EnerHarv 2018

Boston Scientific

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COMPOSITION

Industry 4.0 IoT device retrofit and energy harvesting use cases

Luis Martins

Scope

This presentation outlines the work conducted as a collaboration between Tyndall National Institute and Boston Scientific Clonmel within the EU funded Horizon 2020 COMPOSITION Factories of the Future project, aiming to develop an integrated information management system (IIMS)

The first phase of this work to implement Industry 4.0 technologies is nearing completion and this is presented here today.

Introduction

Goal: optimize internal production processes by exploiting existing data, knowledge and tools to increase productivity and dynamically adapt to changing market requirements.

- Consortium is made up of 12 partners
- Across 7 countries
- 3 pilot partners

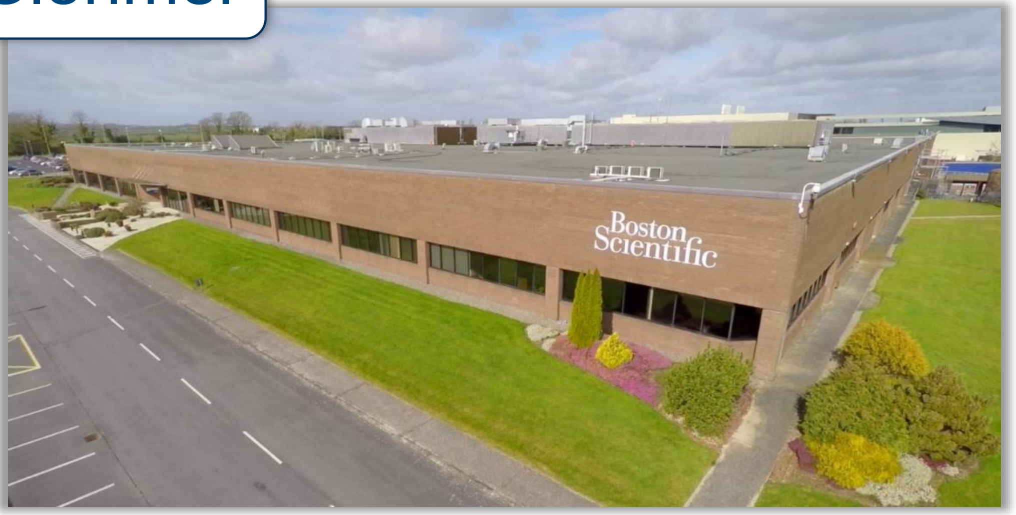
Boston Scientific — Hosting one of the pilot sites at its Clonmel facility. Leads the development of industrial use cases. Involved requirements, business analysis and evaluation.

Tyndall National Institute — Provides coordination, undertakes deployments and gives integration guidance.

Boston Scientific Clonmel

- Worldwide developer, manufacturer and marketer of medical devices
- Over 13000 marketed products
- Manufacturing sites in 15 countries

Clonmel



- Set up in 1998
- Over 1000 employees
- Largest in terms of Value of Production in the Boston Scientific network of plants
- Sole manufacturer of all implantable electronics
- European Capital Equipment Repair Centre
- Metal Additive Manufacturing Department

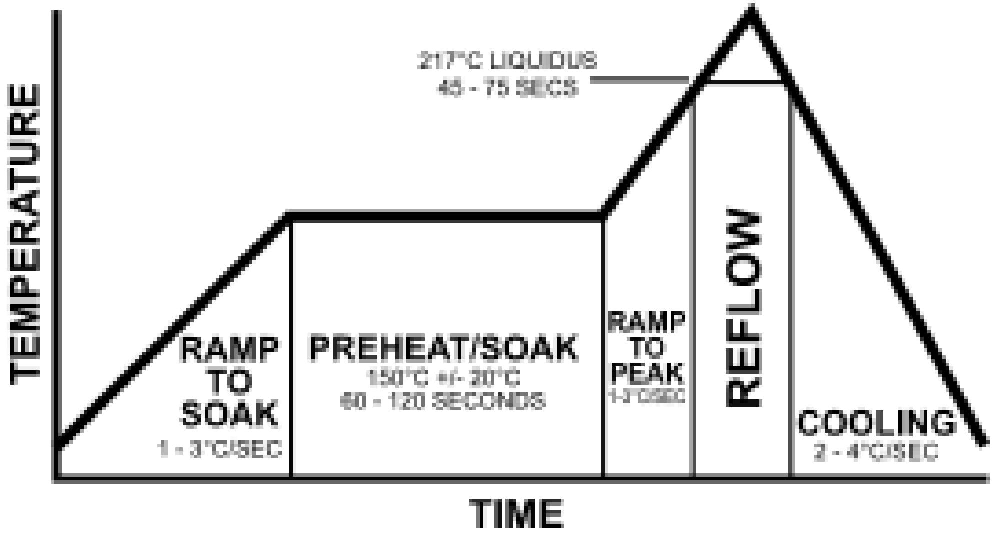
Use Case 1
Predictive oven maintenance

Predictive oven maintenance - The challenge

- Reflow soldering process requires very tight control of the temperature profile
- Correct operation of the fans plays a crucial role in ensuring the correct profile is maintained.
- Fan breakdown leads to high value material in the oven to be scrapped

Predictive maintenance
↓
Preventive maintenance
↓
Scrappage decrease

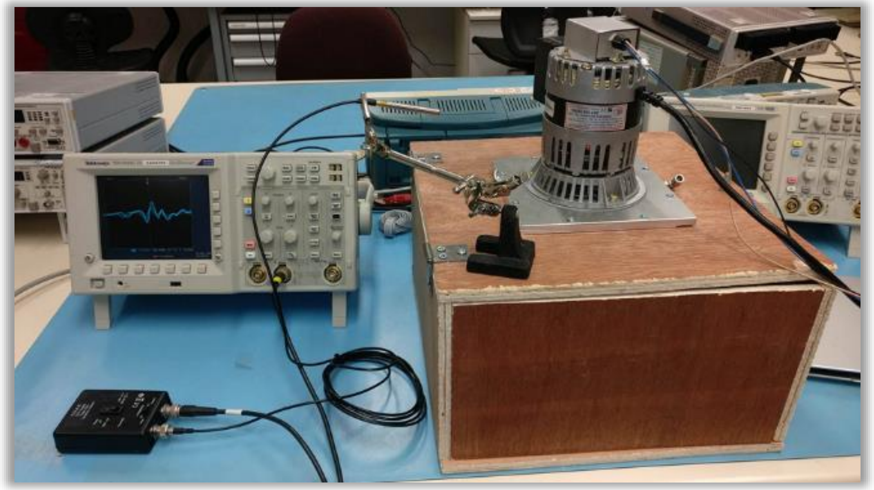
$32000 savings (annually)



