

'Innovation in Construction' ICE  
11<sup>th</sup> January 2012



## Centre for Smart Infrastructure and Construction

Developments in sensor technologies and data  
management tools for construction

Kenichi Soga  
Professor of Civil Engineering



### Innovative sensor monitoring and assessment projects at Cambridge



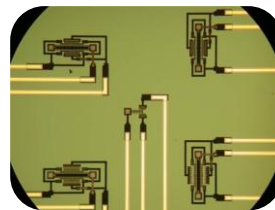
Fibre optics distributed sensors



Wireless sensor network



Computer vision



Micro-Electro-Mechanical Systems  
and Power harvesting

# Fibre optics sensing

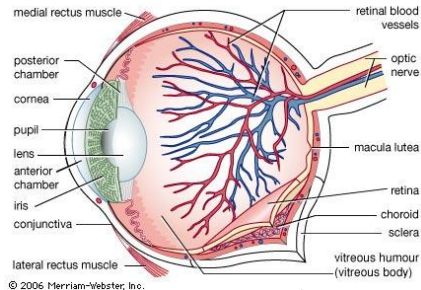
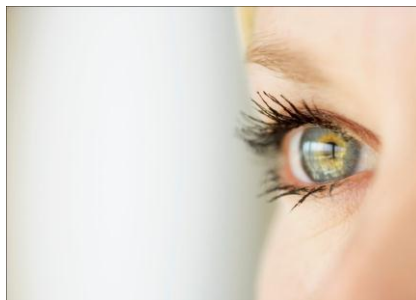
The diagram illustrates the principle of Brillouin Optical Time Domain Reflectometry (BOTDR). An optical pulse input is sent into a fibre optic cable. As the pulse travels, it interacts with the fibre's strain, causing a shift in the Brillouin scattered light. This shift is detected by a BOTDR analyser. A graph shows scattered light power versus distance ( $Z_1, Z_2$ ) and light frequency ( $\nu_{B1}, \nu_{B2}$ ), with strain indicated by arrows. A photograph shows workers in orange safety gear at a construction site with rebar, where fibre optic sensors are likely being used for strain monitoring.

The frequency shift of the Brillouin scattered light is proportional to the strain.

The anatomical diagram shows the human nervous system with labels for various parts: Brain, Cerebellum, Spinal cord, Brachial plexus, Muscularcutaneous nerve, Radial nerve, Median nerve, Iliohypogastric nerve, Genitofemoral nerve, Obturator nerve, Ulnar nerve, Intercostal nerves, Subcostal nerve, Lumbar plexus, Sacral plexus, Femoral nerve, Pudendal nerve, Sciatic nerve, Muscular branches of femoral nerve, Saphenous nerve, Tibial nerve, Common peroneal nerve, Deep peroneal nerve, and Superficial peroneal nerve.

