# ElectroCap Project Proposal

## Low-Power Wearable System for Real-Time Heat Stress Monitoring

TÉCNICO LISBOA

# Team members

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Manuel Costa

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# Problem definition: risks of strenuous activities

70% of workers are exposed to excessive heat

22.87 million annual heat-related injuries

18 970 annual fatalities

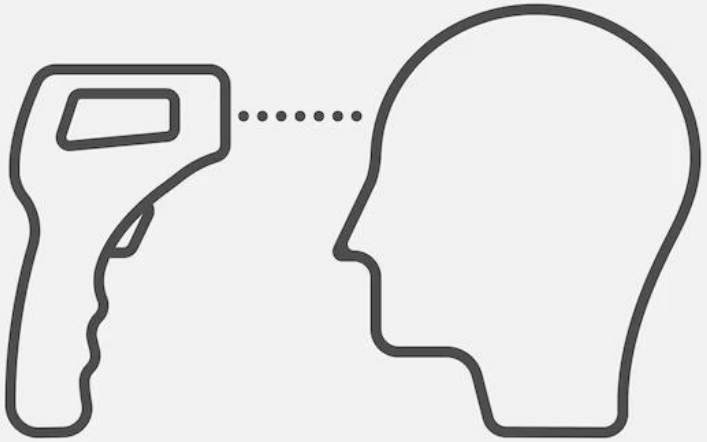
According to the International Labor Organization (ILO), global warming has led to a growth in injuries and health complications related to strenuous working conditions. Therefore, individuals engaged in strenuous activities, face severe risks of heatstroke and dehydration.

# Problem definition: issues of the current methods

Besides the rise in the number of workers in serious risks, we still rely on outdated monitoring methods, like:

- self-reporting
- basic skin temperature checks

Because these approaches are not accurate enough to catch health crises before they happen, critical interventions are often delayed.



# Problem definition: restrictions and constraints of the solution

To fix the problems of current methods, we need to build a battery-efficient wearable that continuously tracks a combination of vital signs. This will allow us to check workers in real time and provide them with personalized risk alerts. The system must also incorporate an accelerometer to correlate the level of physical exertion with the physiological load to enhance predictive capabilities.