Predictive oven maintenance - Solution Exploration

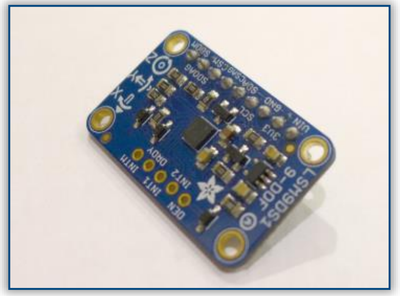
Boston Scientific

1) Determine sensing techniques that provide “early warning” of failures before they occur.
    - *Requires lab testing of known good and known faulty fans*
2) Implement the system on a reflow oven in the factory, to validate the technique.
    - *Where we are today*
3) Optimise sensor design to reduce power consumption to enable powering from available energy sources.
    - *Full/assisted Energy Harvested powering.*



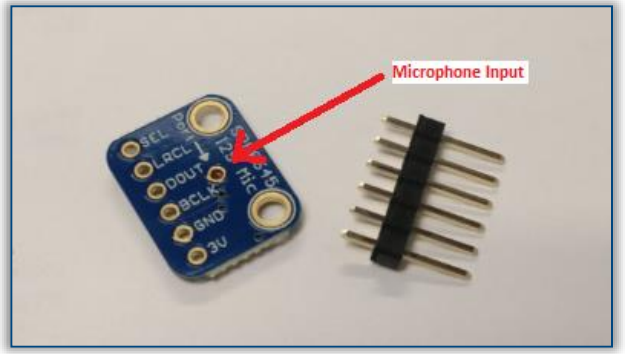
Predictive oven maintenance - Solution Exploration

- Vibrational Data
  - Identifies failures individually
  - Difficult to implement
- Acoustic Data
  - Potential to monitor multiple motors at once
  - Interference in confined space of reflow oven
  - Non-invasive implementation
- Power Consumption
  - Requires individual wiring
  - Potential to determine multiple fans at once
- Temperature
  - High correlation between failure
  - Requires individual wiring
- Speed Sensor (Hall Effect)
  - Already Fitted to individual Fans



LSM9DS1 – Vibration / Thermal

G.R.A.S Free field Array microphone



Knowles SPH0645 – mems microphone

CR3109-1500 Current Probe

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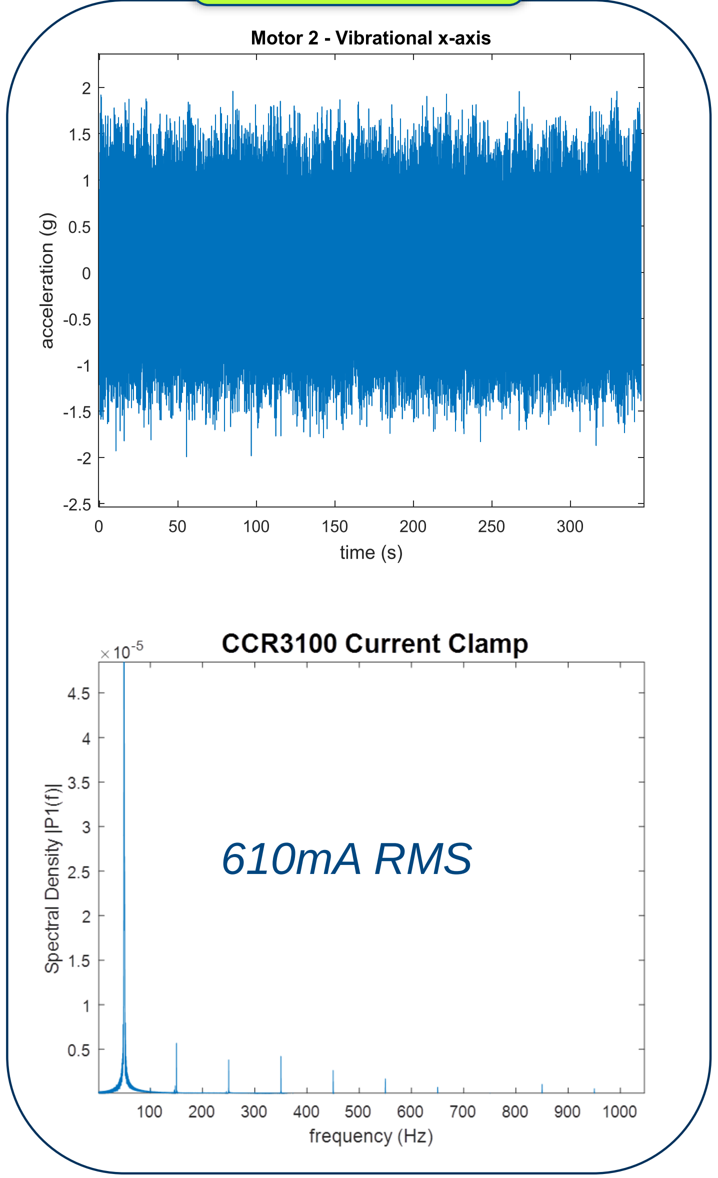
Predictive oven maintenance - Solution Exploration

