MOSYCOUSIS

Intelligent Monitoring System based on Acoustic Emissions Sensing for Plant Condition Monitoring and Preventative Maintenance

Introduction

MOSYCOUSIS project overview

Industrial production failures → Replacement costs, man-hour resources and downtime losses.

↓

Predictive maintenance. → Operating risk reduction
Plant failures minimizations
Equipment reliability
Production maximization




MOSYCOUSIS project overview

Support Predictive maintenance

Main value

Allowing convenient scheduling of corrective maintenance, and to prevent unexpected equipment failures.

Requirements

Earlier information and reliable diagnosis

Current solutions

Manual procedure
Expensive devices
Simple diagnosis algorithms
User experience

expectations

Automatic procedure
Low-cost devices
High diagnosis analysis
Untrained users
maintenance
Flexible & Modular

MOSYCOUSIS

Similar Products

Task 1.1 – Collecting demands

- **Commercial solutions**

Ultraprobe, electrical, mechanical or leak detection by ultrasound level

The Ultraprobe senses high frequency sounds produced by operating equipment, leaks and electrical discharges. It then electronically translates these signals down into the audible range so that a user can hear these sounds through a headset and see them as intensity increments on the Ultraprobe "gun's" LED meter.

Indicators	dB in time, Acoustic level in frequency
Others	from 20KHz to 100KHz, response in < 10 miliseconds, Trisonic Scanning Module.

Ultrasonic Ultraprobe 100: **€ 1400.00**
Ultrasonic Ultraprobe 9000: **€ 5500.00**

MOSYCOUSIS project overview

Advanced diagnosis algorithms

Energy autonomous system

Application adaptability

Wireless communication

Location in non-accessible places

Compact system

Application adaptability

Full Acoustic Emissions analysis

Optimum electronic design

Expert System

Targeted customers

Development of a professional, effective, safe, and accurate mechanical equipment monitoring system for industrial machinery in manufacturing plants.

Main applications

- **Gearboxes and shafts**
- **Slow speed bearings and gearboxes**

Secondary applications

- **Split and planetary gearboxes**
- **Alternative and reciprocating machinery**

Electrical motors, gearboxes, pumps, yaw control and blowers.




Consortium structure

8 Beneficiaries / 5 countries

2 beneficiaries in **Romania**
2 in **Ireland**
2 in **Spain**
1 in **Estonia**
1 in **Poland**

5 **Industrial enterprises**
3 **Research Centers** or **Universities**

2 years project duration:

from October the 1st **2011**
to October the 31st **2013**

Acoustic emissions data analysis

AE data analysis
– Fault Characterization with AE signals

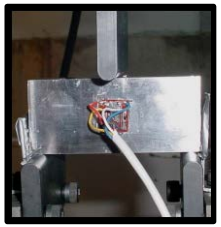
Analysis of Acoustic Emission Signals WP2

"STATIC" EXPERIMENTS:

Experimental Setup:

- Fatigue testing machine

- Tensile test machine



Experiments:

- Micro-Hardness Test
  Characterization of materials

- Spherical Indentation Test (AE)
  Failure Mechanisms in Surface

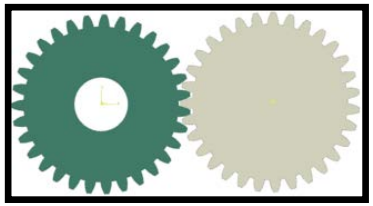
- Three Point Bending (AE)
  Fatigue Crack Initiation and Propagation

- Fatigue Test in Gear Teeth

SIMULATION:

Experimental Setup:
- FEM software

Experiments:
- Different conditions (fault size) evaluated.



DYNAMIC EXPERIMENTS:

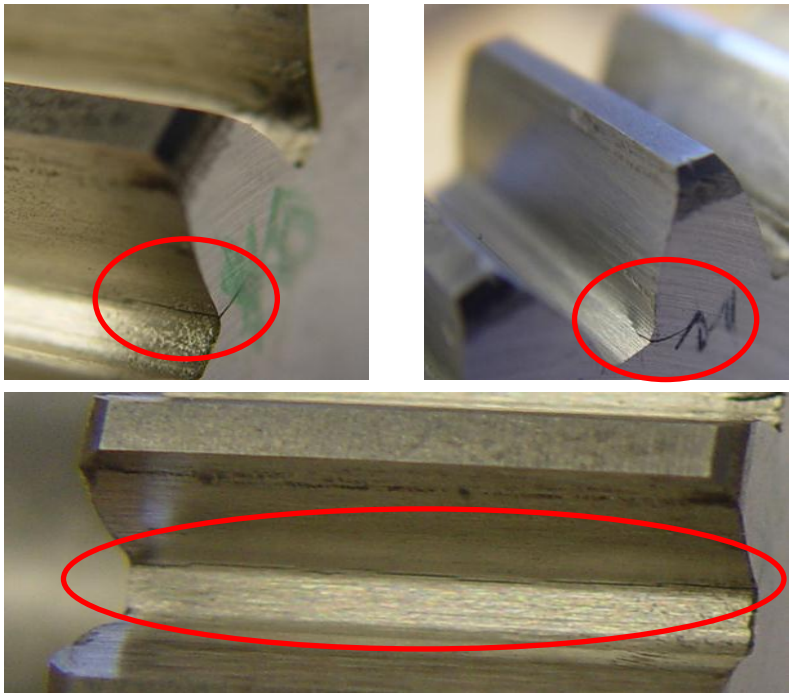
Experimental Setup:
- Gearbox test bench

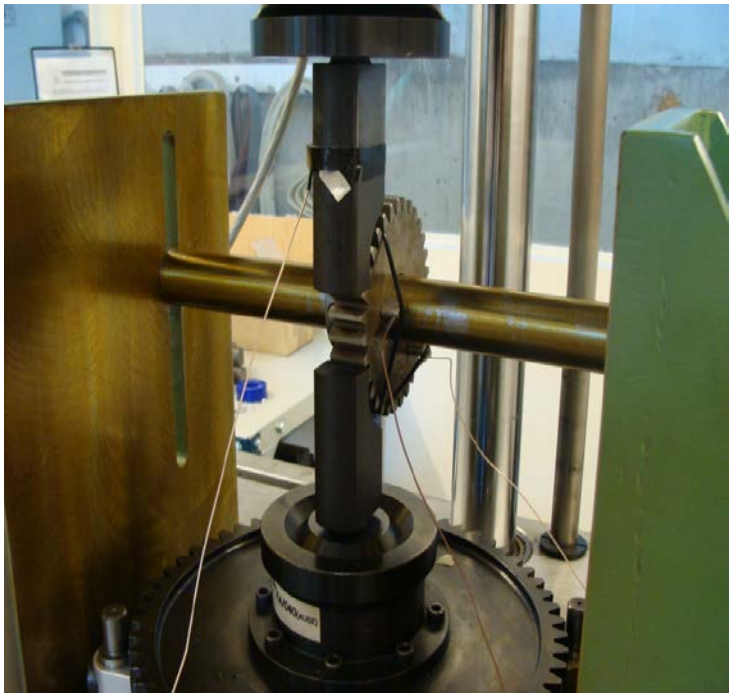
Experiments:
- Different gears conditions

AE data analysis
– Fault Characterization with AE signals

Static Analysis of Acoustic Emission Signals

- Long term testing were conducted to identify the relation between the degradation procedure and AE signal characteristics.





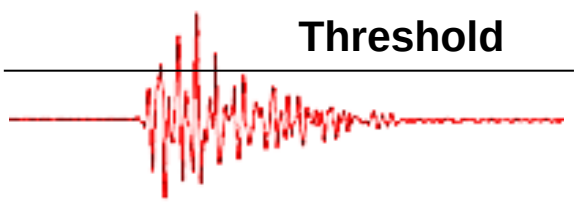
Laboratory Set-up for the fatigue cycle testing in F114 Gears

AE data analysis
– Fault Characterization with AE signals

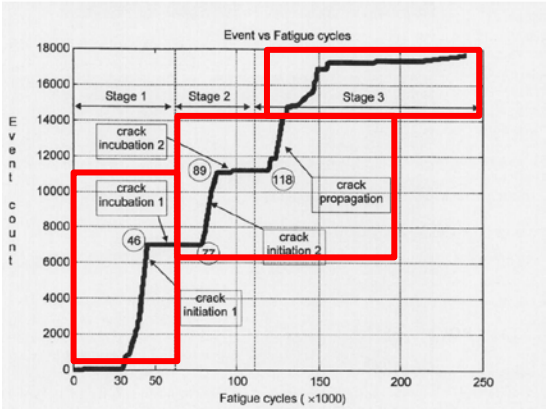
Static Analysis of Acoustic Emission Signals

- Generally, in fracture process, the acoustic activity of a material can be classified in three phases : crack initiation, crack incubation, and crack propagation.