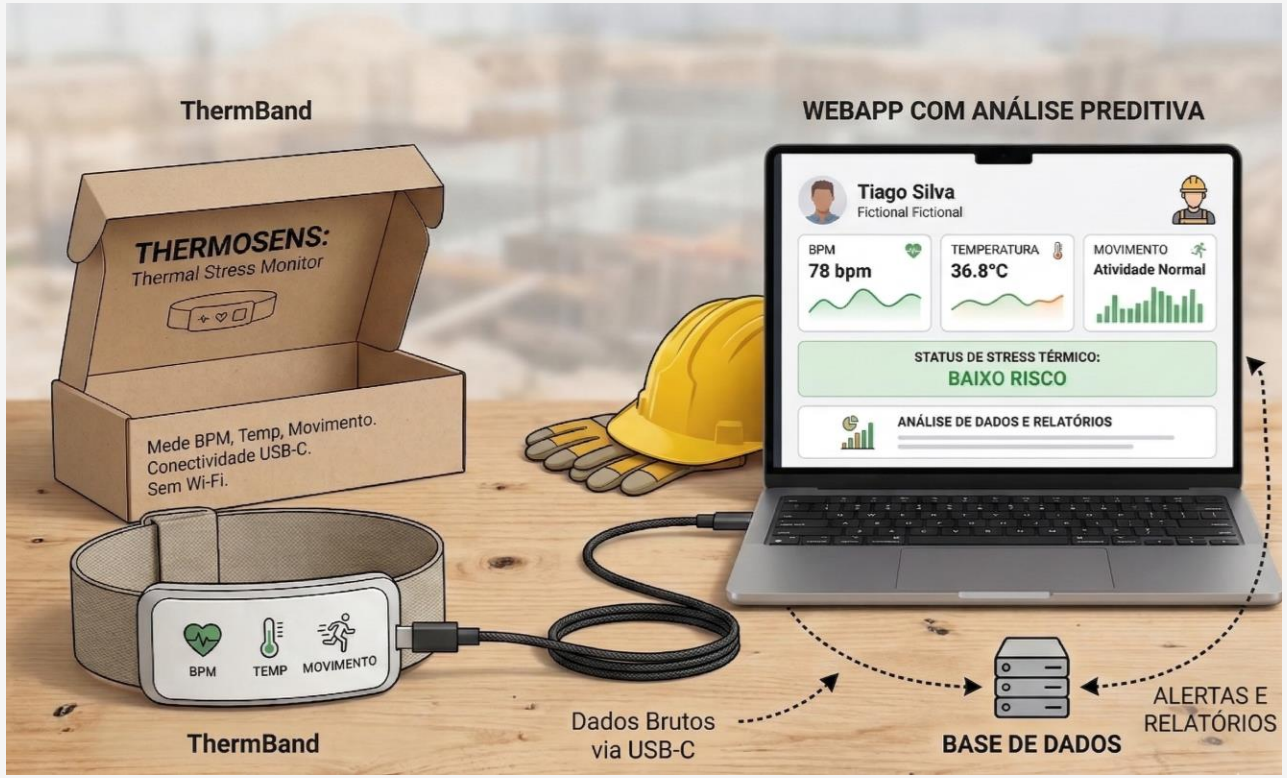
# Solution beneficiaries

**Construction Workers:** Used in contexts of prolonged physical exertion and direct solar radiation, where high risks of **dehydration, heatstroke, and fainting** occur due to extreme effort or excessive heat.

**Civil Protection Operatives:** Applied specifically in **forest firefighting** contexts, where personnel face extreme thermal stress and extenuating working conditions.


# Technological solution

Our proposed solution consists of a sensor-equipped thermband designed to measure skin temperature and heart rate, alongside an embedded accelerometer to assess physiological load.




# Technological solution

The armband processes the information and generates automated alerts for impending exhaustion. At the end of a workday the data is transferred to a device and is uploaded to a webapp.

# Competitors and previous work

- SlateSafety and Kenzen offer advanced upper-arm wearable devices designed to protect industrial workers from heat stress, fatigue, and overexertion in strenuous environments. Both systems utilize non-invasive sensors to continuously monitor key physiological metrics, primarily heart rate and estimated core body temperature. These devices deliver localized haptic feedback to prompt immediate rest and hydration, while simultaneously transmitting real-time alerts to a centralized supervisor dashboard for safety intervention.


# Competitors and previous work

- A different solution to this problem is Bodytrak. This is a non-invasive smart safety solution that precisely monitors CBT, heart rate, heart rate variability and noise exposure.
- However, this solution is not practically viable. Earpiece-based devices present compatibility issues with mandatory safety helmets, can impede essential on-site communication, and generally face lower user acceptance among workers.

