



TÉCNICO  
LISBOA



# VERTEX SHELL

An Active Safety Helmet with Self-Healing LoRa Mesh  
Networking

GRUPO 31

# THE PROBLEM

VERTEXSHELL

## Safety Limitations

- Traditional helmets are passive
- No environmental awareness
- Toxic gases are invisible (CO, O<sub>2</sub>)
- Falls may go unnoticed

## Connectivity Challenges

- Wi-Fi and cellular networks fail underground
- Communication blackouts delay rescue efforts
- Emergency response becomes slower and less reliable



## Passive Protection Only

Most traditional helmets only protect against physical impacts and cannot detect invisible threats such as toxic gases.

## Delayed Emergency Response

Delays in emergency communication can prevent supervisors from responding quickly to critical incidents.

## No Reliable Underground Connectivity

Wi-Fi and cellular networks often fail in tunnels and remote environments, creating communication blackouts.

## Dependence on External Infrastructure

Many existing solutions rely on network coverage or fixed infrastructure that may not be available underground.

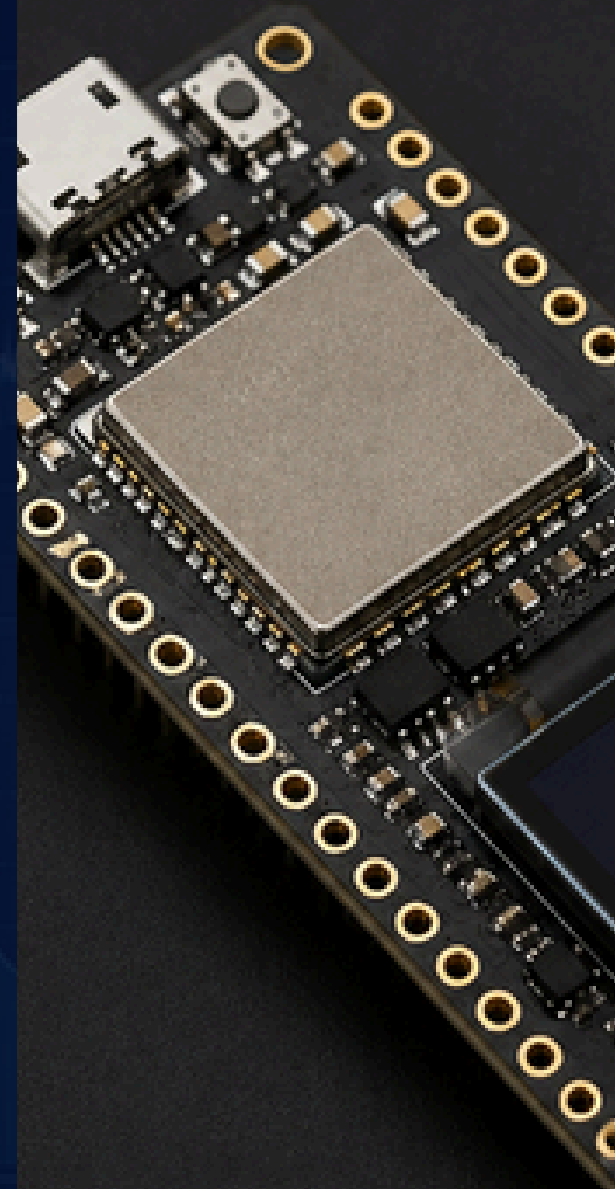
# LIMITATIONS OF CURRENT SOLUTIONS

Existing safety solutions address isolated challenges but fail to provide a fully integrated approach for underground environments. Many systems depend on external communication infrastructure, while gas detection, worker monitoring and emergency alerting are often deployed separately. This increases complexity and reduces reliability in critical situations.



# INTRODUCING VERTEXSHELL

VERTEXSHELL



## ➤ Active Safety Helmet

VertexShell combines gas detection, fall detection and self-healing LoRa Mesh networking into a single platform designed for underground mining and construction environments.

