Nano2sense-Workshop "Semi-conducting Nanomaterials for Health, Environment and Security Applications"

"Sensors platform for health and environmental monitoring"

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Modris GREITANS: **EDI – Latvia**

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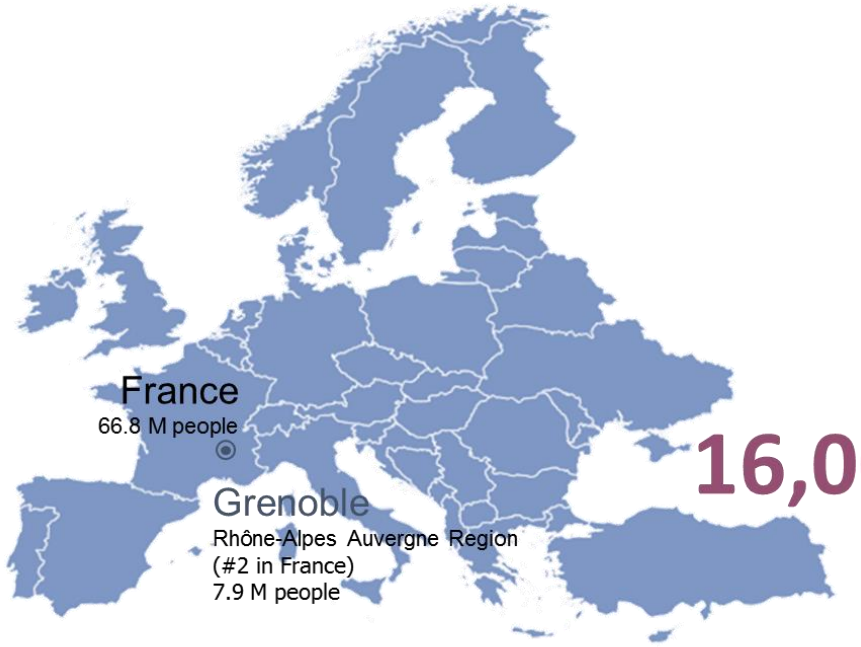
CEA at a glance

- Commissariat à l'Énergie Atomique et aux Énergies Alternatives
  - is one of the largest research organizations in Europe, focused on energy, health, information technologies, and national defense



16,000 **People** (10% PhD and Post Doc)

10 **Research centers**

CEA › CEA TECH › LETI

CEA :

16,000 employees (10 % PhD and post-doc)

10 research centers

CEA TECH :

4,500 researchers

600 priority patent application per year

€650 million annual operating budget

Mission:

Create and transfer innovation to our industrial partners

LETI at a glance

1967 Creation

1,900 People

64 Startups

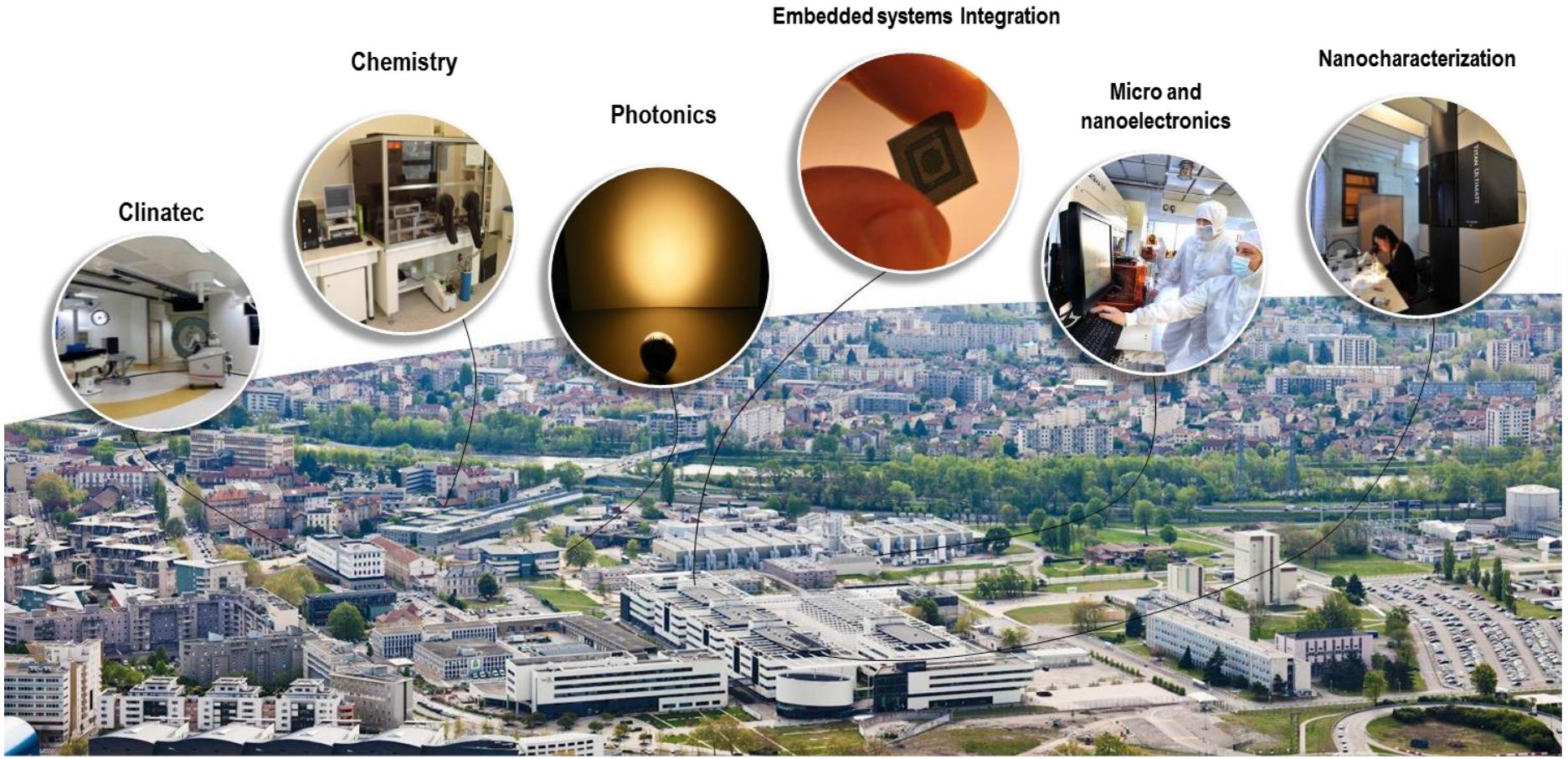
315 Total budget (M€)