# Partners


SMAS

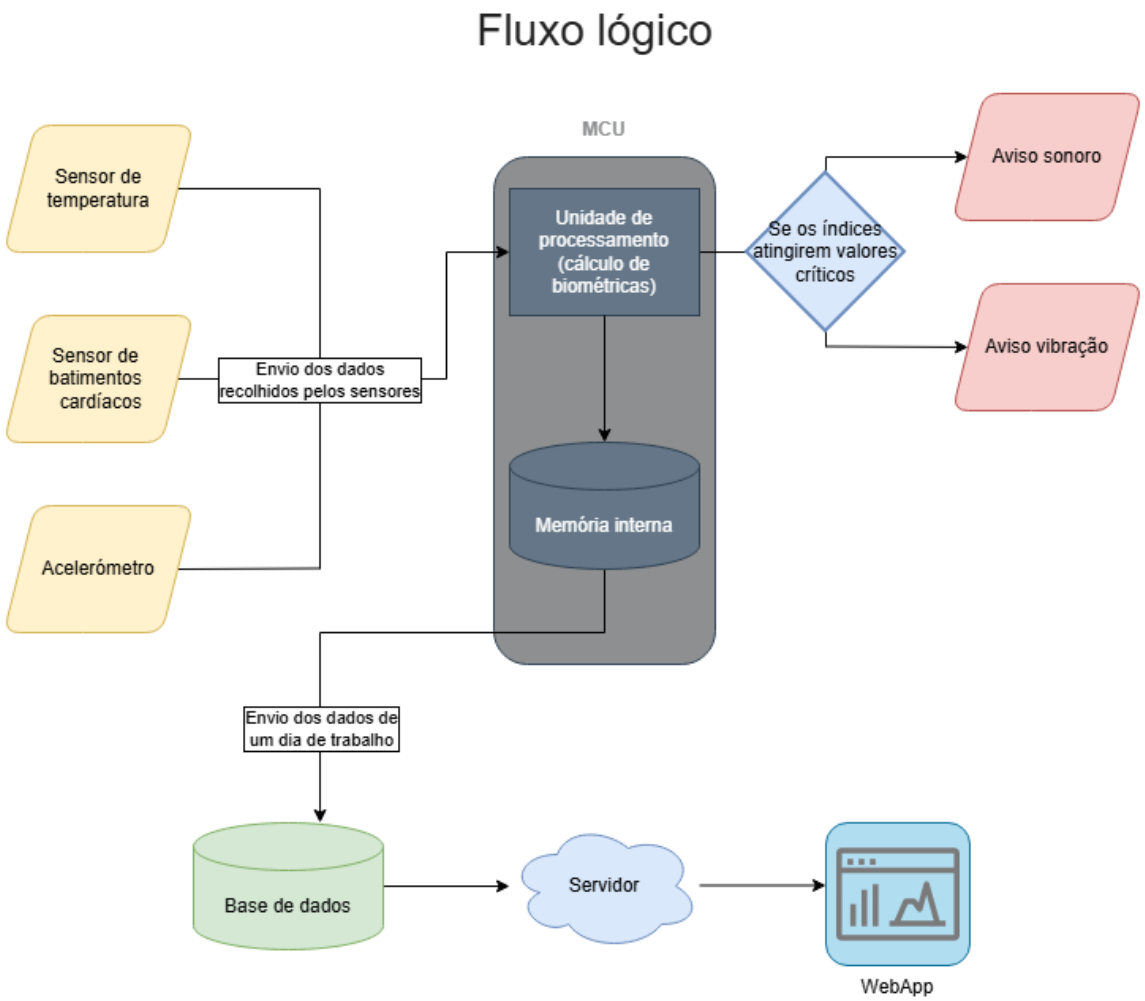

Infraestruturas
de Portugal


MOTA-ENGIL


fMH

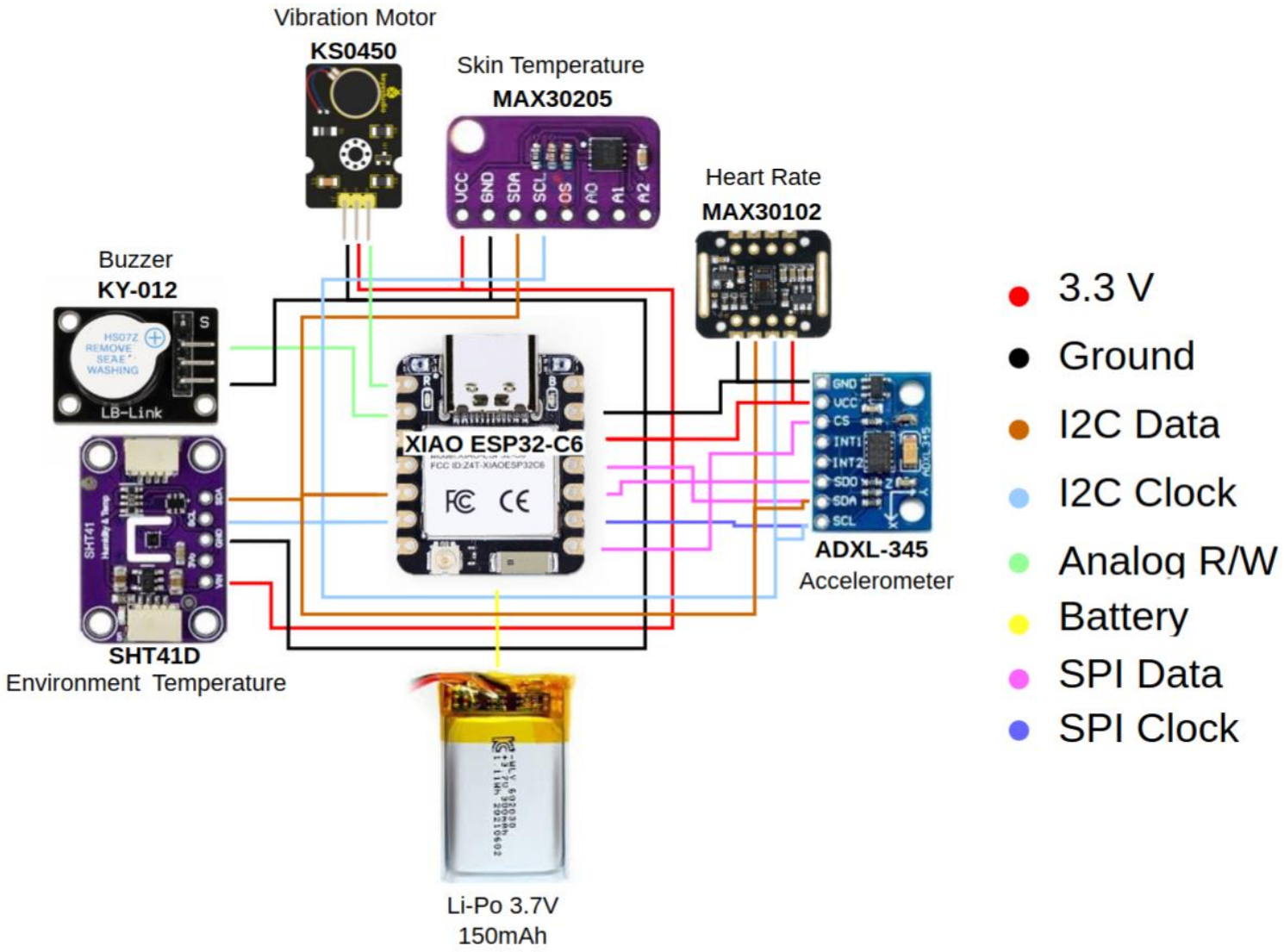

inesc id
lisboa


PROTECÇÃO CIVIL
PORTUGAL




# Mid-program status: system design, architecture and prototyping

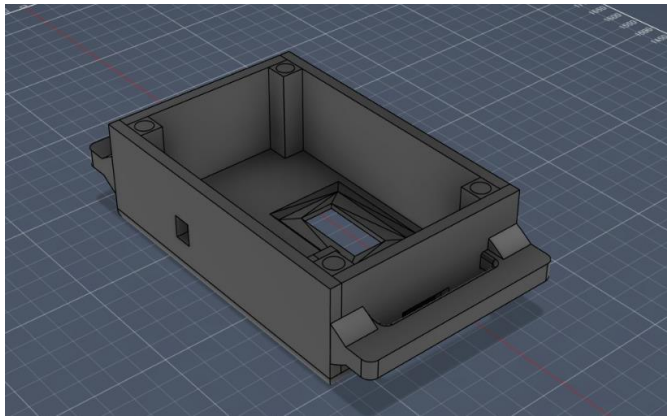
- **System Domains:** Wearable Device (Local Edge) → PC/Laptop Interface (Data Gateway) → Cloud Ecosystem (Remote Analysis)
- **Sensor Interconnectivity:** Integrated I2C Bus (SDA/SCL) for multi-variable sensor reading (Temp/HR/Acc) using minimal pin footprint
- **Data Flow & Persistence:** Serialized sensor data stored via LittleFS on internal Flash memory, ensuring 8h of local data persistence
- **Synchronization & Power:** Dual-purpose USB-C interface for high-speed data extraction and MCU-controlled battery charging/protection
- **Logic Architecture:** Localized MCU risk processing with real-time haptic/acoustic triggers and daily batch synchronization to WebApp