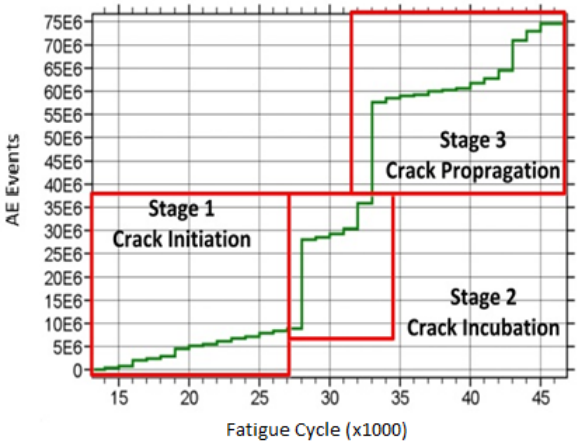
- **AE Event**



Theoretical response



Experimental response



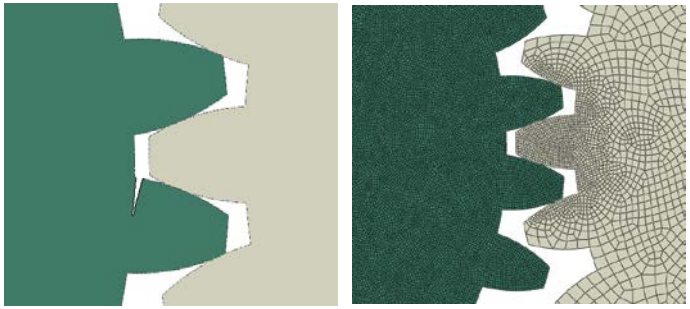
[2] Shi Z, Jarzynski J, Bair S, Hurlebaus S, Jacobs LJ. Characterization of acoustic emission signals from fatigue fracture , Proceedings of the Institution of Mechanical Engineers, 2000 214:1141-1149

AE data analysis
– Fault Characterization with AE signals

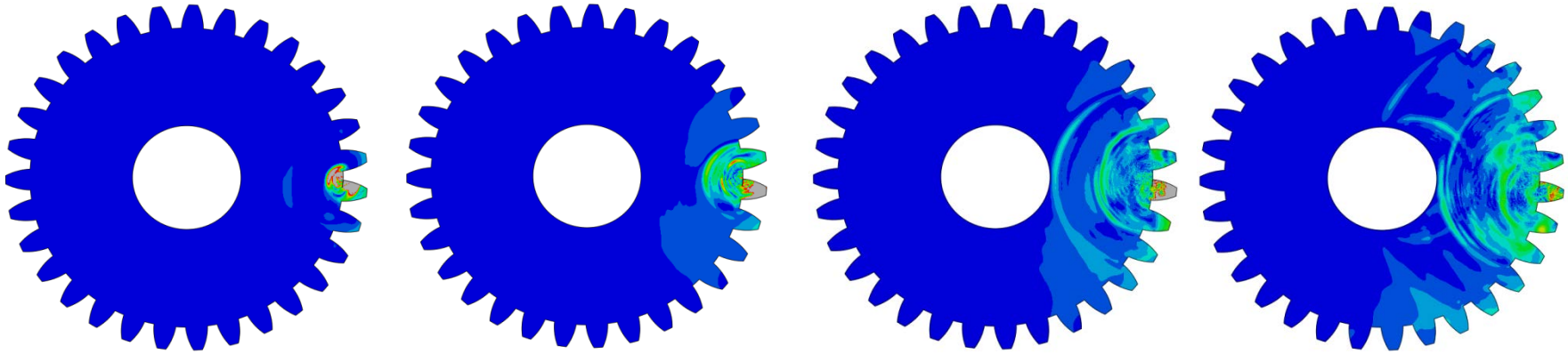
Finite Elements Models Simulations

- Simulations with a gear finite element 2D model
- Identify the relation of the AE signals with:
  - Geometrical aspects of the gear.
  - Size of the fault.
  - The position of measurement.

FEM crack and mesh representations



Evolution and propagation of the AE wave



t = 880 ns ***t = 2040 ns*** ***t = 5160 ns*** ***t = 8800 ns***

AE data analysis
– Fault Characterization with AE signals

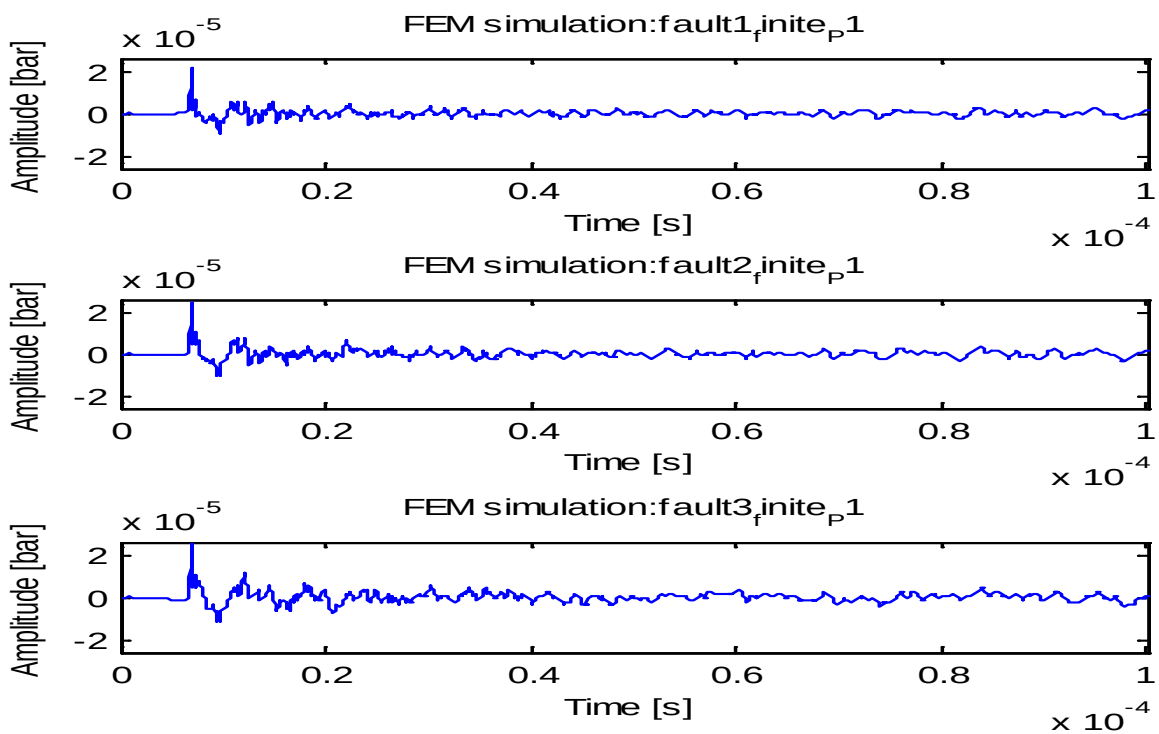
Report of the fault modeling system, acoustic emissions FEM simulations

FEM SIMULATIONS

Study of acquired AE signal

AE signature Vs Fault Size:

Increasing amplitude of the AE signal.

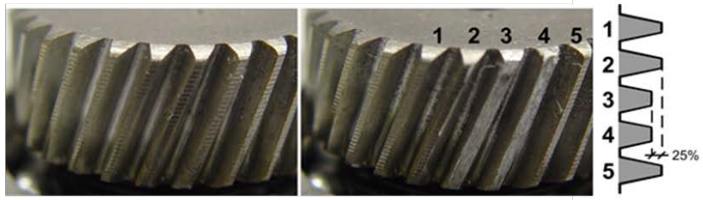


AE data analysis
– Fault Characterization with AE signals

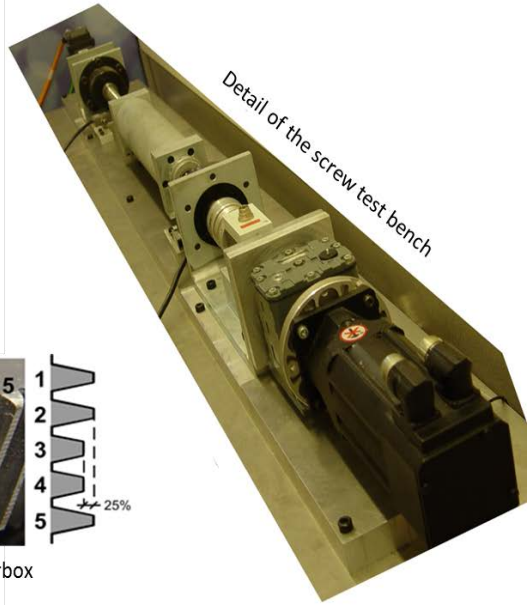
Dynamic Experiments

- Experimental tests were performed with different types of machinery in order to extract AE information and fault patterns in applications under laboratory conditions.

Detail of the double stage gearbox



Details of the fault teeth in a gear of the double stage gearbox



Screw test bench

Basic gearbox test bench

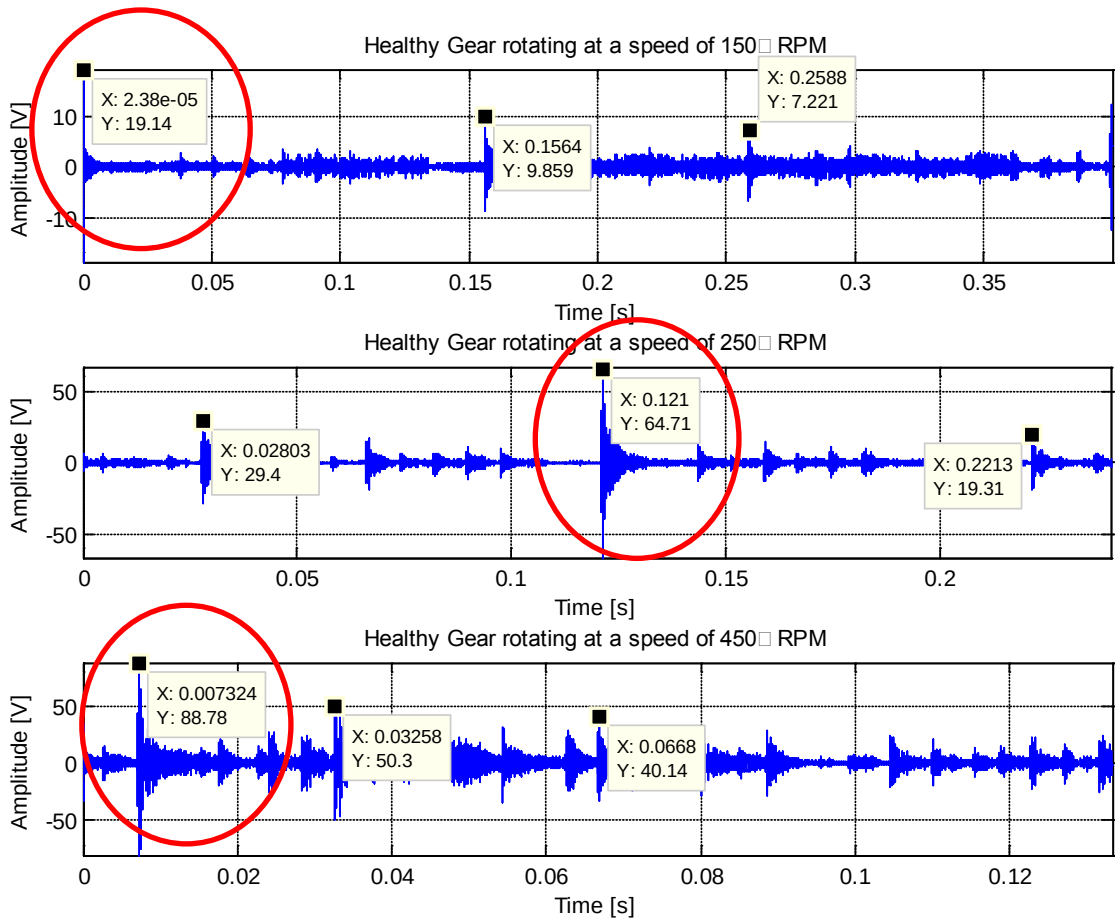
Review of WP2 – Fault condition characterization and Acoustic signal response

Report of the feature extraction.