2760 Patents Portfolio

350 Industrial Partners

8,500 m² Clean-room 200-300 mm

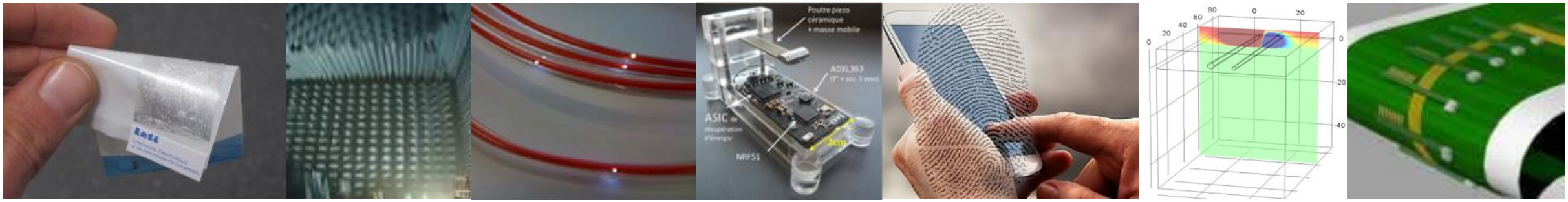
Research platforms in Grenoble



Laboratory Sensor Autonomy & Integration

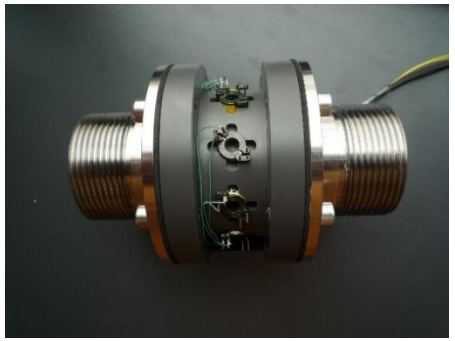
- **Solutions for the integrative industry**
  - Dedicated innovation platforms *in particular SMEs*
  - A variety of application domains *wireless, smart devices, security, space, arts, sports, multimedia, transport, energy, environment, healthcare*

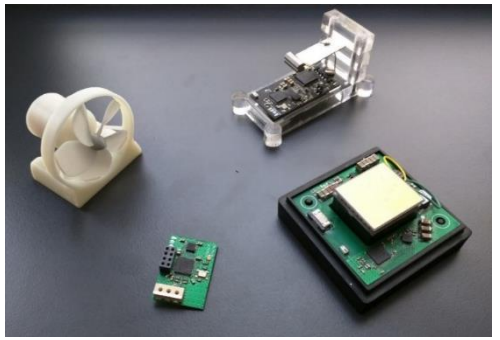
- **Core competences: systems of sensors, energy harvesting, electronics, wireless, RFID, all-integrated functions**



Laboratory Sensor Autonomy & Integration

- **R&D focus**
  - **Electronic function integration** into products of the traditional and advanced manufacturing industry
  - **Environnement** adaptation (harsh environments, high T°, variability…)
  - **Sensor system**: Ultra Low Power electronics
  - **Distributed sensor system:** System architecture; In situ instrumentation
  - **Sensing surface:** Mechanical integration; Nano-system design
  - **Energy harvesting system**: focus on mechanical energy harvesting (vibration and human motion), flow and thermal harvesters + their dedicated power management circuits



