Energy Harvesting 2013
25th March

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Development of Energy Harvesting (EH) Powered Wireless Communication Systems (WCS) for Autonomous Sensing

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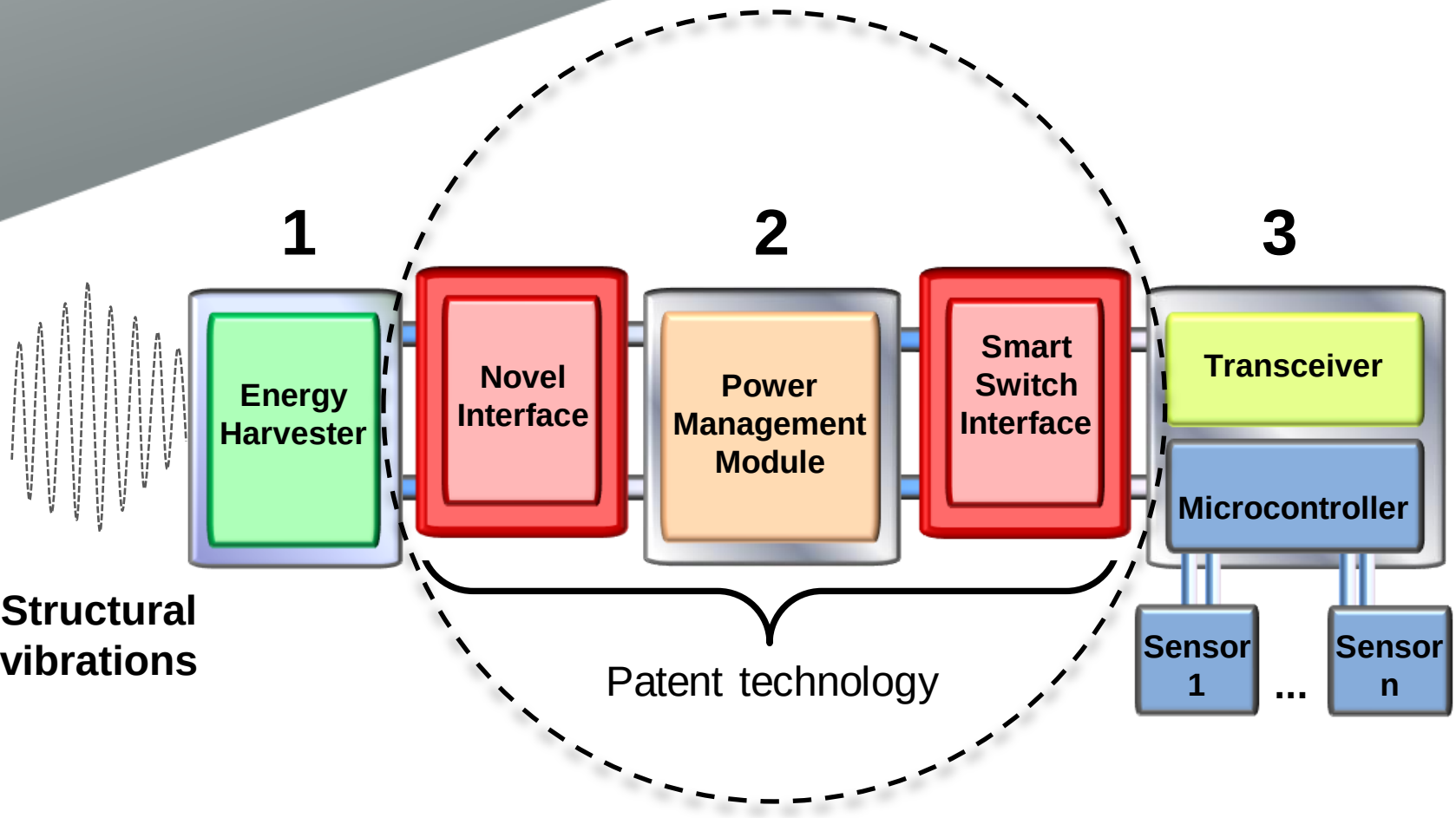
My EH Research Group at Cranfield

- Started EH research in 2007
- Established the EH Group in 2009
- Completed 5 EH projects from EPSRC/IMRC/IMRC and industry
- 3 Current projects form EPSRC and FP-7, around £650K
- 1 project awarded from EPSRC, around £815K
- Current group size and growth:
  - 2 RAs
  - 4 PhD students
  - Will recruit 3 RAs and 1PhD in 2013

Research Areas



- Multidisciplinary research
- Integrated system approach (1+2+3)
- A patented energy-aware configuration
- Achieved battery-free wireless sensing system