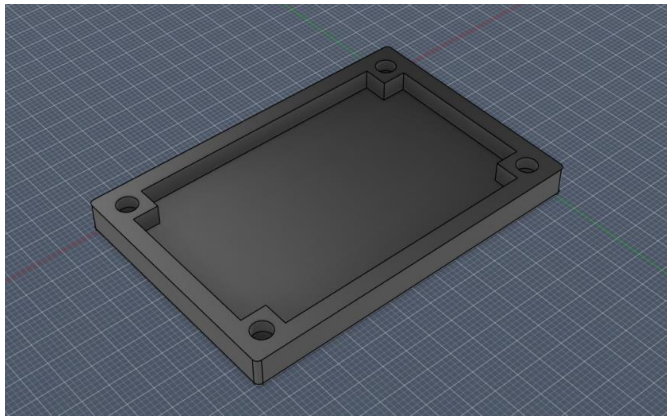


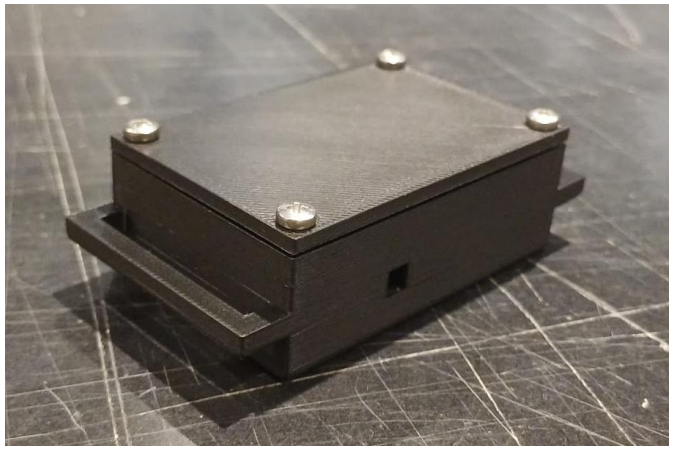

# Wiring Diagram and Communication Protocol


# Results: Backend Software

- As planned, we have successfully developed backend software that estimates core body temperature and calculates the Physiological Strain Index (PSI) and Heat Index (HI).
- We used Loughborough University's 'Prospie' open dataset to train and test our algorithm.
- Our algorithm achieved an RMSE of 0.38°C in estimating core body temperature. This aligns with equivalent results in scientific literature. For instance, Yuanzhe Zhao and Jeroen H.M. Bergman applied the EKF to estimate core body temperature using the same dataset and obtained an RMSE of 0.39°C.