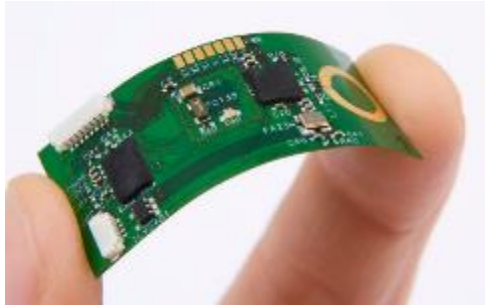


Convergence project

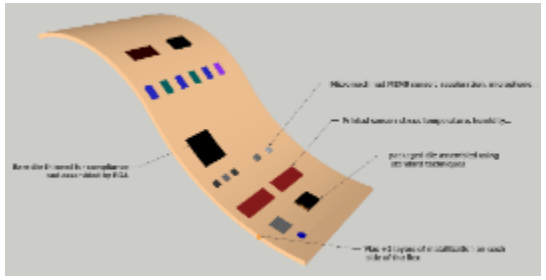
Objective: Develop demonstration platforms for wearable IoT flexible systems

IoT platform on a rigid substrate

IoT platform on a flexible substrate



Heterogeneous integration on flexible substrates hybrid concept



Benefits

- Wearable
- More flexible
- More conformable

How ?

- Bluetooth low energy communication
- System compatible with different sensors and energy harvesting sources

For ?

INTERNET OF THINGS

ENVIRONMENT MONITORING

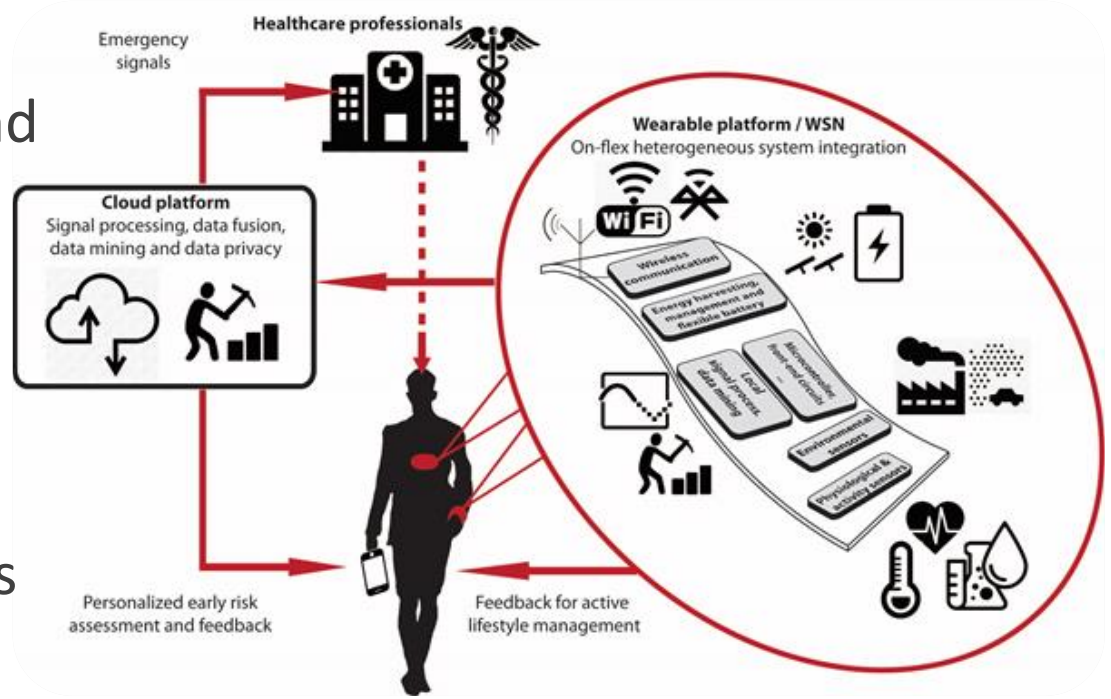
CONNECTED HEALTH & WELLNESS

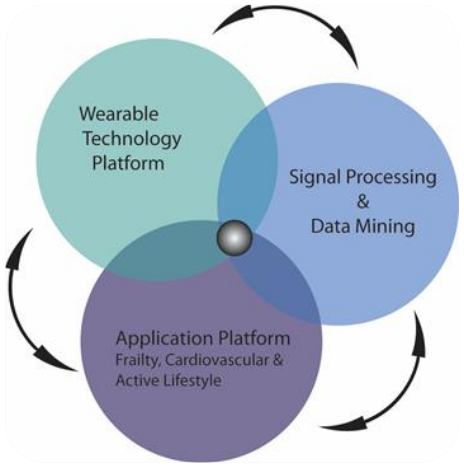
MULTIMEDIA & MOBILE PLATFORMS

Concept & goals

Energy efficient wearable platform

- Embedded wireless low power bio- and environmental sensors
- Energy management
- Wireless communication
- Heterogeneous integration
- Preventive life-style and healthcare applications

