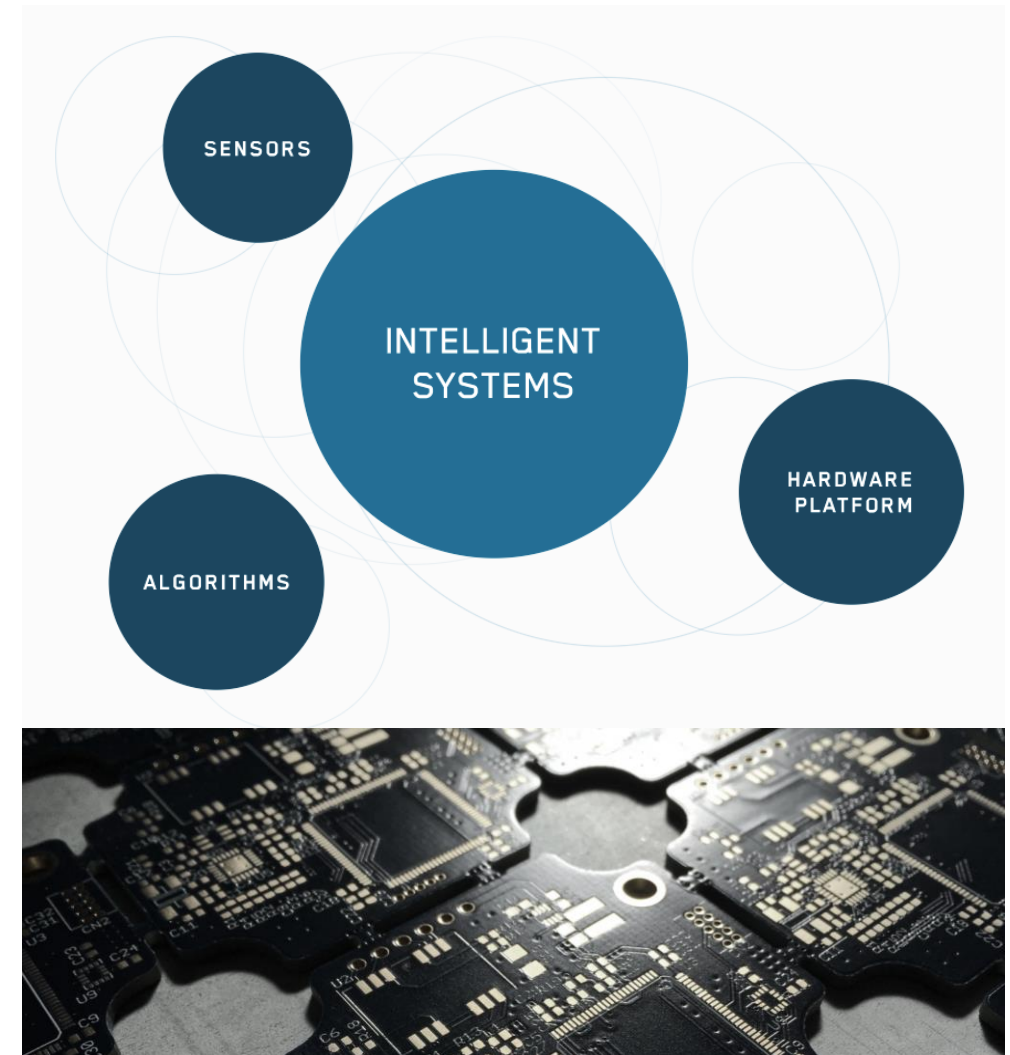


Wearable sensor systems for occupational safety and healthcare

Daniele Comotti, CTO
Daniele Carniello, S&M
221e SRL

About 221e – the company

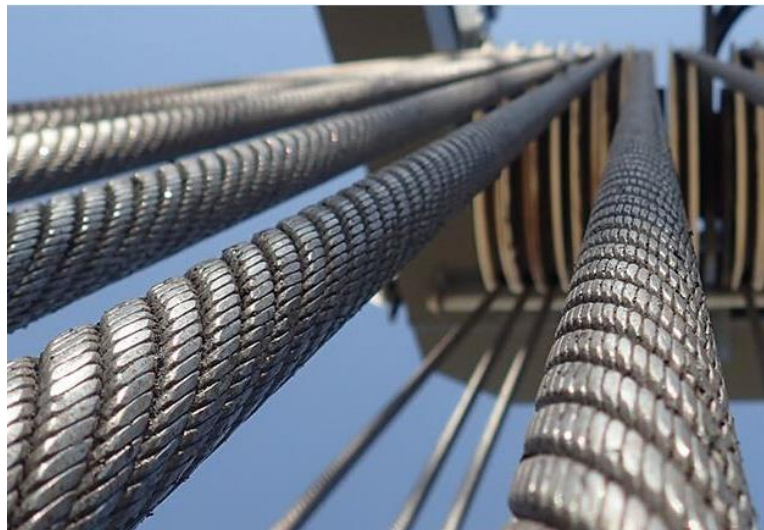
- **Innovative enterprise** active in the development of ideas, projects and products exploiting the convergent advances in the fields of microelectronics, sensors, telecommunication and artificial intelligence.
- **People:** CEO, 9 tech (Ms. C. & Ph. D.), 2 marketing, 1 administration.
- Strong **R&D mindset** and network.
- We market product designs for **wearables** and **IoT solutions**, synthesizing our know-how in **miniaturized low-power smart systems**.
- We offer **R&D services** that lead to the engineering of custom solutions.
- We can follow **product development** from specifications to feasibility study, through engineering, prototyping and manufacturing.



About 221e – sport applications



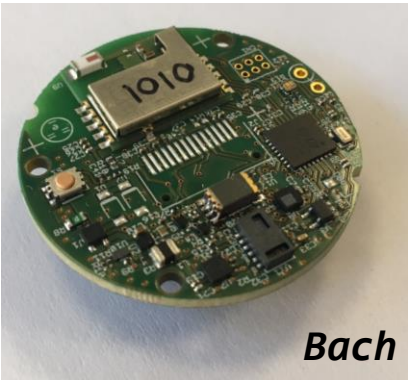
About 221e – predictive maintenance & monitoring



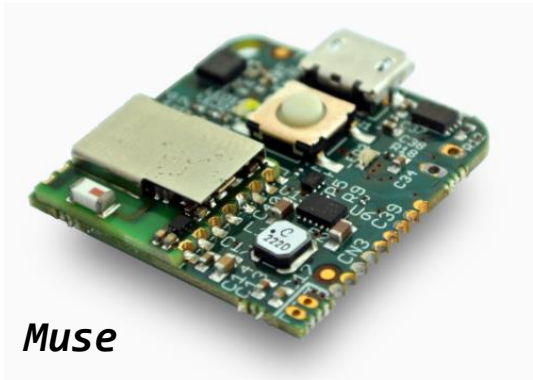
About 221e – other applications



About 221e – hardware ecosystem



Bach



Muse



3 Leads ECG

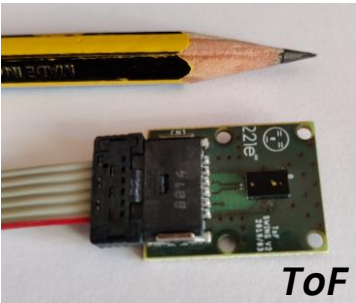
Comprehensive software suite and documentation



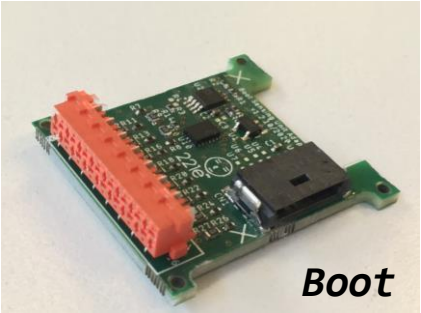
Mitch



PPGs



ToF



Boot



Yeti

About 221e – algorithms ecosystem

- **Portable:** compiled for the most commonly used platforms (x86, x64, ARM Cortex M, ecc).
- **Easy to integrate:** showcase with few lines of code.
- **Modular:** works with any sensor data.
- **Low level implementation:** for an optimized execution time, binary footprint and resource consumption.
- **Documented:** application notes, integration guides, user manuals.
- **Tested:** benchmarks with state-of-the-art systems and datasets.