DYNAMIC EXPERIMENTS:
Time Domain Analysis

The AE signals are highly influenced by the speed conditions of the test [2].

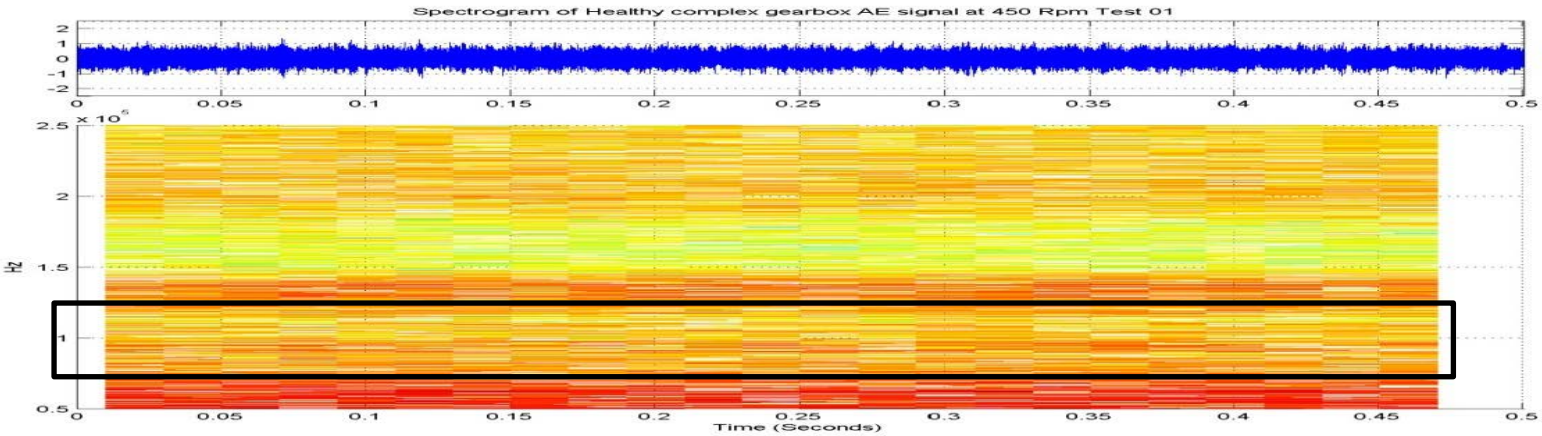
- (v = 150, 250 and 450rpm)
- (sensor: VS150-M)
- (time: 1 revolution)



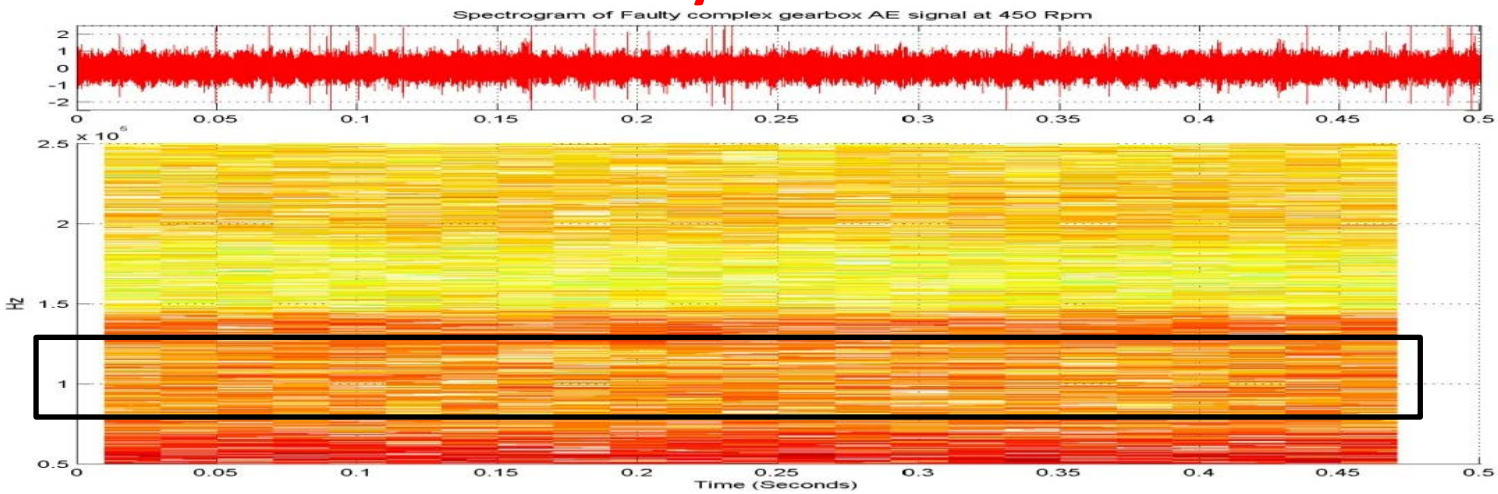
[2] Shen, G. T., Geng, R. S., and Liu, S. F., 2002, "Parameter Analysis of Acoustic Emission Signal," Chinese Journal of Non-destructive Testing, 24, pp. 72–77.

