the statistics here

For more detailed information, you can consult the summary of the meeting with a Fire Department on our website.

Validation & Study Sample

3. Has there ever been a technological system of sensors/cameras implemented in your area of operation?



References:

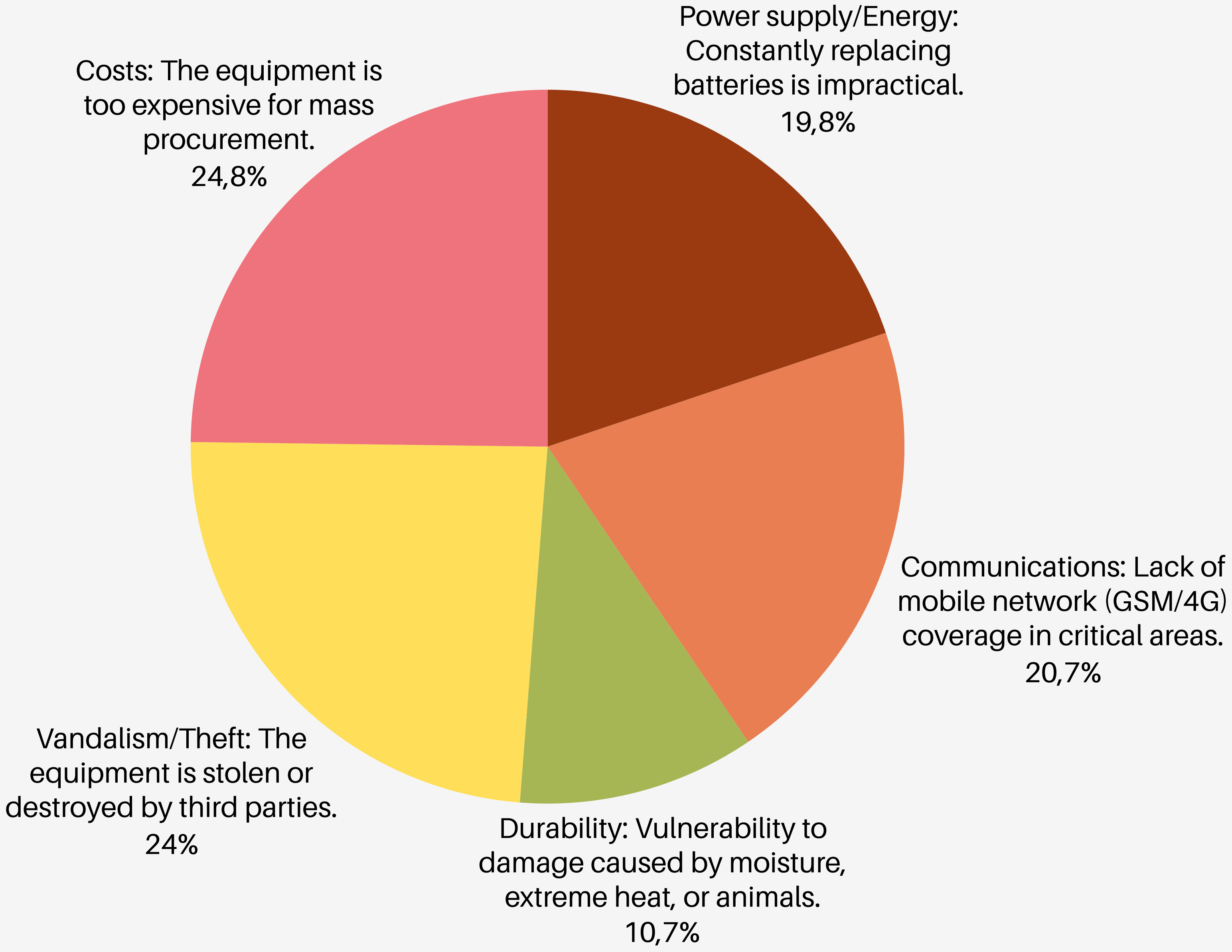
Data compiled from feedback provided by Fire Departments across Portugal via email survey.

Forms sent to Fire Departments here You can see the statistics here

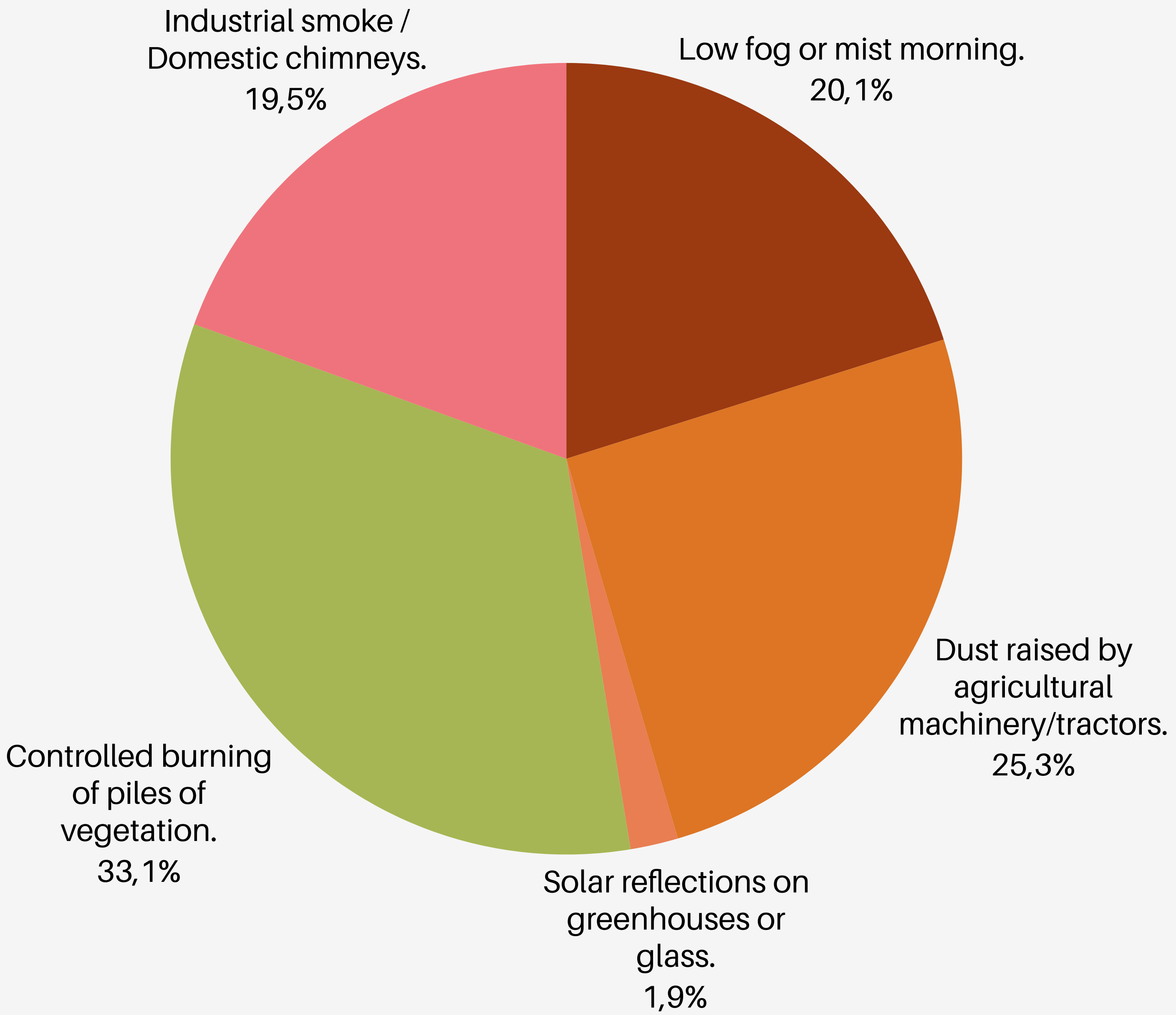
For more detailed information, you can consult the summary of the meeting with a Fire Department on our website.