Research Activities

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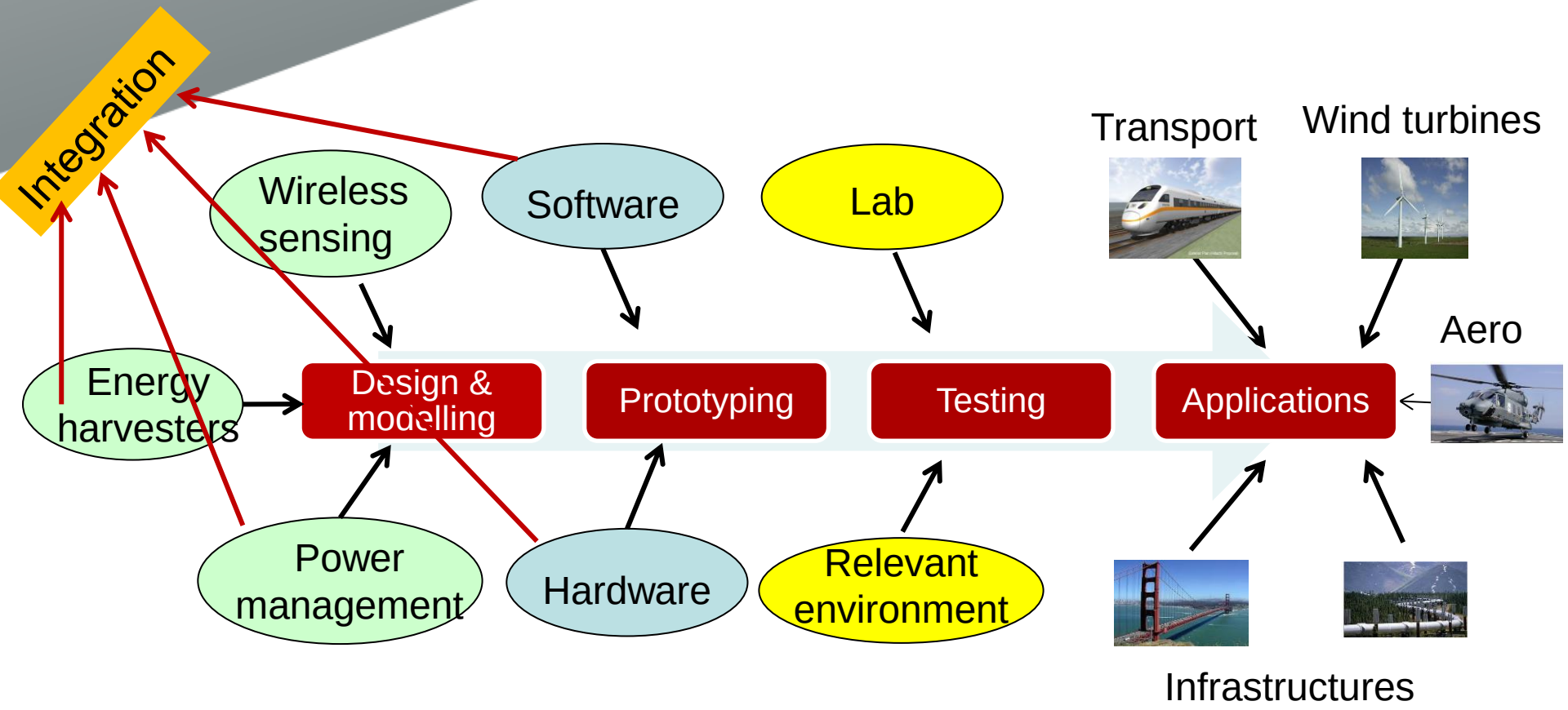
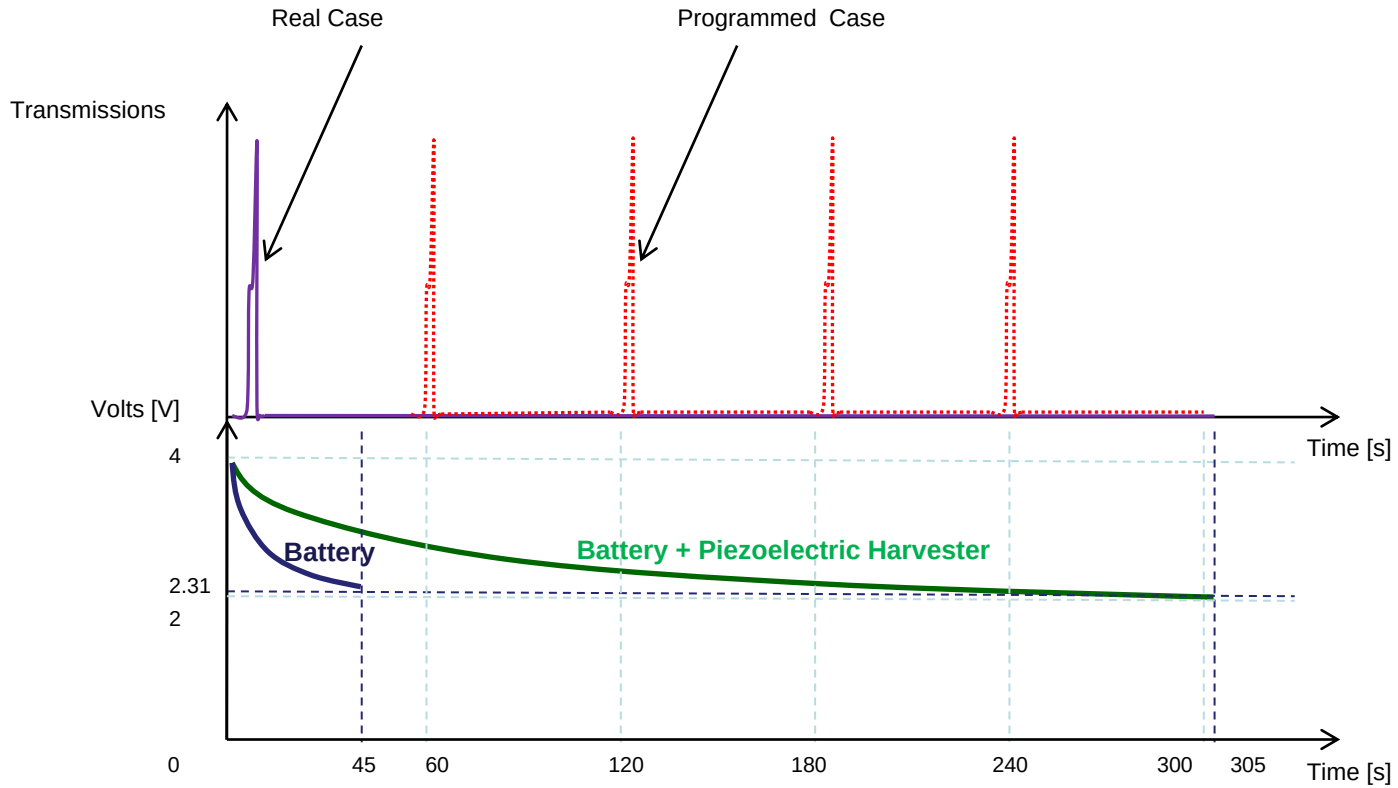


- Established internal and external (UK, EU and international) collaborations
- Working closely with industries, governments and research funding bodies

Problems we faced



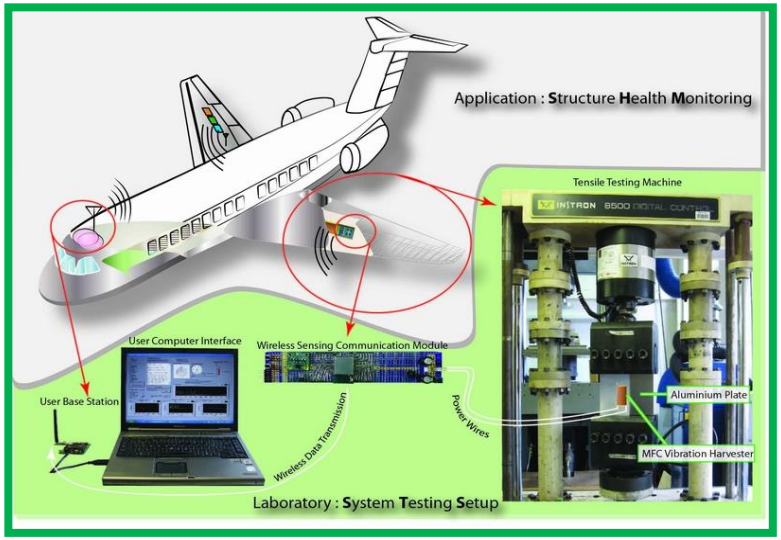
Voltage discharge curve and transmissions for a commercial wireless sensor module tested