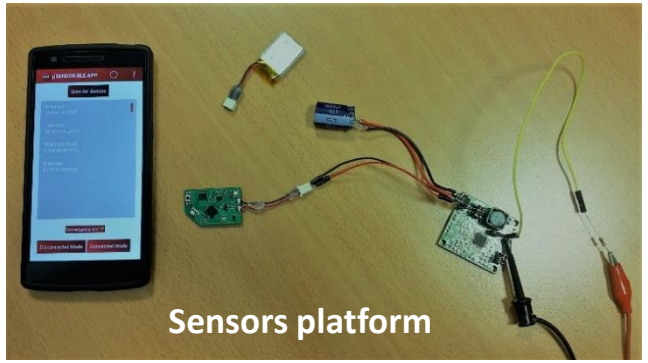




→ Convergence of technologies into smart sensing systems driven by life-style and health care applications

Main achievements

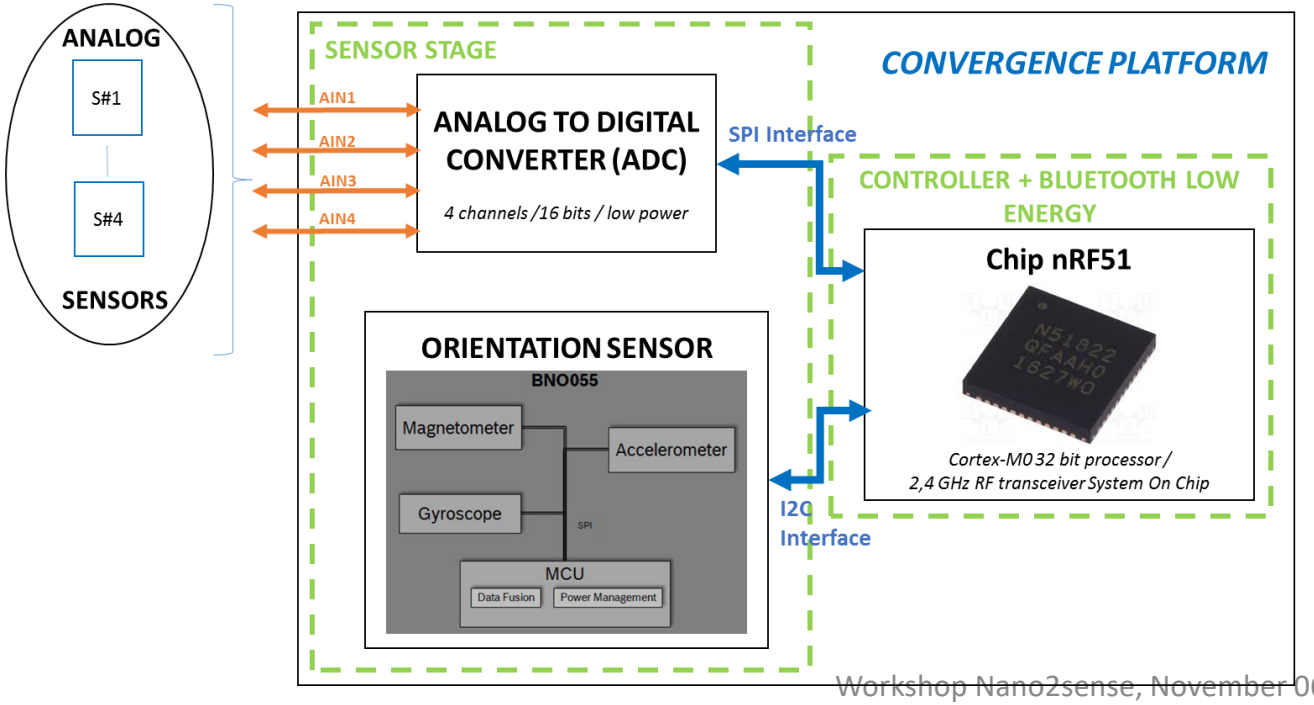
- Sensors test platform on a **rigid** substrate
  - Design and fabrication
  - 1st version: generic platform with Bluetooth Low Energy communication
  - Laboratory tests with the sensors
    - Gas sensors
    - Temperature sensors
    - Activity sensors
    - Nano-power energy harvesting ASICs module

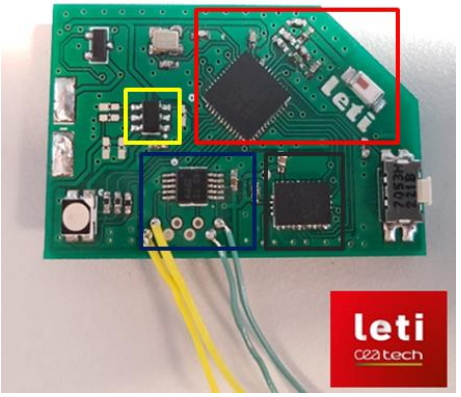


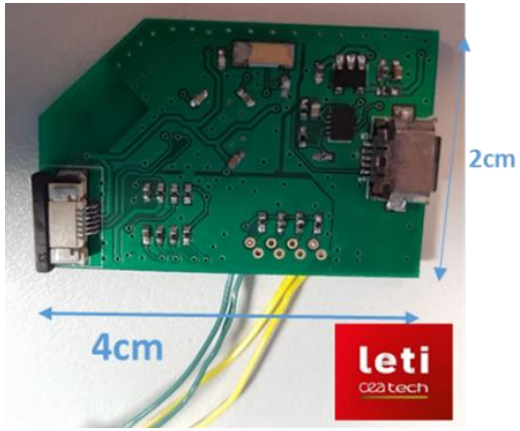
- **Strong cooperation** with consortium partners
  - CEA; UCL; IMT; ENEA; IUNET; EDI; G-INP