Validation & Study Sample

4. What is the BIGGEST technical challenge in maintaining electronic equipment inside the forest?



5. What causes the most visual "false warnings" in the forest that could fool a camera?



References:

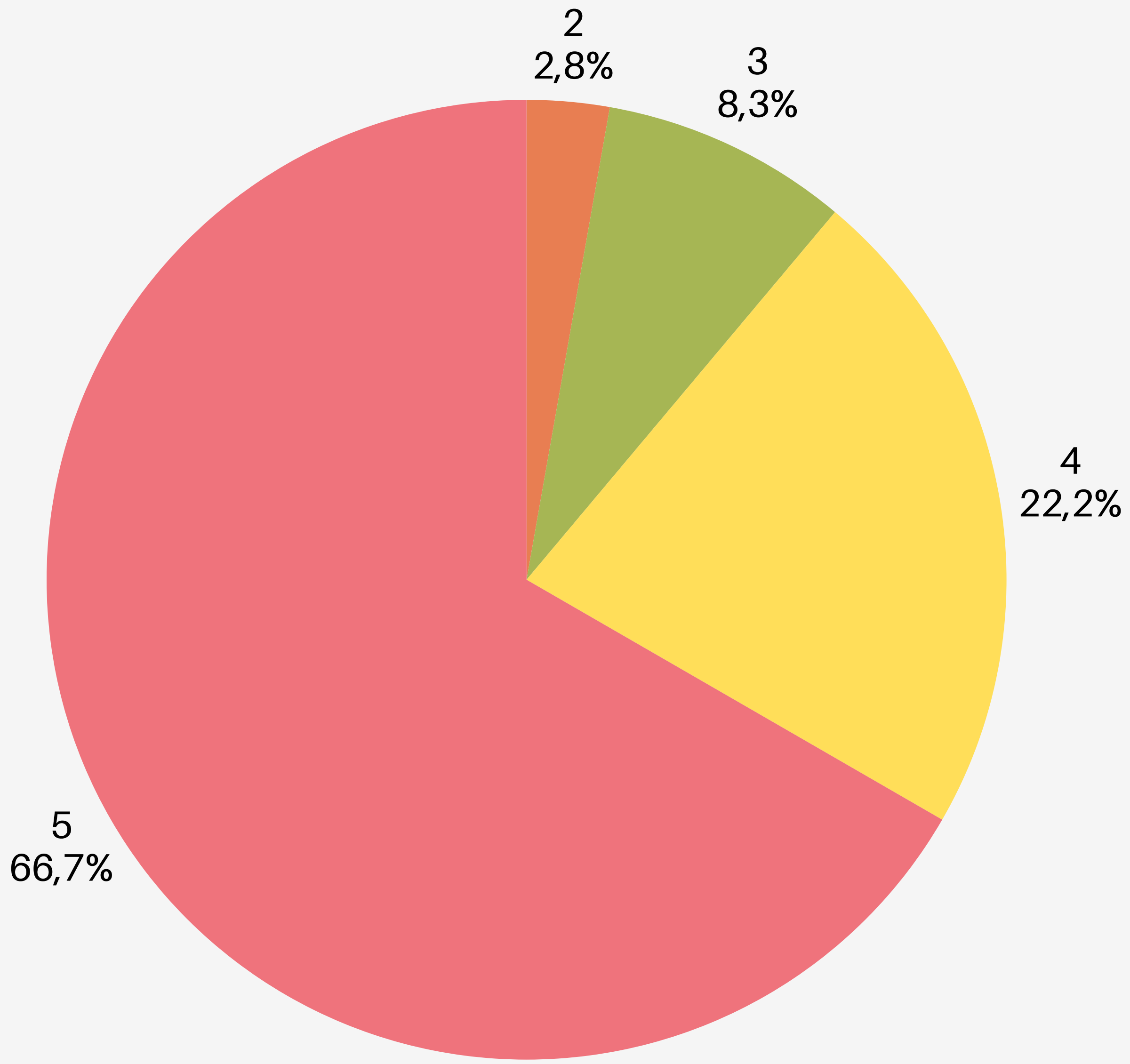
Data compiled from feedback provided by Fire Departments across Portugal via email survey.

Forms sent to Fire Departments here You can see the statistics here

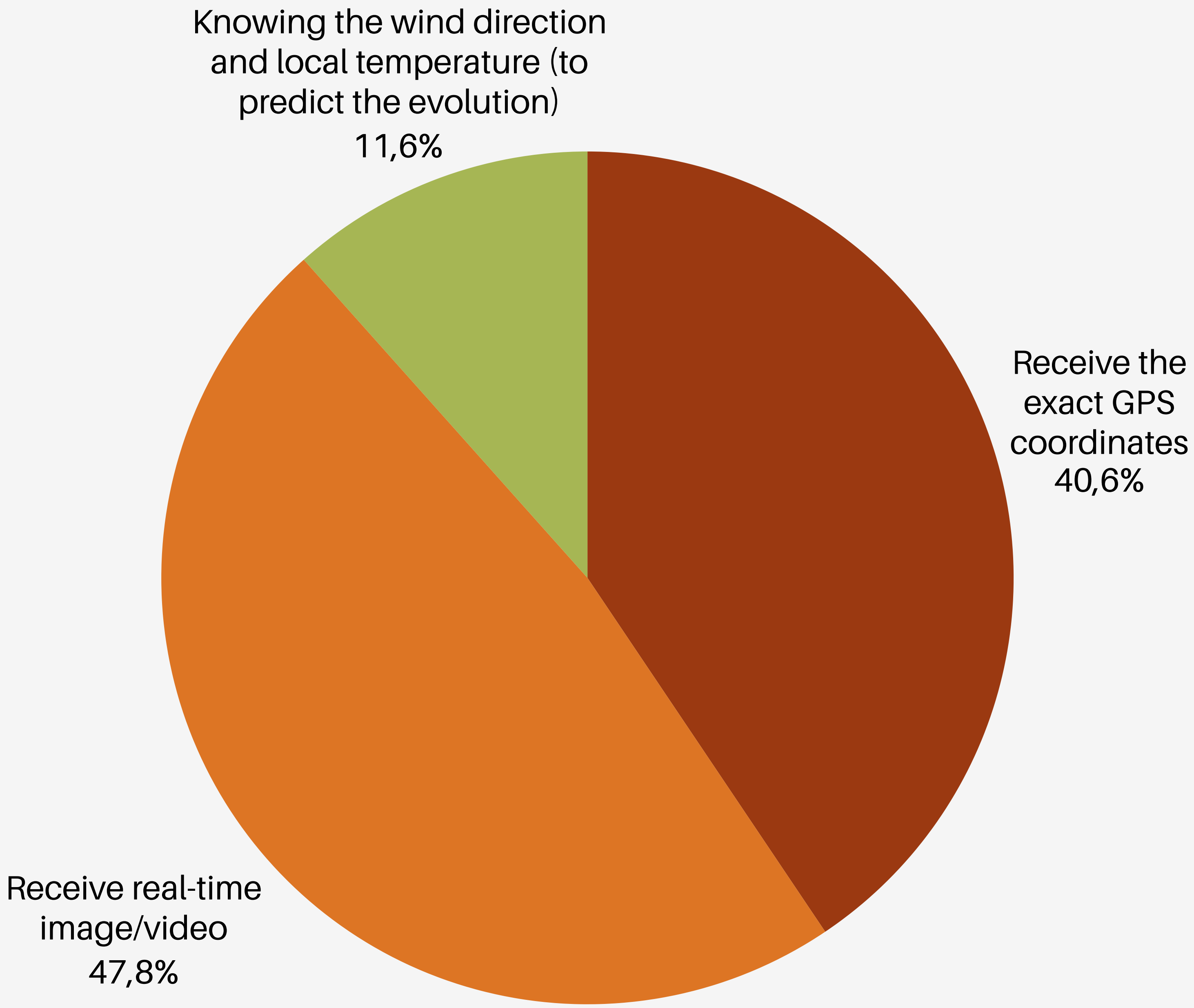
For more detailed information, you can consult the summary of the meeting with a Fire Department on our website.