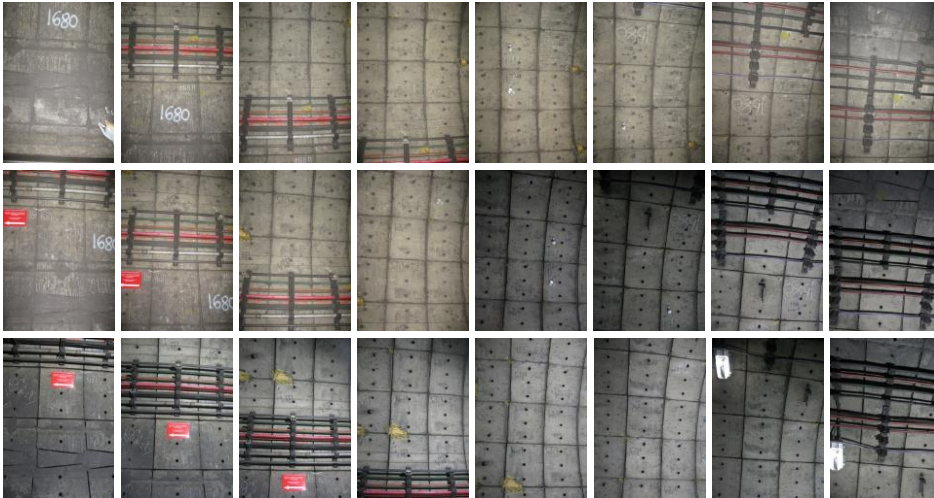
en.wikibooks.org

# Computer vision



www.britannica.com

## Motivation



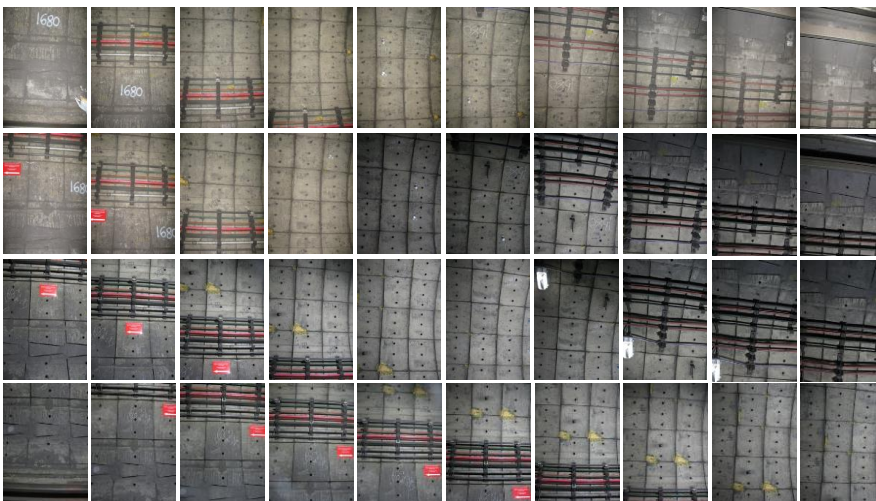
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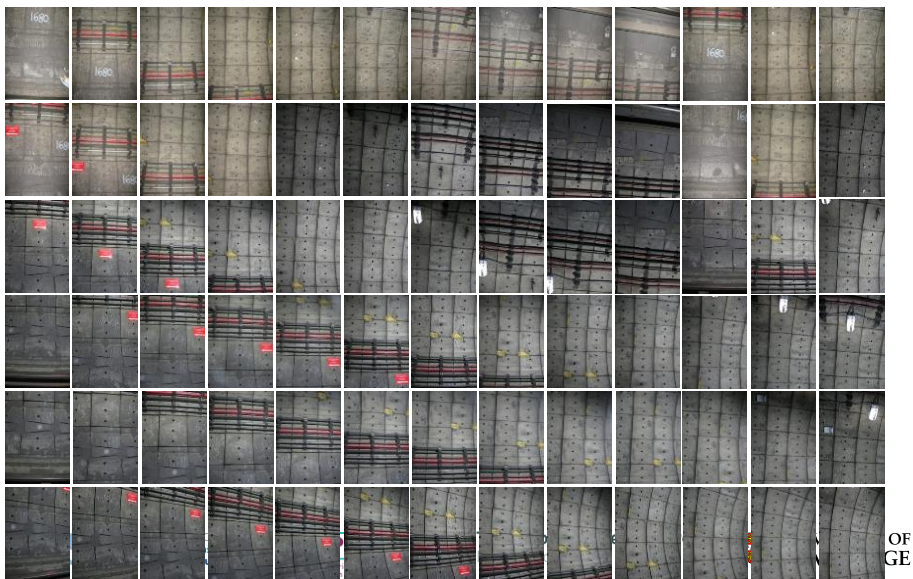
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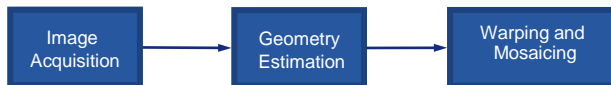
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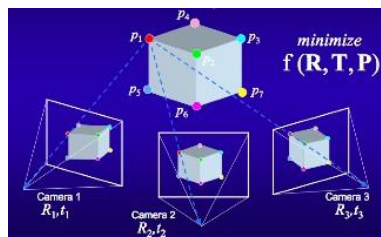


