# Energy Harvesting for Structural Health Monitoring

**Professor KM Holford, Dr CA Featherston, Dr R Pullin, Dr MJ Eaton, Dr A Centeno* and MR Pearson**

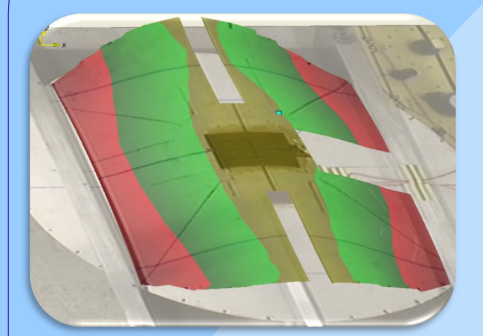
**Cardiff School of Engineering, *Imperial College London**

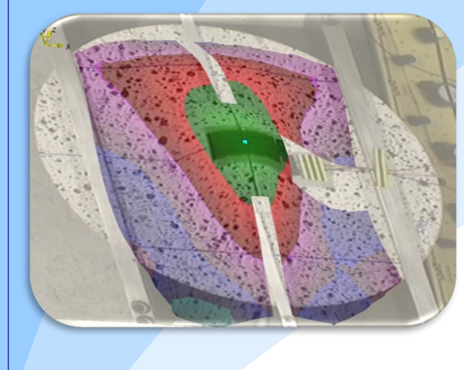
## Research Background

Recent research into embedded sensors, damage detection methodologies, wireless data transmission and energy harvesting in aerospace environments has meant that autonomous structural health monitoring (SHM) systems are becoming a real possibility for both commercial and military applications. SHM systems enable the early detection of the deterioration of a structure and if appropriately applied could make an estimate of damage severity and therefore remaining life. The benefits would include improved safety and reliability, lower maintenance costs and more optimised structures which in turn would increase aircraft performance and lower costs. However providing power for a full coverage active and passive SHM system is one of the potential problems in the uptake of such a system. One solution is to harvest energy from ambient sources such as vibrations and thermal gradients. However these power sources are both dynamic and varying in nature which necessitates a power management system to provide a stable power source for a system. Furthermore due to the low levels of power such a power management system needs to be efficient and use a small amount of power itself. This is especially important when combining different energy sources which have different electrical properties and operating conditions.

This poster reports on research conducted at Cardiff University and Imperial College into developing the use of energy harvested from both vibrations and thermal gradients with a combined power management system.

## Vibration Energy Harvesting

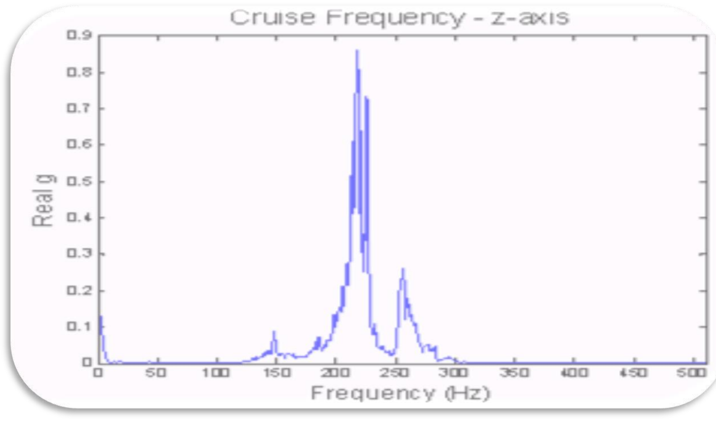


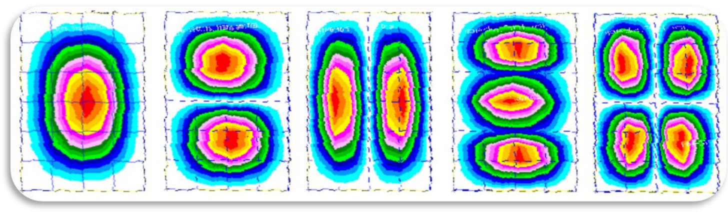


MIDE Quickpak devices were evaluated for the use as vibration energy harvesters. The power output was determined at matched load for vibration frequencies between 20-300Hz. A bespoke test rig was developed to promote curvature in one dimension, this enabled the a relationship between the power output, orientation, geometry and curvature to be established. Utilising a scanning laser vibrometer it was possible to determine the displacement of the panel for all frequencies.