Validation & Study Sample

6. **On a scale of 1 to 5, how useful would it be to receive an alert with GPS location?**

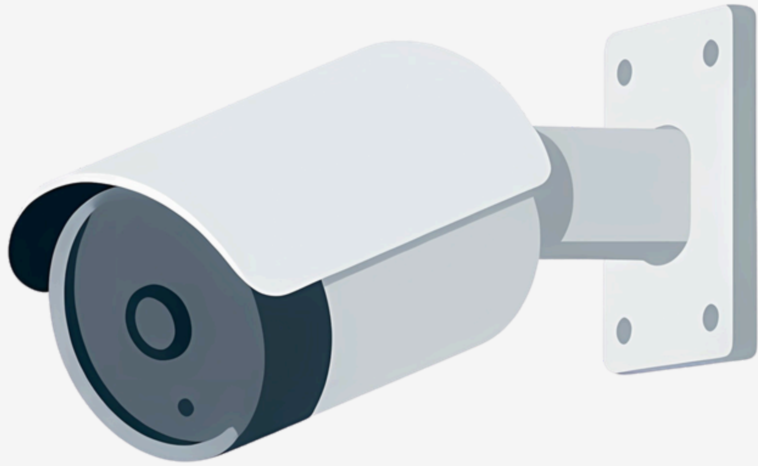


7. **What would be the most important feature in a system like this for your team?**



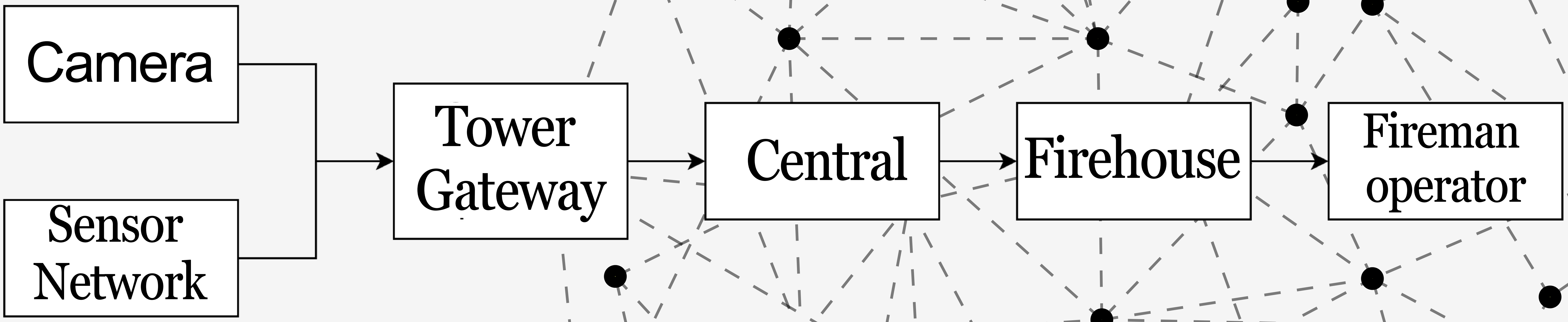
References:
Data compiled from feedback provided by Fire Departments across Portugal via email survey.
Forms sent to Fire Departments here You can see the statistics here
For more detailed information, you can consult the summary of the meeting with a Fire Department on our website.

Technological Solution -General view

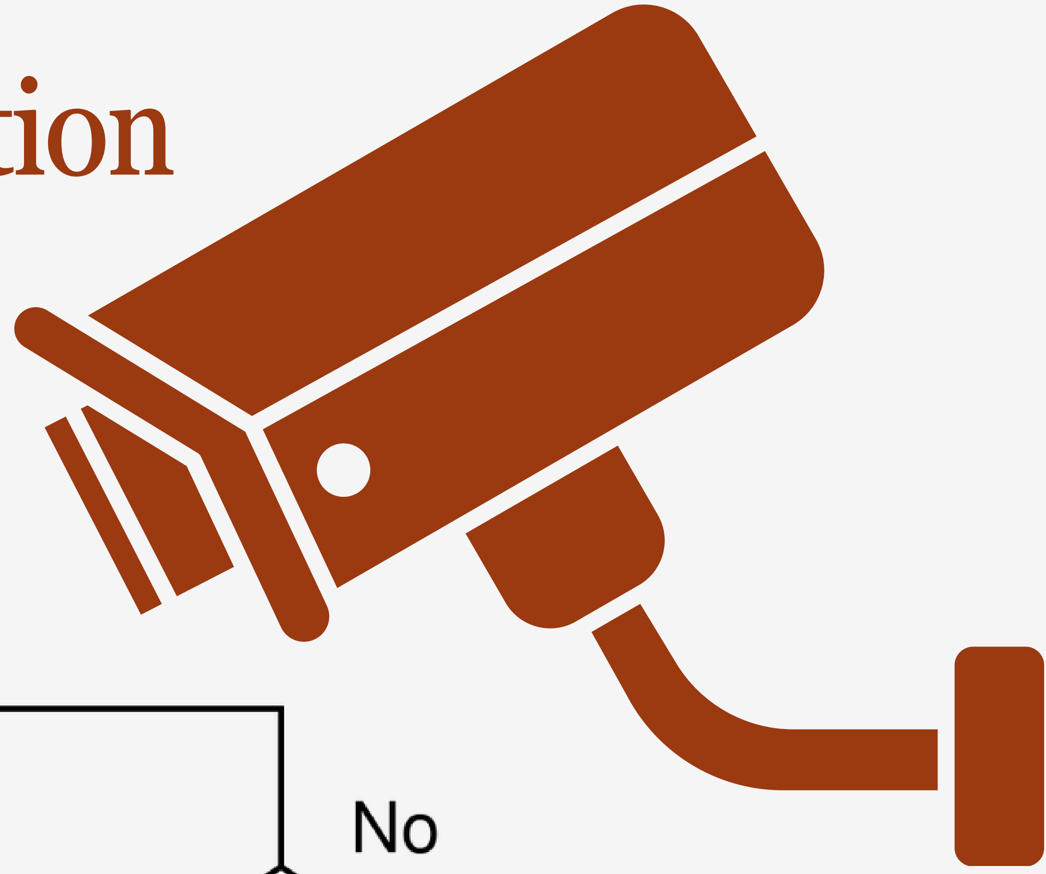


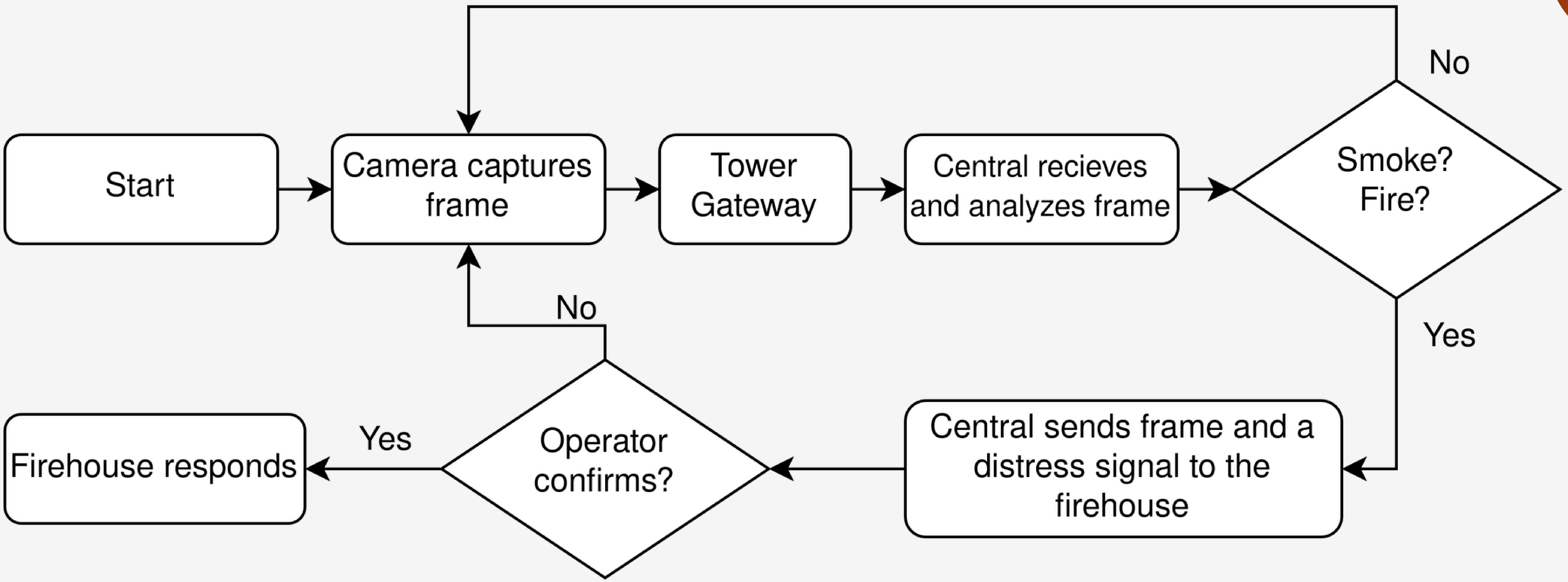
The technological solution proposes an automated forest monitoring system using elevated cameras for real-time visual analysis powered by Artificial Intelligence. To ensure continuous and reliable detection even when visibility is compromised, the system is backed up by a redundant network of ground sensors.