Current Research Focus

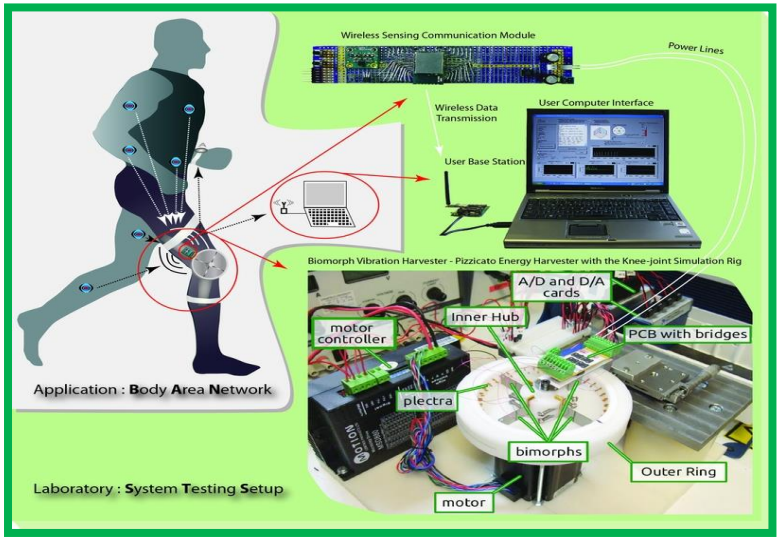
- **Increase** power harvested, through design, modelling and optimisation, and experimental validation, for generation of **significantly usable power for applications**
- **Decrease** power consumptions of wireless sensors, through integrated hardware and software approaches
- **Integrate** the system as a whole, through **smart energy-aware architecture** (patent pending), to deal with mismatch between energy harvested and energy demanded by the end of users

Aim: make the system work at high performance for applications

Two technology demonstrators developed



Strain EH powered WCS for aircraft structural health monitoring



Wearable EH

Harvesting aircraft wing strain energy

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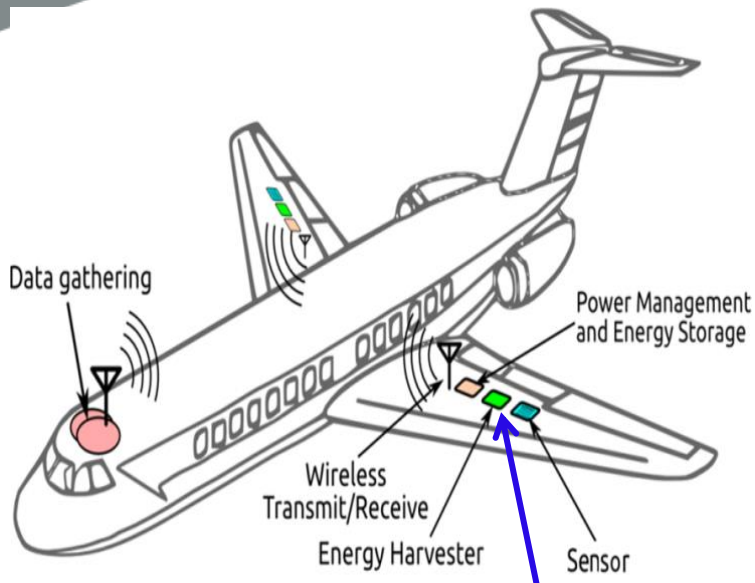
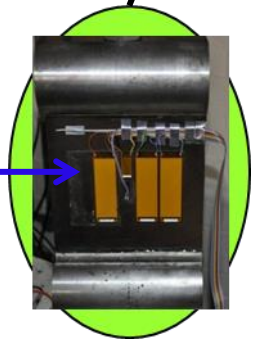
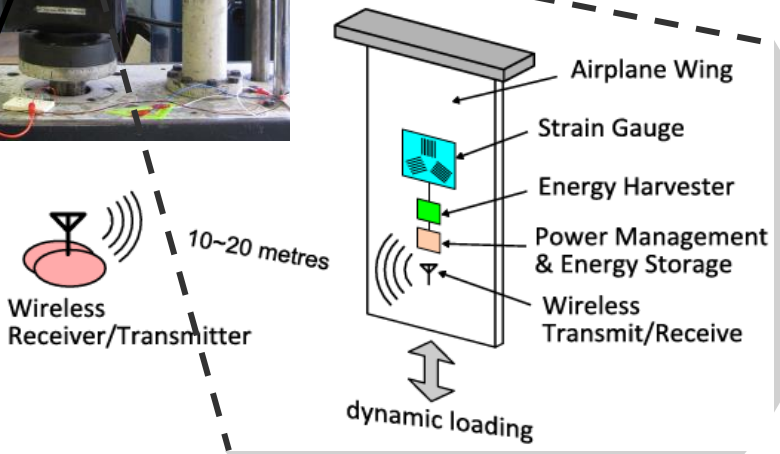


Piezo-fibre composite energy harvester



Real Scenario



Lab testing setup

Real flight scenario

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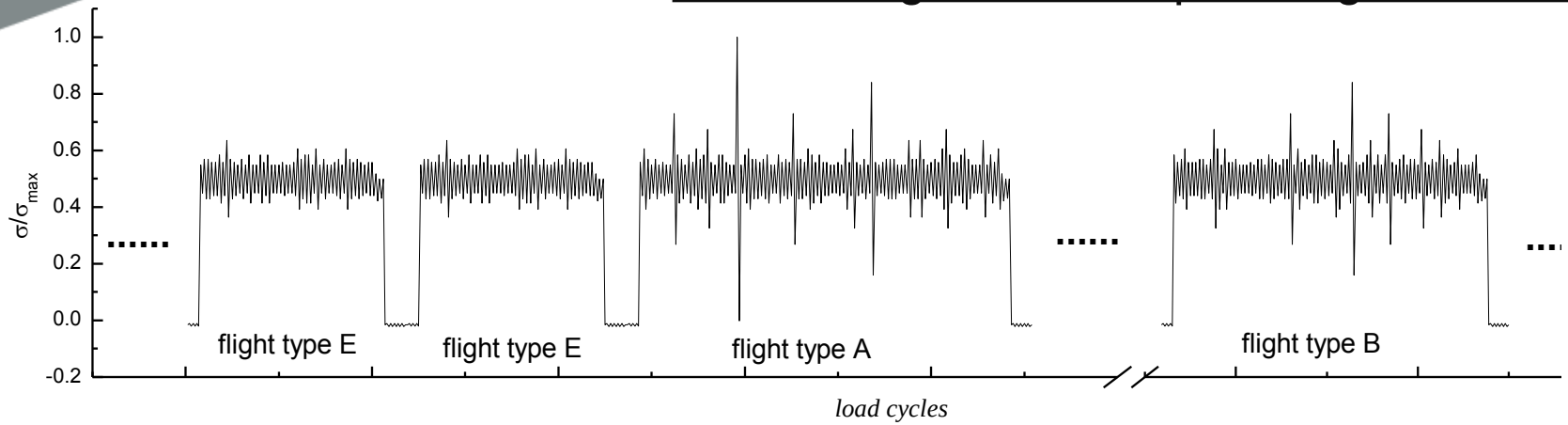
Lower wing cover of a passenger aircraft

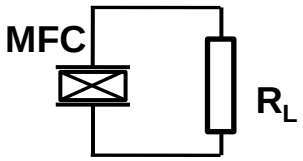


Energy harvesting challenges even more complex...