Application

Man down
detection

Domain

Center of
mass

Toolbox

Quaternions

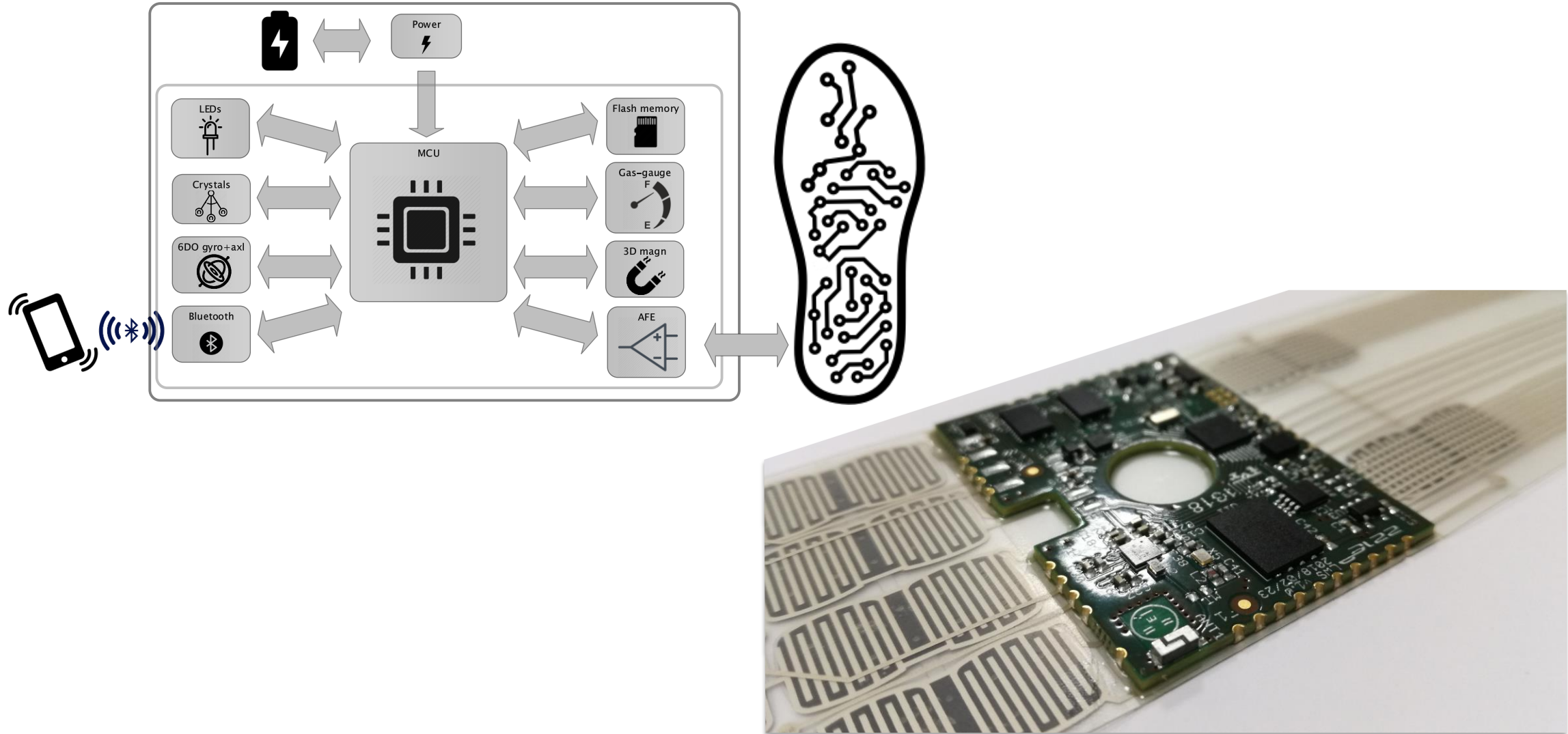


Occupational safety – Lift Warning System

- **Problem:** lifting of heavy objects incorrectly can cause injuries to people, ultimately resulting in time off work and/or health care costs to relieve the trauma.
- **Goal:** to prevent accidents and long-term discomfort by warning people when they are at risk.
- **Solution:**
 - Sensor system which fits within the insole of a safety shoe.
 - Main electronics monitoring kinematics of the user.
 - “Sensing sheet” to detect pressures distribution.
- **Requirements:**
 - Sensing of **foot pressures** and motion (**6DOF**).
 - Short range radio communication via **BLE**.
 - **Thin** and non-invasive.
 - **Durable**, 4000 hours of use.
 - Battery powered, long time between charges.
 - On-board processing of data for real-time monitoring.
 - Warning through BLE and a tactile feedback.