Technological Solution -Solution Architecture

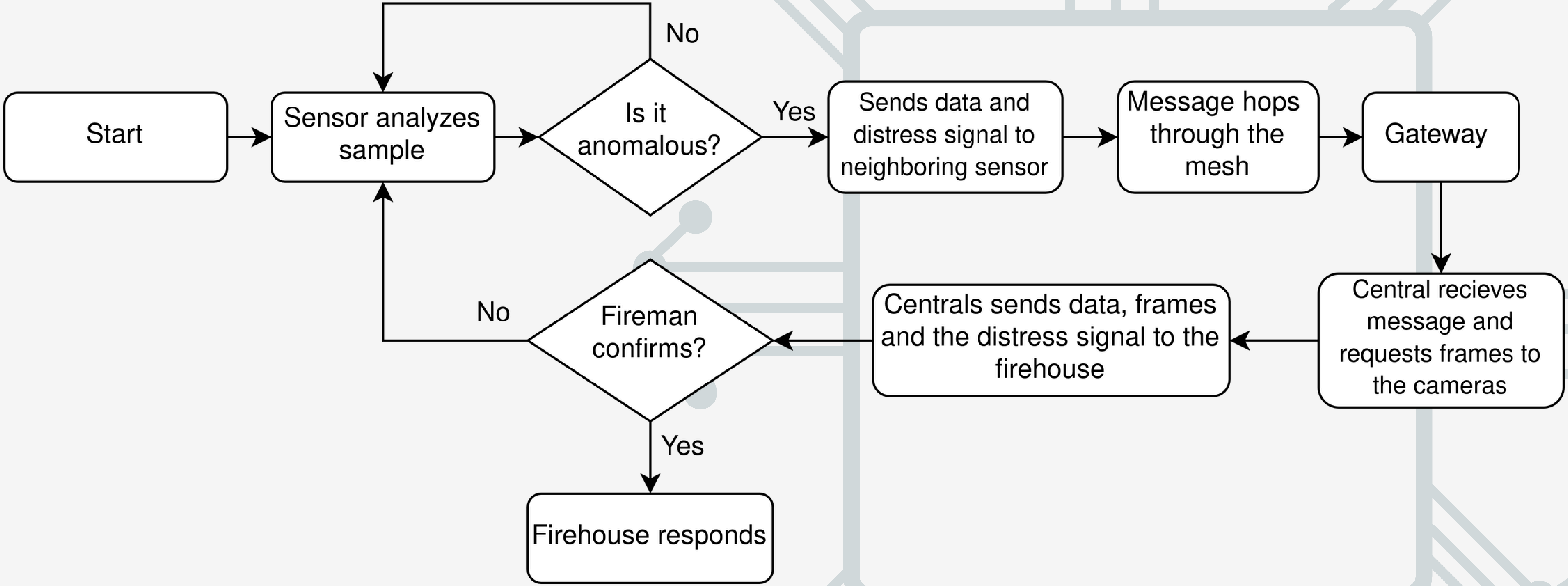


Technological Solution -Camera Operation





Technological Solution -Sensor Operation



Technological Solution -Required Hardware

TOWER ECOSYSTEM

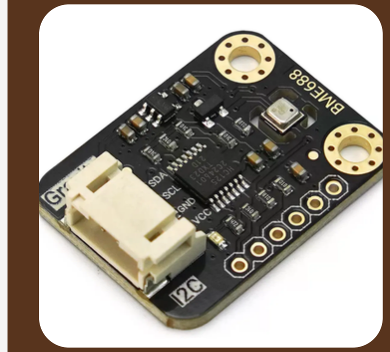
Raspberry Pi 4

Edge computing unit for local YOLO model image analysis and tower control.

Camera Module

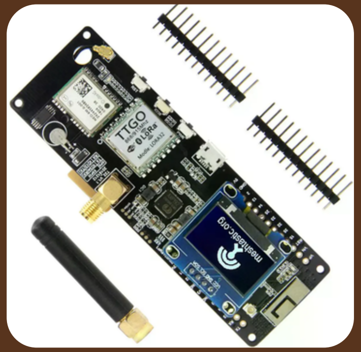
Camera for real-time visual smoke and fire monitoring and fire confirmation.

SENSOR ECOSYSTEM



BME 688 Sensor (2 units)

AI-driven module for VOC, pressure, humidity, and temperature gas detection.



LILYGO TTGO T-Beam

ESP32-based node with GPS and LoRa capabilities for mobile or fixed sensing.

MQ-135 Sensor (4 units)

Air quality monitoring specifically tuned for hazardous smoke and CO_2 detection.

Heltec V4 Node (2 units)

Main connectivity node for the multi-hop sensor mesh network deployment.

Wio Tracker L1

Integrated node for LoRa communications and precise GPS geolocation data.

Router / Gateway

Main connectivity hub bridging local forest nodes to the central fire station.

Technological Solution -Camera/Video

Camera type: Optical Camera

Detection Performance:

- Effective for daytime flame/smoke detection
- Limited visibility for smoke at night
- Thermal cameras offer better performance but are cost-prohibitive

Image & Network Quality

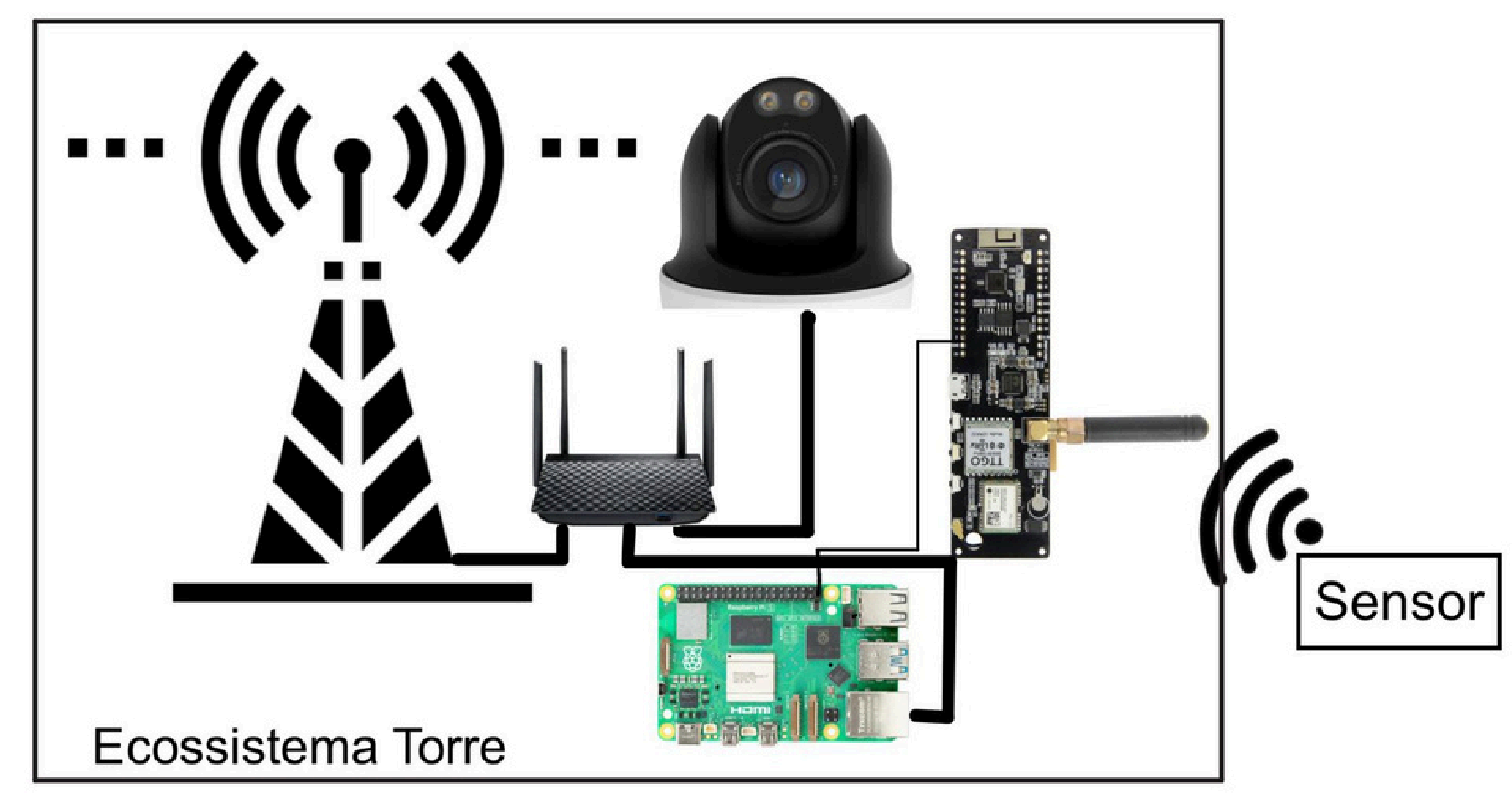
- Max capability: 4K (15–30 Mbps) over 5 GHz
- Expected operation: 1080p (5–8 Mbps)
- Stable under normal conditions (low weather interference)
- Supports 5 GHz connectivity and potential network slicing