Review of WP2 – Fault condition characterization and Acoustic signal response

Healthy Gearbox



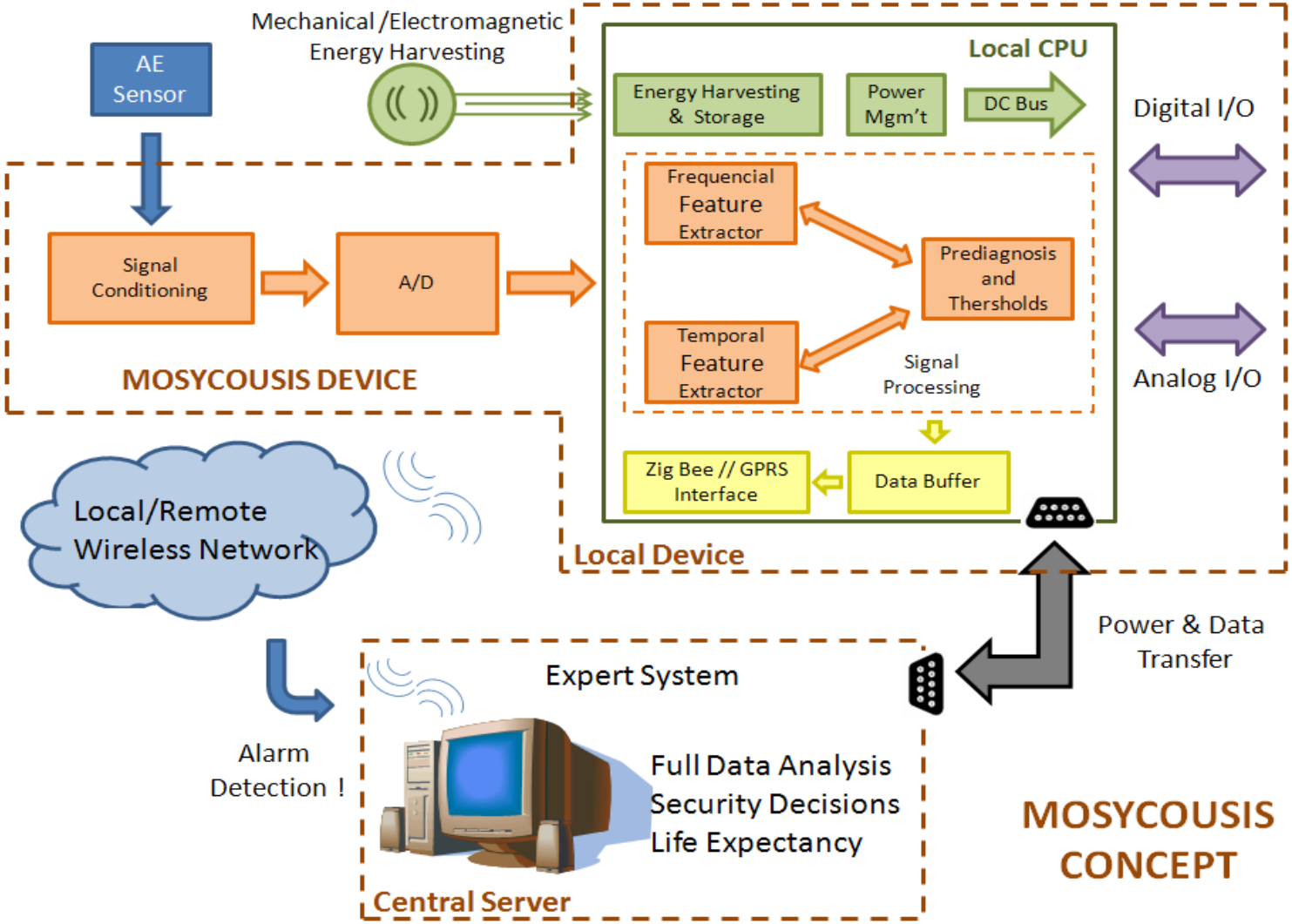
Faulty Gearbox



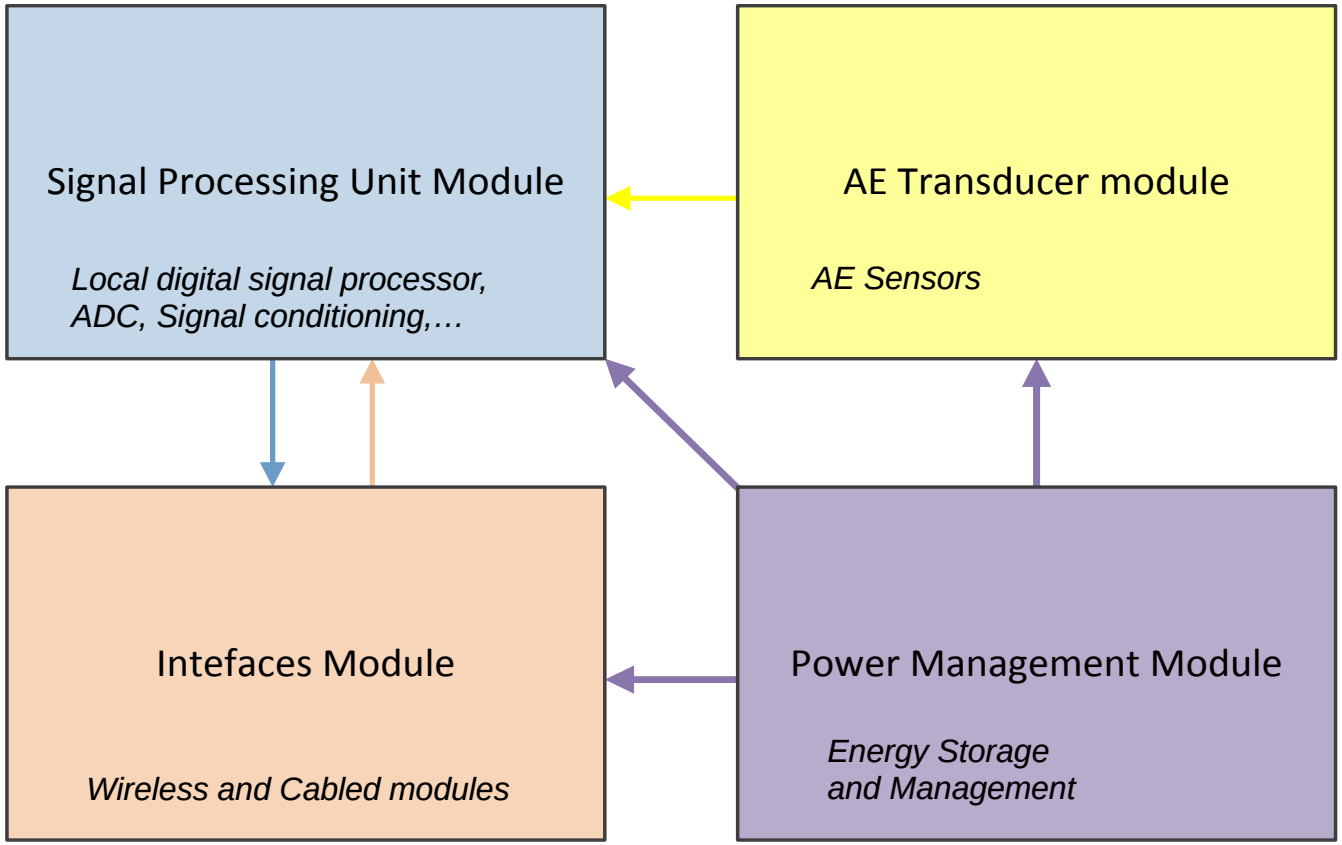
Diagnosis Algorithm

Sensor description

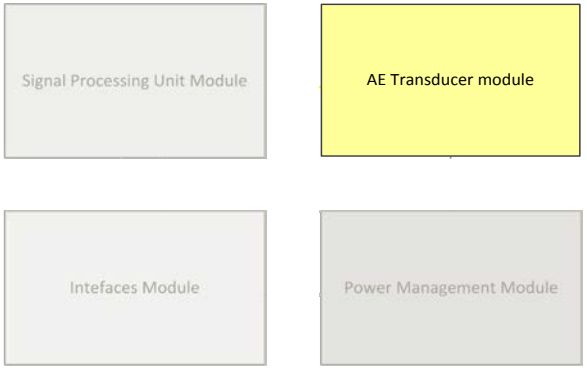
Sensor General Operation



Sensor structure



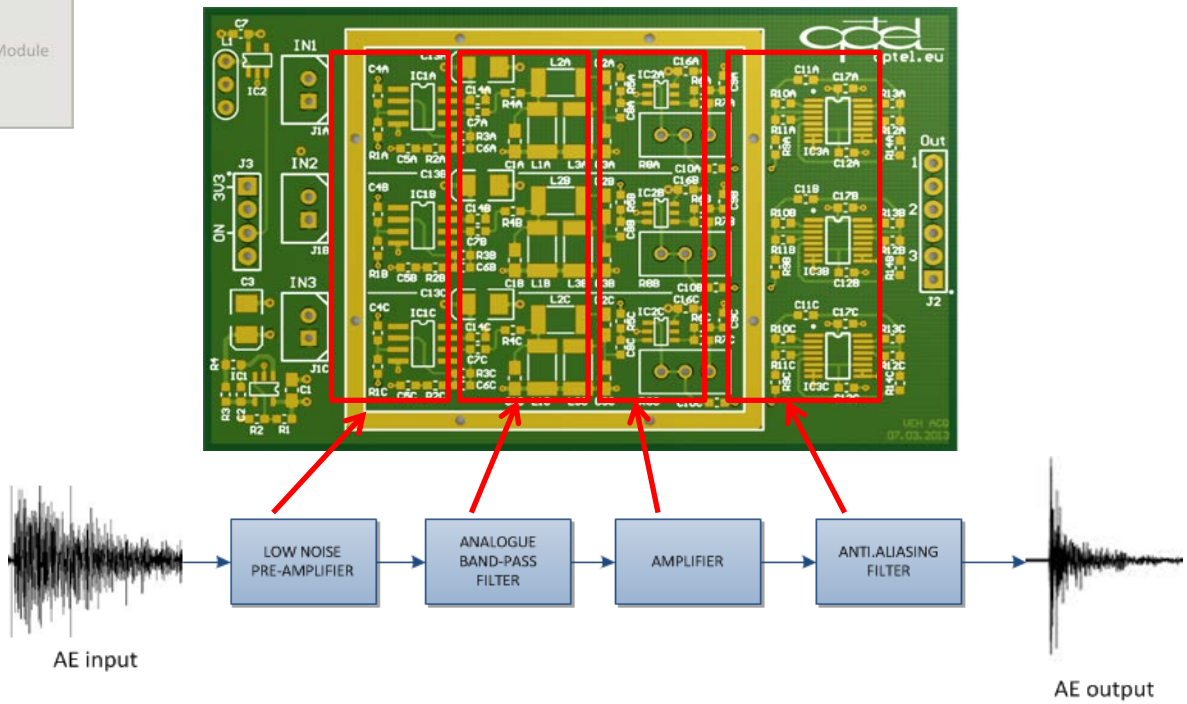
ACQ Board



AE conditioning board

BAND PASS FILTER
100Khz TO 400khz

Sampling frequency: 2Mhz



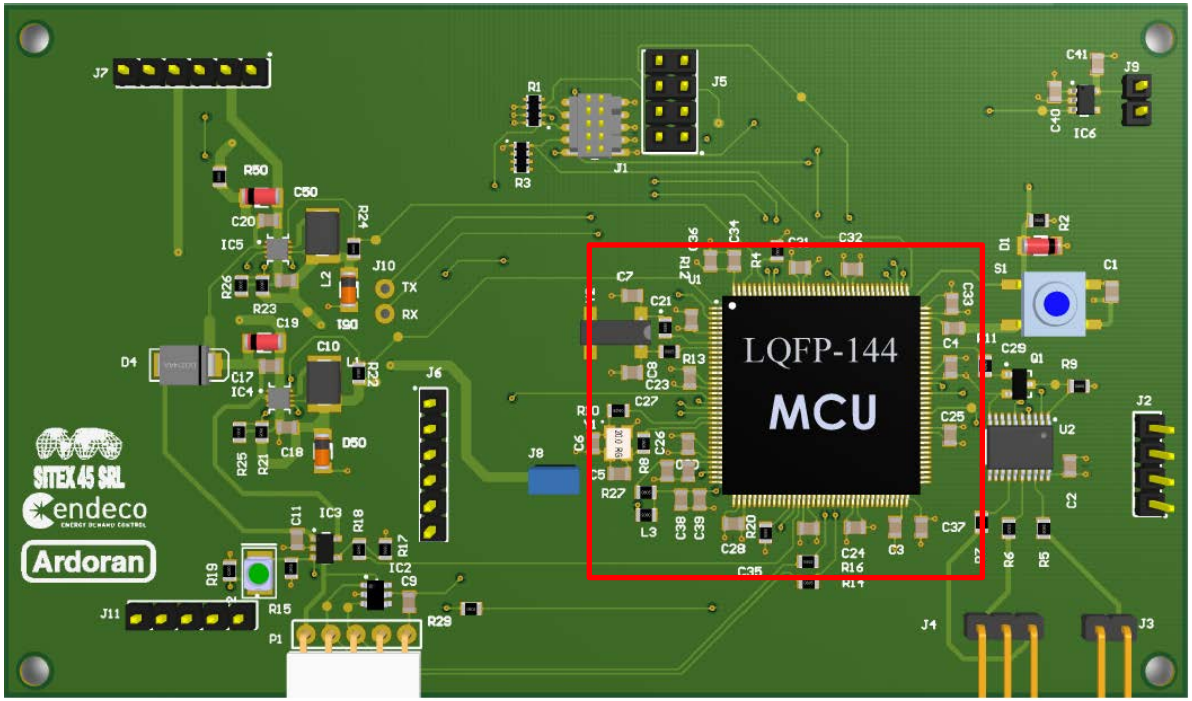
Main Board

Signal Processing Unit Module

AE Transducer module

Intefaces Module

Power Management Module



Signal Processing Unit

Processor core

Low power family
1.8V-3.3V

Sleep, stop and standby mode

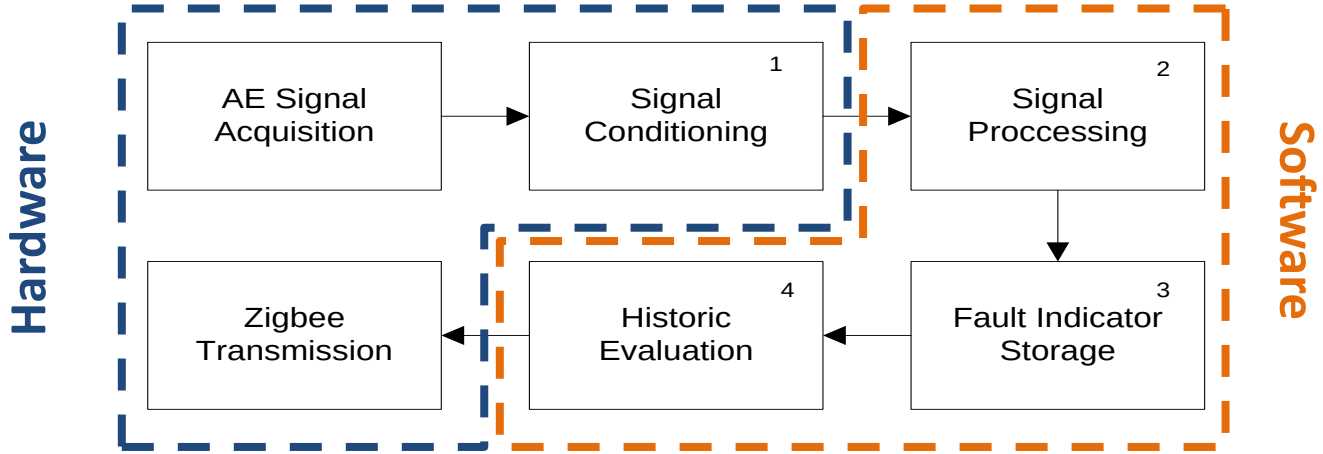
32 bits processor

Peripherals:

1. USB 2.0
2. DIGITAL I/O
3. SERIAL COM.
4. HIGH SPEED ADC

AE data analysis
– Diagnosis Algorithm Implementation

Algorithm Explanation



Sensor's Algorithm flow chart