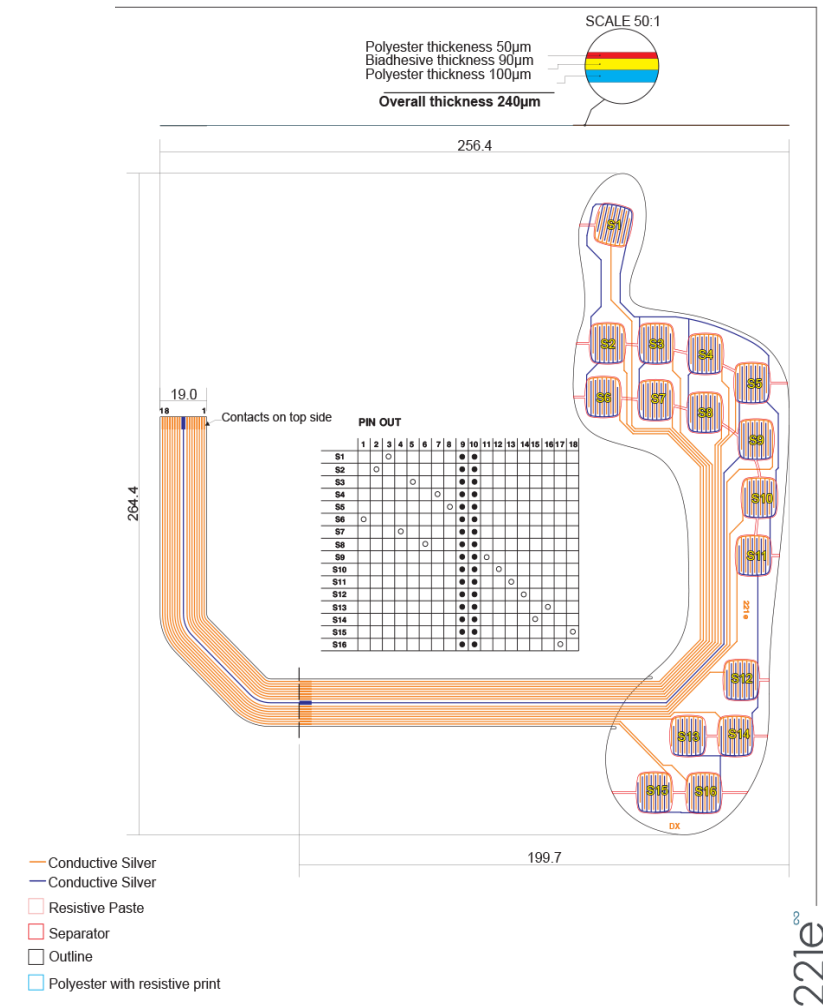
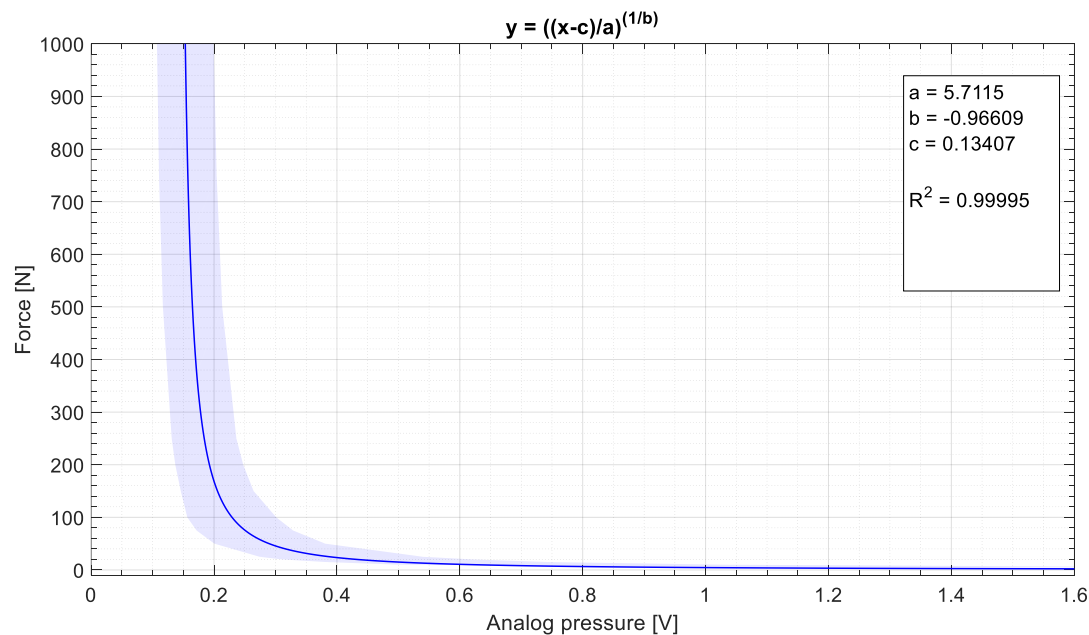


Lift Warning System – overview

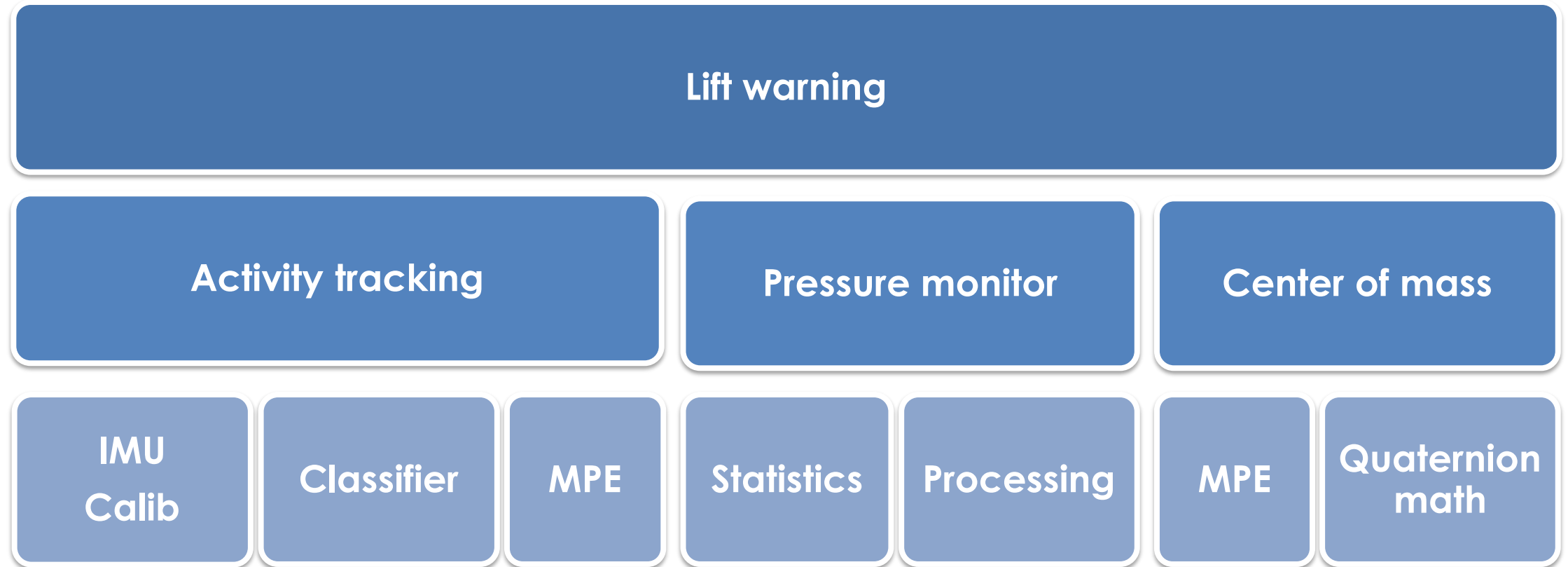


Lift Warning System – pressure sensor (yeti)