- *Frequency* range ~0.5-10Hz
- Normal conditions: *stress* ~80-85MPa

  strain ~$1.2*10^{-3}$

Power harvested at different frequencies



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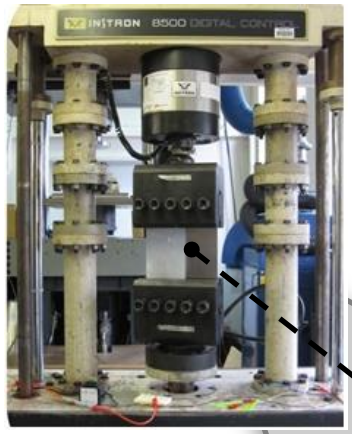
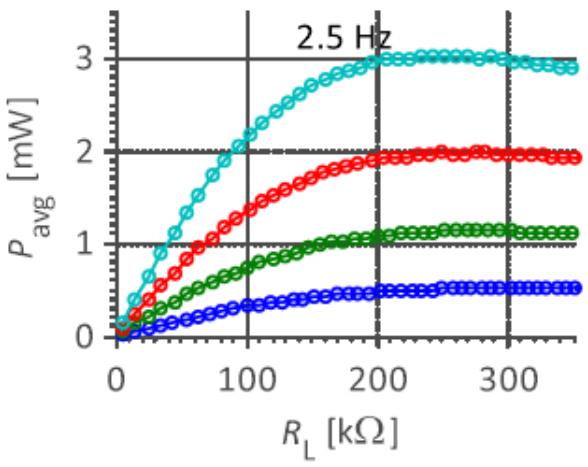


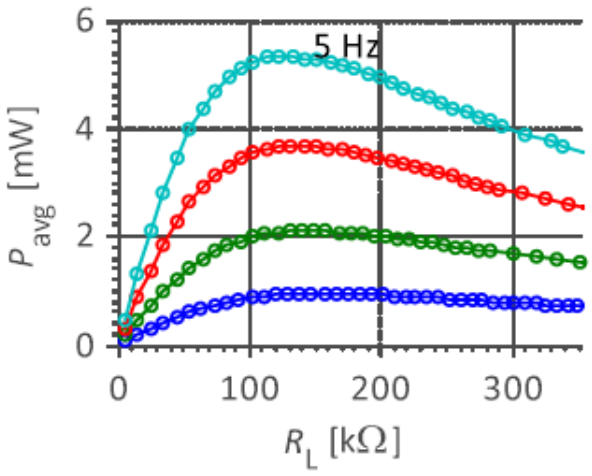
Instron machine

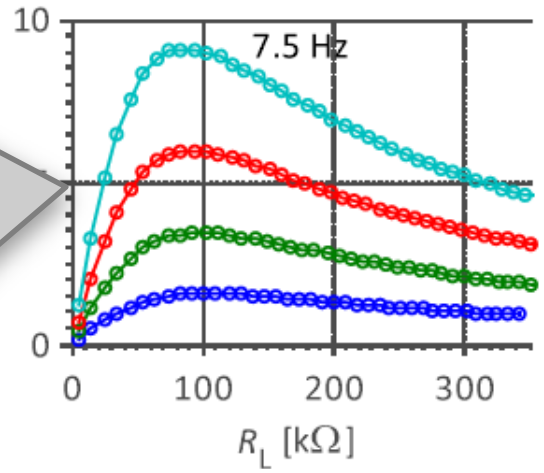
Aluminium

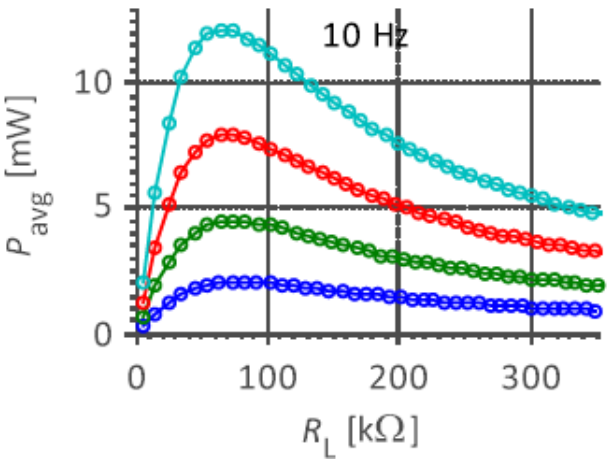
Y=70GPa

ρ=2.7g/cm^3









228 με, 342 με, 456 με and **570 με**

Proof-of Concept System Implementation

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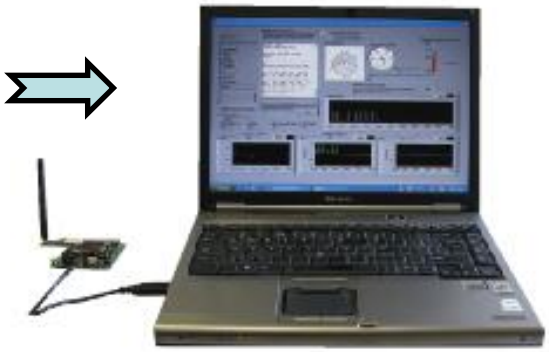

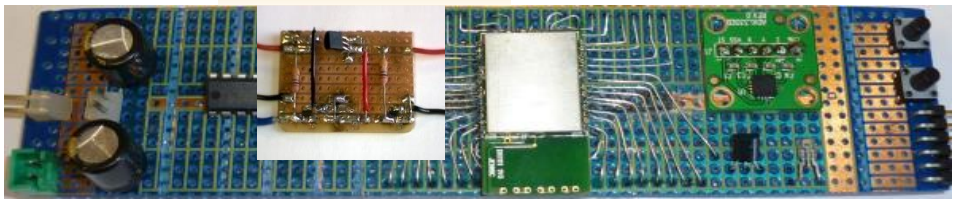

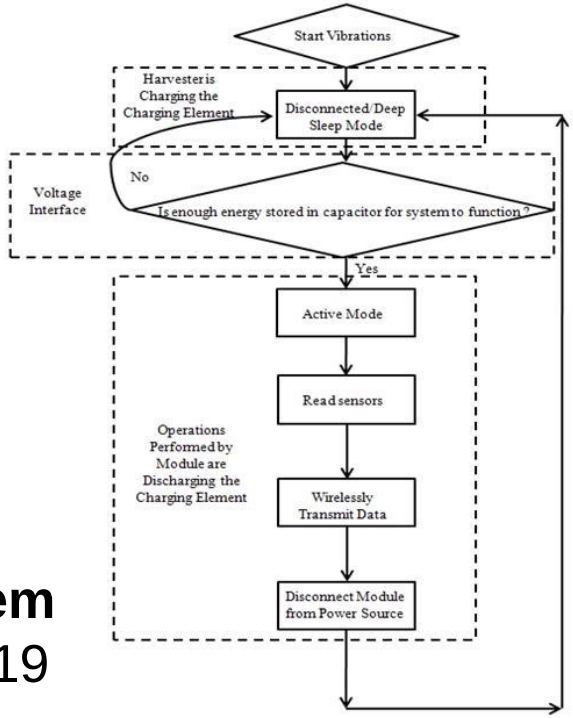

3 characteristics of the wireless sensing system

- Low power consumption in sleeping modes: 1.19 µA
- Smart energy-aware for energy flow management
- Multi-sensors