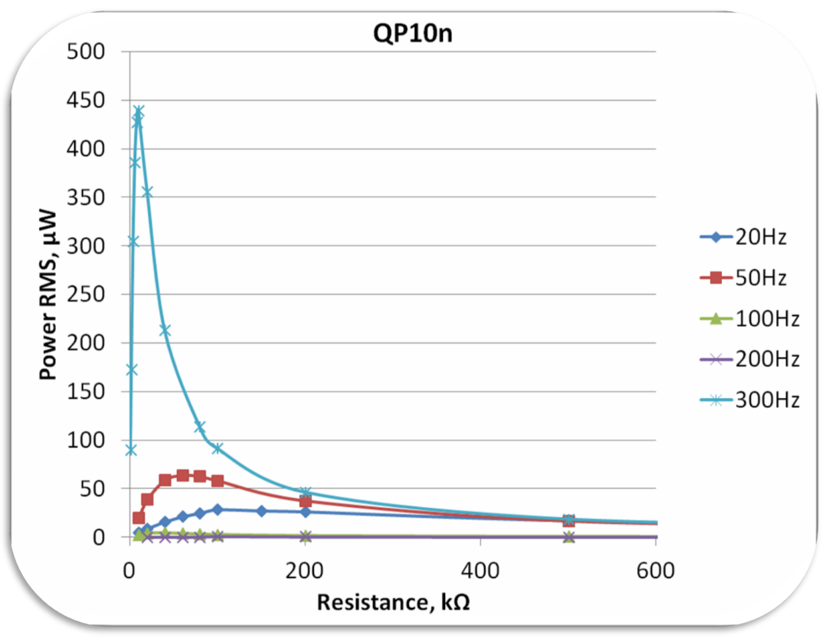
### Optimisation Programme

An optimisation programme has been developed to allow the best position of harvesters to be identified to ensure maximum output. The process utilises real aircraft data, mode shapes and an accumulated strain analysis to locate the optimum position of a harvester for a given geometry.



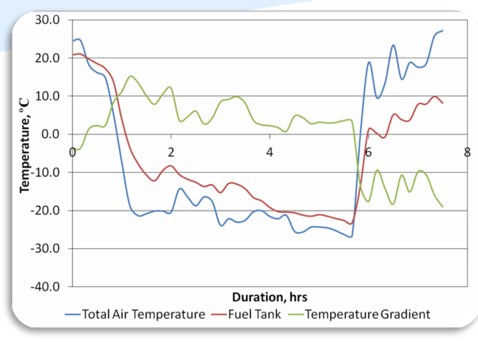



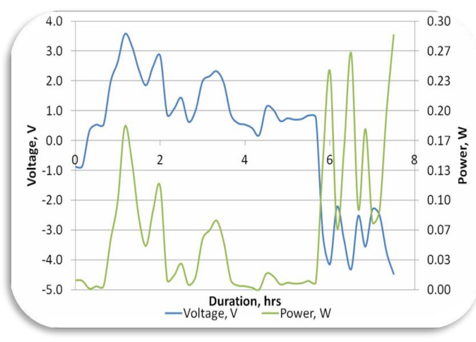
### Vibration Energy Harvesting Output




Results of vibration testing demonstrated that the energy harvested was heavily dependent on position, orientation and the geometry of the device. RMS power levels showed the potential to generate between 4-500µW depending on the frequency.

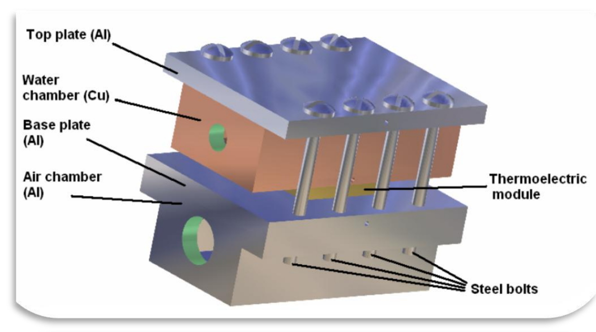
## Thermoelectric Energy Harvesting

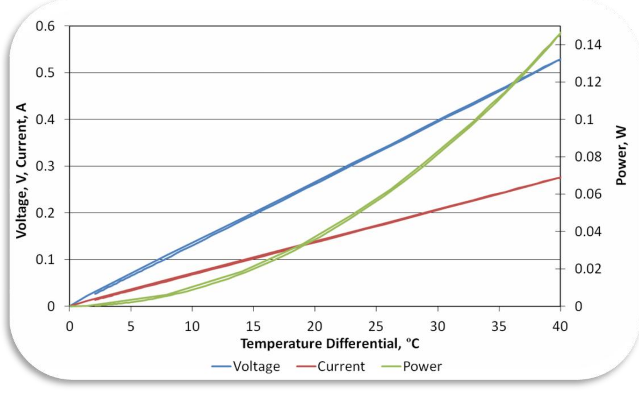



The power output of thin film high tech TEG's (MPG-D751) manufactured by Micropelt was evaluated using the "mypelt simulation tool". A system of 51 devices was configured to provide adequate power for a 4 channel wireless AE system utilising the temperature gradient that exits between the fuel tank and the outer wing skin on an aircraft. The analysis showed that for this system a peak power of 285mW could be generated and the average power over the flight period was 68mW.