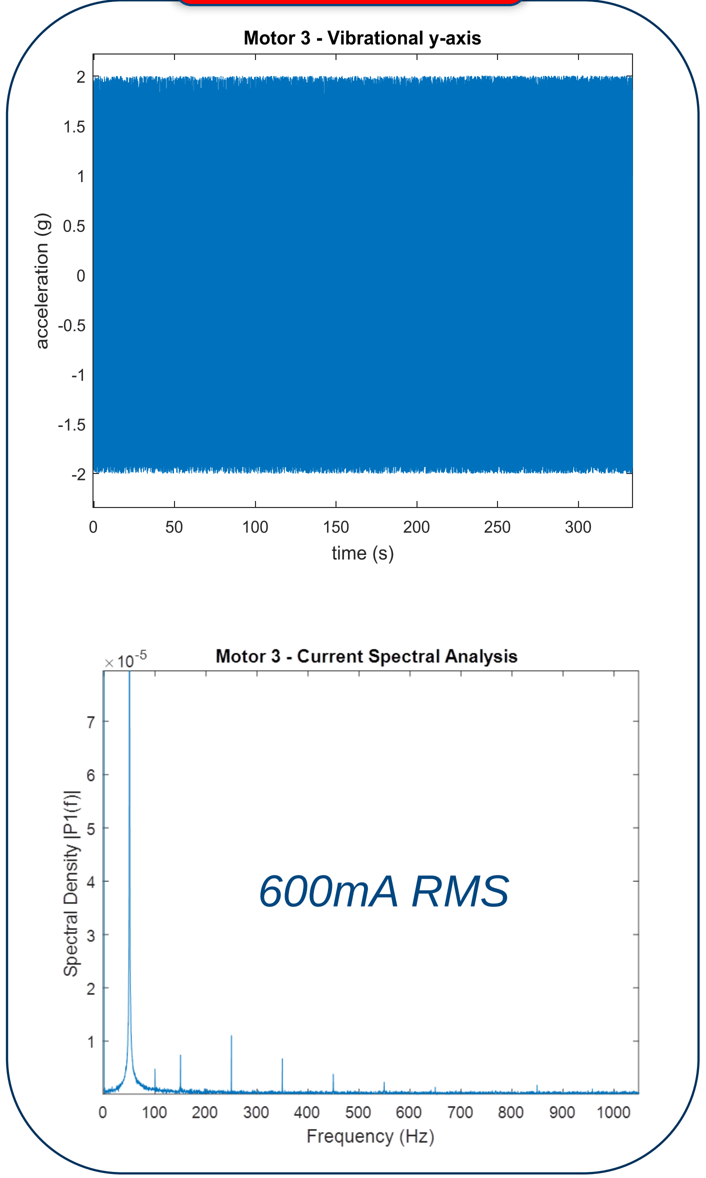
Boston Scientific

- Vibration, Power and Thermal sensing are all able to detect faulty fans
- Some examples of Vibration and current detection are shown.
  – *Relatively small changes in characteristics detects fault condition*
- Acoustic sensing provides clear and early detection of a fan going faulty and is easily retrofitted without modification

Good motor



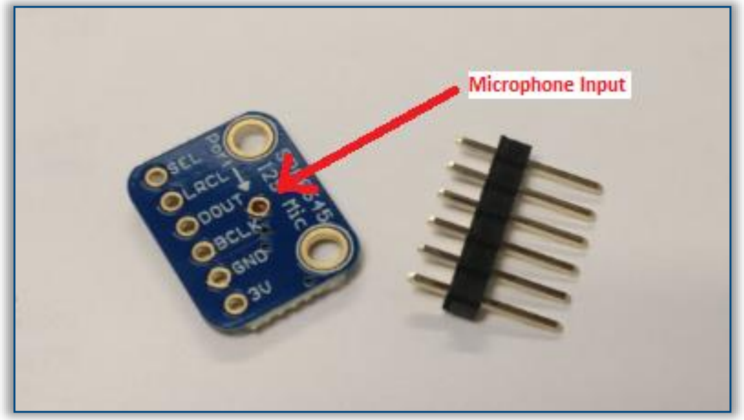
Faulty motor



Predictive oven maintenance - Solution Exploration

- G.R.A.S. free field microphone
  - *High Precision free field condenser microphone*
  - *Factory calibrated with 20dB noise from 3.15 to 20KHz*
  - *Expensive*
  - *Requires pre-amplifier and high power (2 to 20mA)*

- Knowles SPH0645 – mems microphone
  - *Low power digital mems scale I2S microphone*
  - *26 dBV sensitivity at 1kHz and a relatively flat frequency response in the ultrasonic band*
  - *600uA during operation and 10uA during sleep mode*



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Predictive oven maintenance - Implementation on-site

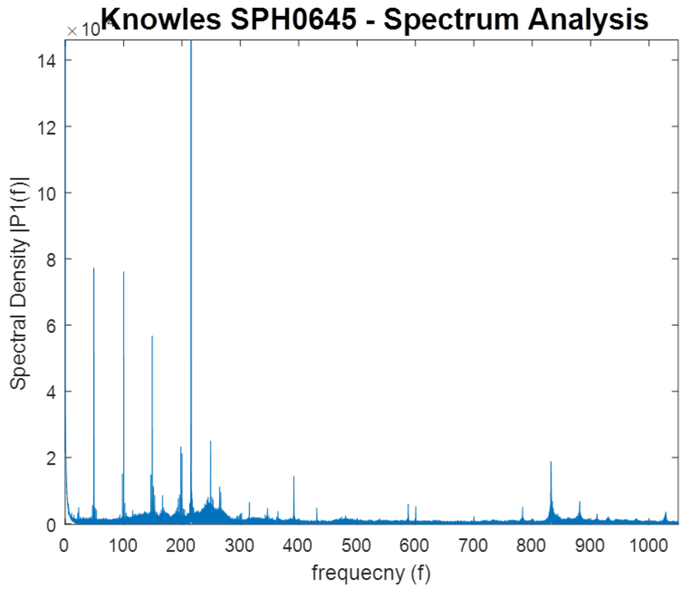
Boston Scientific

- 5 SHP0645 acoustic sensors fitted into the Rhythmia reflow oven on the BSL factory floor
- 16bit mono acoustic data being recorded for 20s every 5 minutes
- Data logging started beginning of 2018

