

# IGNIS Intelligent Ground Network for Independent Surveillance

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## Executive Summary

Traditional forest fire detection in Portugal is predominantly dependent on human surveillance, resulting in severe operational delays and positioning inaccuracies. IGNIS addresses this critical gap through a hybrid autonomous surveillance system that combines computer vision and edge processing on elevated towers and a redundant ground network of sensors in a LoRa mesh. This architecture ensures uninterrupted monitoring, immediate visual validation, and precise georeferenced alerts (with an approximate 25-meter deviation), operating with complete independence from public telecommunications infrastructures at the sensor network level.

## 1. Hybrid and Autonomous Forest Fire Detection

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The system introduces a robust, double-layer detection mechanism that eliminates exclusive reliance on direct human observation. The primary layer utilizes 360° optical cameras installed on watchtowers for continuous visual scanning and processing of the forest canopy. To overcome visibility limitations (such as fog, dust, or industrial smoke), the platform is safeguarded by a network of independent ground sensors. By cross-referencing local meteorological and analytical data with the automated positioning of the cameras, IGNIS autonomously validates fire outbreaks and mitigates false alarms, ensuring effectiveness in both urban-forest interfaces and complex mountain topographies.

## 2. Advanced Technical Integration

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The technical infrastructure coordinates edge computing, local data processing, and decentralized communications for maximum resilience. Each tower acts as a gateway equipped with a Raspberry Pi 4 unit, running a locally optimized YOLO model for visual smoke and fire detection. On the ground, the nodes combine Bosch BME-688 and MQ-135 sensors to identify chemical signatures of smoke and CO<sub>2</sub>. Communication completely bypasses cellular networks, propagating data through a self-healing multi-hop mesh network via Heltec V4 LoRa modules. The exact coordinates are processed by LILYGO TTGO T-Beam and Wio Tracker L1 nodes, then transmitted via the MQTT protocol.

## 3. Performance Benefits and Technical Advantages

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IGNIS provides substantial improvements compared to conventional methods. Computer vision validation achieves a maximum confidence score of 84% in recognizing fire outbreaks. Additionally, it issues real-time alerts with a GPS deviation of approximately 25 meters, directly addressing the operational requirement rated with maximum importance by 67% of surveyed Portuguese firefighters. By mitigating network failures through the LoRa mesh, coverage is guaranteed in shadow zones (a priority for 79% of operational personnel). The hardware was designed for economic and energy sustainability: ground nodes operate in Deep Sleep mode with enclosures that guarantee around 8 years of durability.

## 4. Sector Transformation and Impact on Civil Protection

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Developed in close collaboration with the Vendas Novas Fire Department, IGNIS modernizes civil protection by transitioning disaster management from a reactive posture to a technologically supported preventive response. The automated workflow allows operators to visually validate occurrences in seconds before the costly dispatch of ground or aerial resources. The project's evolution plan foresees the modular integration of wind direction sensors to predict fireline progression, infrared cameras for night-time surveillance, and direct interoperability of alerts with the FEB Monitorização platform used operationally by firefighting forces.

## 5. Conclusion

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IGNIS redefines forest preservation by successfully fusing edge computer vision and LoRa mesh sensor networks. By overcoming the limitations inherent in manual human monitoring and ensuring complete independence from public telecommunications infrastructures, this technological advancement delivers unprecedented speed and accuracy in localizing early fire outbreaks. IGNIS establishes a robust, durable, and cost-effective standard for environmental safety, positioning Portugal at the forefront of automated ecological asset management and civil protection modernization.