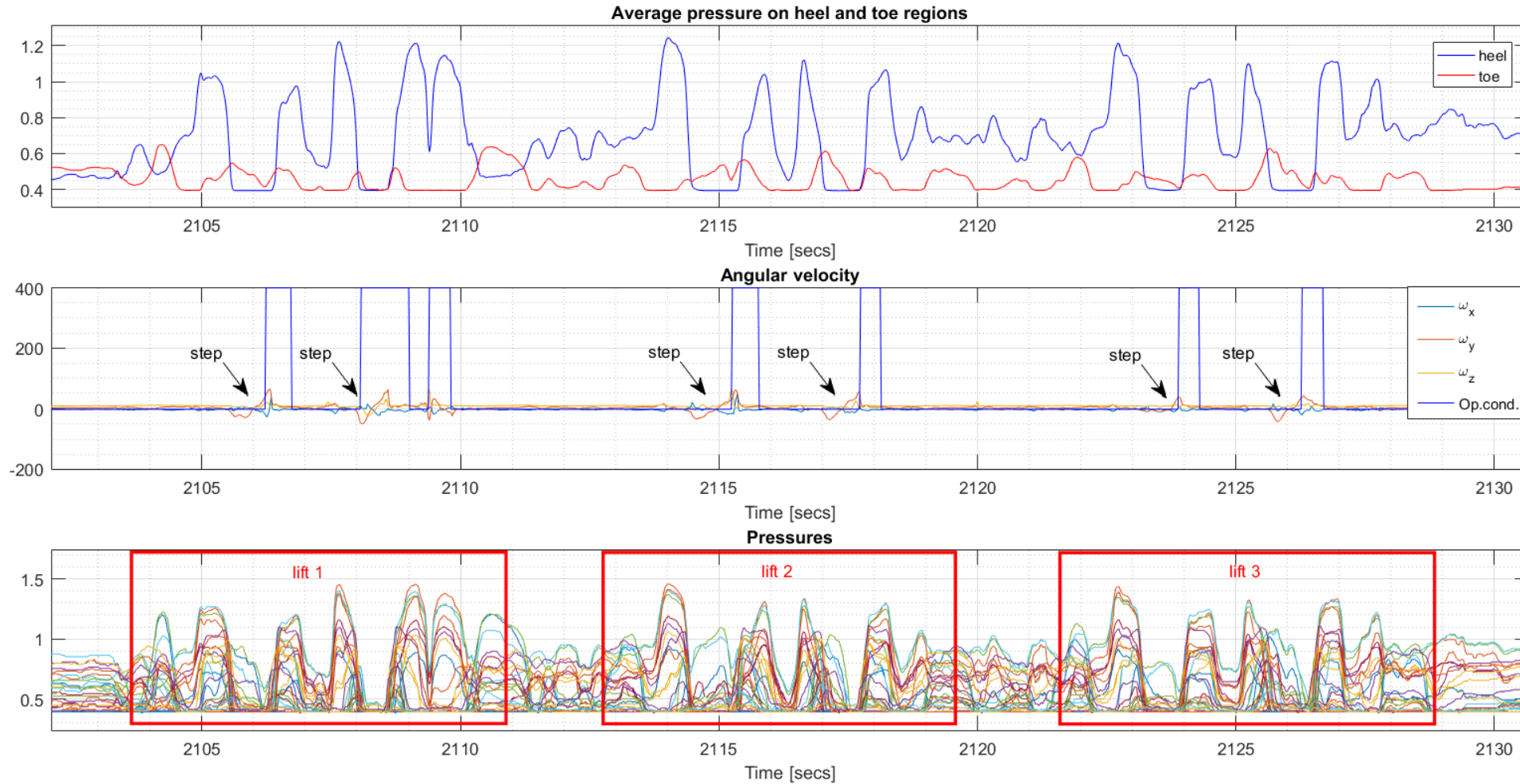
- **FSR** based pressure sensors.
- **Shunt mode** configuration.
- Resistance varies with the pressure/force applied to the pad.
- Relatively **thin** (240 µm).
- Easy to source and manufacture.
- Available in **different sizes**.
- Easily **portable** on different kinds of design.



Lift Warning System – embedded algorithms



Lift Warning System – embedded algorithms



Occupational Safety – Man down tracker

Problem:

- Uneven road surfaces affect delivery times and represent a potential risk.
- Postman hazardous conditions not always managed.

Goal:

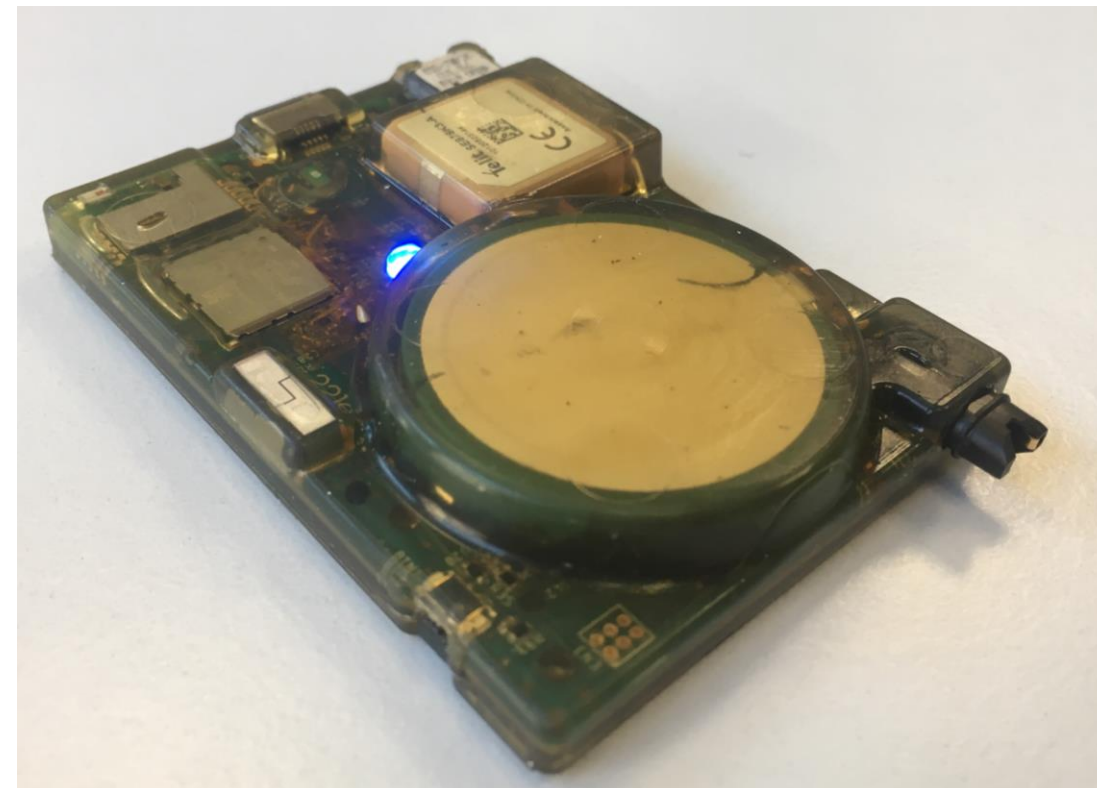
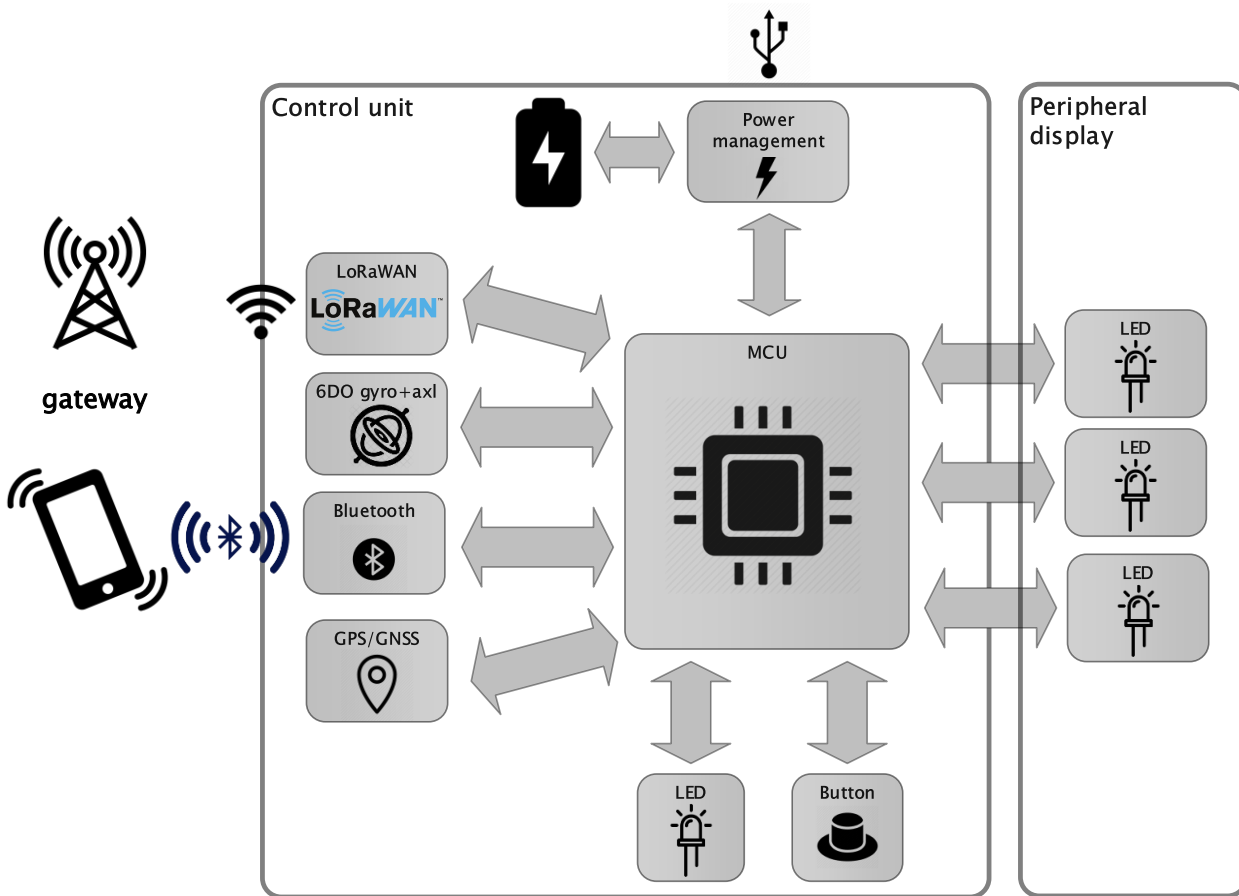
- Tracking of road surfaces for path routing purpose.
- Tracking possible man-down conditions for the postman.
- Tracking of tyres wearing along time for maintenance purpose.