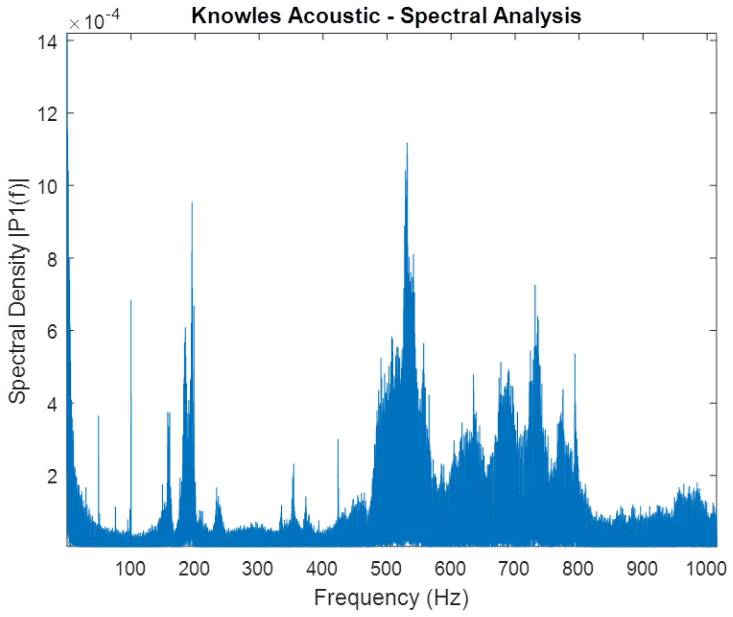
Predictive oven maintenance - Fault Detection

- In the case of acoustic detection there is a significant difference in amplitude (>10dB) between a good and a faulty fan.
  - *Enables simple threshold detection*

- The volume tends to increase some time before the fan fails to the point it effects the temperature of the oven



Good motor



Faulty motor

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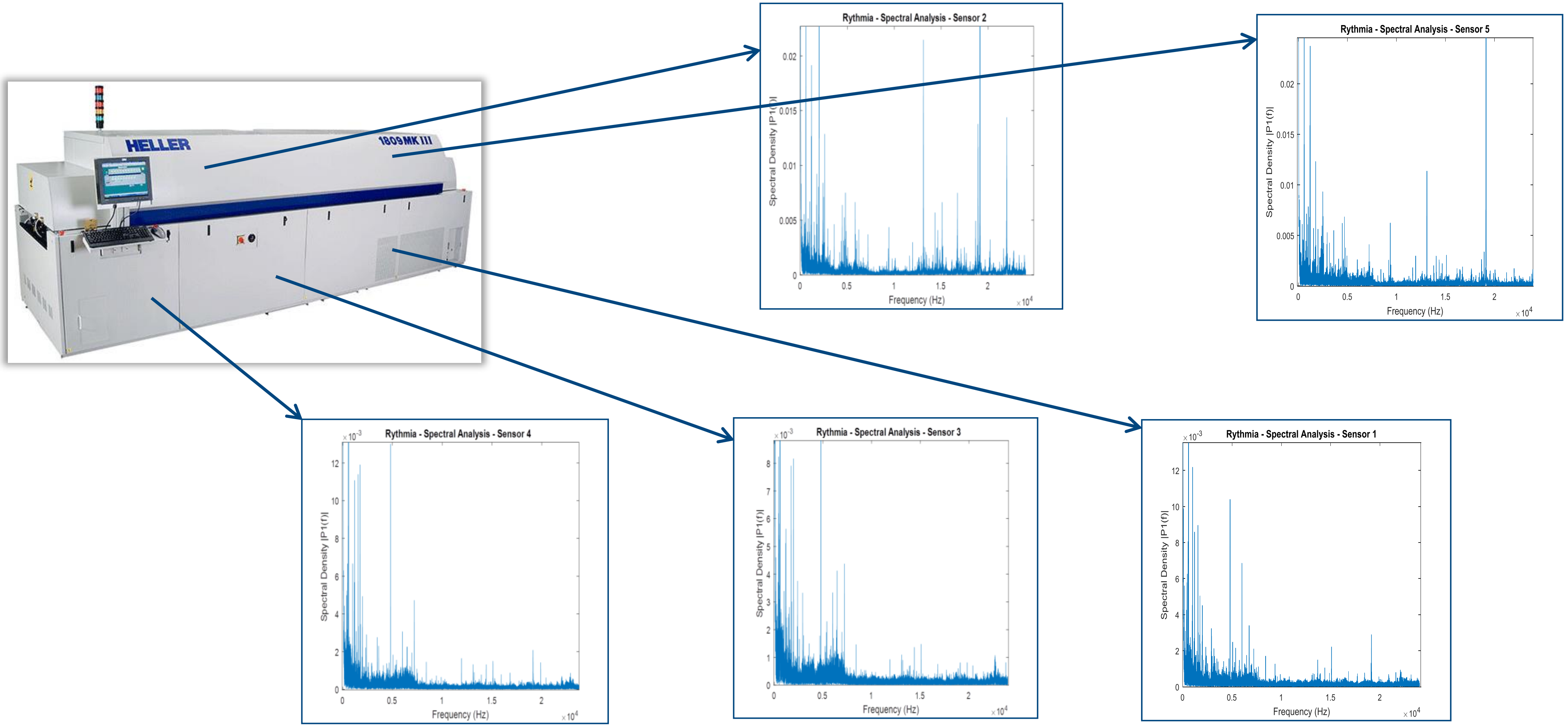
Predictive oven maintenance - Implementation

Boston Scientific

- Acoustic data recorded from 5 areas of the oven where the fans are located.
    - *- Enables quick location of the oven area with a faulty fan*



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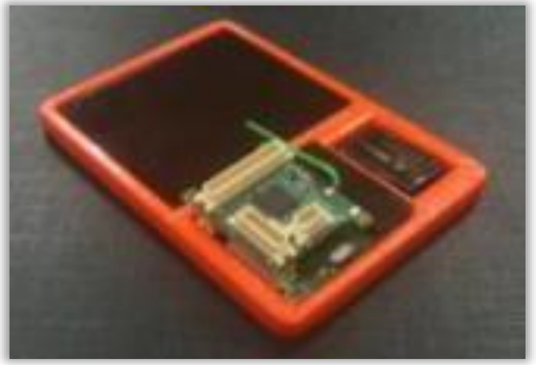
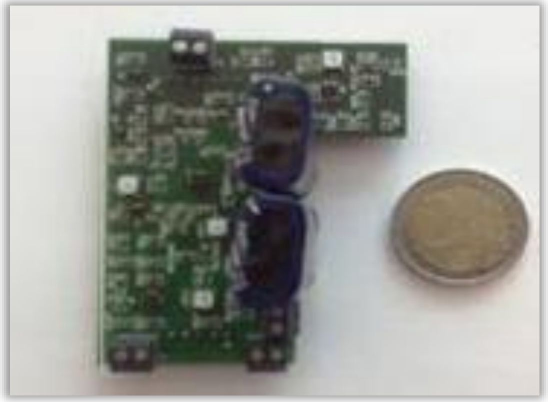
Predictive oven maintenance - Why incorporate Energy Harvesting?