Testing results

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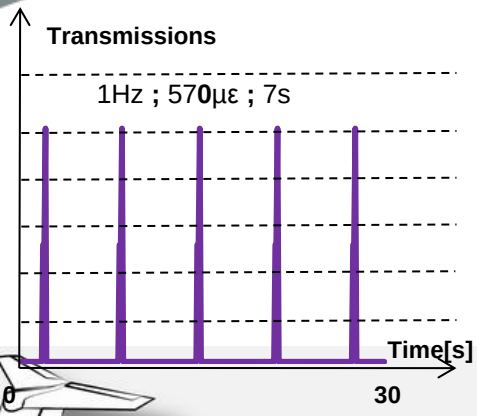
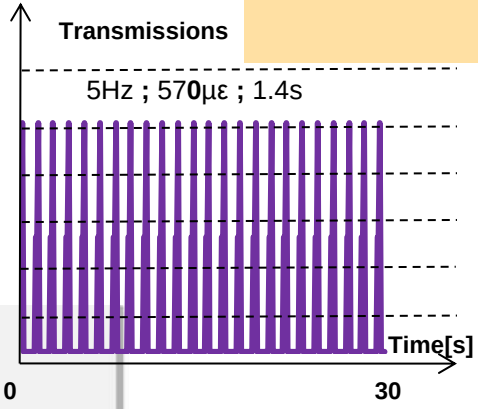
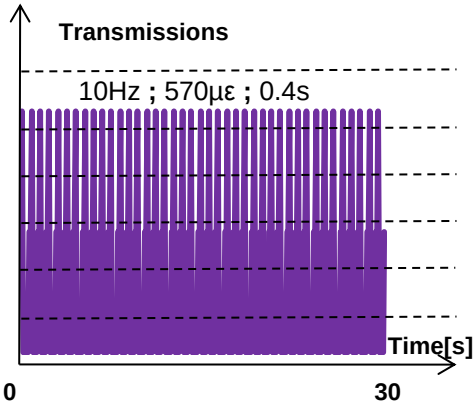
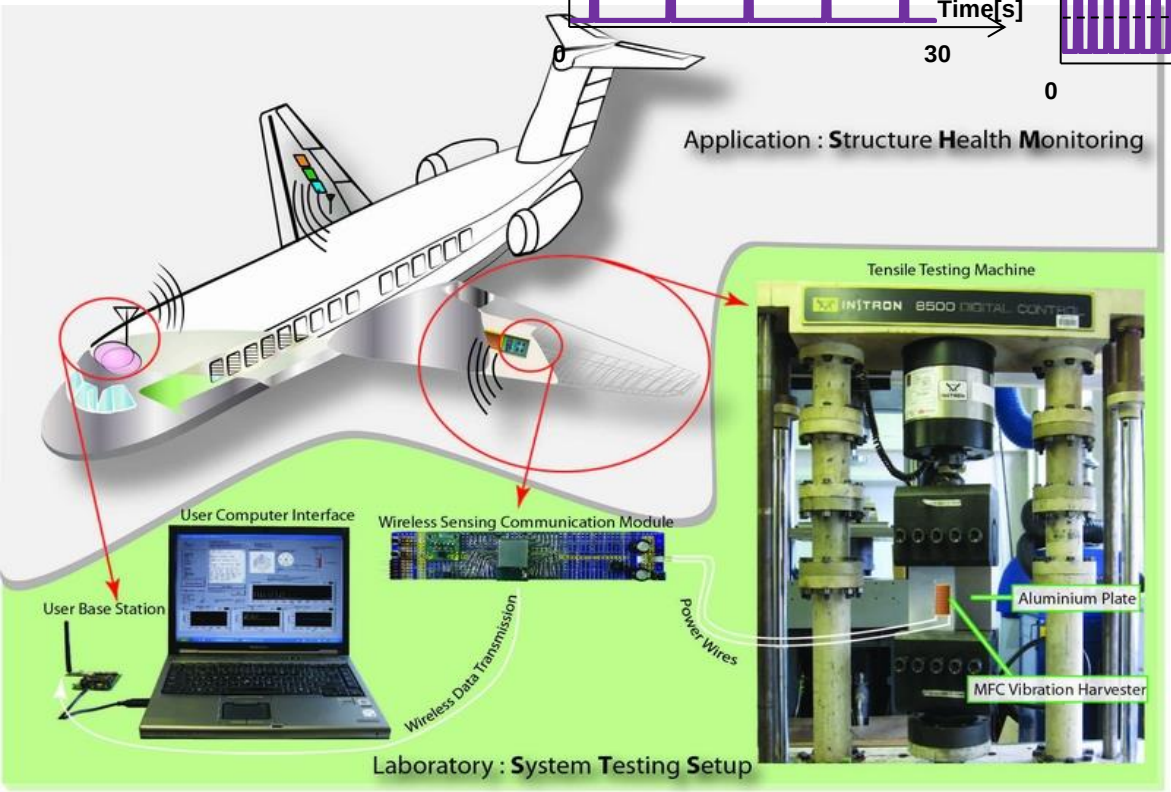
Increased capability to continue powering









Wearable EH for Battery-free Soldiers

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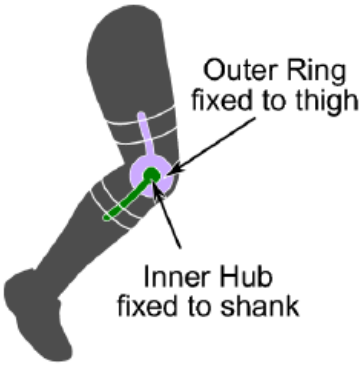
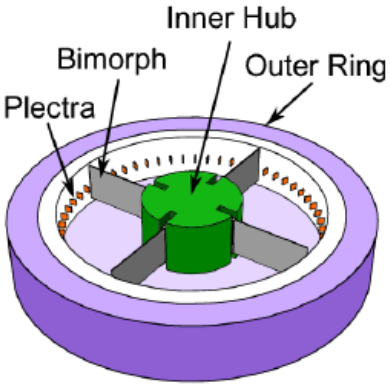
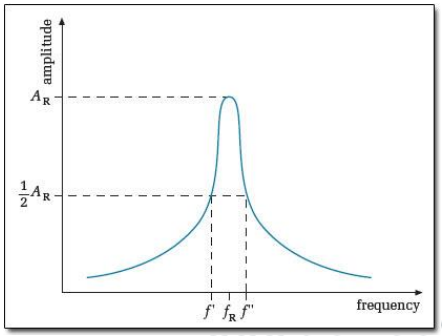
Generation of electricity from human movement that makes soldiers “battery-free”