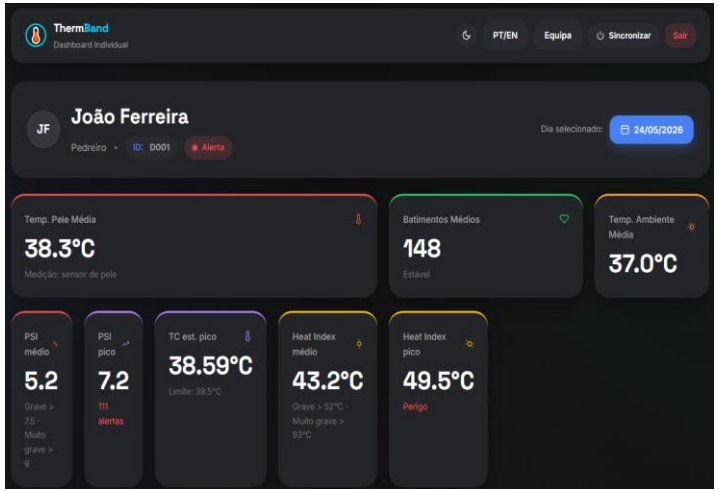




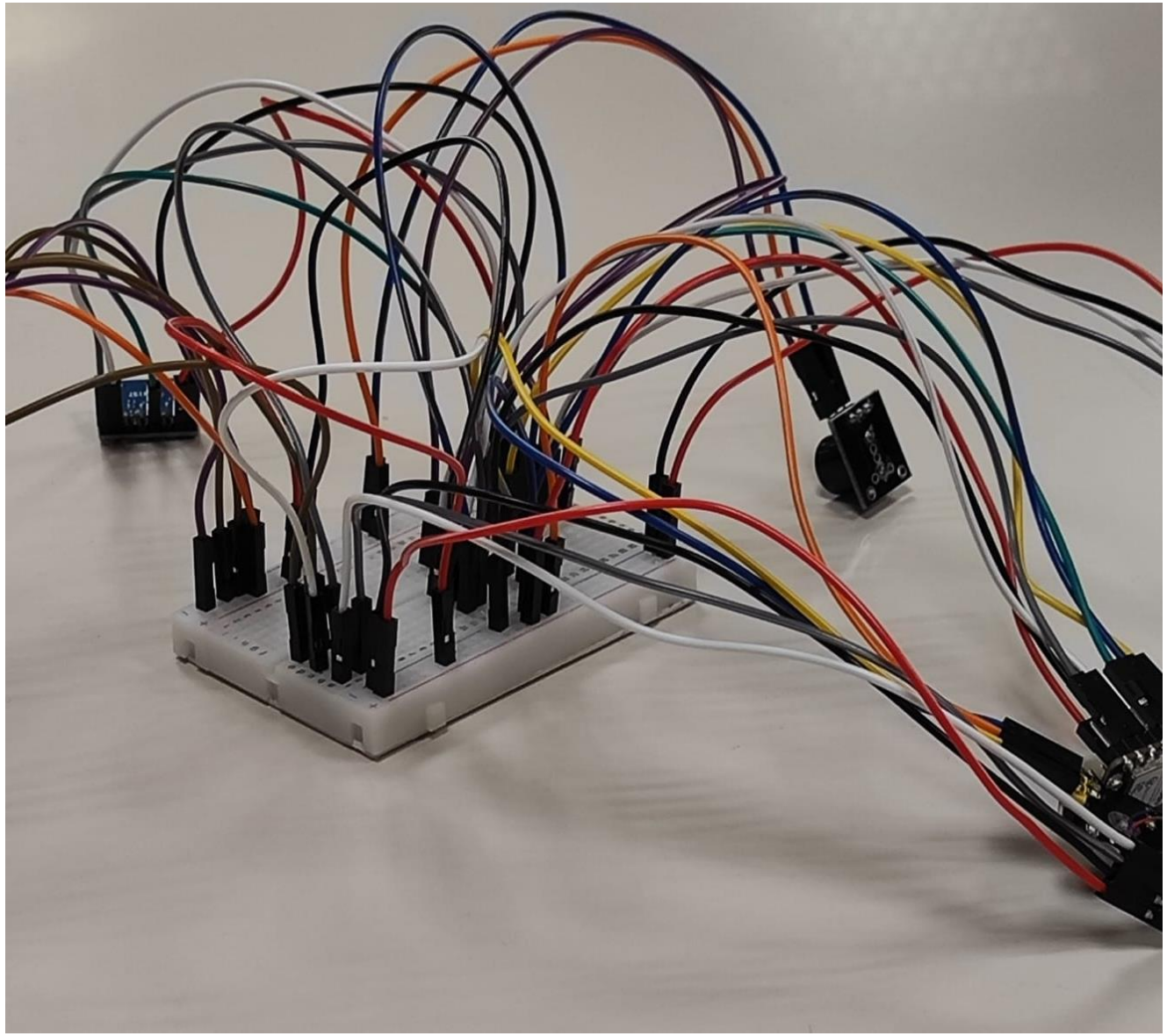
# Results: Enclosure Development

- The proof-of-concept enclosure evolved through three 3D-printed iterations (supported by eNGN and iStartLab) to optimize ergonomics, functionality, durability, and weight.
- Built with PETG for high impact resistance, the enclosure integrates brass heat-set inserts to ensure durable, wear-free opening and closing cycles.
- Features a curved face for prolonged user comfort and geometrically reinforced lateral arms for adjustable elastic straps, preventing mechanical failure under stress.

# Results: Webapp


- Built a secure remote database using the IST Sigma server to store and track workers' health, movement, and environmental data.
- Designed a secure synchronization system that automatically uploads data from the wearable device to the server when connected via USB-C.
- Created an easy-to-use digital dashboard that allows managers to monitor multiple users, view health averages, receive safety alerts, and check historical data from past work shifts.



# Results: Electronic Development

Implemented the different sensors and actuators in a single system, being able to retrieve data from all of them. The calibration of the sensors was done independently from each other to ensure the correct functioning of each of them.

The signal processing was done with the help of libraries present in Arduino IDE, this made the development much easier and faster.