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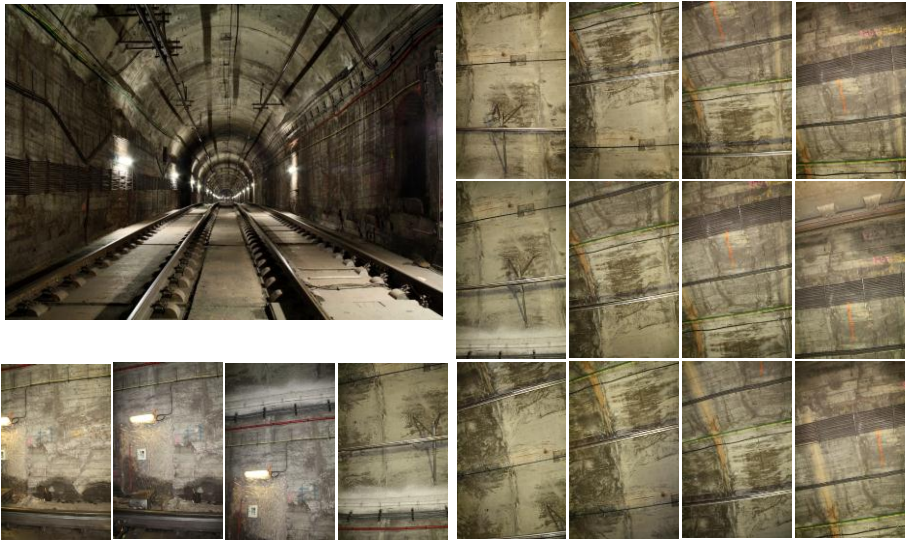
## System Pipeline



Picture from "Modeling the world from Internet Photo Collections", Snavely(2007)



Sagrada Familia Station



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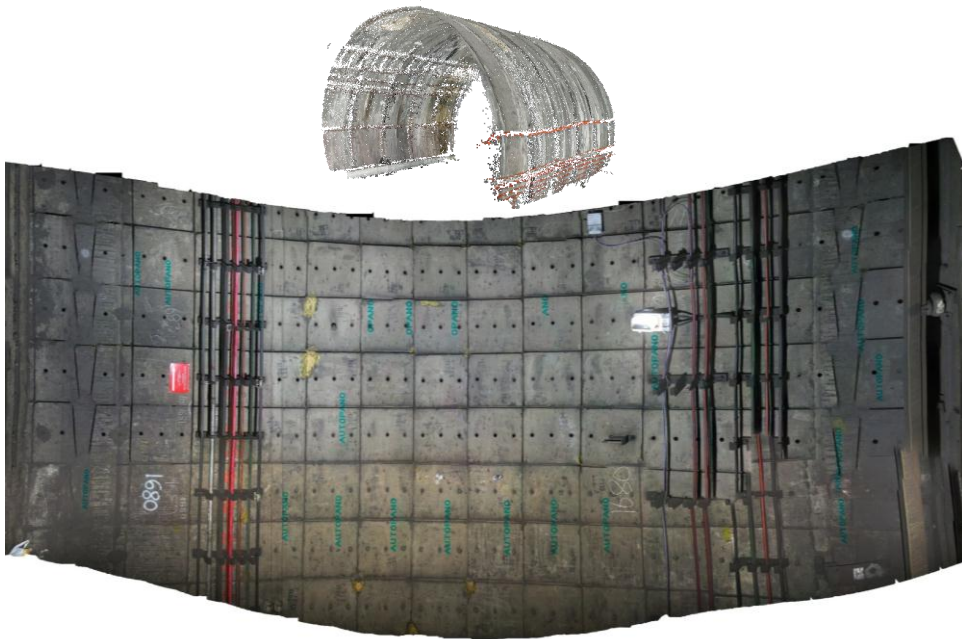
Barcelona Metro