Using harvesting mechanism of “Pizzicato” excitation to increase the efficiency of EHs for low frequency wide bandwidth operation

Collaboration with **DSTL** and 6 other Universities in the UK



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Modelling and Characterisation

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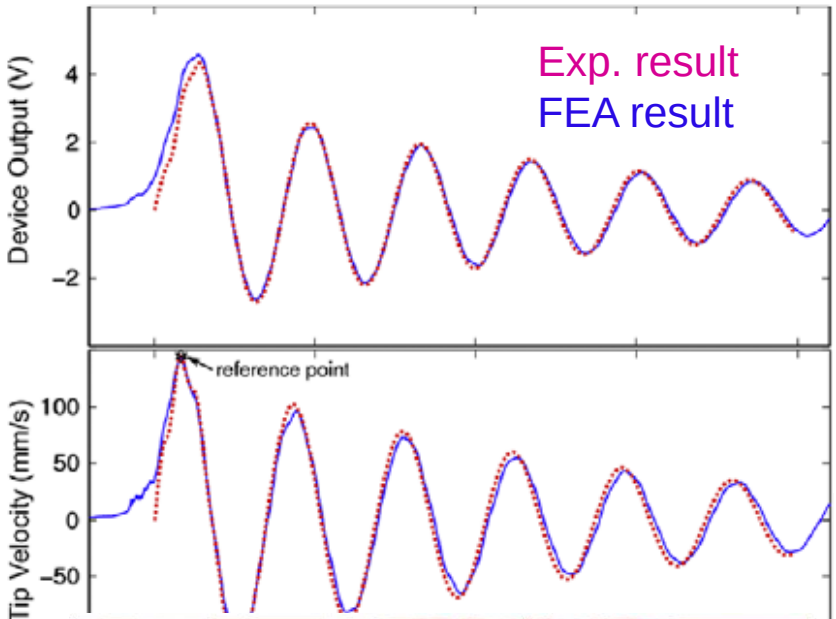
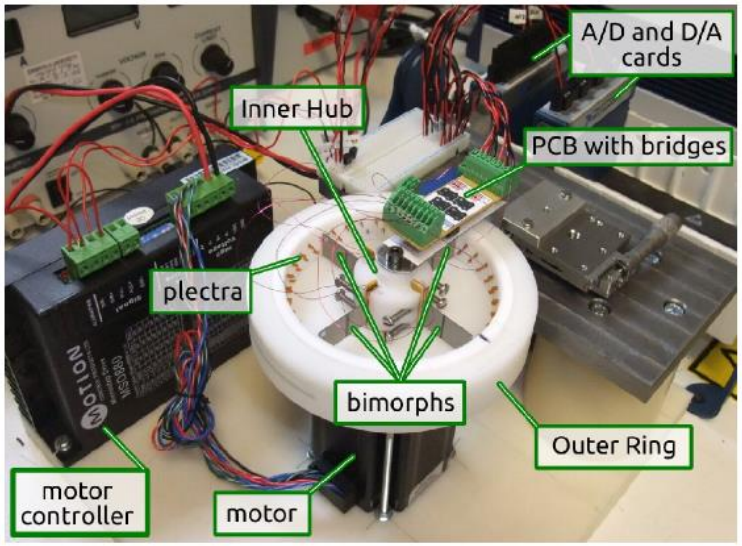
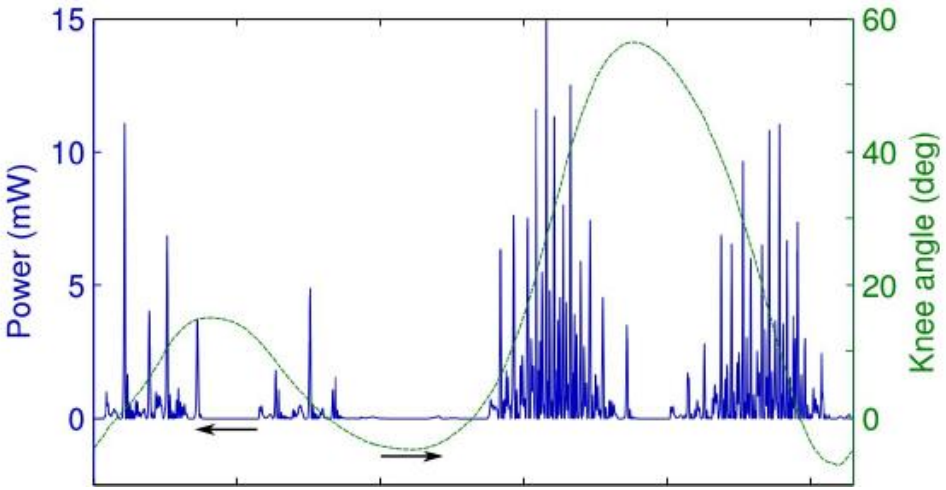
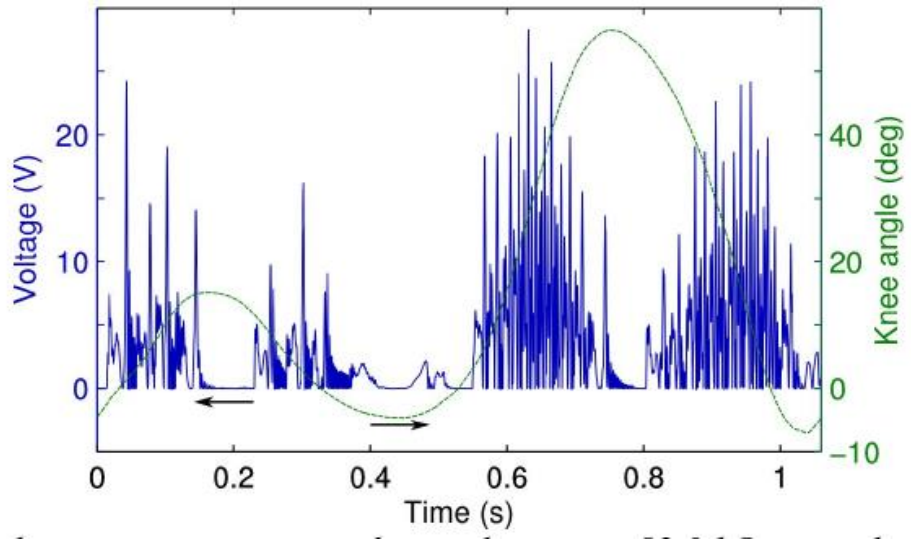
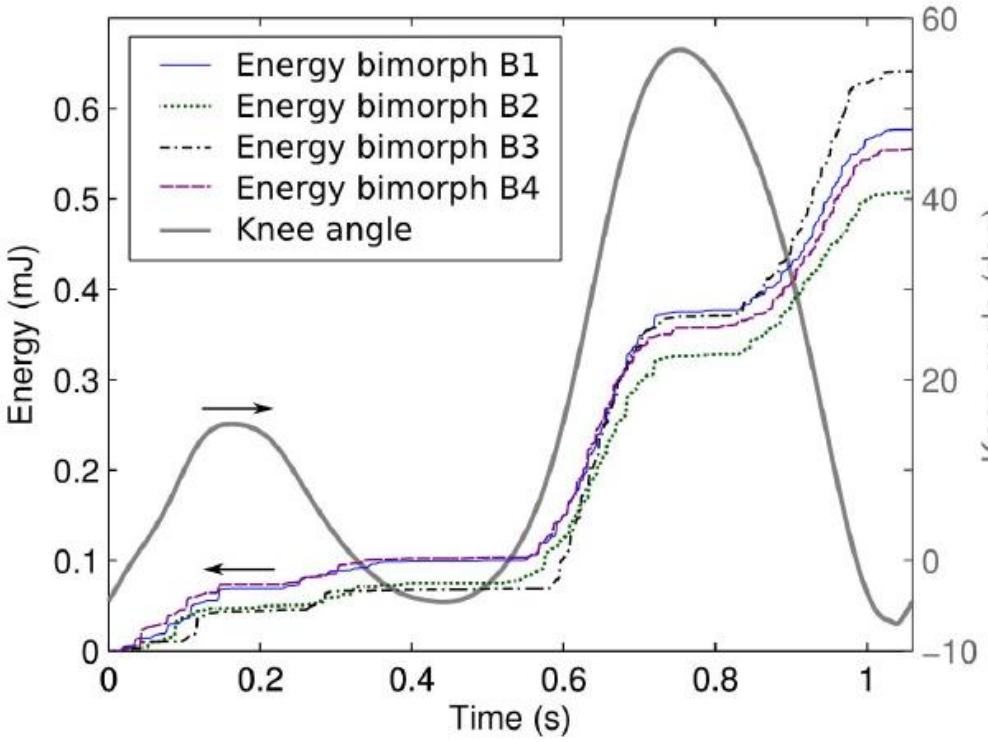