AE signal acquisition considerations:

- **20.000 Samples @2MHz, 12 bits resolution.**
- **10 ms of signal.**

Review of WP2 – Fault condition characterization and Acoustic signal response

MOSYTRON as the resulting machine health indicator

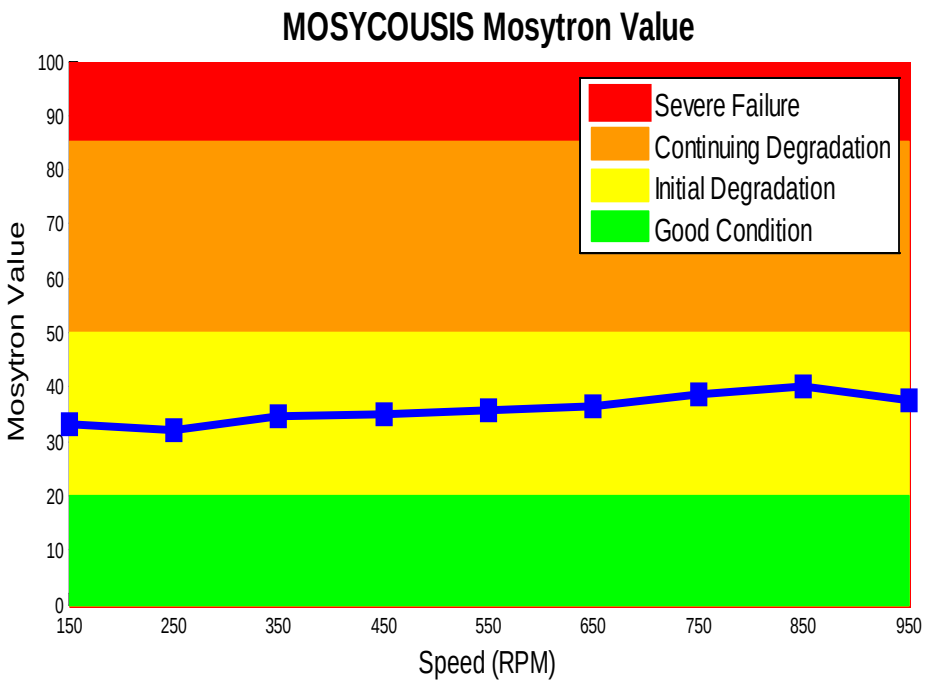
Machine Health Condition

Stage 1: From 00 to 20 %:
- Status: Good Condition.
- Periodic inspection of sensor's alarm.

Stage 2: From 21 to 50 %:
- Status: Initial Degradation.
- Common maintenance actions.

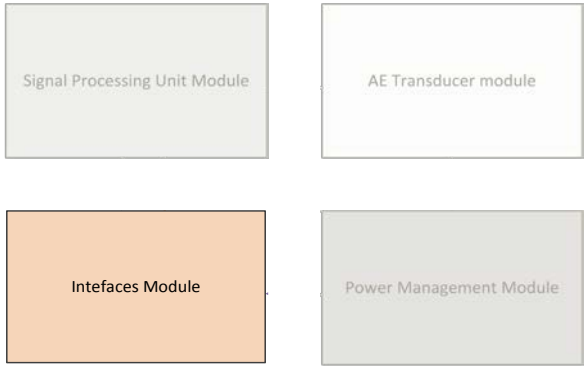
Stage 3: From 51 to 85 %:
- Status: Continuing degradation.
- Carry out Expert system full analysis.

Stage 4: From 86 to 100%:
- Status: Severe failure.
- Mechanical components replacement.

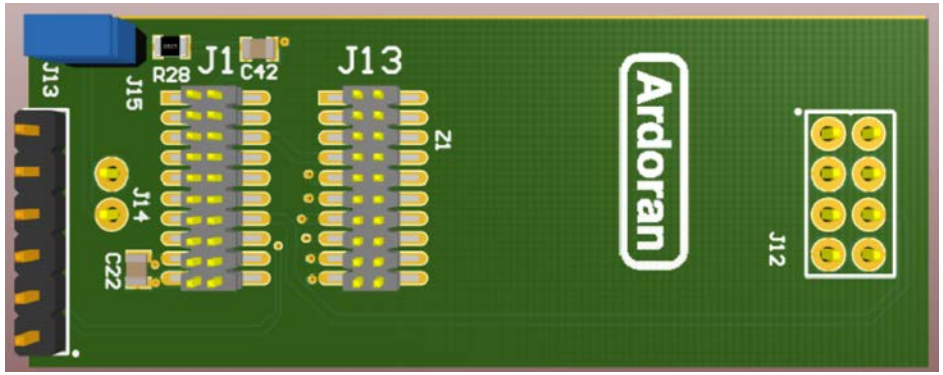


Non dependent of the laboratory test conditions!

Zigbee Board

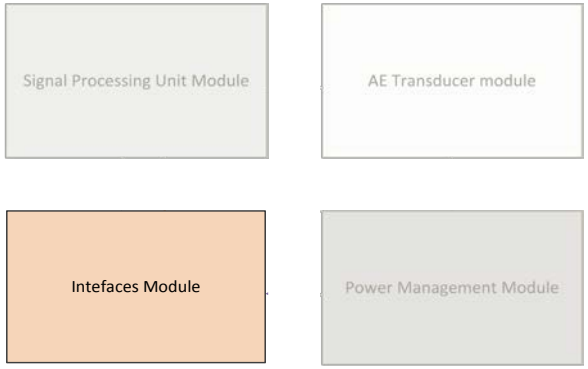


Zigbee module



Zigbee- uC SPI protocol communication.
Totally turned off if is not trasnmitting.