Sensor platform: board architecture

- Modular multi-sensors platform
  - Developed for sensor data acquisition
  - BLE transmission
  - Low-power system (5µA to 15mA max)



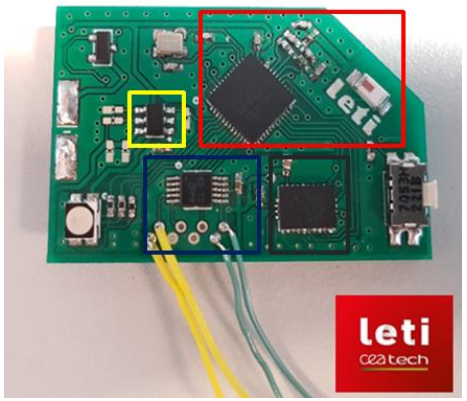


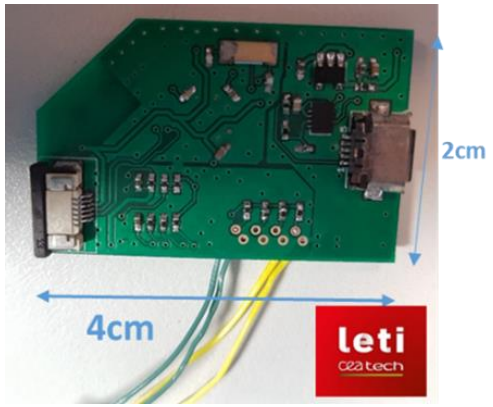


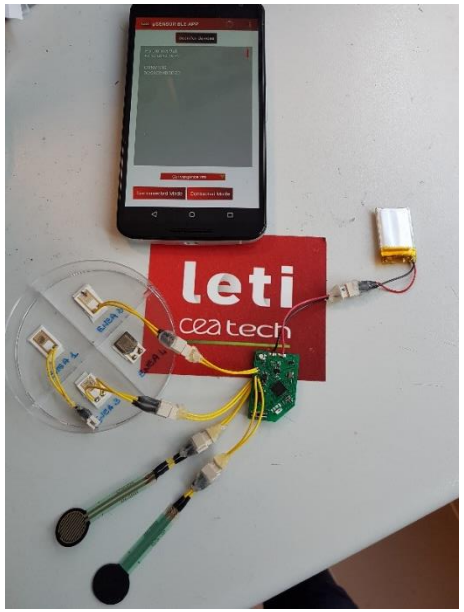
Analog sensor (CEA)

- Test with commercially analog sensor
  - Data emission in BLE (**bluetooth low energy**) at 10 Hz
  - **Battery supply: 3,7V**
  - **Analog sensor (FSR) :** resistor values change depending on how much it's pressed

→ Data collection on mobile phone



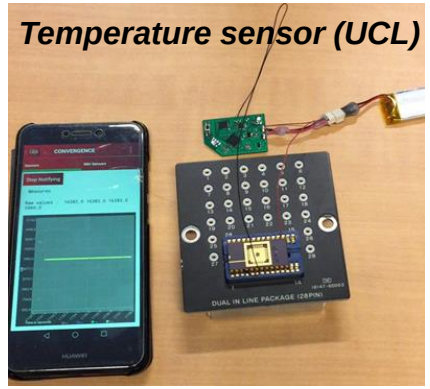


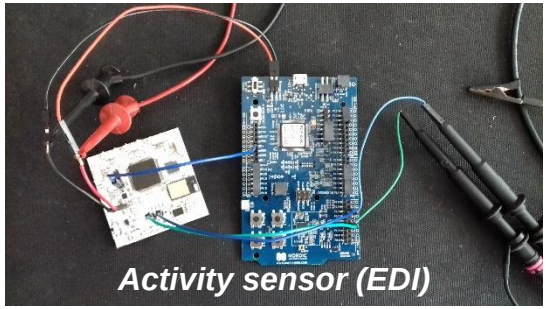


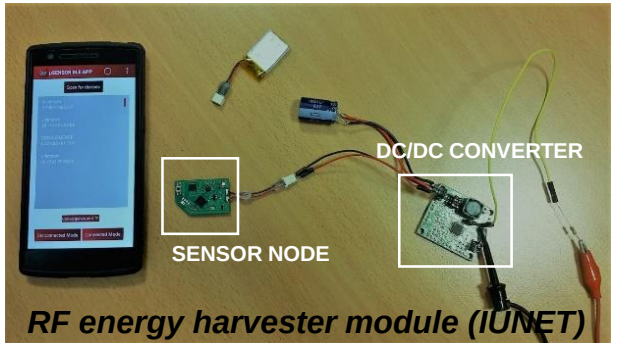
Sensor platform: tests

- **Gas sensors**
  - NO_2 gas (ENEA)
  - CO gas (IMT)
- **Temperature sensors**
  - Temperature (UCL)
  - GreenTeg Core Body Temperature (EPFL)
- **Activity sensors**
  - BNO055 (EDI)
- Nano-power **energy harvesting** ASICs module (IUNET)