- Retrofitting of self powered sensors using energy harvesting makes installation easier and maintenance free.
  - *Personnel costs to replace the batteries.*
  - *The cost of the batteries themselves (especially when scaled to a large manufacturing facility)*
  - *Environmental Impact is moving up the agenda*



Indoor solar Powered WSN



MOSYCOUSIS Multisource Energy Harvester

Predictive oven maintenance - Future work towards Energy Harvesting

Boston Scientific

- Raspberry pi implementation is power hungry.
  - *Initial project focus was to implement acoustic sensing and provide data to our partners*

- Acoustic Sensor selected is power efficient and suitable for use in a low power implementation.

- Low power optimisation requires the development of an embedded system.
  - *ST Microprocessor selected as suitable for an Energy Harvested system.*

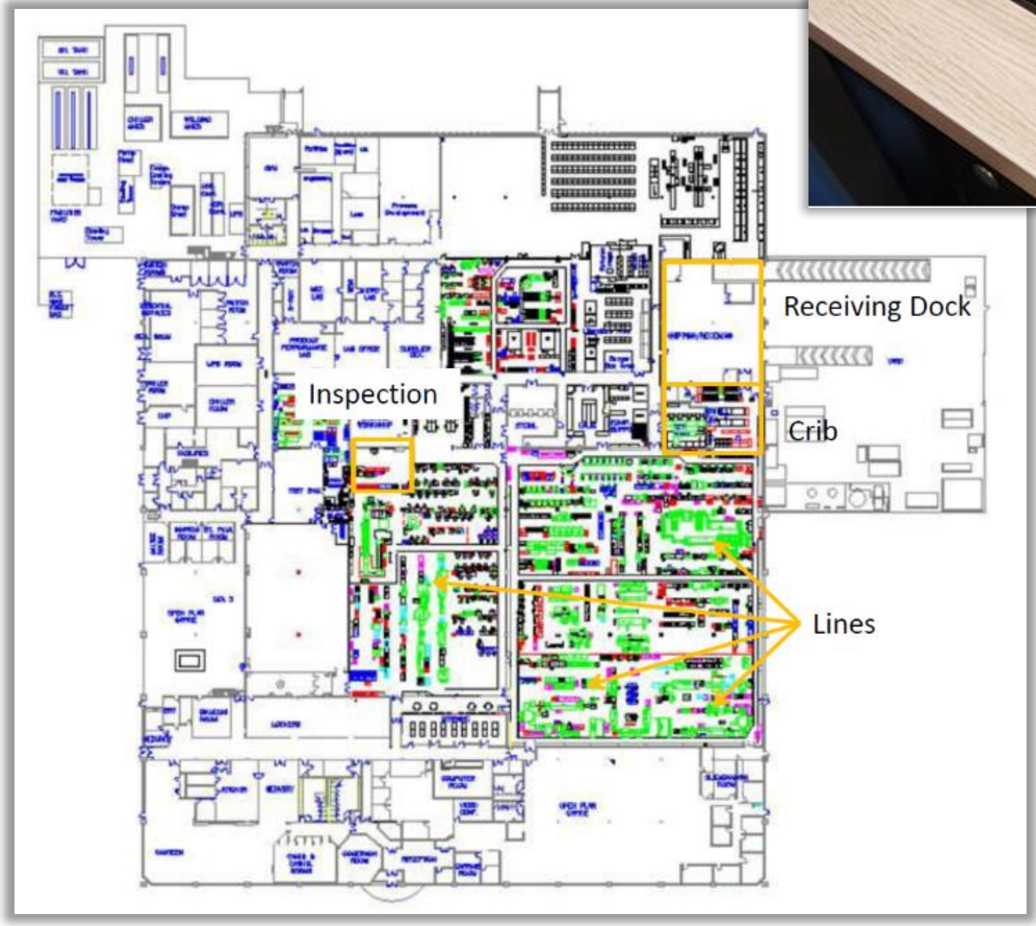
- Moving towards a low energy communication system such as Bluetooth Low energy enables ease of deployment as well as data communication power efficiency.

Use Case 2
Asset Tracking

Asset Tracking - The challenge

- Knowing the location of materials, products and equipment in real-time has significant impact to **costs** (especially high value materials) and **operational efficiencies** (misplaced materials increase product completion led time).

  - *Some components are carried in small trays (A4 size)*
  - *Tracker needs to be small, lightweight, low power requirements*
  - *The items need to be tracked through a complex large sized facility.*