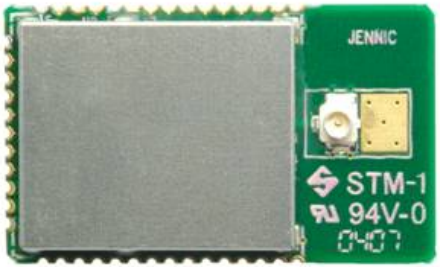
Zigbee transceiver



Local communication

Wireless

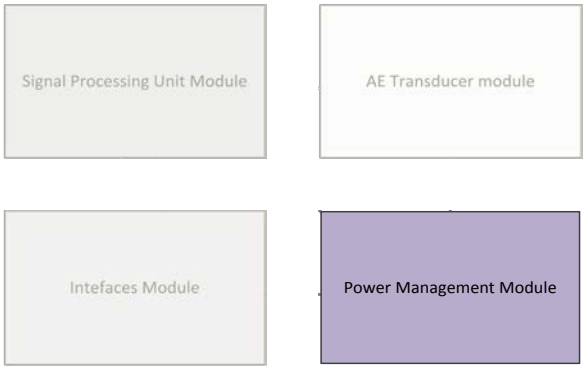
WSU concept

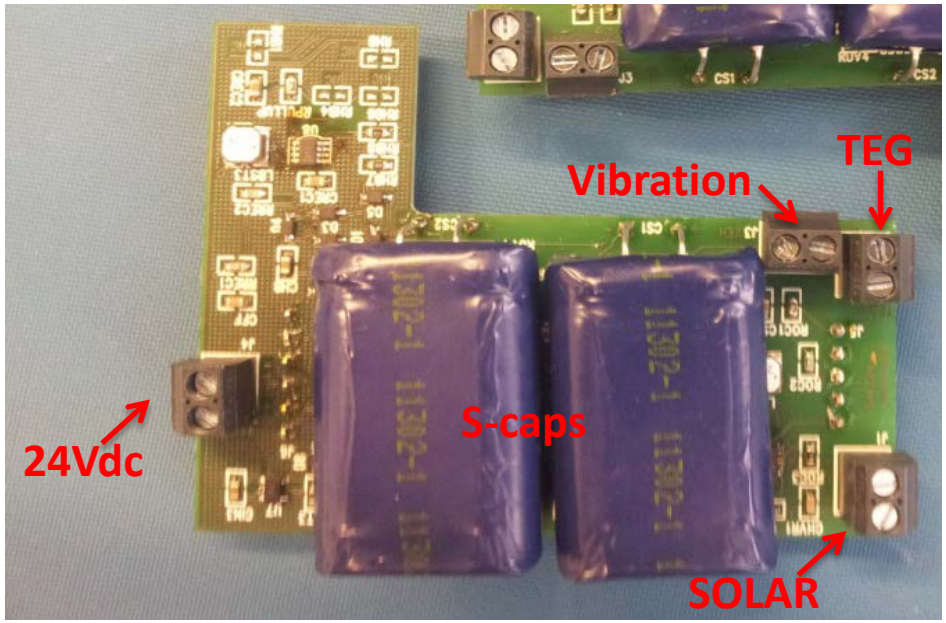


Features: Module

- 2.4GHz IEEE802.15.4, JenNet and ZigBee PRO compatible
- Sleep current (with active sleep timer) 2.6µA
- **JN5148-001-M00/03**
  up to 1km range (Ext antenna)
  M00: integral antenna 18x32mm
  M03: uFl connector 18x30mm
  - TX power +2.5dBm
  - Receiver sensitivity –95dBm
  - TX current 15mA
  - RX current 17.5mA
  - 2.3-3.6V operation