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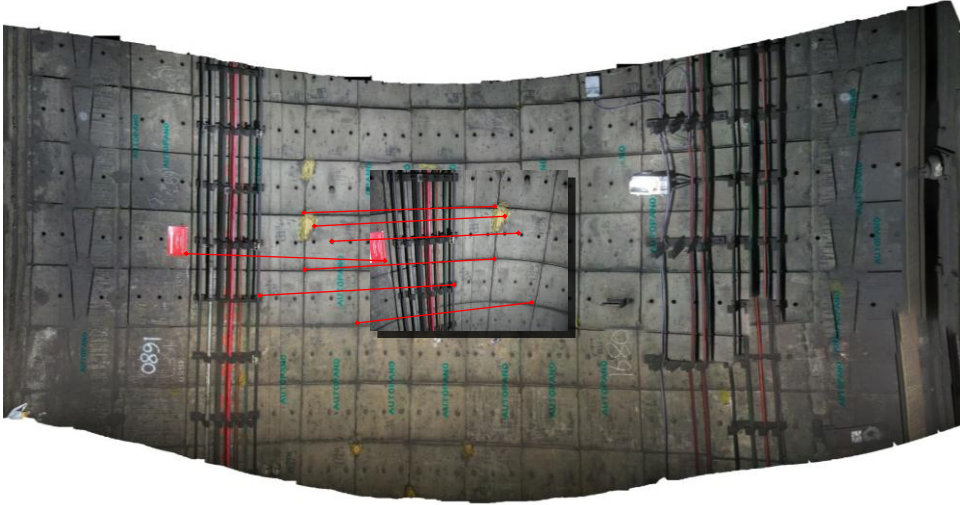
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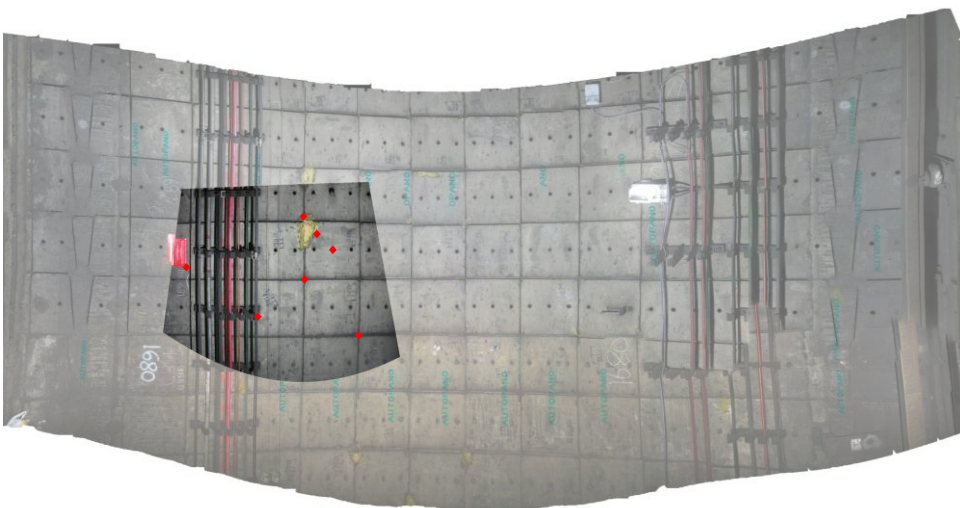
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# Challenges and Opportunities