Deployment strategy:

- Install on existing surveillance towers (cost-efficient)
- Use new minimal towers if necessary
- Position cameras at maximum feasible height (terrain-dependent)

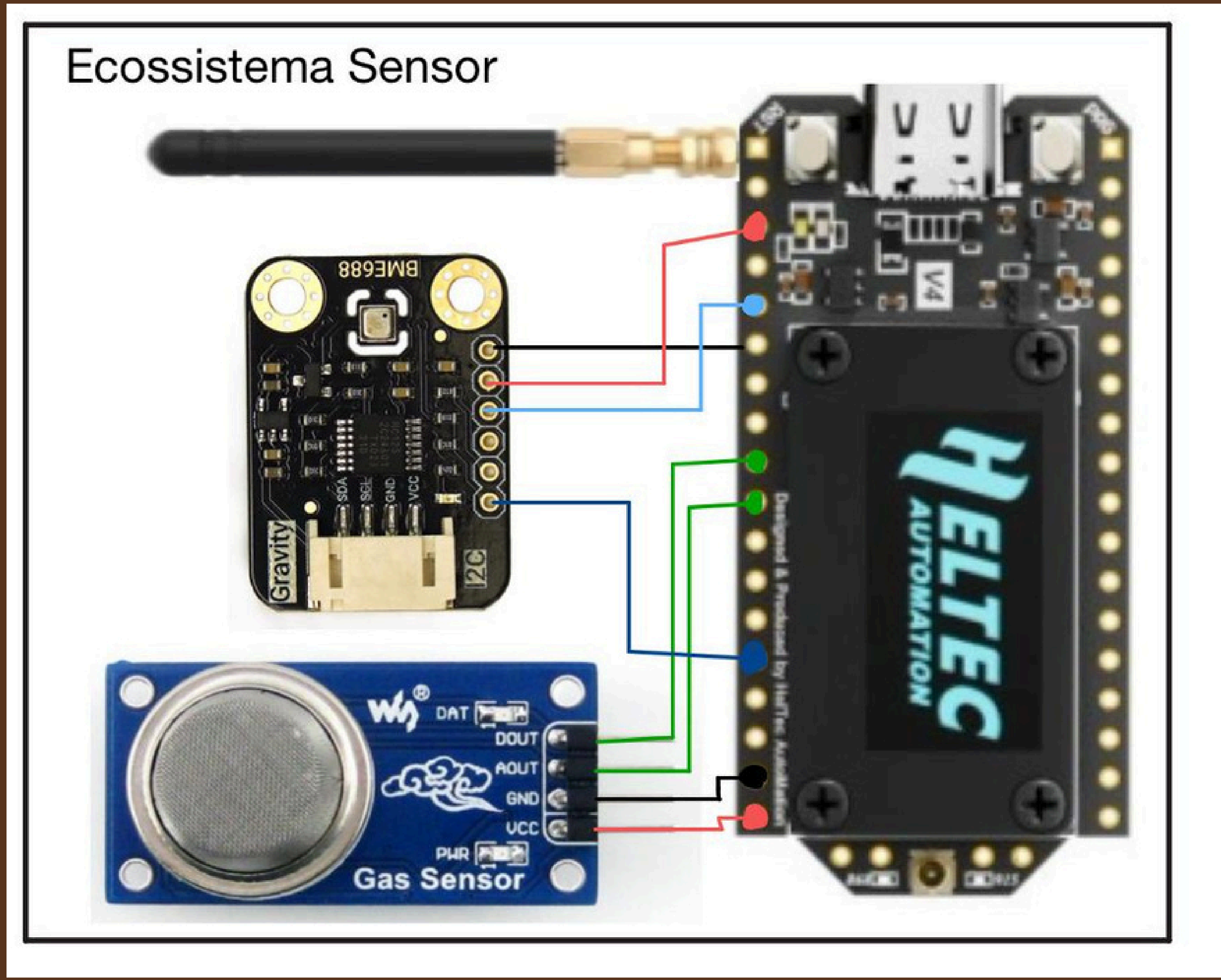
Architecture Diagram

Tower's Ecosystem



They are separate ecosystems but can communicate via multi-hop sensor networks. When smoke is detected, the signal reaches the tower, which redirects the camera to the affected area and sends the information to the central system using a stronger antenna.

Sensor's Ecosystem



Competitors and similar previous works

- **Pano AI:** Solution implemented using Ultra High Definition 360º cameras

  Our solution offers a more affordable, but similar, approach

- **IQ Fire Watch:** Solution implemented using costly, but precise, sensors

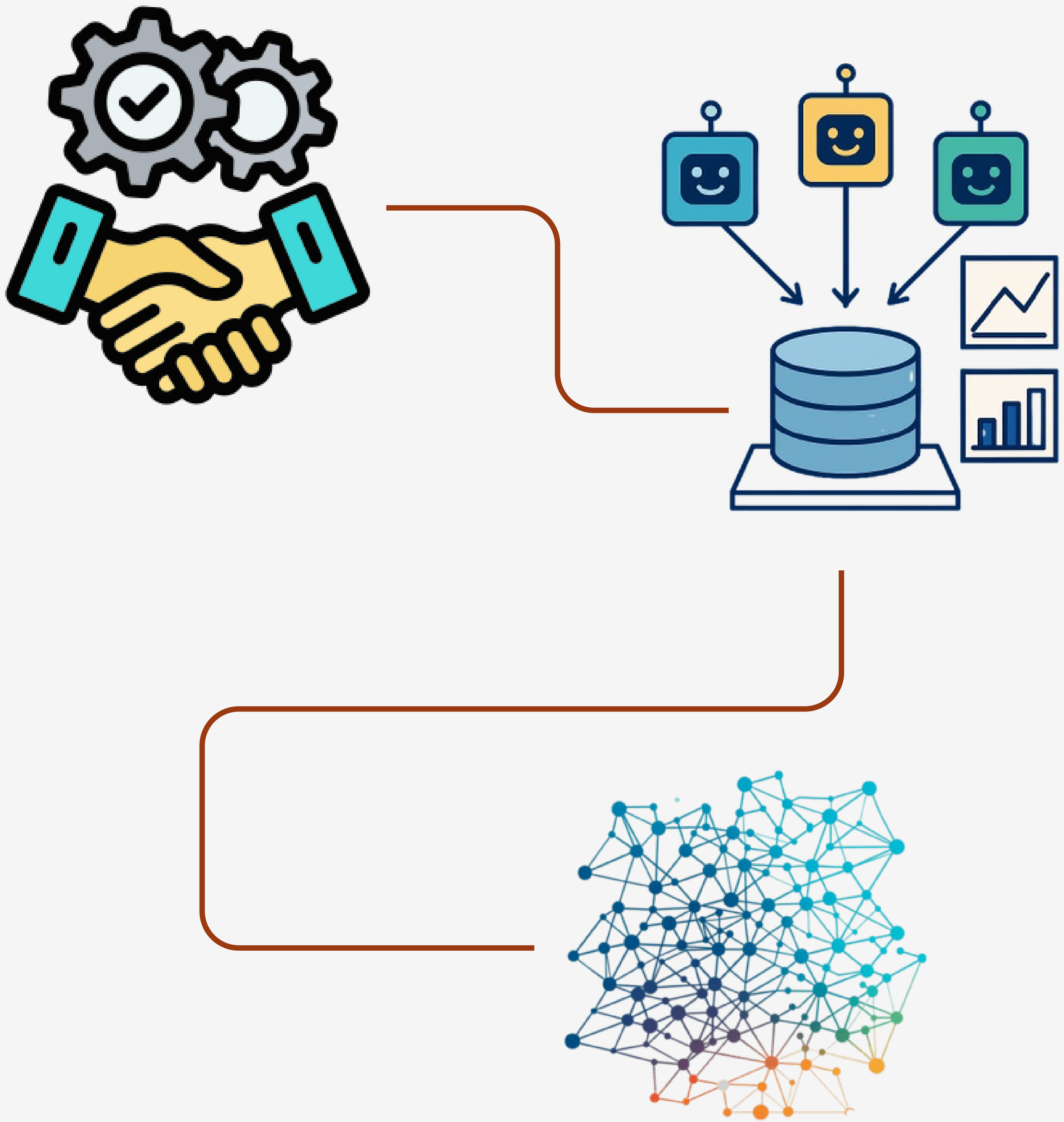
  Our sensor implementation is lighter, more energy efficient and more affordable