## ➤ Real-Time Hazard Detection

- Toxic gas monitoring
- Fall detection
- LED and buzzer alerts
- Worker safety awareness

## ➤ Self-Healing Communication

- LoRa Mesh networking
- Multi-hop message relay
- No Wi-Fi required
- No cellular coverage required



## Worker Helmet

- Gas Detection
- Fall Detection
- LED Alerts



## LoRa Mesh Network

- Multi-hop communication
- Self-healing routing
- Long-range connectivity



## Repeater Node

- Extends network coverage
- Placed in tunnels or surface
- Bridges helmets to supervisors



## Supervisor Dashboard (planned)

- Receives alerts
- Monitors workers
- Emergency notifications

# SYSTEM ARCHITECTURE

VertexShell creates a self-healing LoRa Mesh network where each helmet acts as a communication node. Alerts can be relayed across multiple workers until they reach a surface repeater and supervisor dashboard, even in environments without Wi-Fi or cellular coverage.

# HARDWARE COMPONENTS

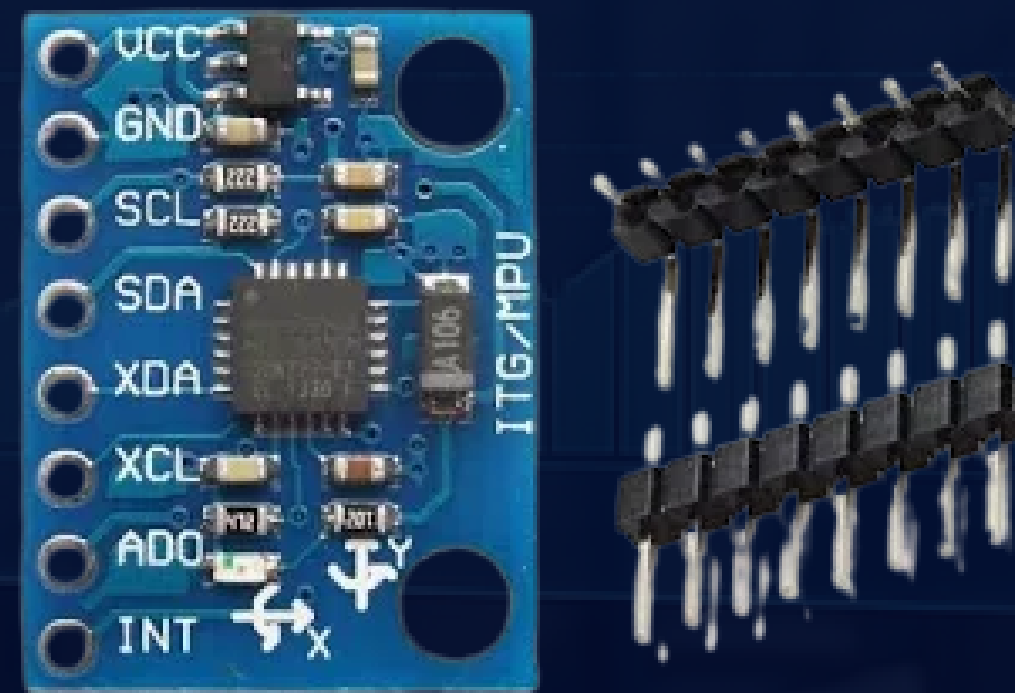
## LILYGO TTGO T3 LoRa32

- ESP32 microcontroller
- LoRa SX1276 communication
- OLED display



## LMPU6050 IMU

- Motion sensing
- Fall detection
- Accelerometer & gyroscope



## Gas Sensor

- CO, O<sub>2</sub> detection
- Toxic gas monitoring
- Real-time hazard alerts



# HARDWARE COMPONENTS

VERTEXSHELL

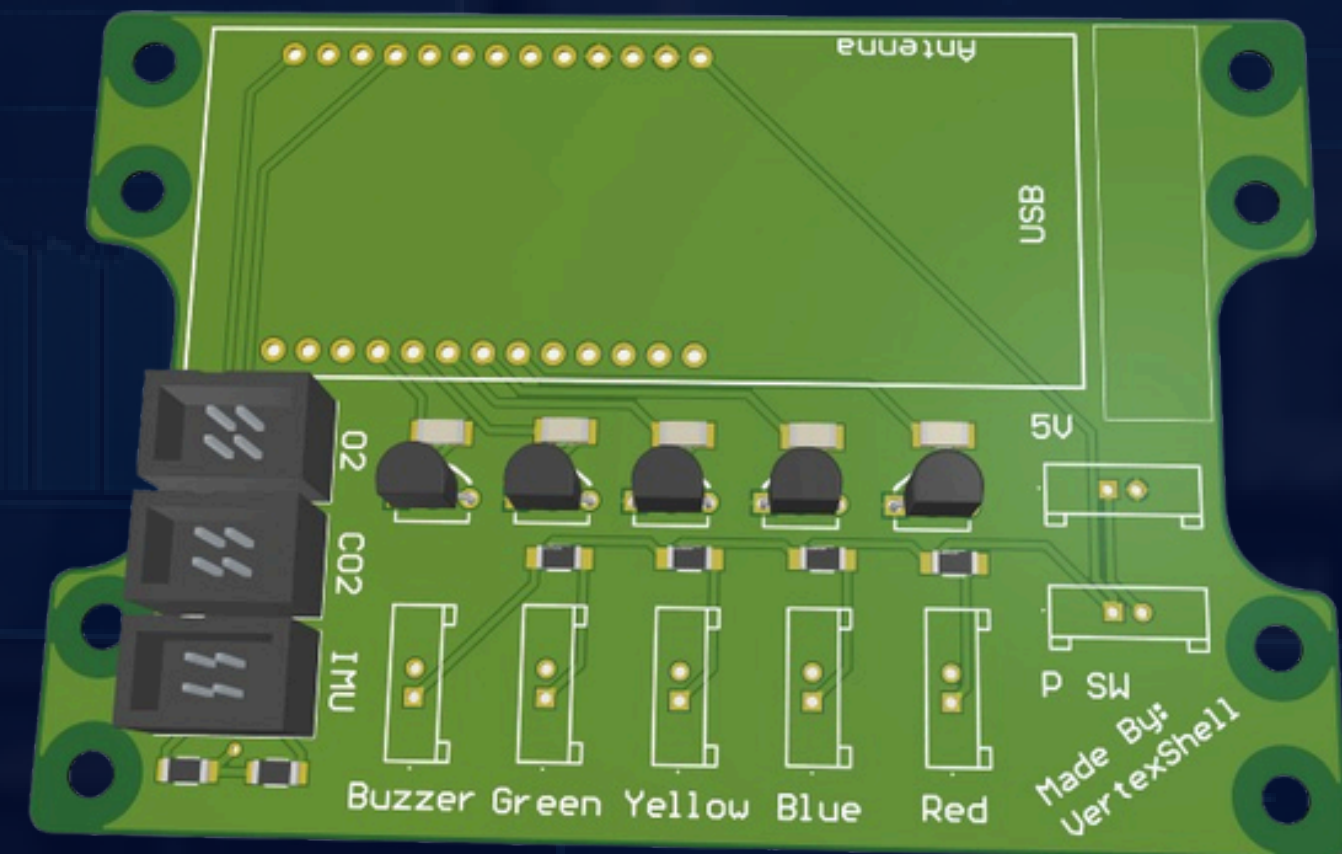
## Alert System

- LED visual indicators
- Buzzer audible alerts
- Emergency feedback (visual + sound)



## Aisler PCB

- PCB design and fabrication
- Connects all hardware components
- Custom layout for helmet integration