NO_2 sensor (ENEA)


Temperature sensor (UCL)

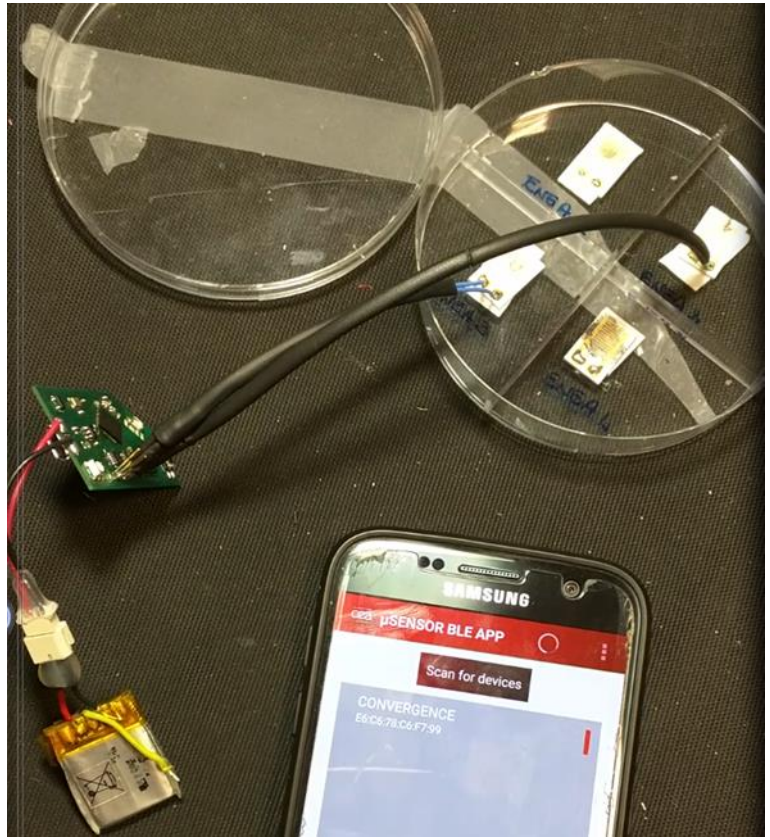

Activity sensor (EDI)



RF energy harvester module (IUNET)

NO_2 gas sensor (ENEA)

- Test with ENEA sensors
  - ChemiResistors based on graphene for NO_2 detection
  - Resistive values change depending on NO_2 detection

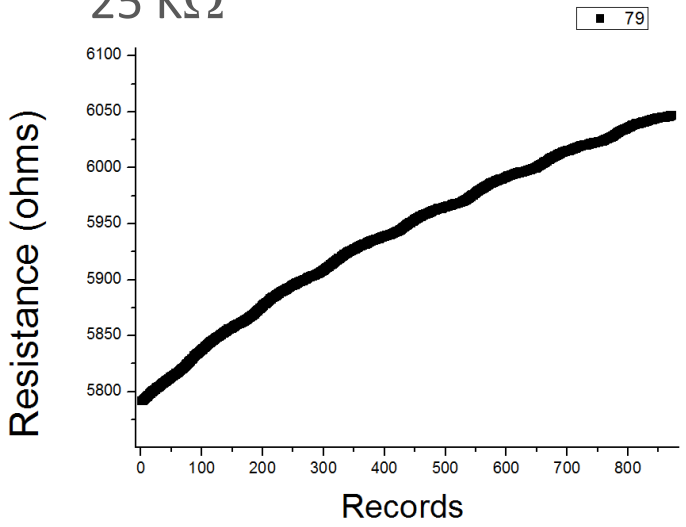


→ resistive values of the sensor measured by platform are similarly the same as measured with a multimeter.

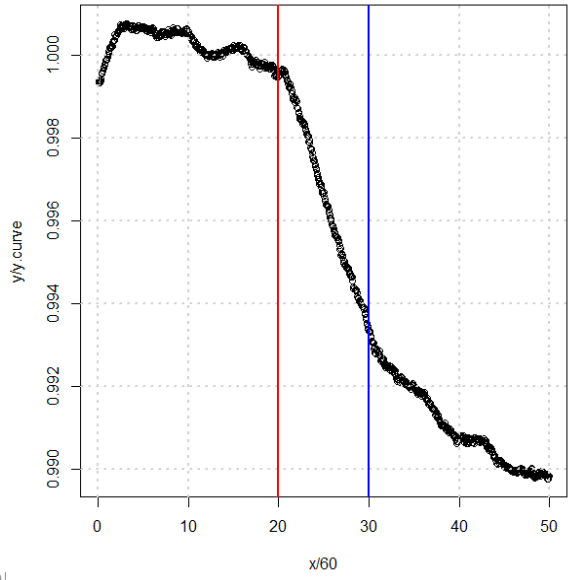
CO gas sensor (IMT)