- **YOLO Early Detection Thesis:** Solution focused on static image analysis

  Our solution goes a step further, being implemented to run on a more efficient computer (Raspberry Pi 4), analysing real time images and working together with sensor data

Institutional Collaboration: INESC-INOV

- **Formal Partnership:** Key milestone achieved by establishing a strategic collaboration with INESC-INOV.
- **CICLOPE Framework:** Secured institutional access to specialized image datasets via the CICLOPE Project.
- **Model Optimization:** Direct integration of high-fidelity data into the training and refinement of our YOLO detection model.
- **Performance Edge:** Leveraging professional datasets guarantees superior system accuracy and detection capabilities.



Division of labor

Bárbara Trigueirão	Gonçalo Caetano	Salvador Carvalho	Carolina Rodrigues	Marco Mendonça	Diogo Vicente
Lead Sensors Developer	Lead Computer Vision Developer	Lead Telecom Developer	Lead Frontend Developer	Lead Hardware Developer	Lead Data Analyst
PitchDeck	PitchDeck	PitchDeck	PitchDeck	PitchDeck	PitchDeck
Firefighters interviews	Circuits Designer	Hardware Selection	Web Developer	Data processing from sensors	Firefighters interviews
Sensor Programmer	Software development for Multi-hooping	Data processing from sensors	Data Processing for YOLO	Software development for Multihooping	Create a response form for firefighters + analyses
Web Developer	Sensor's Programmer	Web Developer	Graphical Designer	Computer Vision Developer	General communications Developer

Achieved Results -Fire Detection - Model Evolution

Pre-trained on public online datasets, then fine-tuned with the proprietary Cyclope dataset to maximize detection accuracy.

Achieved Results -Fire Detection - Model Evolution

Phased training roadmap starting with static images, progressing to video analysis, and culminating in real-time live feed processing.

The detection software had to be optimized to ensure low computational overhead on the Raspberry Pi.

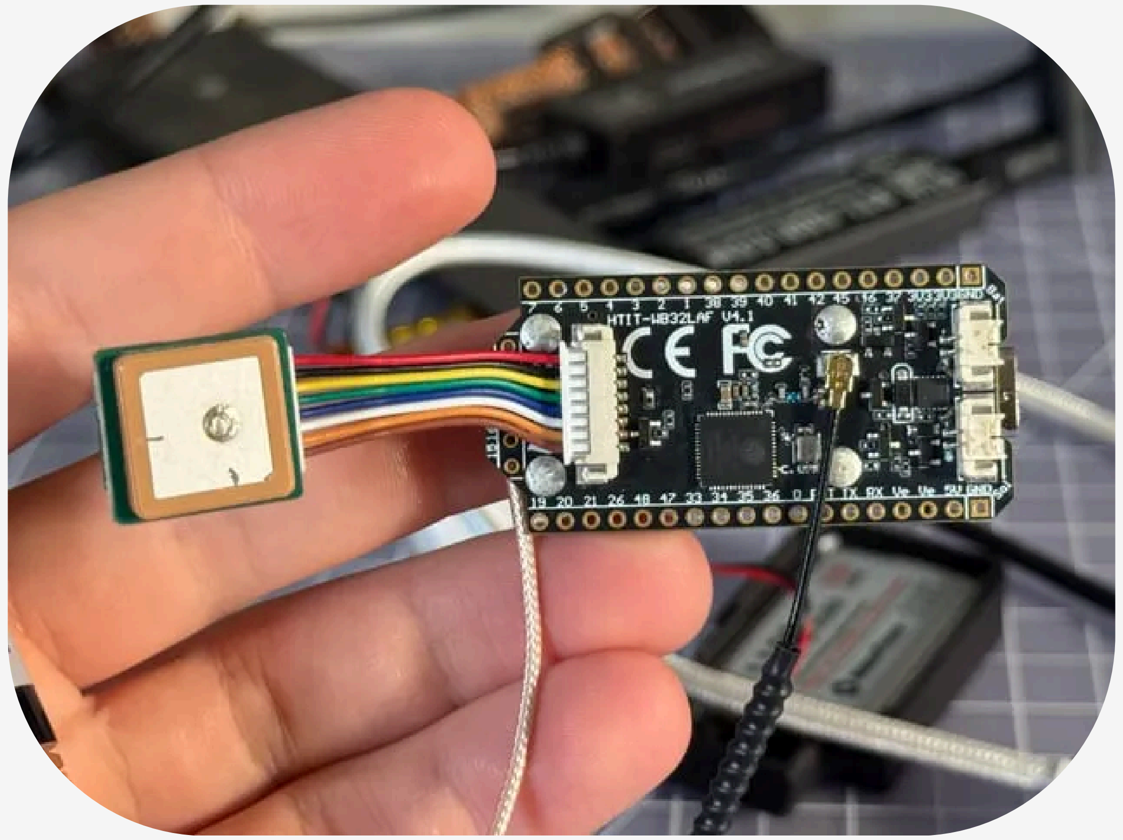
Achieved Results - Sensor Nodes

Stage 1: Peer to Peer Communication

- **Heterogeneous Architecture:** Established direct, cross-platform LoRa communication between the Heltec's V4 and Wio Tracker L1.

- **Unified Packet Delivery:** Validated a custom, hardware-agnostic data structure to cleanly transmit GPS positioning and multi-sensor telemetry payloads.

- **Hardware Optimization:** Overcame architectural differences by mapping custom power-up sequences for external RF amplifiers and local GNSS modules.



Achieved Results - Sensor Nodes

Stage 2: MultiHopping (Mesh Networking)

- **Managed Flood Logic:** Bypassed the overhead of heavy mesh libraries by building a custom, lightweight "Flood and Relay" protocol.
- **Deduplication Memory:** Edge nodes utilize memory-mapped arrays of recent Message IDs to actively prevent infinite relay loops and network congestion.
- **Self-Healing Architecture:** The decentralized design ensures that if one node fails or loses power, packets are flooded through alternate neighboring nodes to reach the Gateway.

Achieved Results - Sensor Nodes

Stage 3: Sensor Data Collection

- Bosch BME688 metal-oxide sensor detects hydrogen, CO, and VOCs produced during early pyrolysis, providing a fire signal before visible flame or significant temperature rise.

- Purpose-built flood-and-relay protocol with a 15-slot deduplication ring buffer to suppress relay loops, and Channel Activity Detection before every transmission to avoid collisions.