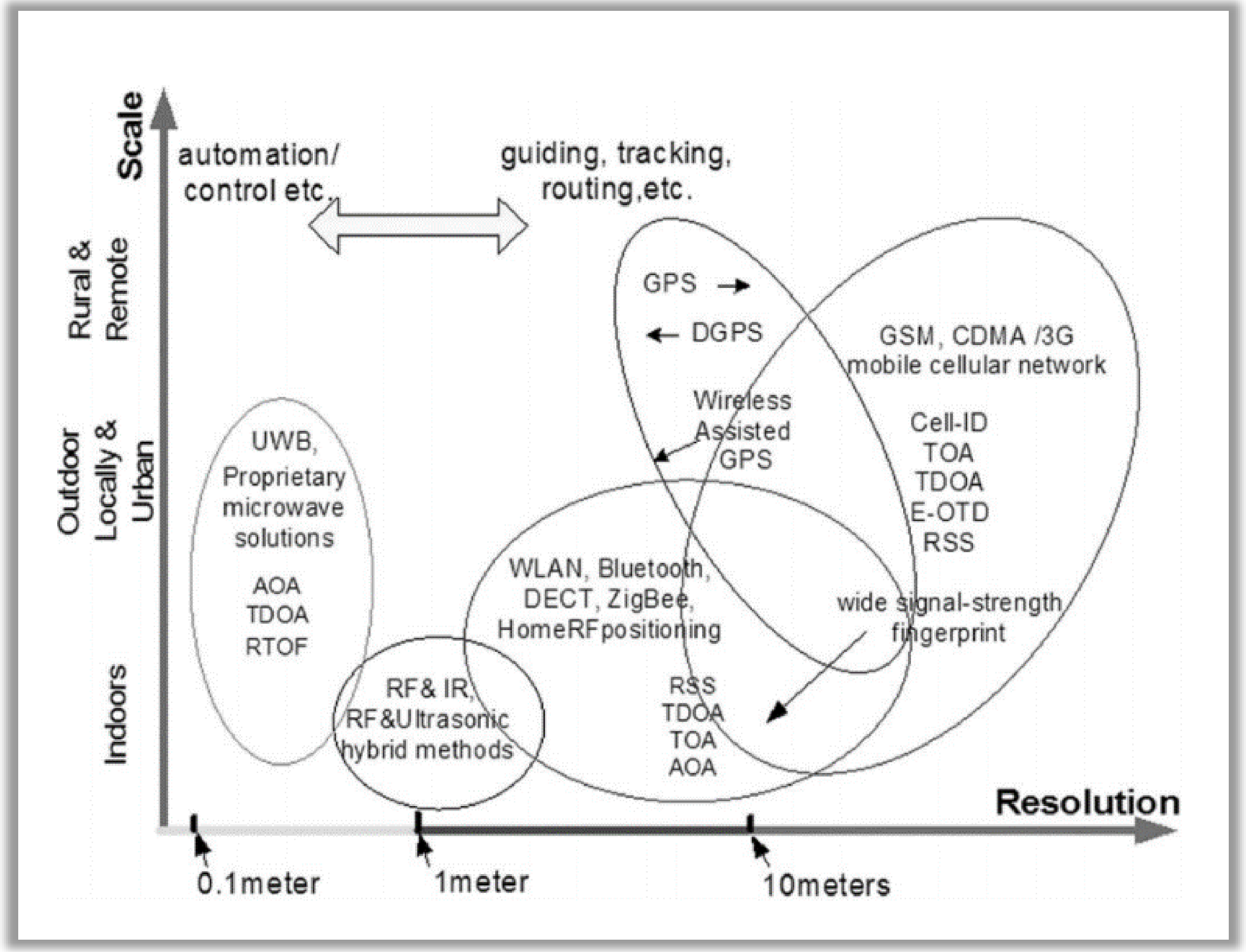
Asset Tracking - Approach

- Approach

  1) Down select appropriate trackers that are low power, accurate, robust and small

  2) Implementation of a tracking system inside a large scale facility to gain experience of robust asset tracking operation.