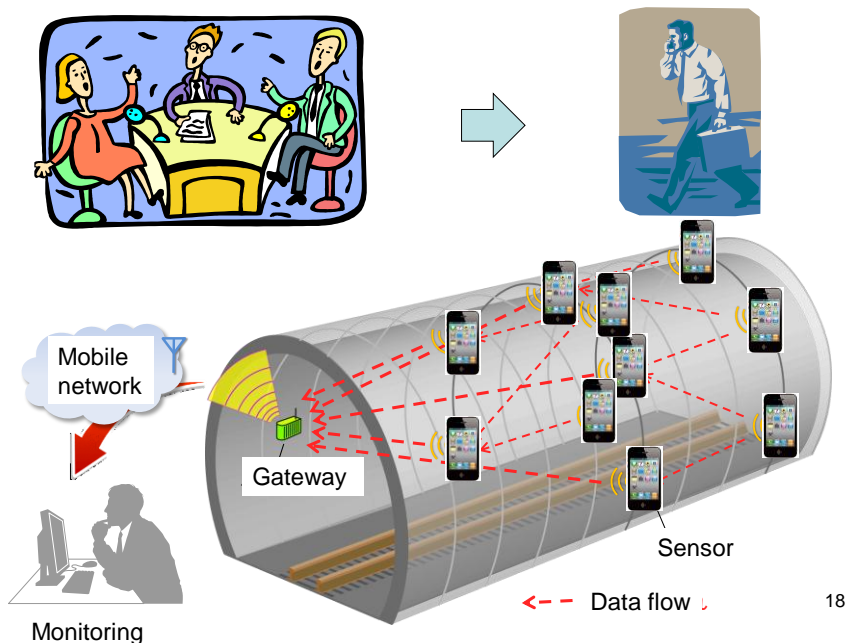
## 3D reconstruction and registration

- Record of construction and maintenance details
- Link to Building Information Modelling for existing and new infrastructure