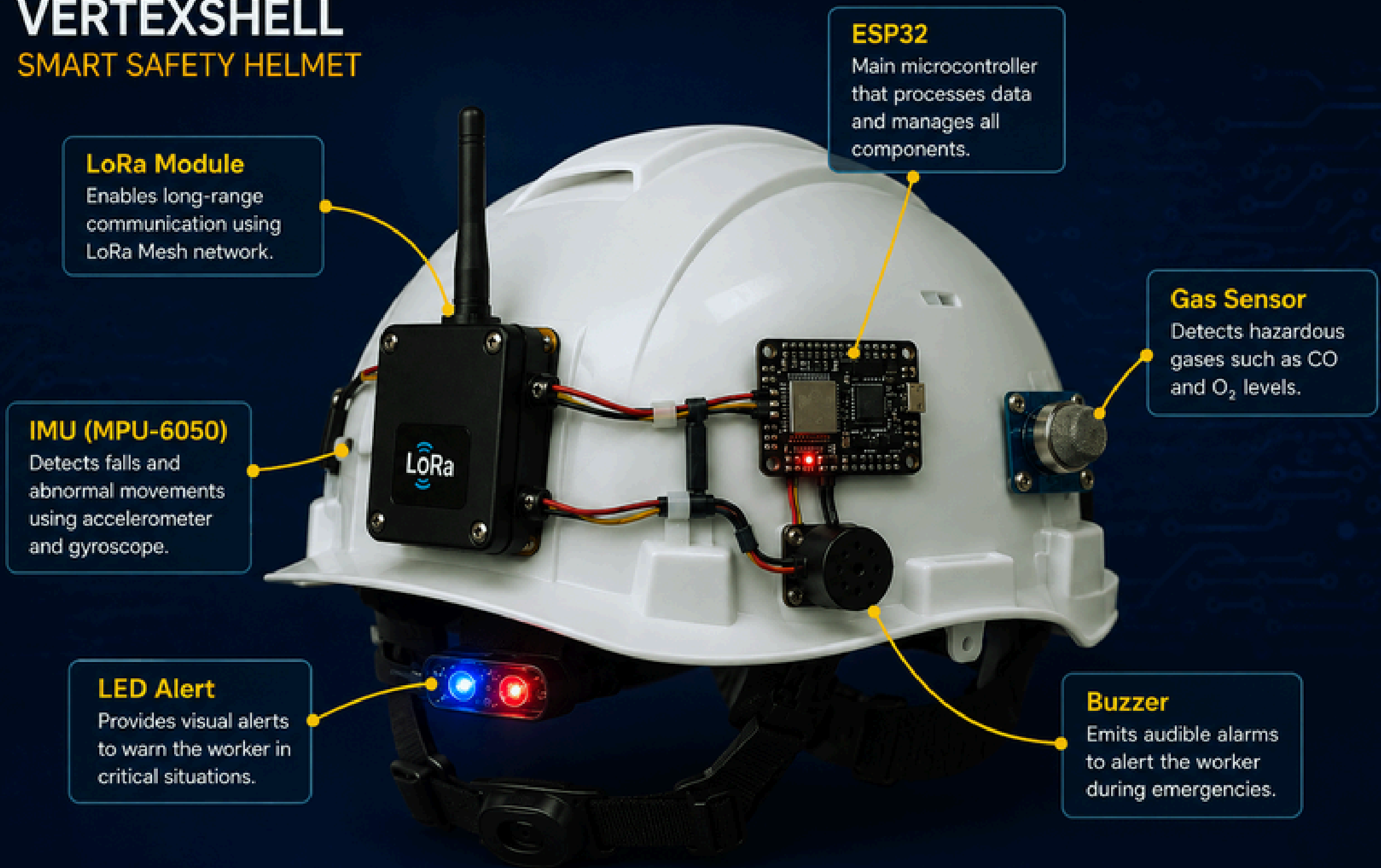


# VERTEXSHELL PROTOTYPE

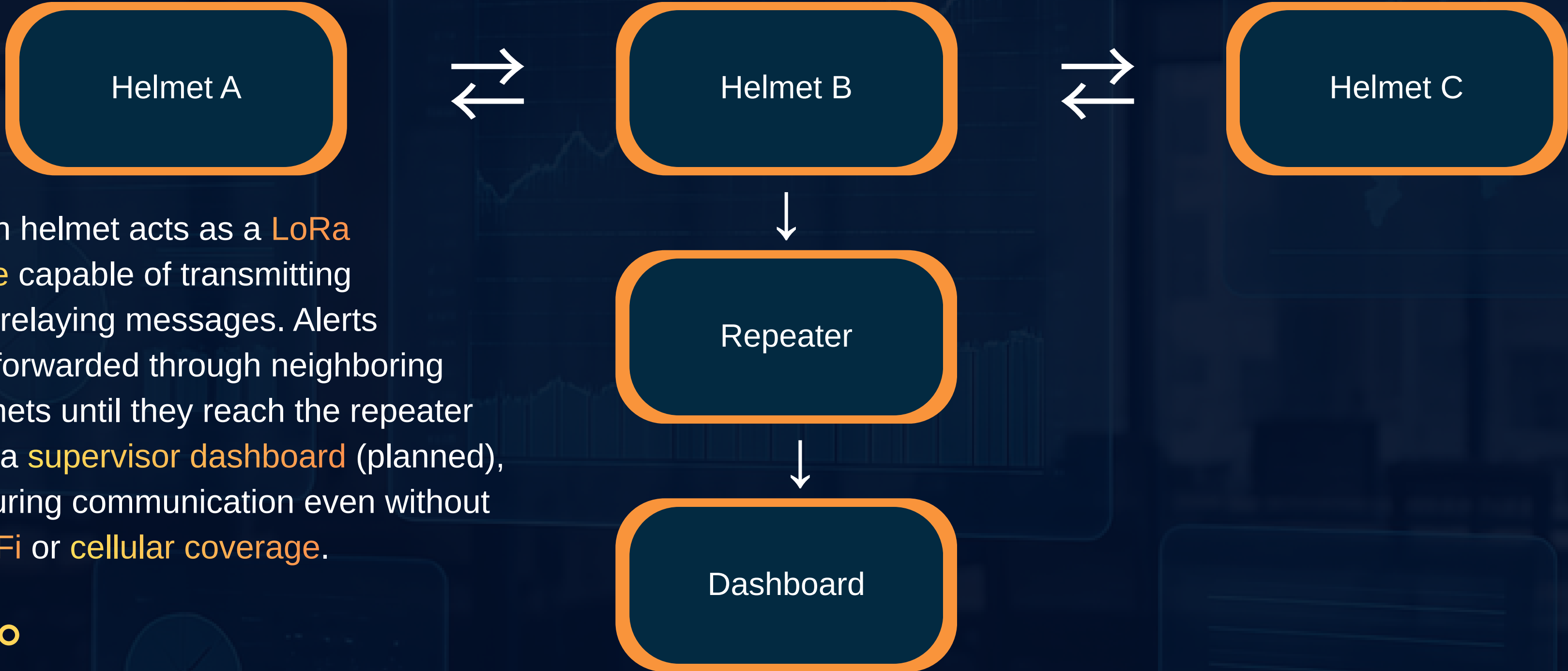
- ESP32
- LoRa Module
- Gas Sensor
- MPU6050
- LED Alert
- Buzzer

Fully integrated  
safety platform

## VERTEXSHELL SMART SAFETY HELMET



# LORA MESH COMMUNICATION



Each helmet acts as a **LoRa node** capable of transmitting and relaying messages. Alerts are forwarded through neighboring helmets until they reach the repeater and a **supervisor dashboard** (planned), ensuring communication even without **Wi-Fi** or **cellular coverage**.

# Technical Challenges

## Integration of EPOS sensors

The sensors provided by EPOS were too large to fit into the helmet. Smaller components had to be acquired, which required a budget review.

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## LoRa Mesh communication

Ensuring reliable communication in tunnels and obstructed environments was a challenge, solved by implementing the RadioLib library and multi-hop tests.

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## Power management

Balancing LoRa range with battery life for a full shift (12h+) required the implementation of sleep modes and firmware optimization.

# Testing & Validation

- ✓ LoRa Mesh communication tested and fully operational between multiple nodes.
- ✓ Gas sensors (CO, O<sub>2</sub>) and fall detection (IMU) successfully integrated and validated.
- ✓ Multi-hop message relay confirmed through intermediate helmets.
- ✓ Battery life tested and meets the 12h+ target for a full shift.
- ✓ Field test successfully completed in a simulated tunnel environment.
- ✓ All emergency alerts delivered within the required time.

All validation criteria were successfully met.

# Future Developments



## Improve energy efficiency

- Optimize sleep modes and power management to extend battery life beyond 12 hours.