Proof-of-Concept:

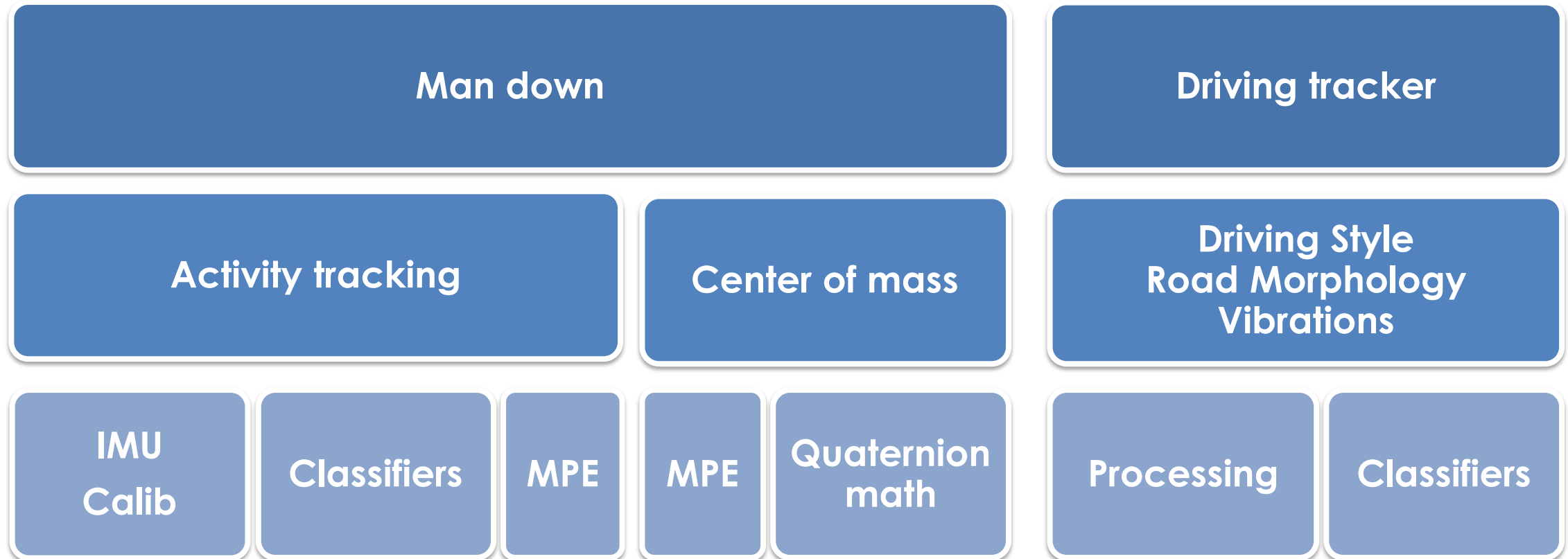
- 6 weeks data collection period with Muse.
- Sensor system which fits within the postman uniform.
- Capability to track position, driving style and to detect hazardous conditions.
- Short range radio communication via BLE.
- Long range radio communication via LoRaWAN
- Battery powered, long time between charges.
- 3D axl, 3D gyro, 3D magn, ambient pressure.
- On-board processing of data for real-time tracking of parameters.
- IP67 compliance.
- Warning through BLE, LoRaWAN and sound alarm.