- Periodic Duty-Cycled Sensing millis()-based timers decouple sensing (every 30 s) and display (every 3 s) from the main loop, keeping the processor free between events and laying the groundwork for deep-sleep power optimisation.

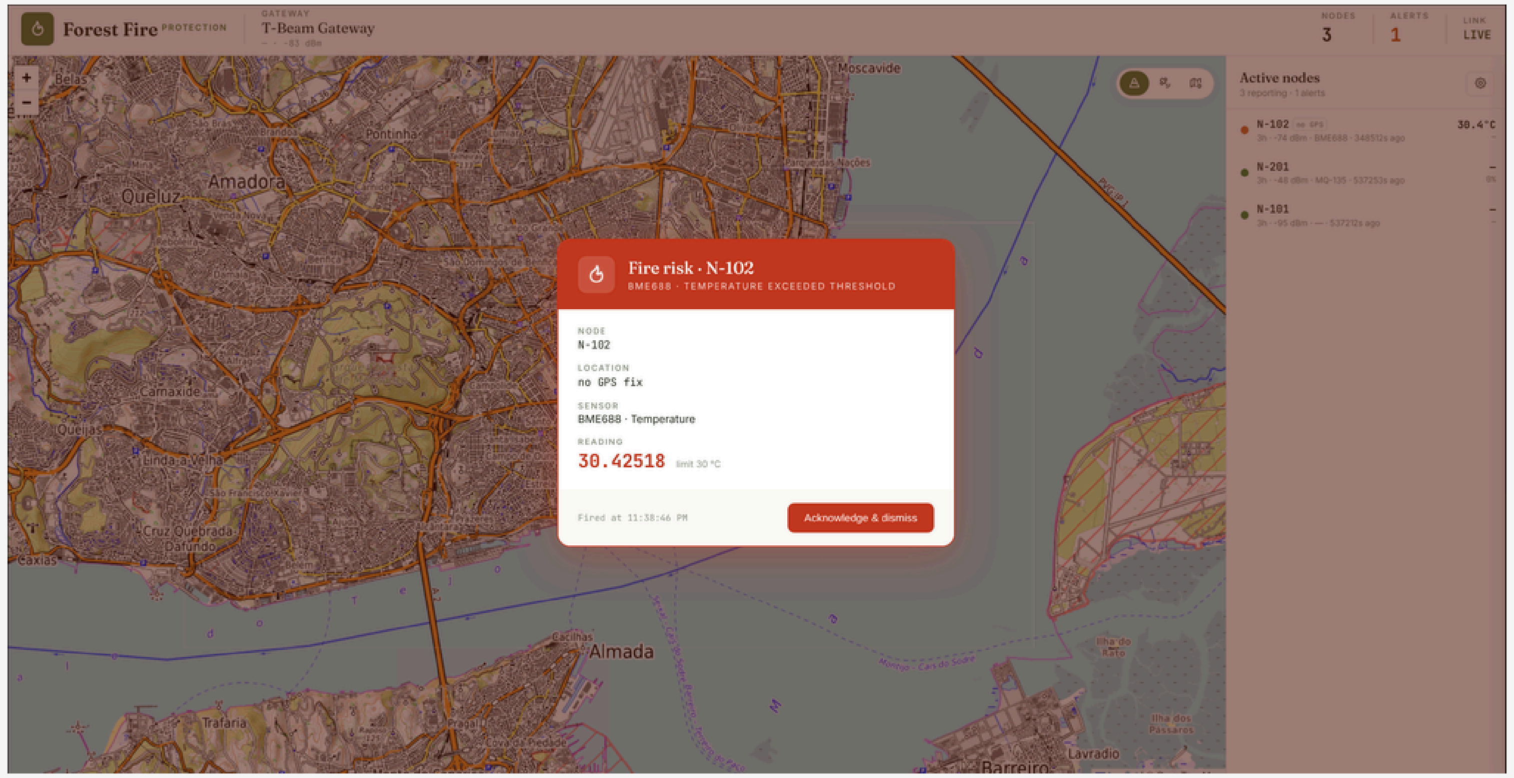
Achieved Results - Sensor Nodes

Stage 4: Dashboard Data Exposed

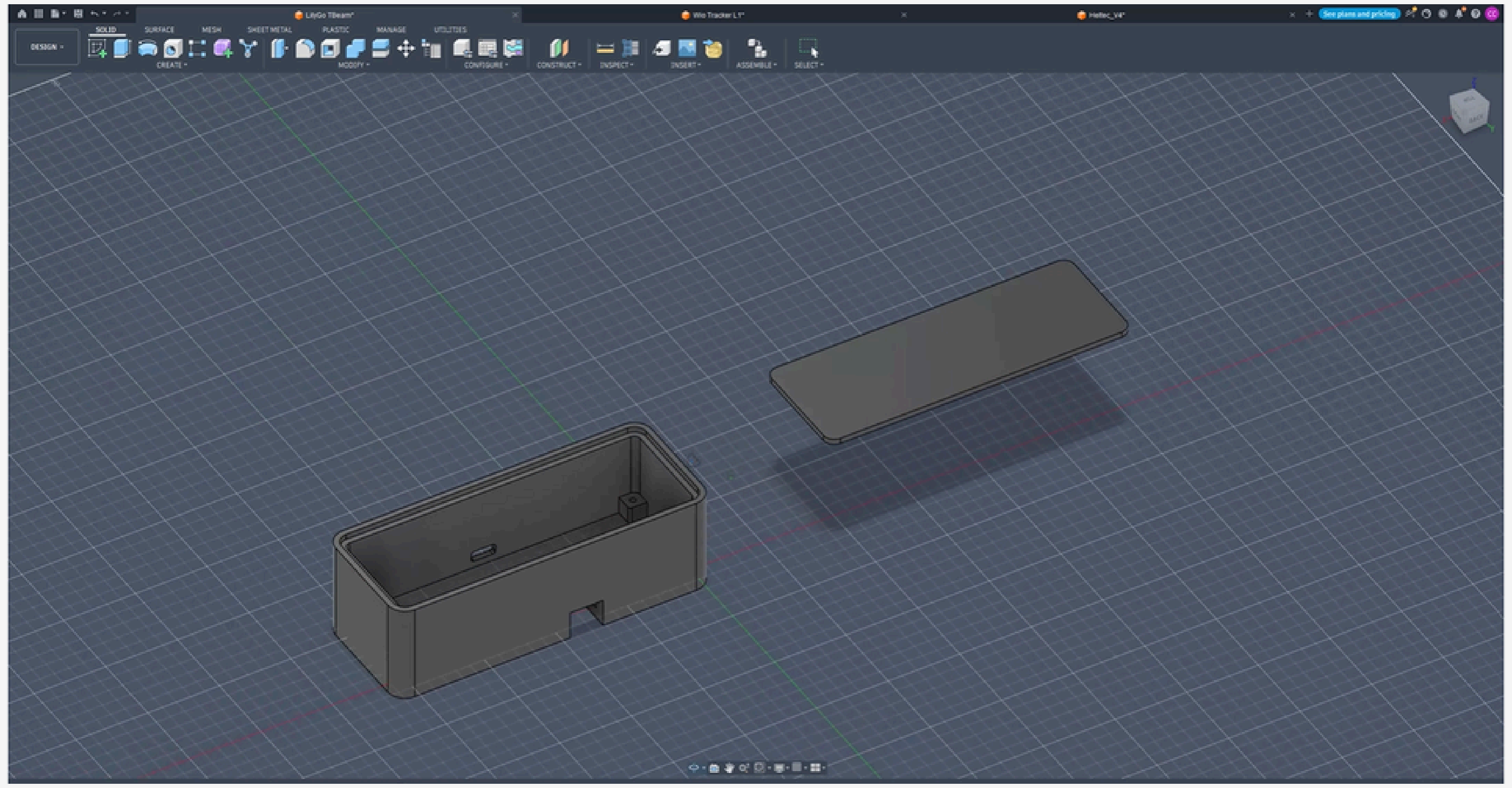
- **MQTT Telemetry Pipeline:** The Gateway bridge translates raw LoRa structs into standardized JSON payloads, pushing them securely to an MQTT broker.