## Enhance sensor accuracy

- Calibrate gas sensors for even more precise real-time readings.



## Integrate real-time location tracking

- Add GPS to locate workers underground.



## Reduce size and weight

- Miniaturize the PCB and use lighter components for better helmet ergonomics.

# EPOS

EPOS (Empresa Portuguesa de Obras Subterrâneas) is a leading Portuguese engineering firm specializing in complex underground construction, tunneling, and mining operations.



## Strategic Contributions to VertexShell

- Hazard Profiling: Guided our sensor focus by identifying the most critical and frequent atmospheric threats in active mines (specifically CO2 and O2 levels).
- Hardware Sourcing: Supplied specialized construction materials to build a physically relevant prototype.
- Field Deployment Access: Provided our team with exclusive access to an active underground mining site to serve as a real-world testing ground.

# AISLER

AISLER is a leading European electronics manufacturing platform specializing in rapid, high-quality Printed Circuit Board (PCB) prototyping and assembly.



## **Strategic Contributions to VertexShell:**

- Hardware Sponsorship: Granted a €500 manufacturing budget to fund our custom electronics development.
- Rapid Prototyping: Enabling the transition from bulky breadboard setups to a professional, miniaturized PCB.

# OUR TEAM



## Afonso Lopes

- ▶ Data and System Architecture;
- ▶ Sensor Data Processing;
- ▶ System Workflow Design;
- ▶ Demonstration Video



## Duarte Biscaia

- ▶ Material Search;
- ▶ Circuit Design;
- ▶ PCB Design;
- ▶ Website Development;
- ▶ Sensor Data Acquisition;
- ▶ Code Development;
- ▶ Project Logistics



## João Campos

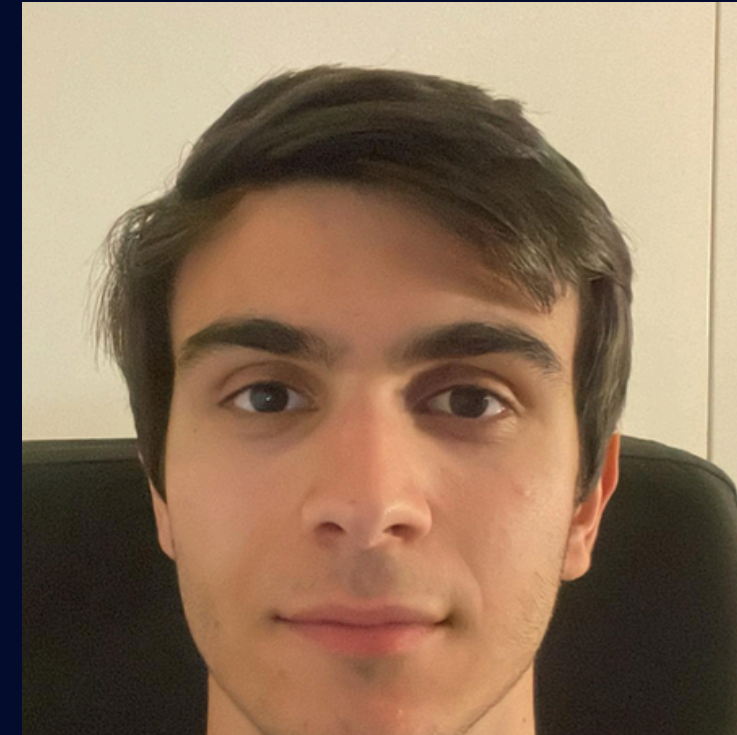
- ▶ Material Search;
- ▶ Pitch Deck;
- ▶ Demonstration Video;
- ▶ Corporate Meetings;
- ▶ Code development

# OUR TEAM



## Vivian Chipanga

- ▶ Lora Mesh Network;
- ▶ Communication Software;
- ▶ Project Logistics;
- ▶ Poster and Pitch Deck;
- ▶ Corporate Meetings



## Tomás Santiago

- ▶ Pitch Deck;
- ▶ 3D Printing;
- ▶ Packaging



# THANK YOU FOR YOUR ATTENTION

We appreciate your interest and look forward to  
creating something great together.



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