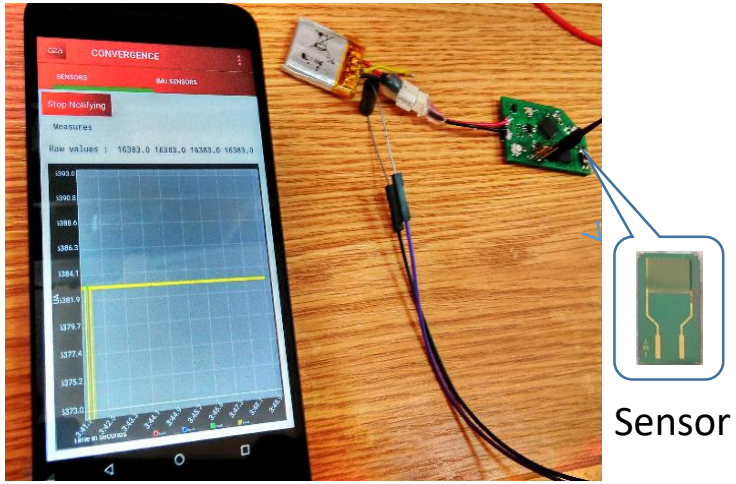
- Chemo Resistors based on polyaniline electrochemical deposition on 15nm Ti/150nm Au interdigitated electrodes on SiO_2/Si substrate (4x4 mm^2) for CO detection
- Resistive values change depending on CO concentration

  → Excellent correlation of sensor values measured on CEA's Platform, compared with DMM and IMT's platform in the range 5KΩ-25 KΩ



CO sensor characterization on the gas mixing station at ENEA





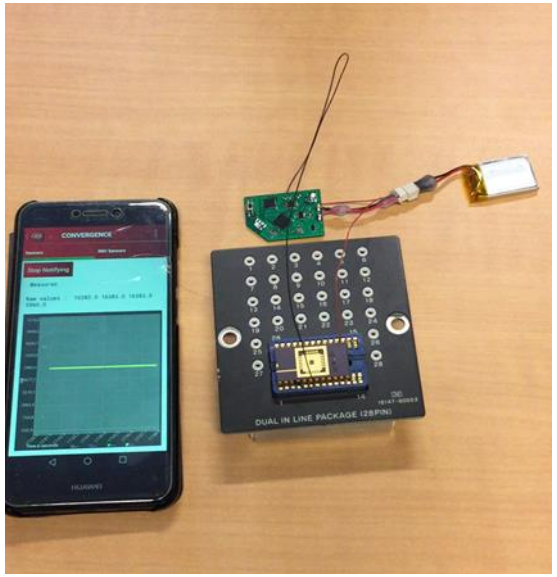
CEA Platform

IMT Platform

Temperature sensor (UCL)

- Temperature sensor from UCL based on a PIN diode for body temperature monitoring (2x2 mm^2)
- Constant current, voltage measurement: $Vd=V_0-d(T-T_0)$
- Temperature response time:
  - depends on packaging
  - unpackaged: < 20 ms

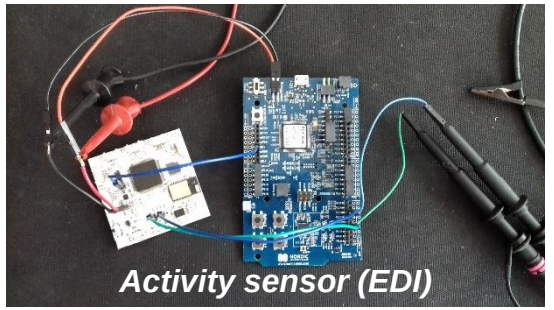
Power consumption	Sensitivity	Precision	Readout
60 µW	~1 mV/°C	0.5°C without averaging	ADC + voltage divider



Physical activity sensor (EDI)

- 3 sensors in single device:
  14-bit **accelerometer**, 16-bit **gyroscope**, full performance **geomagnetic** sensor
- Sensor data fusion output:
  Quaternion, Euler angles, Rotation vector, Linear accelerationm Gravity, Heading
- Intelligent power management: normal, low power and suspended modes
- Voltage supply range: 2.4V – 3.6V
- Digital interfaces: HID-I2C, I2C, UART
- Data rate in sensor fusion mode: up to 100 Hz
- Daily activity monitoring: feature extraction (movement speed, rate, angles, gestures, posture, calories), activity classification (standing, sitting, walking, running, stairs ect.)