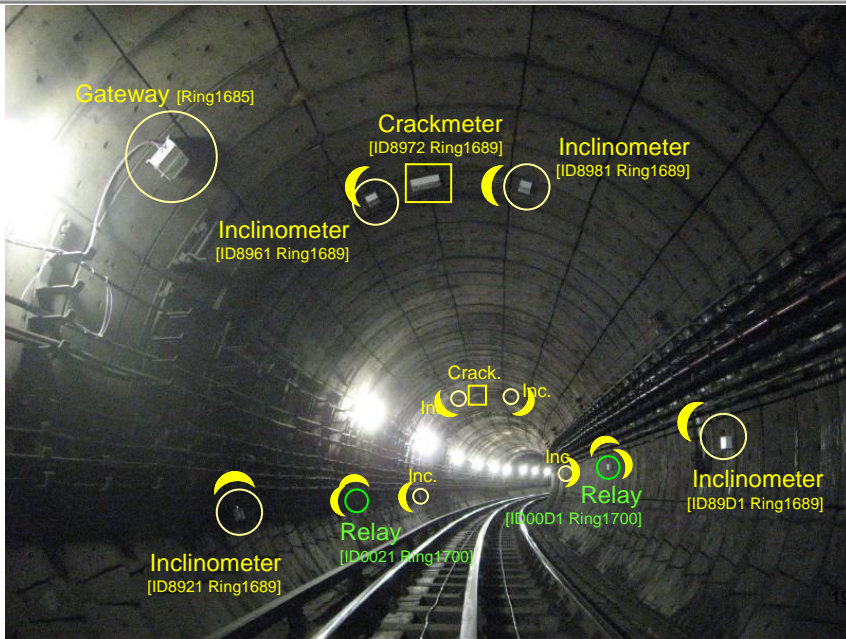
## Change detection for monitoring

- Changes in appearance and deterioration
- Movements and crack developments

## Wireless sensor network



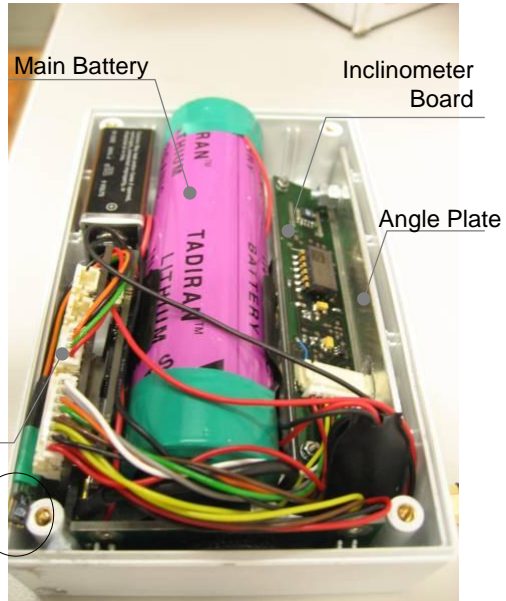
## Sensor Locations



## Inclinometer

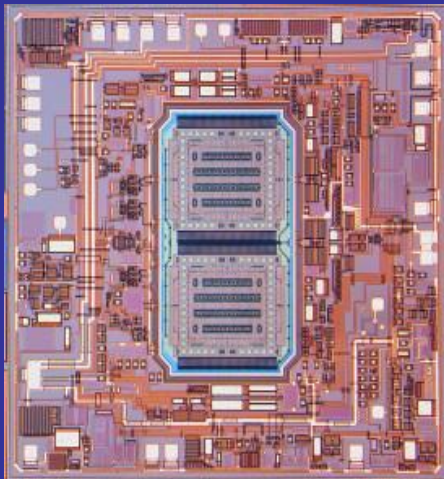


Resolution 0.001°  
 Range  $\pm 15^\circ$   
 External 16 bit ADC

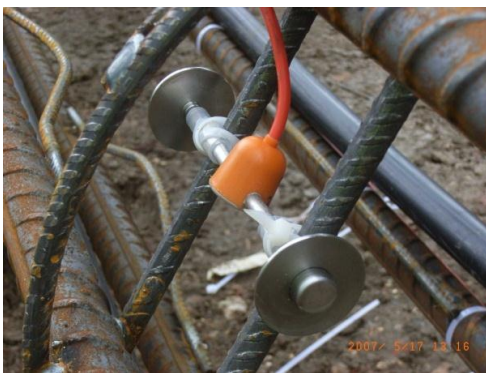


Temperature & Humidity sensor

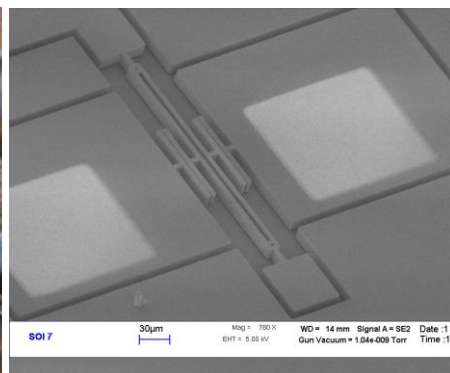
# MicroElectroMechanical Systems



- Leverage complexity in mechanics *and* electronics

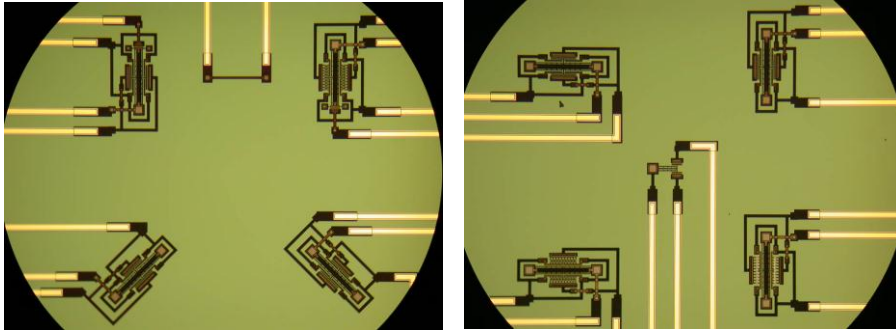


Conventional vibrating wire strain gauge  
1-10 $\mu\epsilon$  resolution

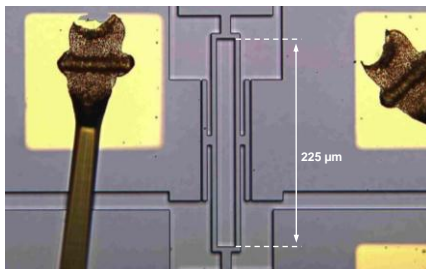
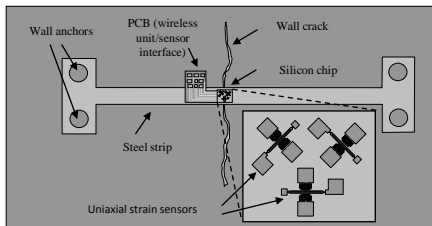
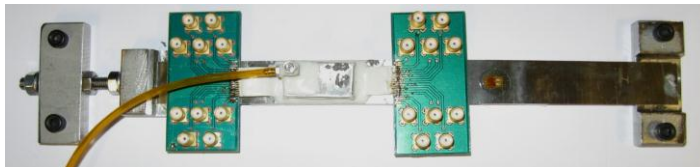