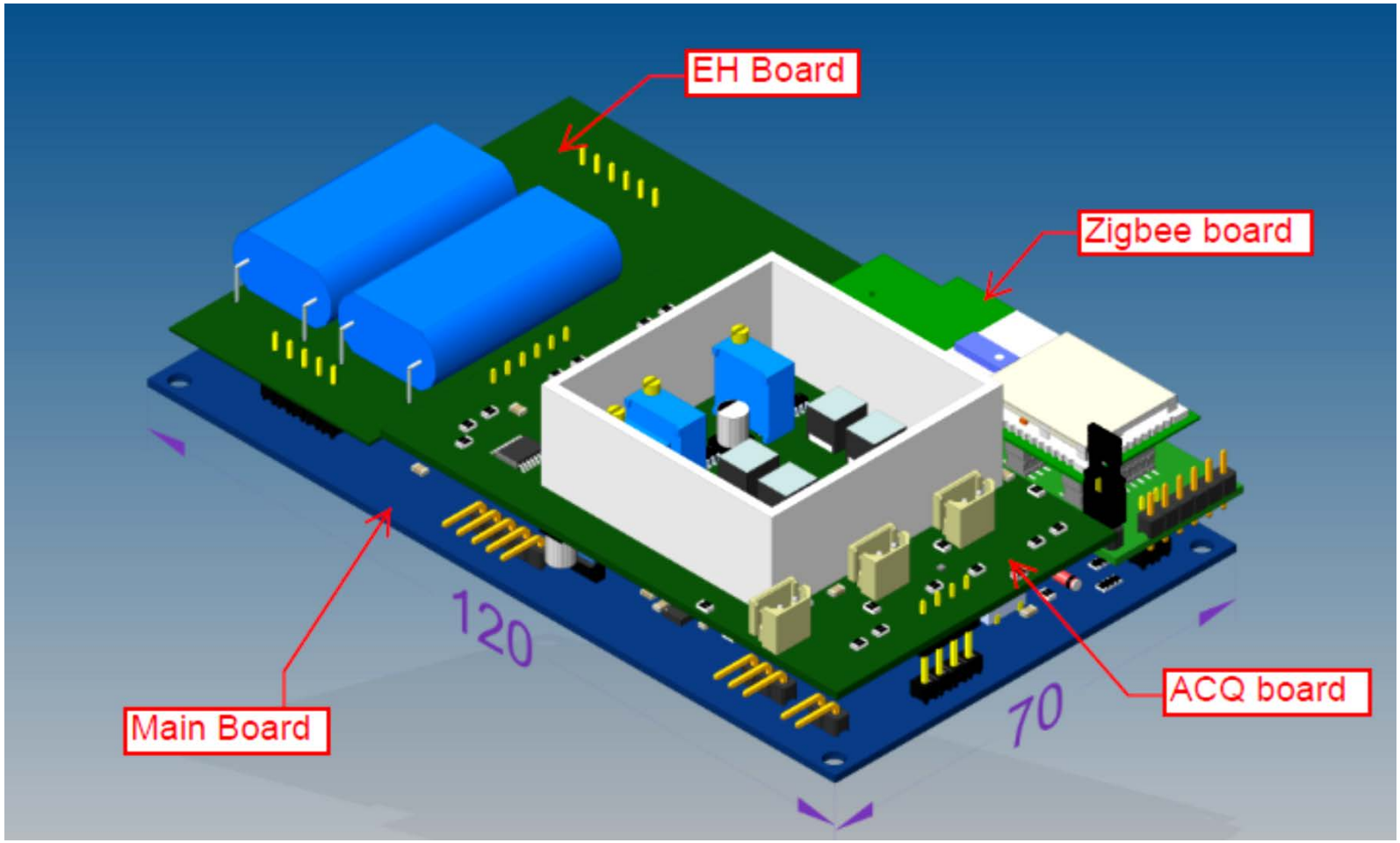
Energy Harvesting Board



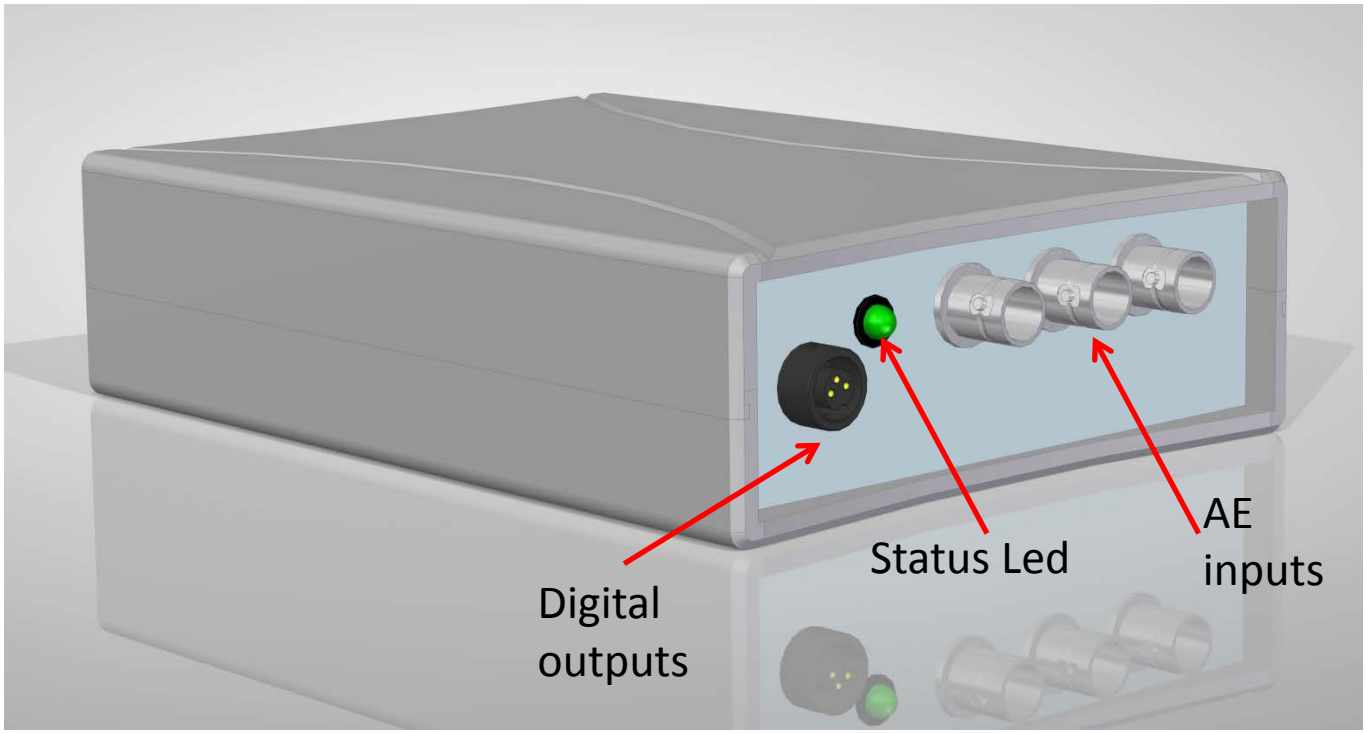


MOSYCOUSIS Sensor Integration

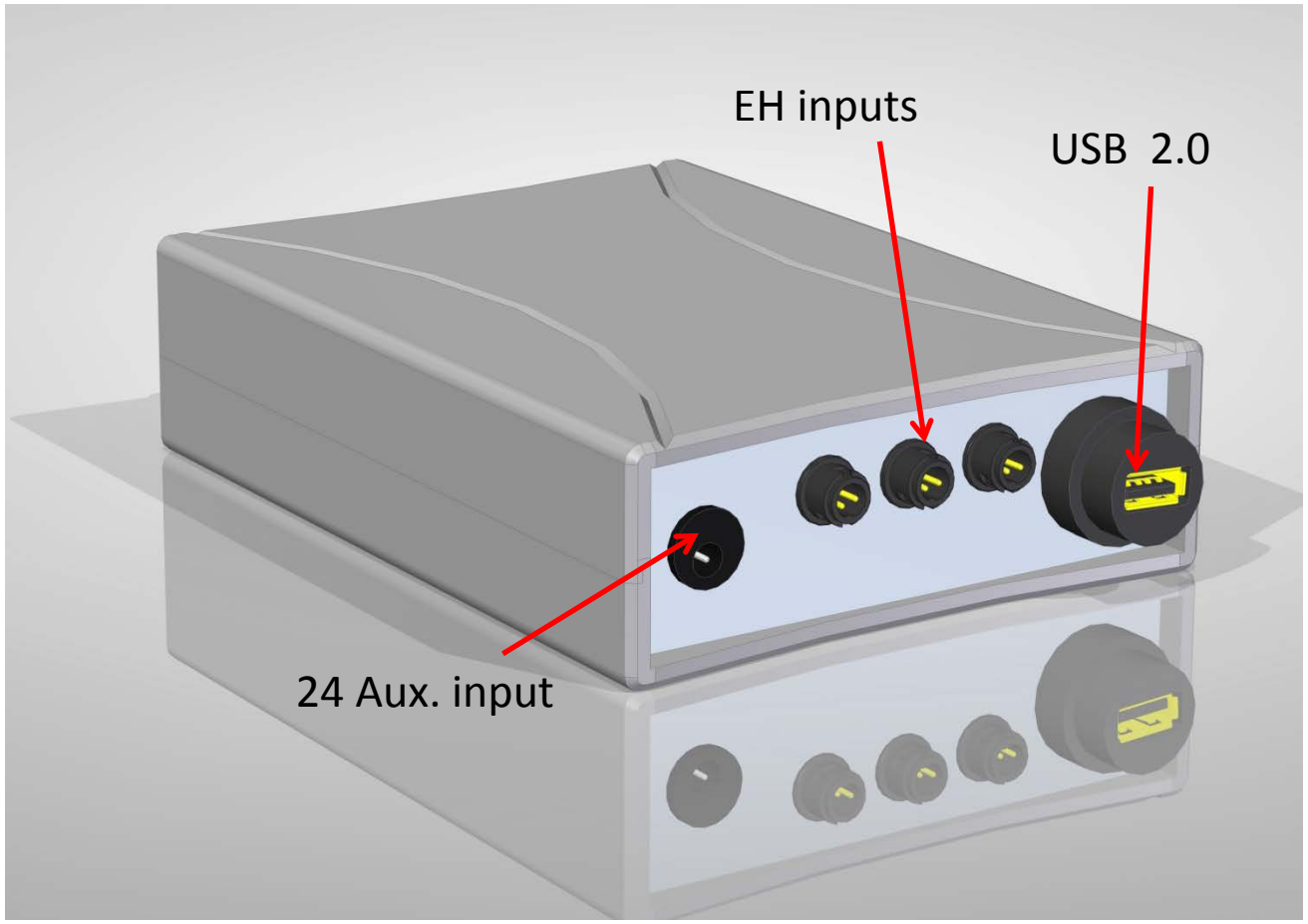
BOARDS DESCRIPTION



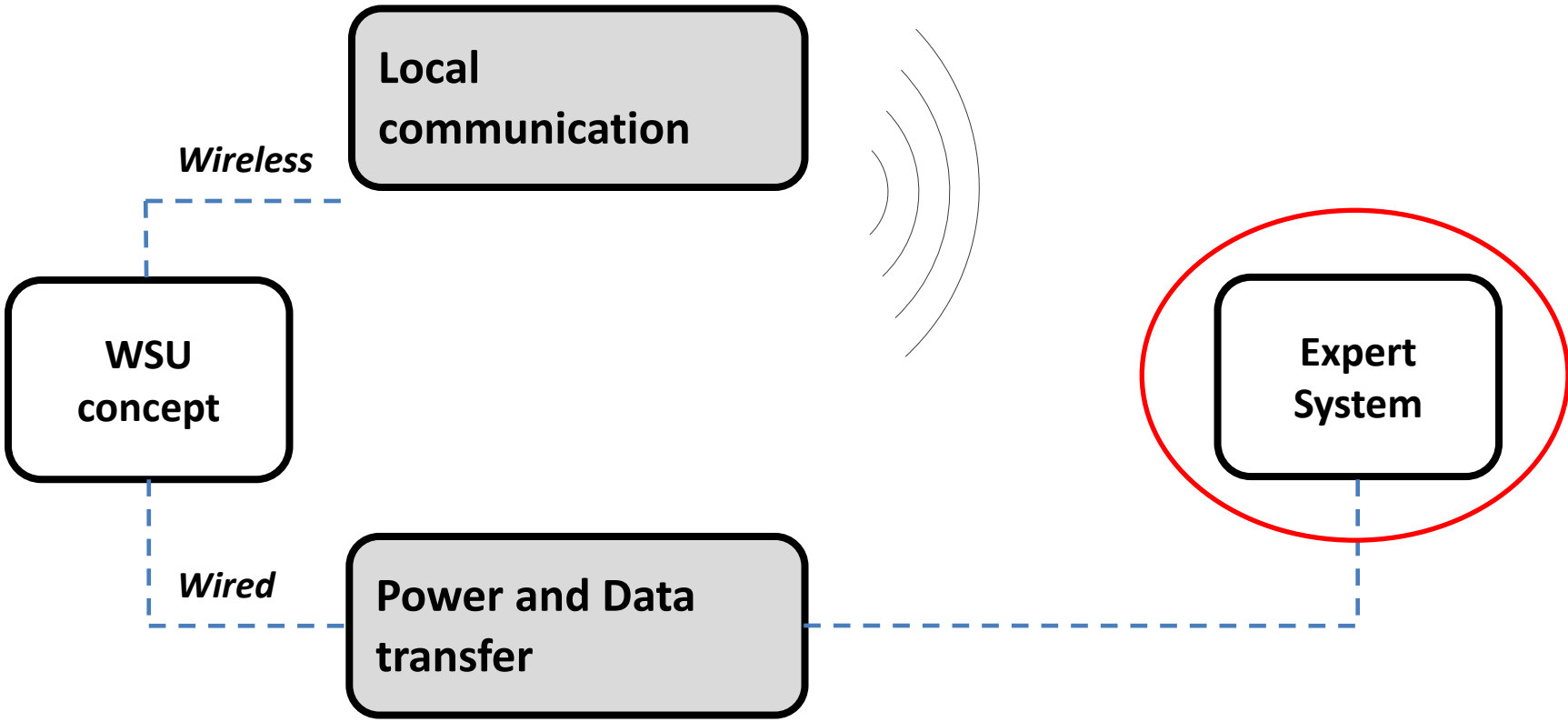
Mechanical Design



Mechanical Design



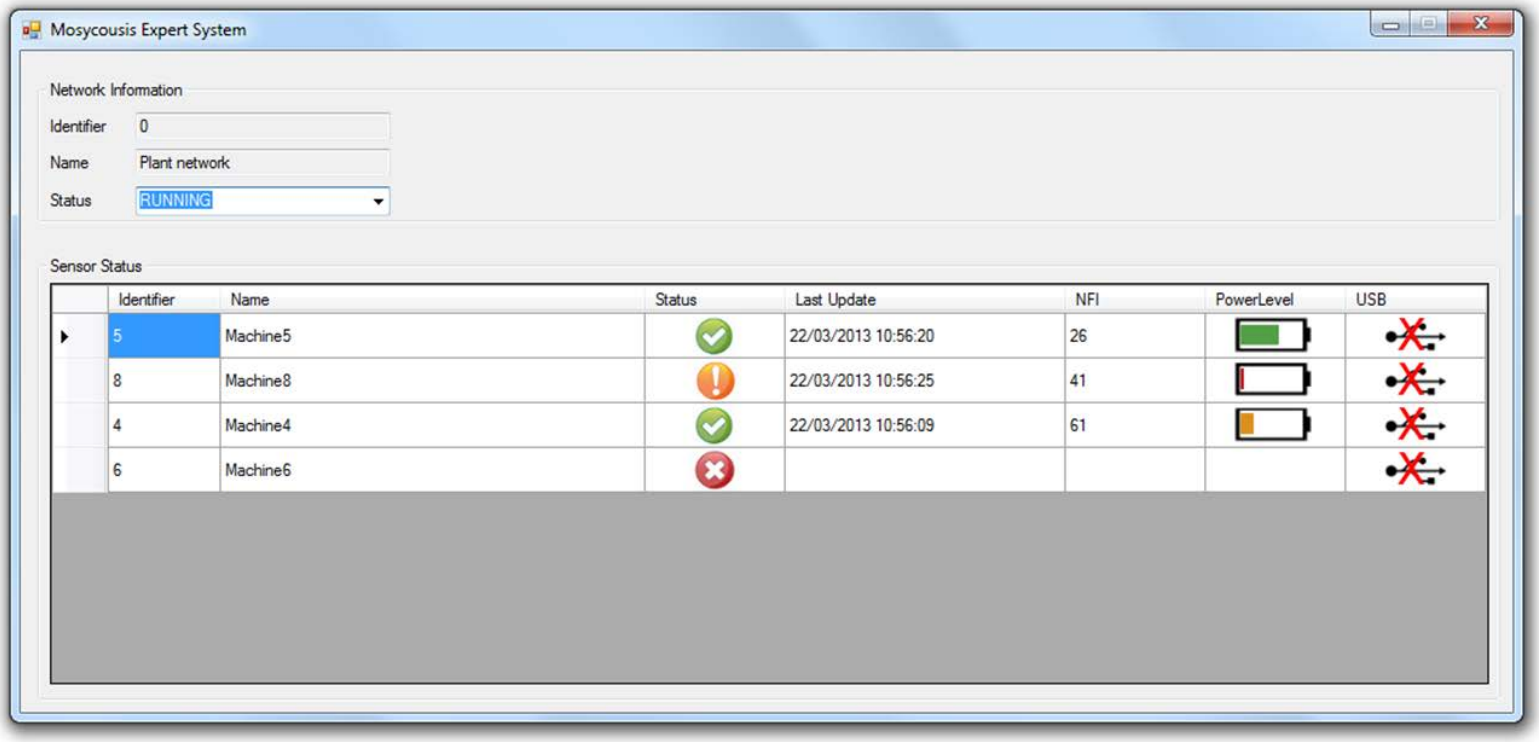
Added Features



Comms network and expert system

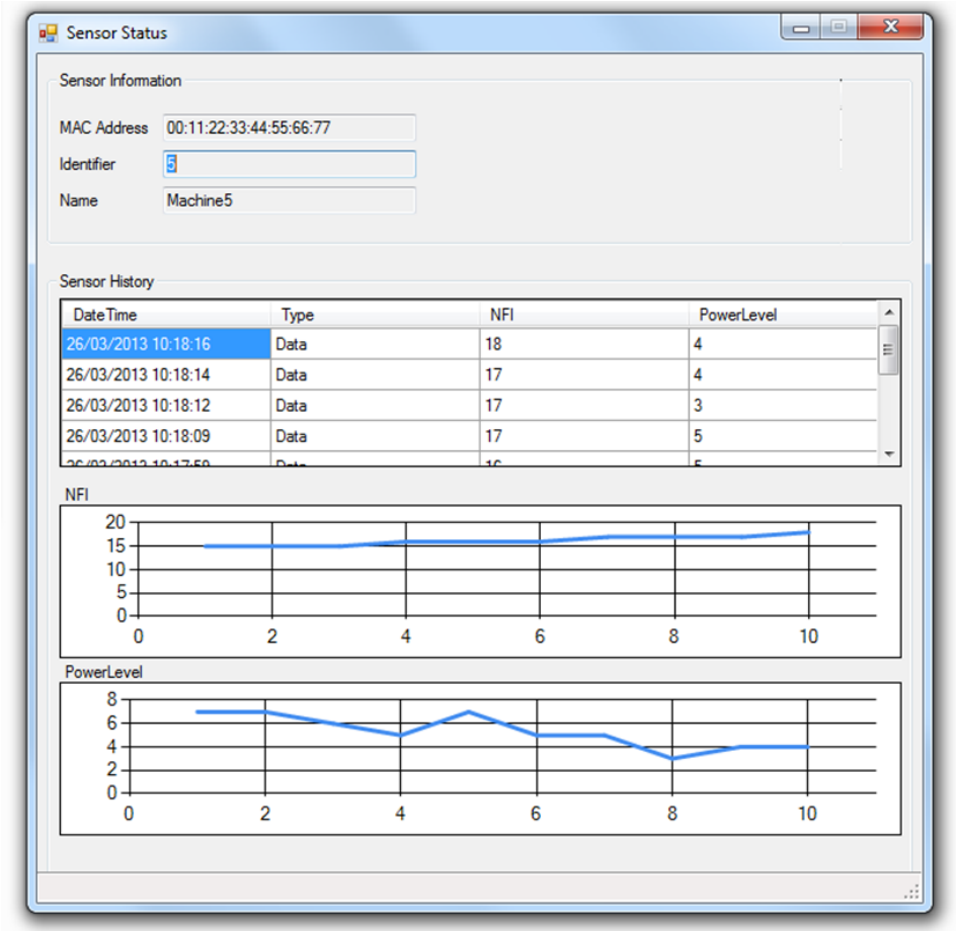
Graphical User Interface

Default view in ES user interface



Comms network and expert system

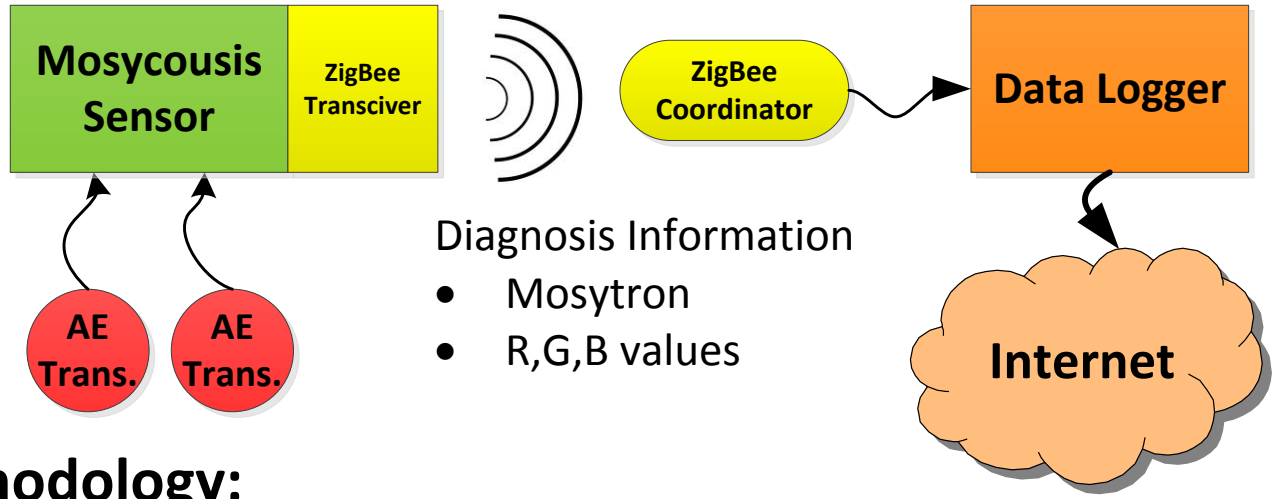
Sensor status window



Industrial Validation

AE data analysis