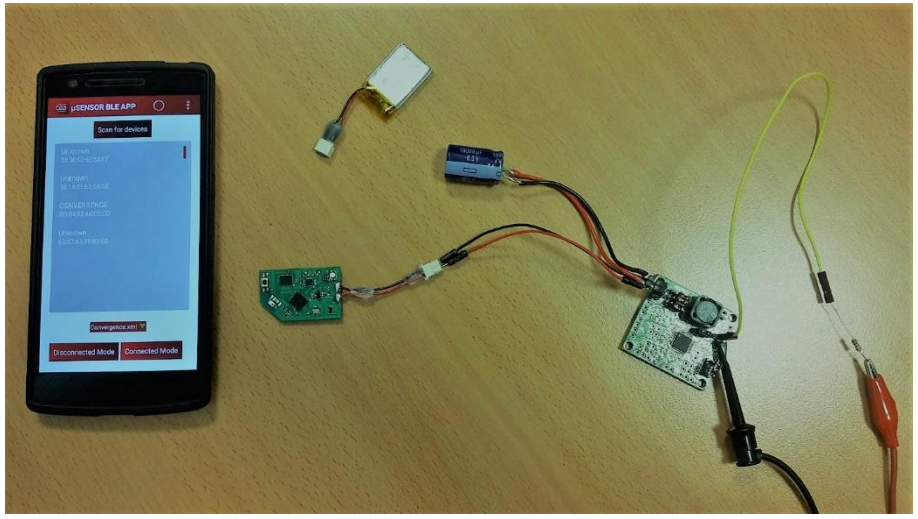
3.8 x 5.2 x 1.1 mm housing (LGA-28)
RoHS compliant, halogen-free,
Operating temperature: -40°C - +85°C


Activity sensor (EDI)

Nano-power energy harvesting ASICs module (IUNET)

- Module based on nano-current energy harvesting ASICs.
- DC/DC converter

→ Validation of effectiveness of the sensor platform with optimized power harvesting circuit



Conclusion & perspectives

→ **Generic** demonstration platform on a rigid substrate with Bluetooth Low Energy communication compatible with different kind of sensors and energy harvesting sources

Next:

- Develop an IoT demonstration platform on a flexible substrate to provide a Wireless Sensor Node (WSN) fully conformable and compatible with wearable applications.
- Board with at least one gas, one activity and one temperature sensors.

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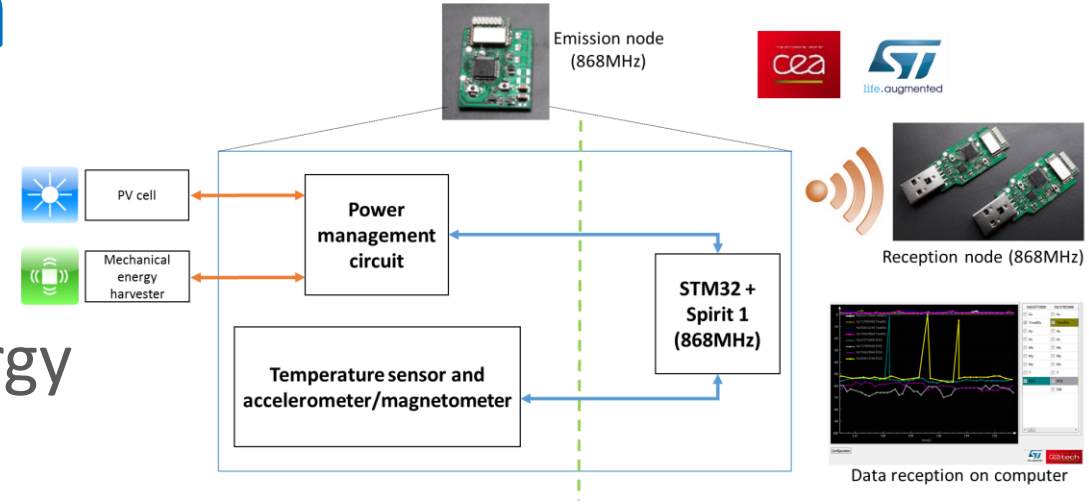
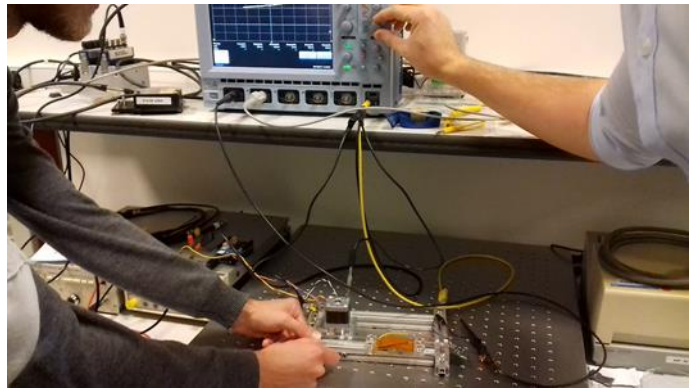
Energy harvester platform

- developed for low-power energy harvesters (typically <10µW)
- system compatible with different energy harvesting sources (light, vibrations, flows,…)



- platform tested with:
  - PV cell at CEA
  - Piezoelectric generator at G-INP



→ compatible with commercial piezoelectric device but some didn't provide enough voltage, current to charge the capacitor of the EH: power consumption of the platform too high