# Results: Validation with partners

- **Problem Relevance: 4/5** — High priority in operational contexts.
- **Risk Reduction: 5/5** — Exceptional potential to reduce heat strokes and workplace accidents.
- **Value Over Current Methods: 5/5** — Far superior to standard practices (e.g., empirical breaks, water distribution).
- **System Performance: 5/5** — Webapp is highly user-friendly with flawless data transfer.
- **Future Adoption & Integration: 3** — Growing interest during summer, heavily dependent on wearable comfort.

# Results: Validation with partners

- **Prototype Comfort: 4/5 –** Good comfort during an 8-hour shift.
- **Weight and Lightness: 3/5 –** Assessment of the device's physical mass and portability.
- **Ergonomics and Mobility: 4/5 –** How freely the device allows the movement necessary for daily work.
- **Usability: 3/5 –** How easy and intuitive the process is for putting on and adjusting the device.
- **PPE Compatibility: 5/5 –** How well the device integrates with required Individual Protection Equipment.

# Contribution of each team member (1)

| Vicente Rosa | Manuel Costa | André Alves |
|---|---|---|
| **Hardware Component Research** | **Partnership Development** | **Software backend development** |
| Technical Research, Communication Protocol Analysis, and Sensor Datasheet Specification | Eletrocap project proposal | Eletrocap project proposals |
| Solution requirement and material lists | Partner communication, meeting scheduling and attendance (SMAS, EDA, IP), including the validation of the armband placement | Research, Calculation, and Validation of Physiological and Environmental Strain Indexes (PSI & HI) |
| Arduino Firmware Development: Sensor Data Acquisition and Algorithmic Code Integration | Research on formal prototype testing and validation methodologies | Research, Development, and Validation of Core Body Temperature Estimation Algorithms |
| Physical Hardware Assembly and Testing: Sensor Integration, Component Placement, and Electronic Circuit Wiring | Ergonomic Strap Design and Hardware Mounting Procurement | Hardware Assembly and System Integration Support |

# Contribution of each team member (2)

| Martim Neves | André Branco | Artur Moreira |
|---|---|---|
| Web development | Project management and design | Web development |
| Webapp Development for Employee Data Telemetry and Biometric Analytics | Research on design development and participation in partner meetings to discuss design aspects | Eletrocap project proposal |
| Prototype Assembly: Electronic Circuit Wiring and Sensor Integration | Project Management: Partners Scheduling and Collaborative Meetings | Website development and updating |
| Participation in multiple meetings with our partners | Mechanical Design and Additive Manufacturing of the Prototype | Interviews report on the blog |
| Project Summary Video Production | Project Communication: Scientific Poster Design and Development | Solution requirement list |

# Costs and benefits

## TOTAL PROTOTYPE COST (HARDWARE) 59,70 €

- **Core Electronics (Mauser): 30.74 €**
  FireBeetle 2 ESP32-C6 microcontroller, ADXL-345 accelerometer for physical activity tracking, active piezo buzzer, and integrated 3.7V Li-Po battery.

- **Biometric Sensors (Others): 18.96 €**
  MAX30102 heart rate module, MAX30205 high-accuracy skin temperature sensor, and PWM vibration motor.

- **Torso Strap & Protective Enclosure: 10.00€**
  Robust enclosure optimized and 3D printed in PETG (with eNGN/iStartLab support) mounted on an ergonomic, washable elastic band.

## BENEFITS & IMPACT

- **Torso-Worn Design (Zero Ergophobia):**
  100% compatible with uniforms and PPE (helmets, harnesses). Ensures biometric measurements with far less mechanical motion noise than wrist-worn alternatives.

- **Highly Accurate Sensing:** Safe torso placement minimizes motion noise, helping confirm our temperature estimation algorithm with an outstanding **RMSE of 0.38°C**.

- **Proactive Local Alerts:** Edge computing instantly triggers physical haptic vibrations and acoustic buzzers directly on the chest to alert workers of heat risk.

- **Simple & Direct Data Reading:** A highly straightforward web platform and dashboard for intuitive, immediate health-log tracking via automatic USB-C synchronization.

# Check more info

- Our website: Website - ThermBand Project
- Our blog: Blog - ThermBand Project
- Our video: Video - Thermband Project