Man down tracker – overview

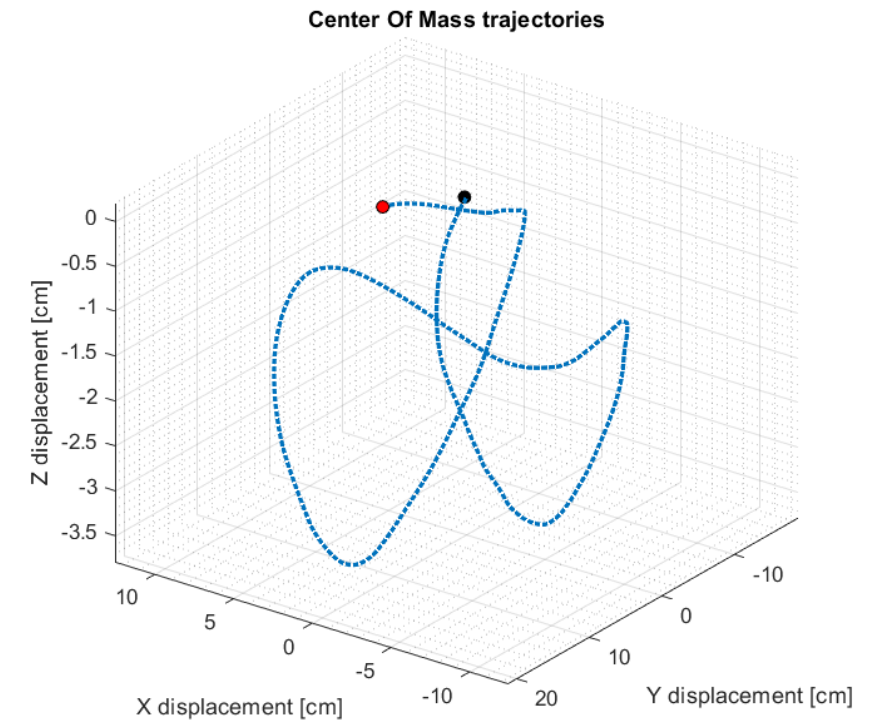
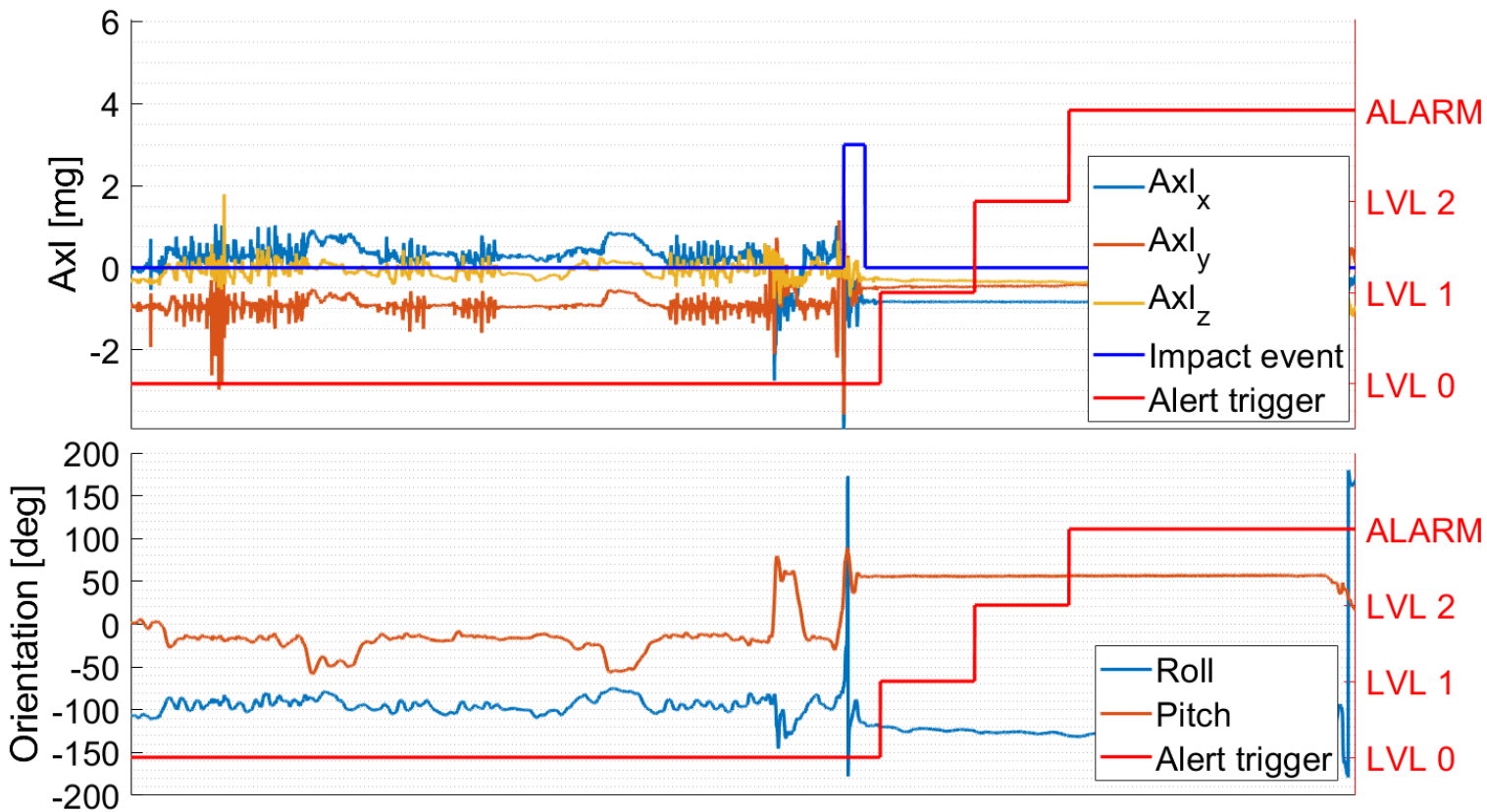


Man down tracker – embedded algorithms

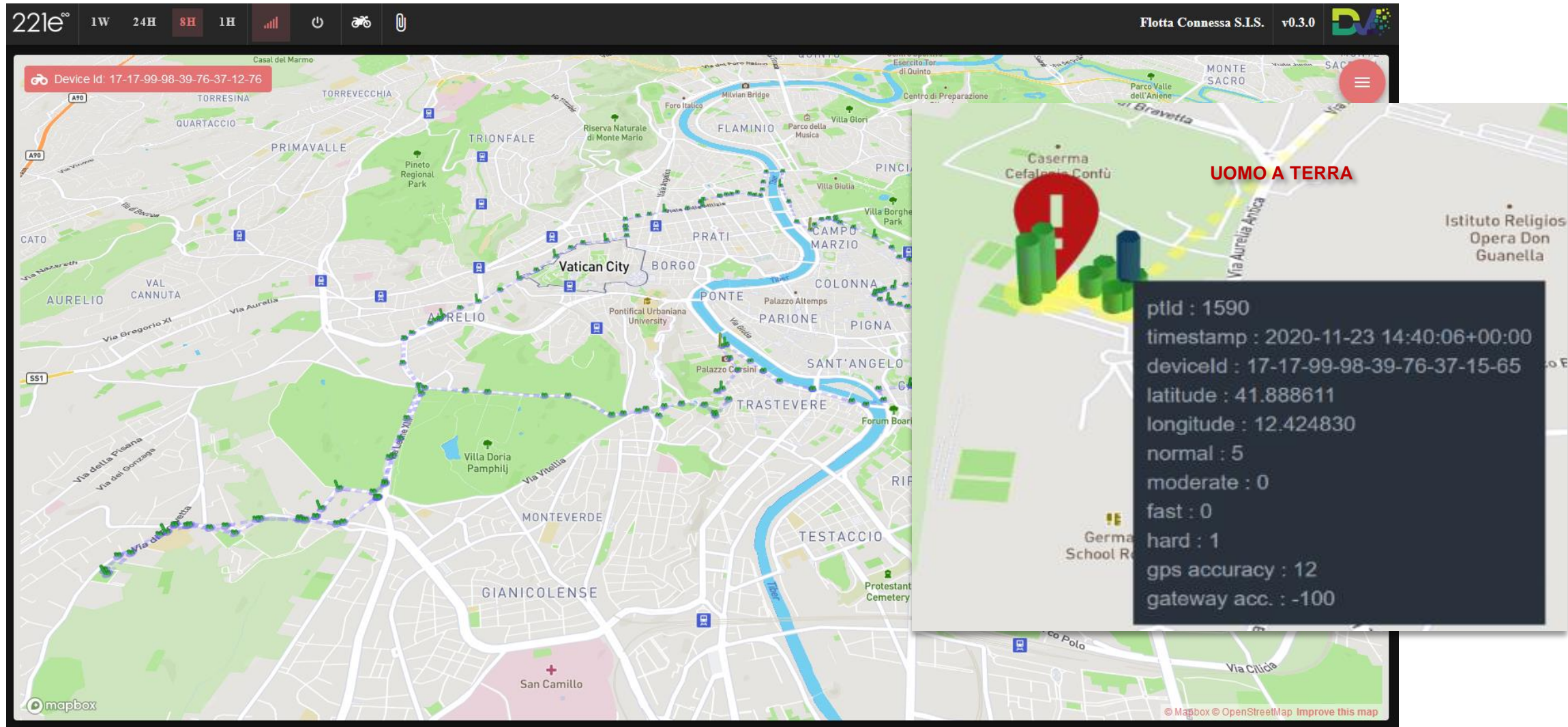


Man down tracker – embedded algorithms

- Different **alarm levels** based on severity
- Low level alarms may reset automatically based on data, to prevent FP
- Only the most severe level requires external reset