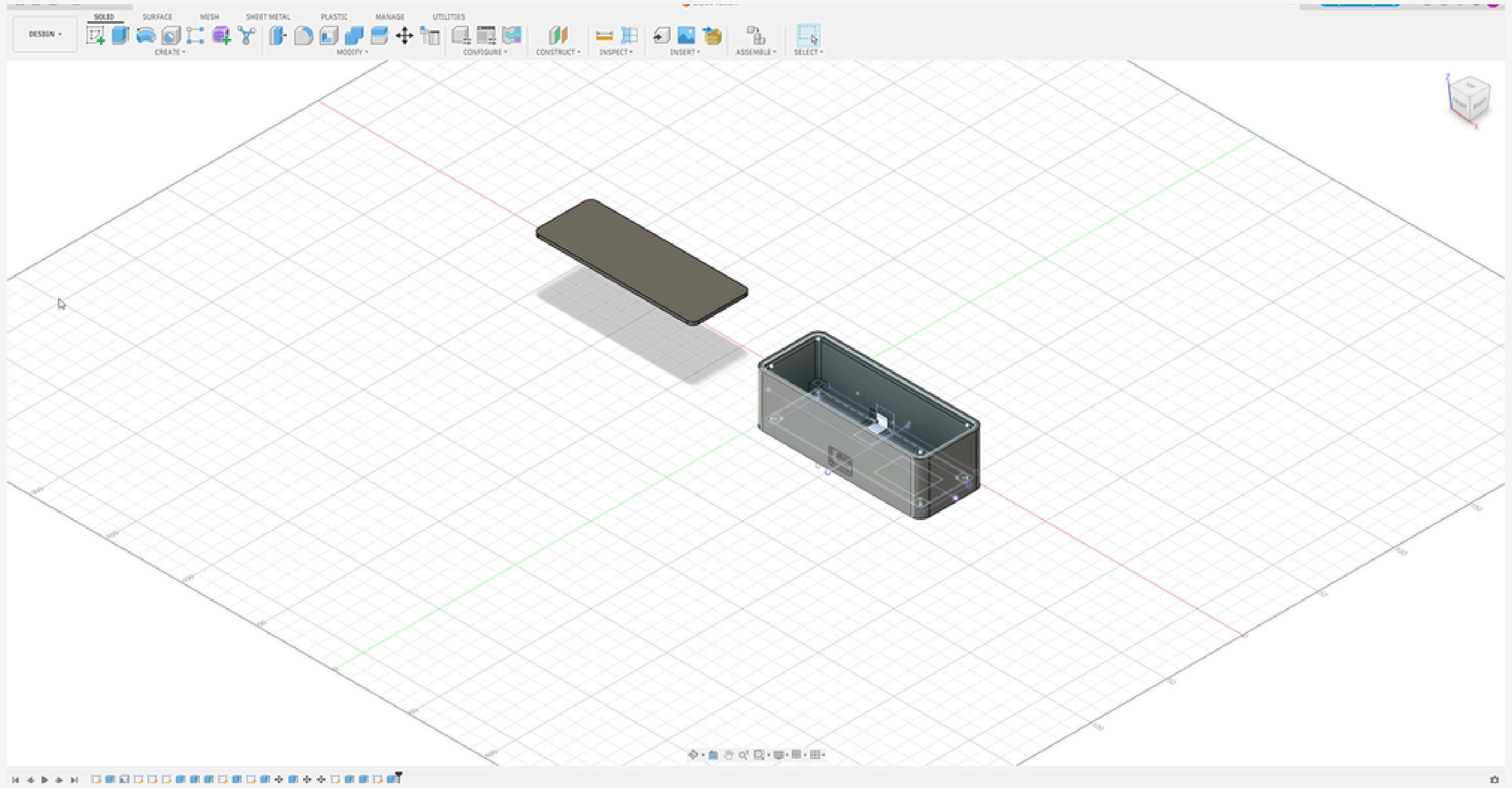
- **Real-Time Geospatial Mapping:** Live GPS coordinates extracted from edge nodes are dynamically plotted onto a high-resolution satellite dashboard.

- **Automated Threat Alerting:** Time-series sensor data (gas resistance and temperature) is constantly evaluated, triggering instant visual alerts and warning dialogues the moment pyrolytic thresholds are crossed.



3D Modelling & Printing





Tower's Ecosystem

Raspberry Pi 4

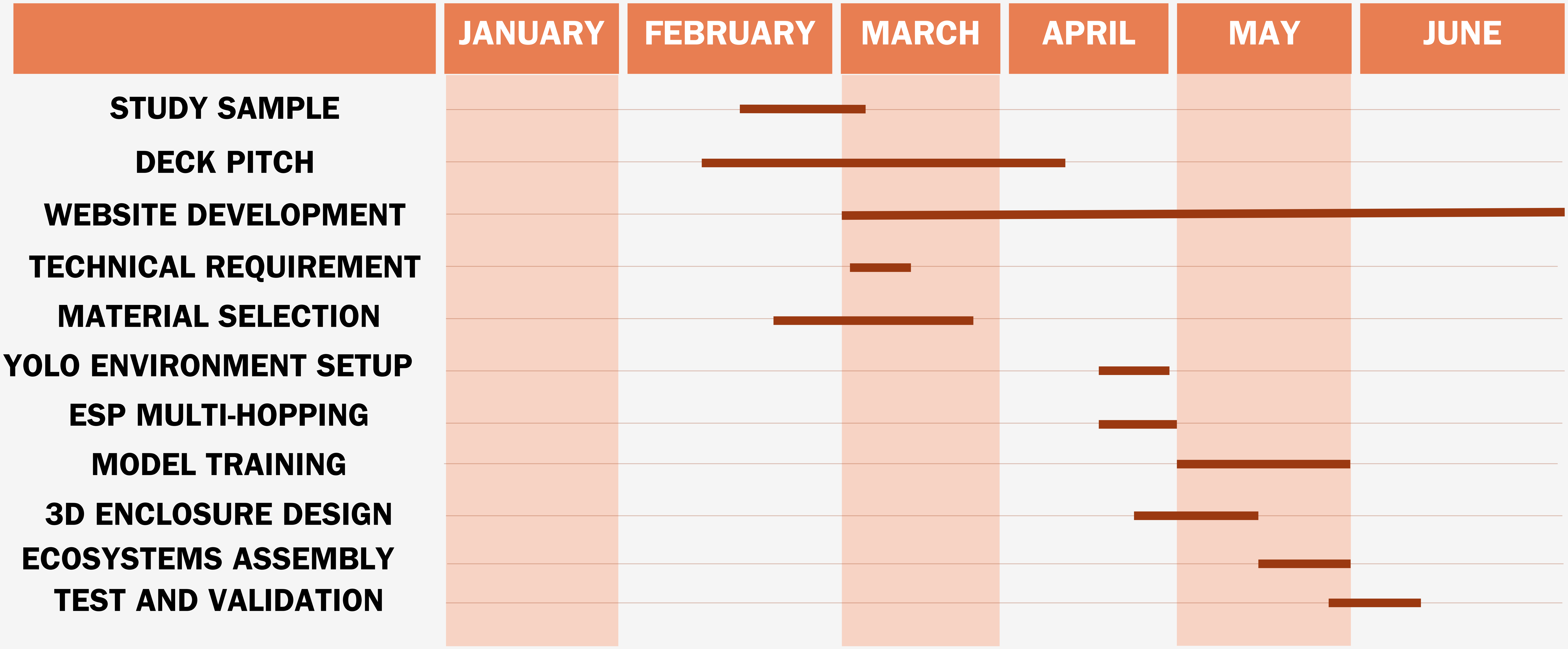
- Custom enclosure for edge computing unit;
- Ventilation slots for heat dissipation;
- Tower-mountable design.

Sensor's Ecosystem

Sensor Node Enclosure

- Compact housing for BME688, MQ-135 & GPS modules;
- Air-exposure openings for accurate gas readings.

Schedule



JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
STUDY SAMPLE
DECK PITCH
WEBSITE DEVELOPMENT
TECHNICAL REQUIREMENT
MATERIAL SELECTION
YOLO ENVIRONMENT SETUP
ESP MULTI-HOPPING
MODEL TRAINING
3D ENCLOSURE DESIGN
ECOSYSTEMS ASSEMBLY
TEST AND VALIDATION

Links

Website

Video

ElectroCap Project Proposal

Thanks!

TÉCNICO LISBOA