– Industrial Validation

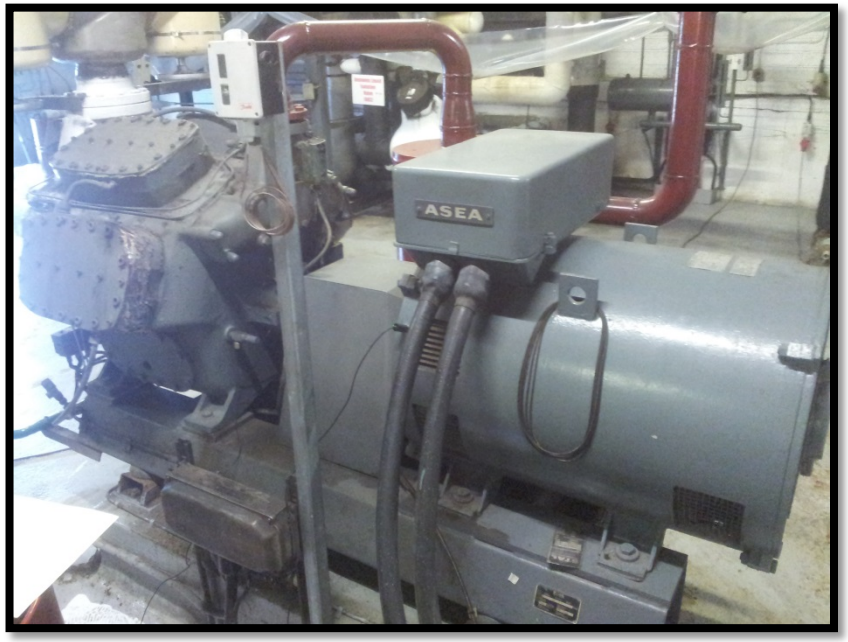
General Set-Up Description



- **Methodology:**
  - **Initial Analysis:** Retrieve AE data from the machines under different working scenarios.
  - **Continuing monitoring:** Long term experiment in order to test the real functionality of the sensor .

AE data analysis
– Industrial Validation

Set-Up in CGI facility



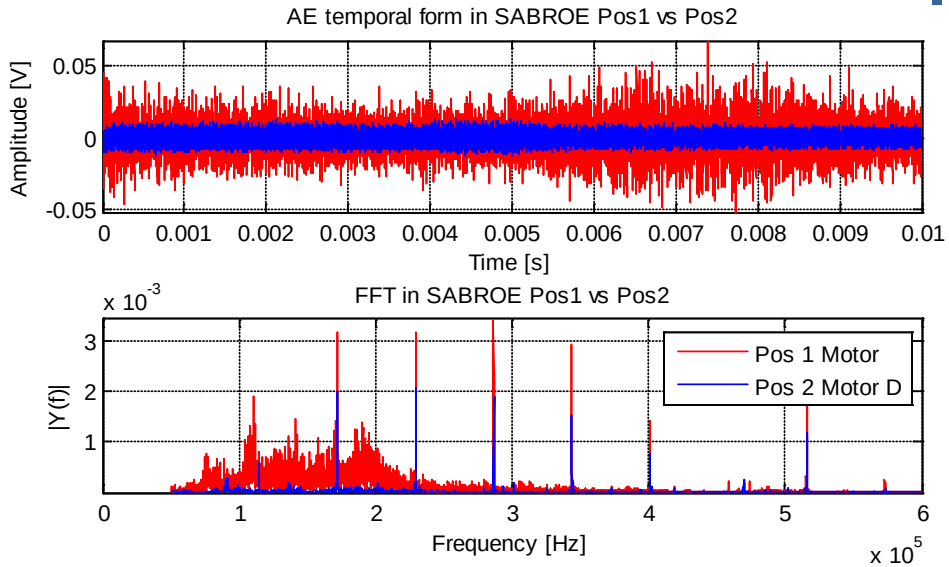
Compressor model ASEA

Compressor model Sabroe

AE data analysis
– Industrial Validation

Time vs. Frequency domain AE signal

Initial Analysis in Sabroe



Mosytron Value in the Motorside