### Thermoelectric Energy Harvesting Test Apparatus

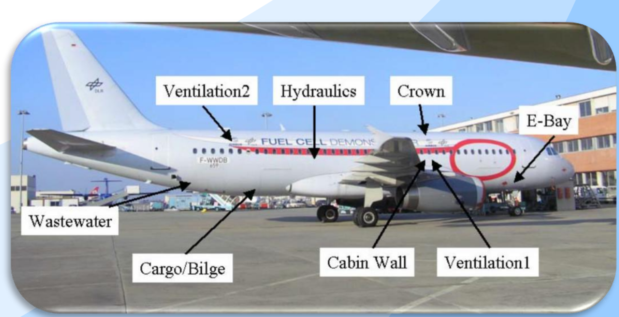



A test rig was developed to provide a representation of the temperature differential that exists between the fuel tank and outer wing skin. Cold air supplied by a vortex tube and a cold water supply are used to generate temperature differences of up to 40°C for testing the power output and efficiency of devices and for validation of the modelling. Utilising this apparatus average power levels of 50mW were generated.

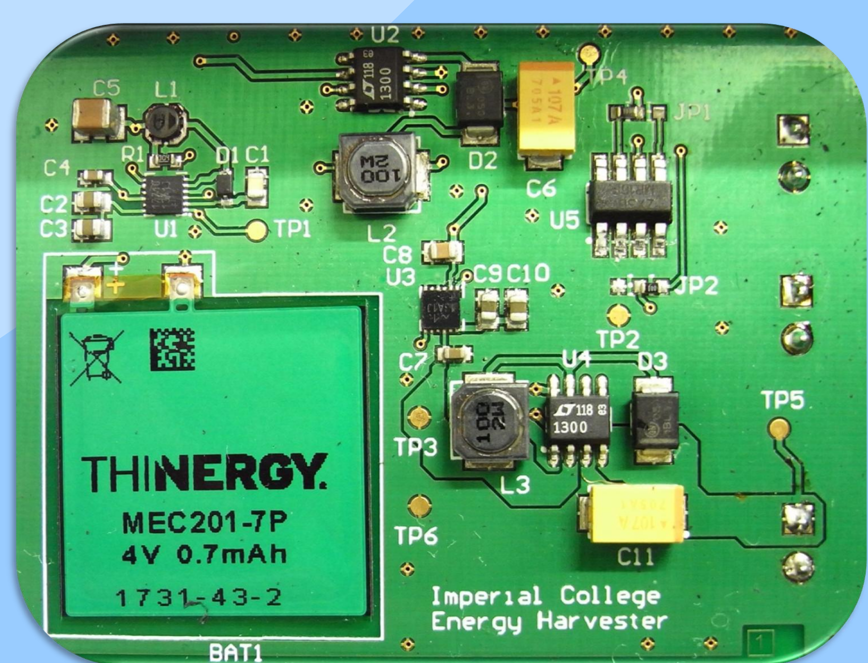
### Thermoelectric Energy Harvesting Potential

Utilising the above simulation tool further analysis of temperature scenarios from various locations on an aircraft for various flights was conducted to show potential power levels. Depending on location the average power levels over a flight period of 0.15-1.15W could be generated.




## Combined Power Management Solution

Due to varying nature of the harvesting techniques it is necessary to have a power management system , further research at Imperial College has enabled a combined power management system to be developed utilising commercial available components . The power management module consists of two separate stages. The first stage is used to charge a solid state cell (MEC200 cell) for DC input voltages below 1V, where a power management IC (MAX17710) is configured for boost regulator operation. The output of this stage is regulated to 3.3V and then stepped up to 5V using DC/DC converter (LT1300). The second stage is for high voltage inputs where a second power management IC (MAX17710) is configured for charge regulation. This stage accepts high voltage (>4V) AC and DC inputs, including the output from piezo electric elements and the first stage 5V DC output, to charge a second MEC200 cell. The output from the second stage is regulated to 3.3V and is then up-converted to 5 V using a LT1300.

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**Cardiff School of Engineering**

Cardiff University, Queen's Buildings, The Parade, Cardiff, CF24 3AA

Pearsonmr@cardiff.ac.uk

http://www.engineering.cf.ac.uk/