  3) Optimise for size and power consumption

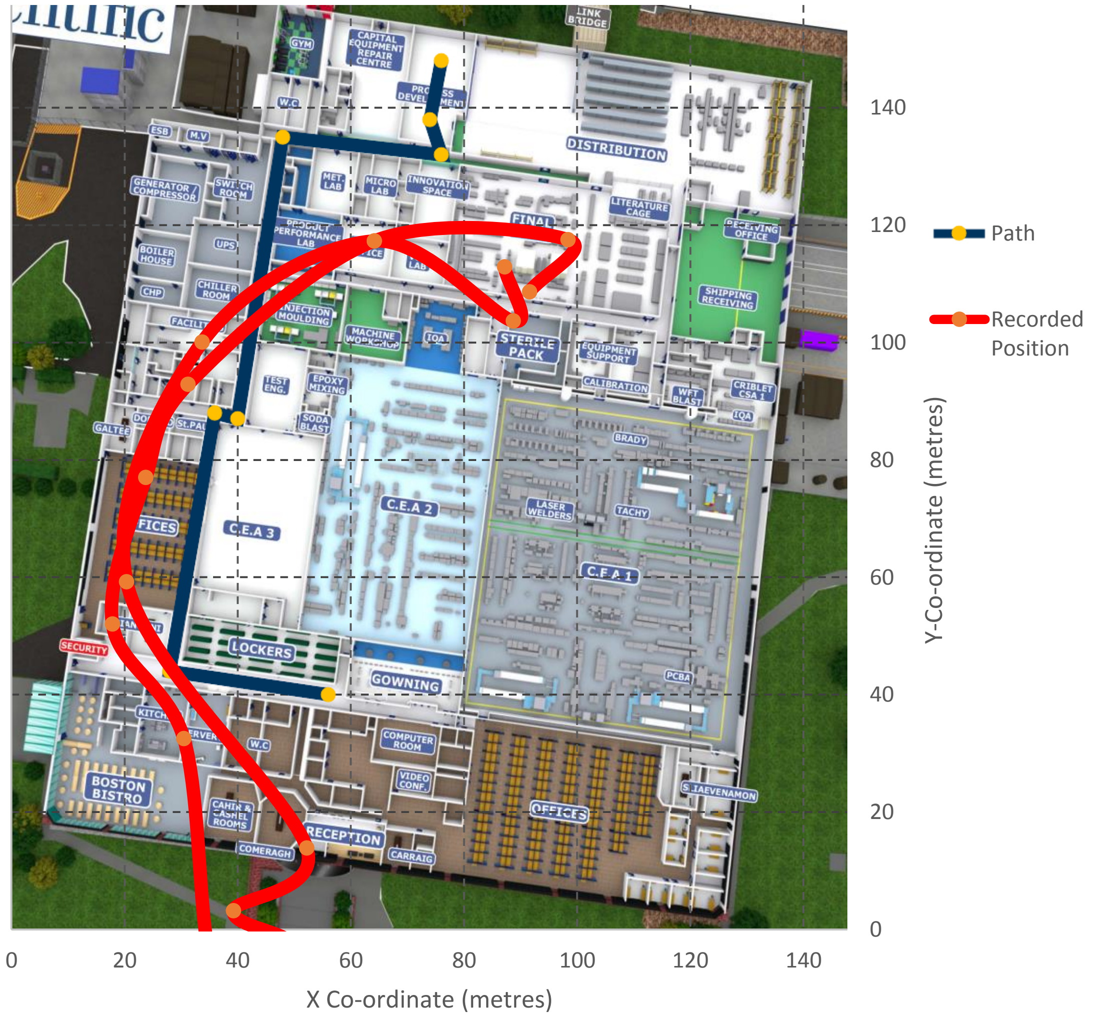


Asset Tracking - Technology comparison

Wireless Technologies	Accuracy	Range	Complexity †	Scalability †	Robustness †	Cost	Power Consumption*
Active RFID RSS	3	3	3	4	4	3	3
Passive RFID (proximity only)	3	1	4	1	3	3	5
UWB	5	2	2	3	4	2	1
WLAN RSS	3	2	4	3	3	5	3
WLAN Fingerprint	3	2	3	3	2	5	3
Bluetooth	3	3	4	3	2	4	4
Bluetooth & IMU Fusion	4	4	2	3	4	4	3
ZigBee	4	2	3	4	2	4	4
LoRa	1	5	4	5	2	1	4
Inertial Sensor IMU	4	4	2	3	3	4	4
UWB & IMU Fusion	5	4	2	3	4	2	4

Asset Tracking - Technology Selection

- UWB and BLE chosen as candidate technologies
  - *BLE is a low power proximity based technology. The challenge is getting good enough accuracy*
  - *UWB is higher power but has significant accuracy advantages. The Challenge is to reduce power consumption*
- GPS/Cellular tracking also tested but proved to be high power and low accuracy accuracy issues indoors



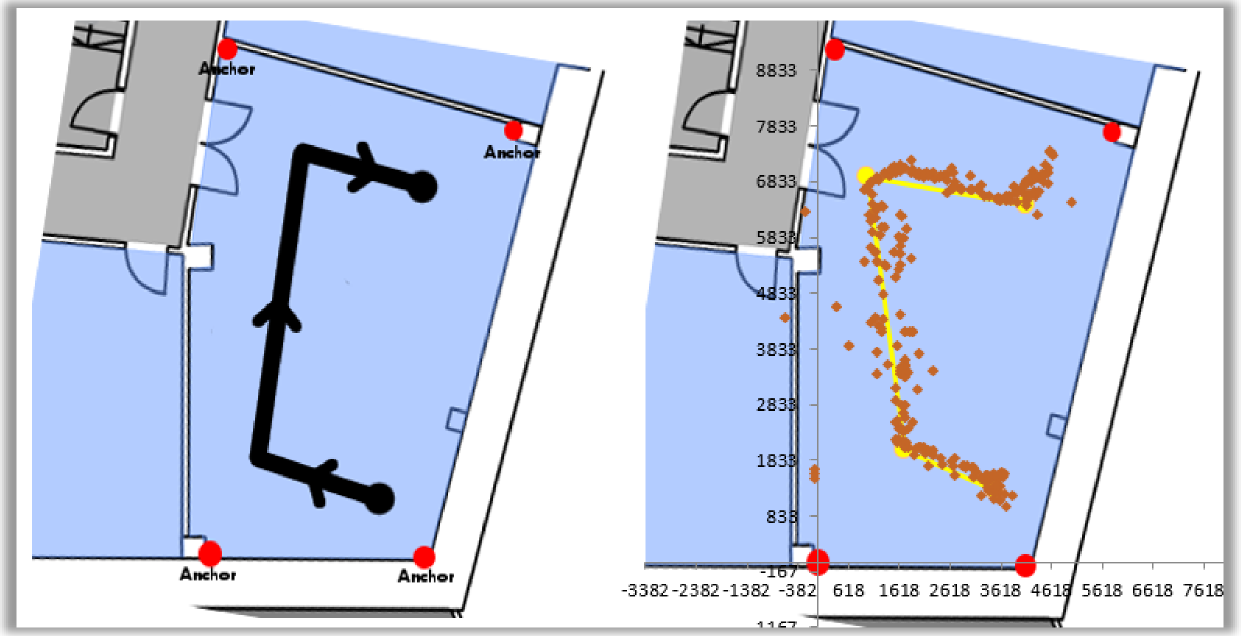
Asset Tracking - Vendor Selection

- Pozyx Labs UWB & IMU tracking kit chosen to verify UWB
  - *Customisable (Python), availability, visualisation path*
- Link Labs Airfinder tracking kit chosen to verify BLE tracking
  - *Provided pre-production model for various industrial use cases*
  - *Good visualisation tools*
  - *Have agreed to collaborate on energy harvesting research*

Asset Tracking - Implementation

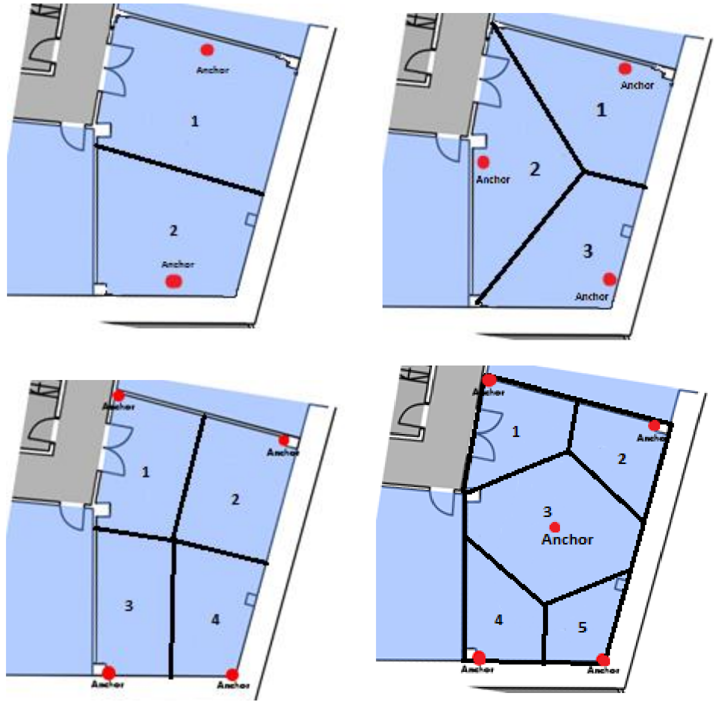
- Tests of UWB and BLE tracking carried out in perfect Line of Sight conditions