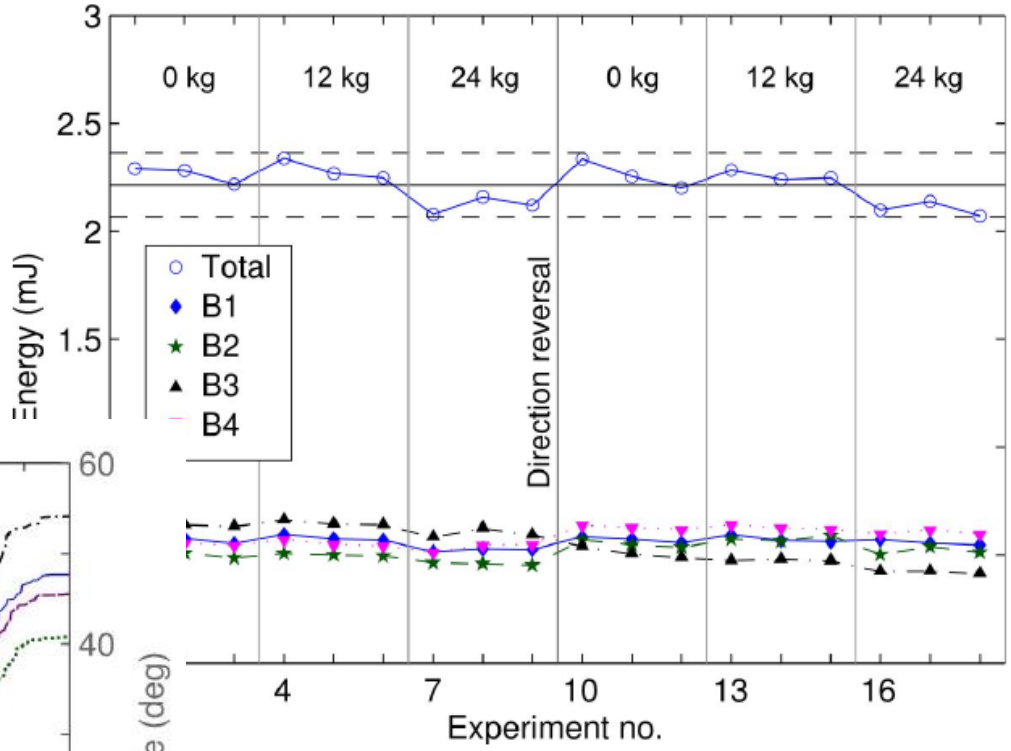




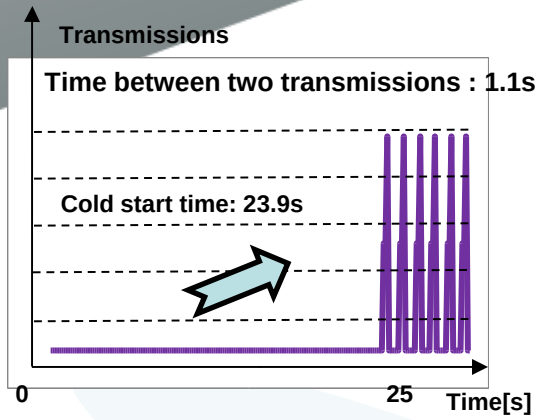


Energy harvested

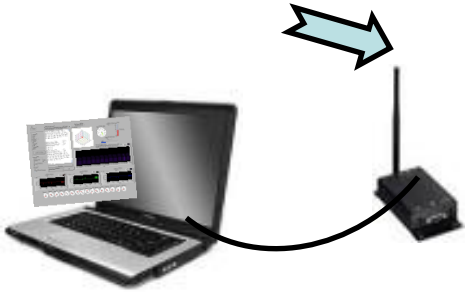


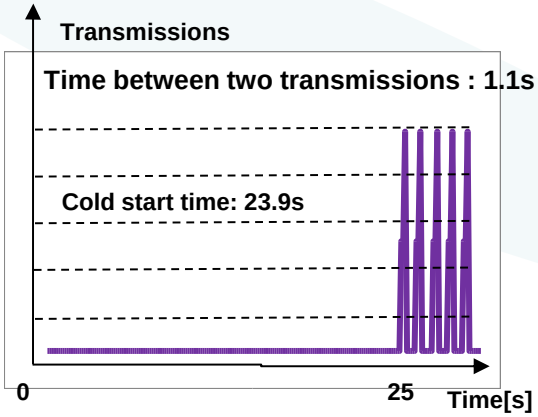


Autonomous sensing testing

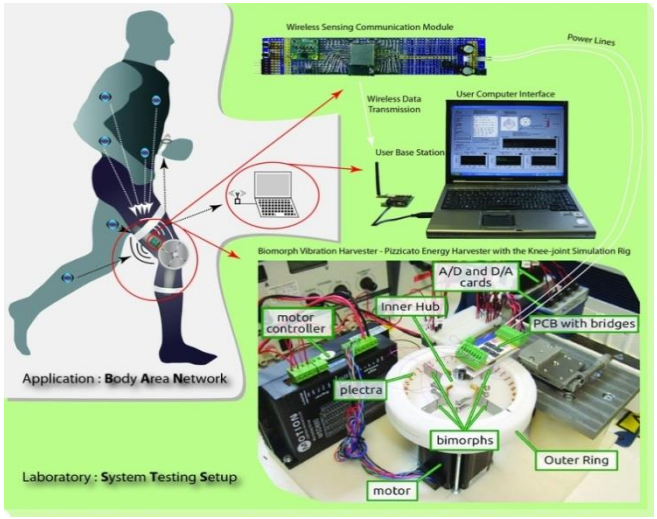


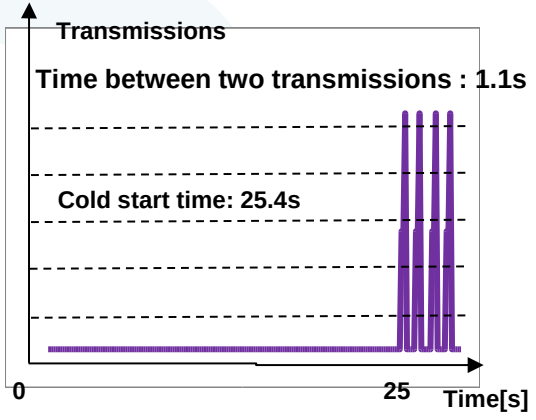
Subject carries no backpack





Subject carries 12-kg backpack





Subject carries 24-kg backpack

Demonstrator Performance

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Achieved system performance:

- Power harvested: 1.2-20mW at 1-10Hz and 230-570με for 20cm^2
- Capability to power wireless sensors continuously: 0.4-15 seconds
- Ultra-low current consumption in sleeping mode: 1.19μA
- Multi-sensors on-board:
  - 3-axis accelerometer,
  - temperature sensor
  - Light detector

EH Research Cluster in

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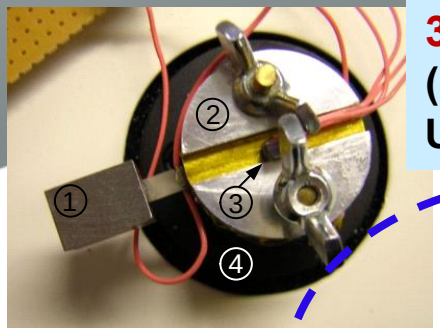