Man down tracker - dashboard



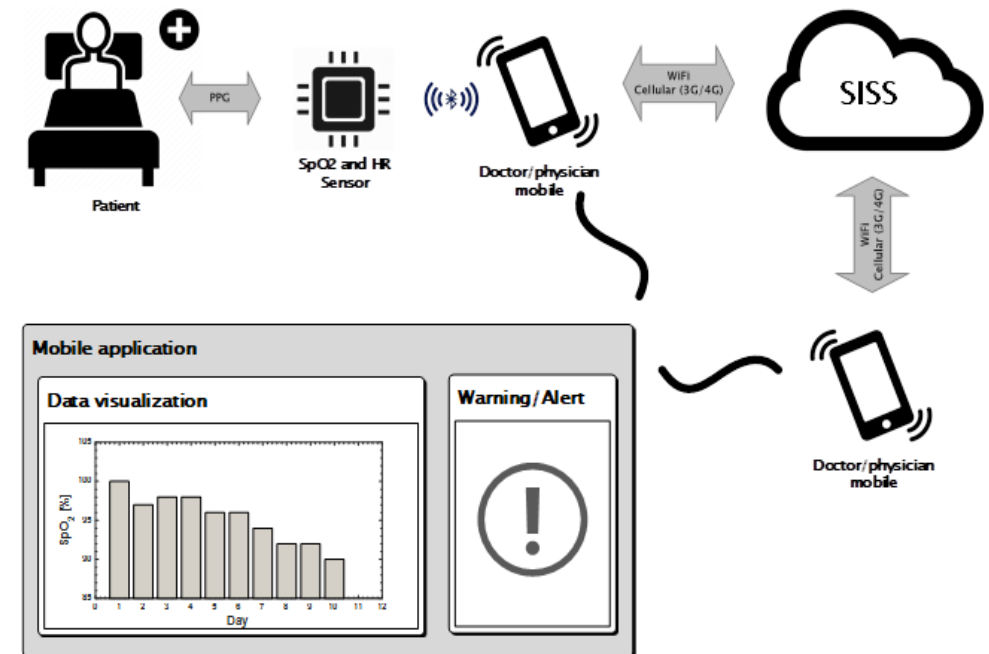
Context:

- the COVID-19 pandemic has demonstrated how crucial is to monitor certain parameters for an early diagnosis of the disease and for controlling its degeneration.
- 221e has in-house competences on biosignals and physiological parameters monitoring.

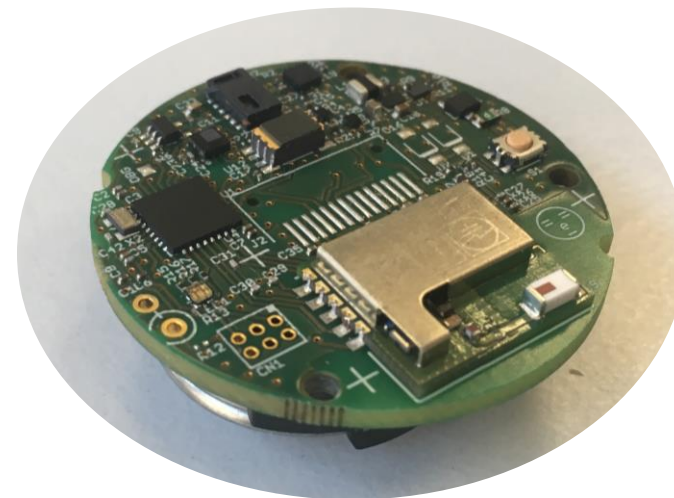
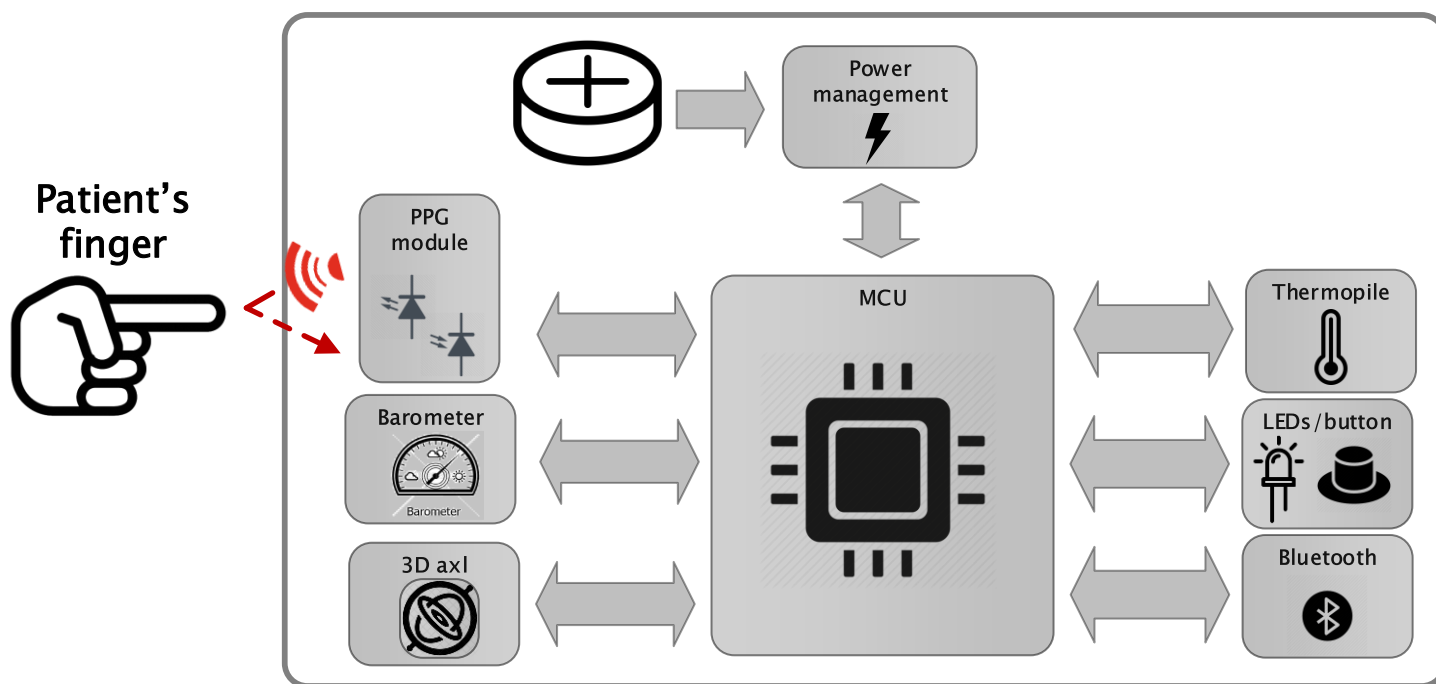
Motivation: to take part to the fight against the COVID-19 pandemic by developing an easy-to-use and portable platform for a remote monitoring of heart rate, blood oxygenation, body surface temperature.