- Results showed greater accuracy for UWB but lack of robustness and much higher power consumption in comparison to BLE



Asset Tracking - BLE Implementation

- BLE positioning systems are based on proximity detection method
  - *Which ever anchor receives the strongest signal then tag is assumed closest to that anchor position.*
  - *Higher density of anchors increases positioning accuracy, as well as infrastructure costs*
- Tests conducted by Tyndall shows accuracies of approximately 2m is possible in a lab environment
- BLE is a low power solution with average tag current measured at 500uW



Layout	Positioning Accuracy
2 Anchors	4m
3 Anchors	3m
4 Anchors	2.5m
5 Anchors	2m

Device	Vin (Vin/V)	Average Current (Iavg/uA)	Average Power (Pavg/uW)
BLE Tag	3V	173	519
BLE Reference Node	3V	374	1122

Asset Tracking - UWB Implementation

- UWB positioning systems are based on measurement of Time of Arrival / Time Difference of Arrival techniques.
  - *At 500MHz bandwidths accuracies of 10cm are possible in ideal conditions.*
  - *Generally require less infrastructure than proximity based systems for the same accuracy.*
- Tests conducted at Boston Scientific show accuracies of approx. 2m in the process development room
- Current consumption in the order of 10s of milliwatts

Realistic NLoS Conditions

Test Point	Average Horizontal Error (mm)
A	948
B	1572
C	919
D	1018
E	2278
F	2824
G	1476
H	519

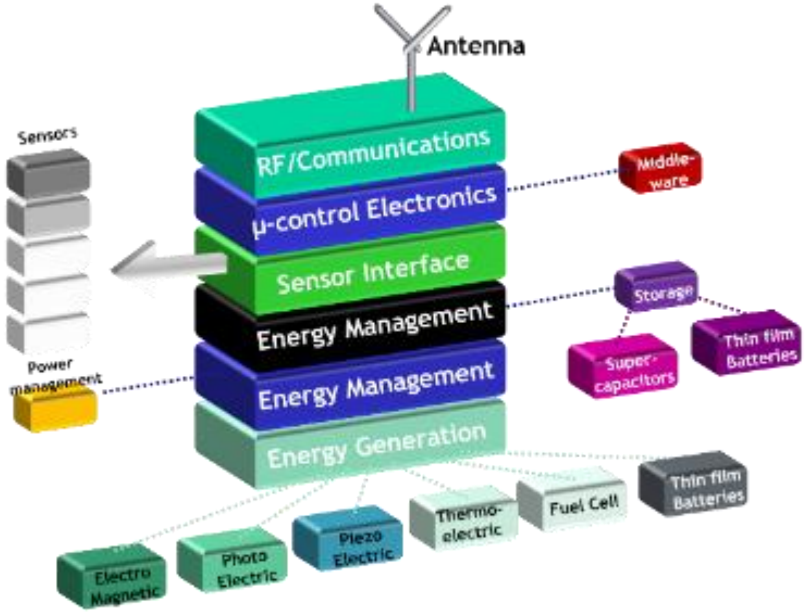
Ideal LoS Conditions

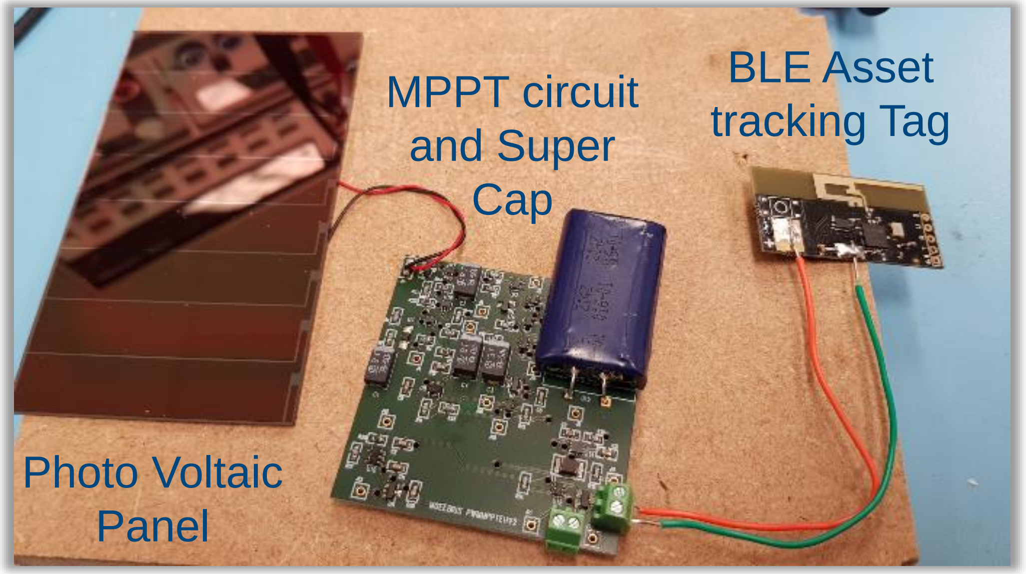
Test Point	Average Horizontal Error (mm)
A	153
B	241
C	359
D	404
E	91
F	354
G	379
H	381

Asset Tracking - Investigate potential for Energy Harvesting

1) Assess and model ambient energies that can be captured according to the required power requirements.

2) Implement the viable energy harvesting solutions to extend battery life of sensors
   - *Indoor solar, Vibrational, Thermoelectric, etc.*





Conclusion

- The two presented use cases are being implemented in live factory conditions

- First phase was to enable sensing, data analysis and improved efficiencies and intelligent maintenance

- Next phase moves towards optimisation of the sensor system to enable energy harvested technologies to be incorporated

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