MEMS strain sensor  
1-10n $\epsilon$  resolution

## MEM Resonant Strain Gauge



Multiple sensors on one chip

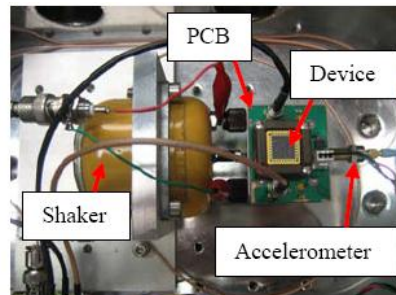
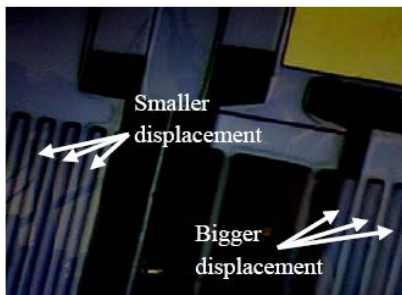
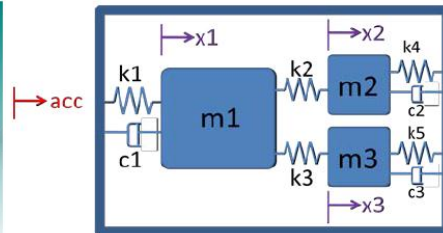
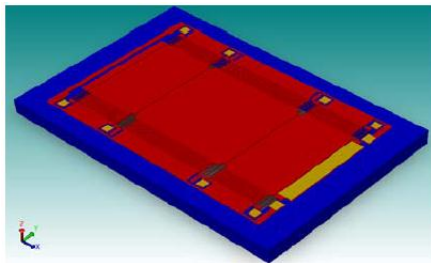


# Lower Power Sensing and Communication

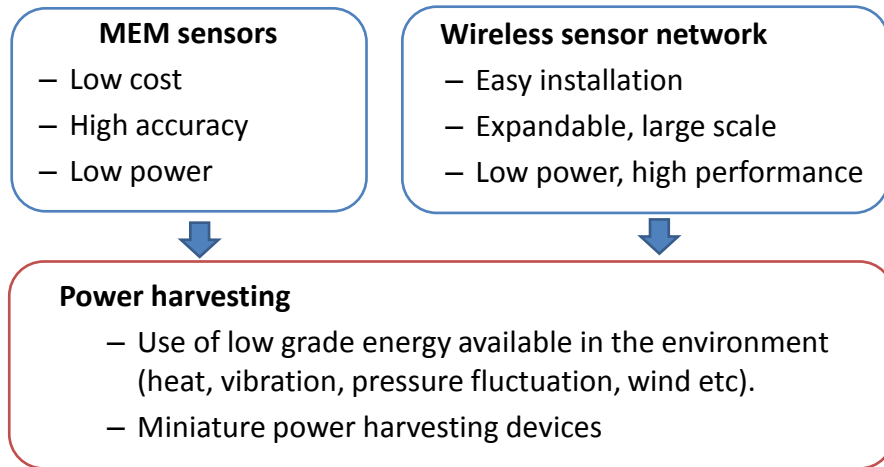
Laptop	10 W	  
Sensor board	1 W	
Ipod nano	100's mW	
Wireless communication	5-15 mW	
MEMS Sensor	1-10 $\mu$ W	
Electronic Watch	1 $\mu$ W	
Target : 10 mW		



## MEMS power harvester



## Challenges and Opportunities



Realisation of  
“Self-supporting embedded monitoring system”

## Proposed IKC projects - Sensors

- Highly distributed fibre optic sensors
- Computer vision for asset information modelling
- Robust wireless sensor network
- Low power, low cost MEM sensors
- Power harvesting for embedded sensors