Requirements:

- Suitable for table-top and carry-on use.
- Powered by an easy-to-replace primary battery.
- PPG module for HR and SpO2 estimation.
- Thermopile for skin temperature measurement.
- 3D axl for further enhanced features.
- Short range radio communication via BLE.
- Open-source design approach.
- Mobile app for potential syncing with the healthcare information system.



Bach – overview



Severity estimation

Heart rate

SpO2

Temperature

Processing

Processing

Classifier

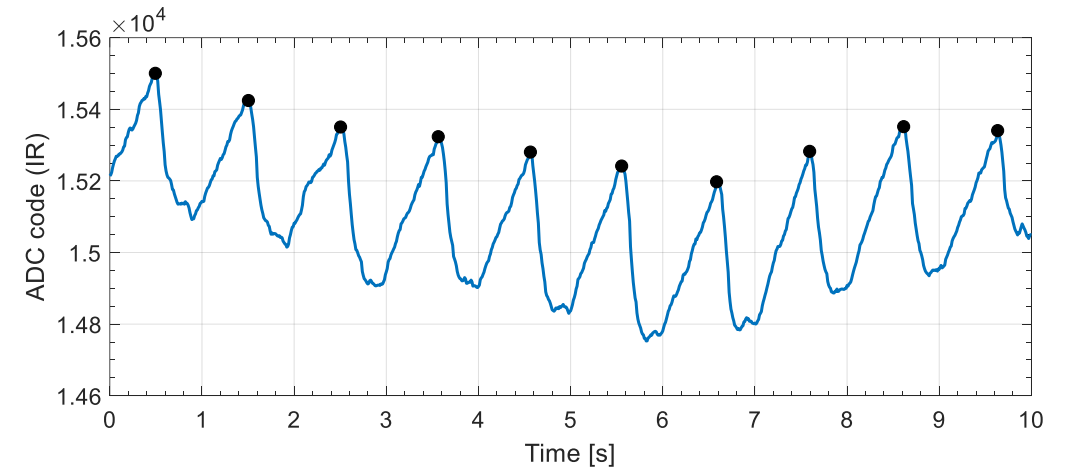
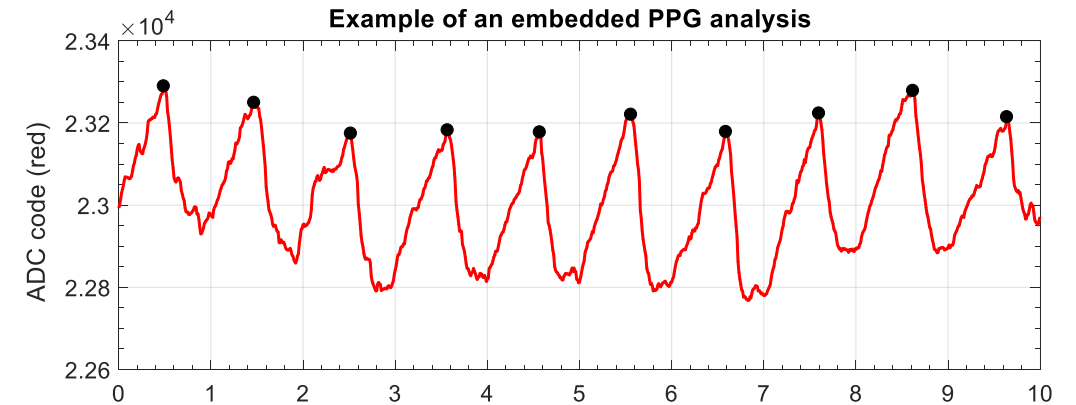
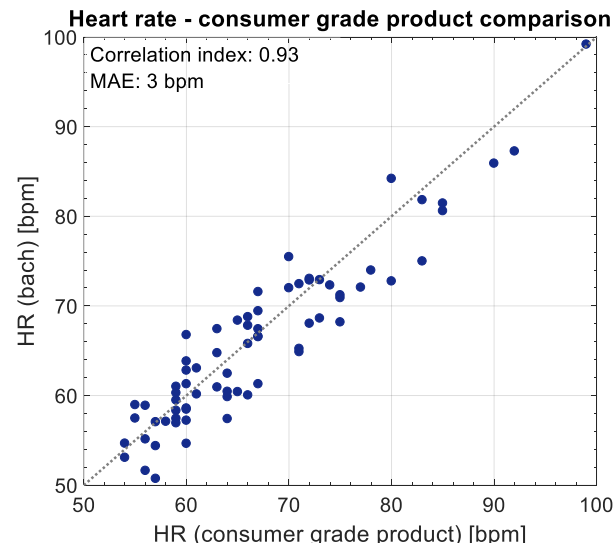
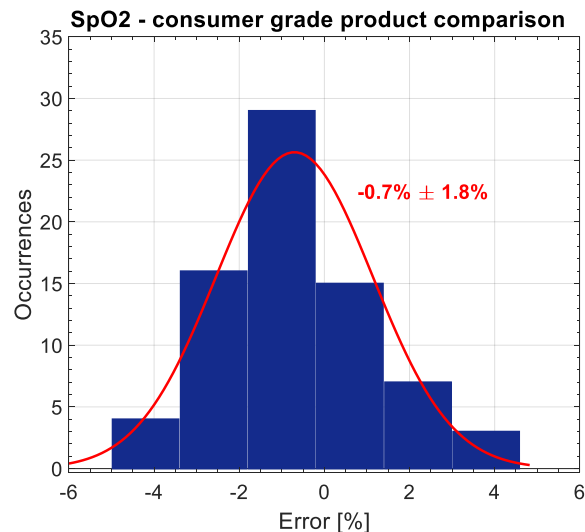
Processing

Future add-ons:

- Actigraphy.
- Ballistocardiography.
- Seismocardiography.
- Gyrocardiography (requires 3D gyro).
- Man down.
- Social distancing via BLE.

Bach – embedded algorithms

- **10 control cases** data acquisition campaign.
- Comparison with consumer grade products.
- **Algorithms** successfully **validated**.
- **Embedded** estimation and tracking of **HR, SpO2 and temperature**.
- CE certification ongoing.
- Dashboard development ongoing.
- Beta version of the system foreseen by March.



Conclusions

Case studies based on 221e's ecosystems:

- Lift warning system
- Man down tracker
- Bach

Pushing the edge closer to the sensor:

- **Form factor:**
 - Keep diving deeper.
 - Processing vs power consumption vs system resources.
- **System integration:**
 - Sensing units.
 - Interconnections.
 - Energy storage.
- **Bandwidth** vs lightweight **embedded AI**
- **Modularity** - from the hardware to the AI