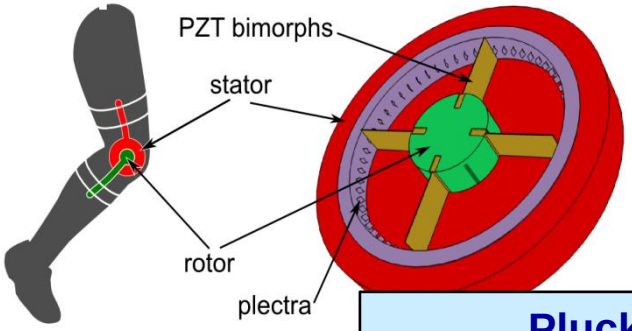
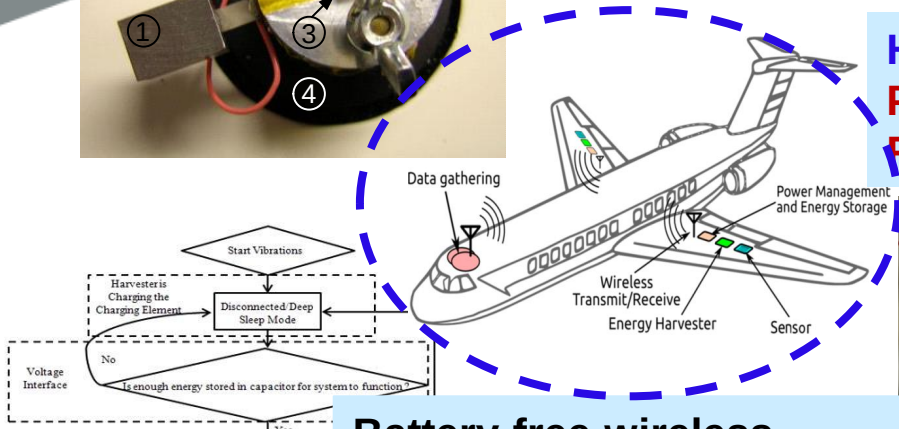


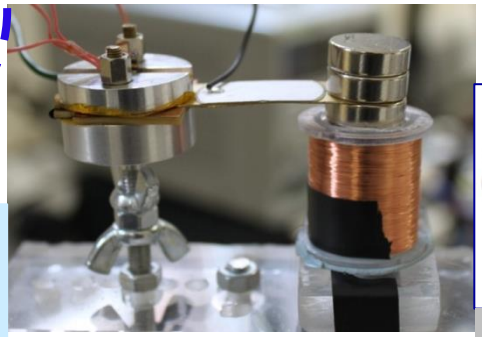
Piezo cantilever harvester:
375μW/cm³ at 87 Hz & 0.23g
(average at 200μW/cm³ in the UK and the EU)



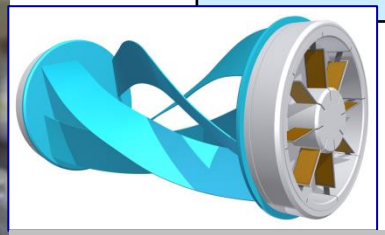
Plucked bimorph using pizzicato excitation for frequency-up-conversion



Hybrid: piezo/electromagnetic
Power increased at least 100%
Frequency tuneable



Battery-free wireless sensor demonstrator
One of the best in the world



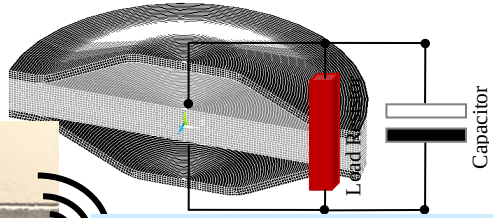
Wind energy harvester on-going

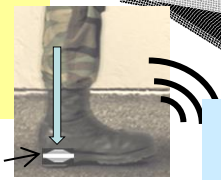
Hardware

Software

Communication

Coupled piezoelectric-circuit finite element analysis (CPC-FEA)
The first published FEA work in the world using ANSYS to analyze power output





Embedded in shoes harvester

Battery-free Wireless sensors