

Energy Harvesting at Morgan

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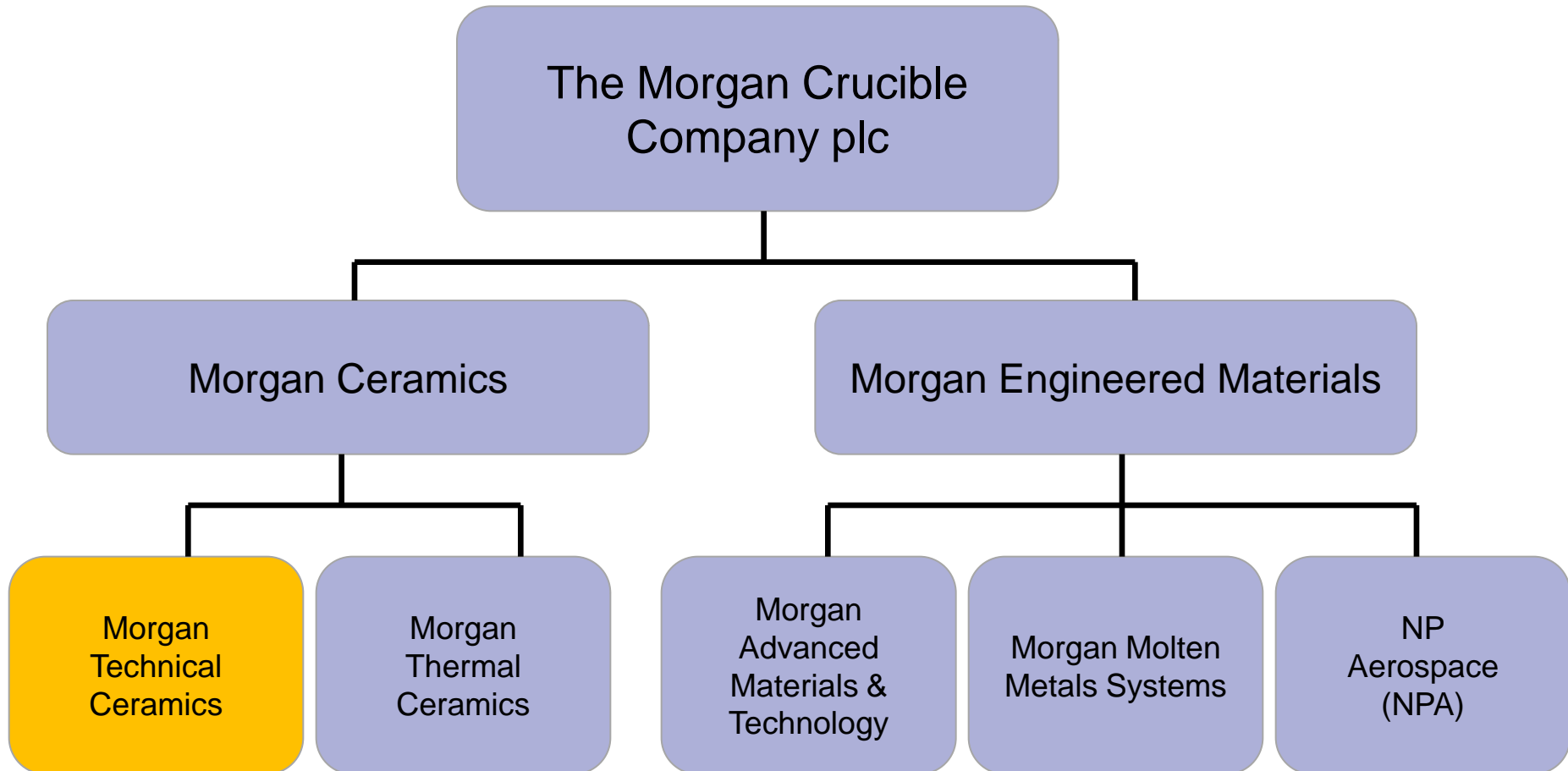
The Morgan Crucible Company plc

Morgan Crucible is an advanced materials company that provides technically complex, bespoke solutions to its customers, enabling them to address global trends such as energy demand, healthcare and environmental sustainability

- 2012 revenue £1B
- Two divisions
- 97 sites in 34 countries
- 10,000 employees
- Serving customers in >100 countries
- A member of the FTSE 250 index
- Listed on the London Stock Exchange
- Registered in Windsor, Berkshire, England



A clear divisional structure



Our products give us a leading position in the markets we serve

Morgan Ceramics



Fibre



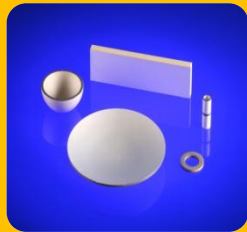
Engineered
Ceramics



Insulating
Firebricks /
Castables



Braze Alloys



Piezoelectric
Ceramics



Assemblies

Morgan Engineered Materials



Electrical
Carbon



Soldier
Survivability



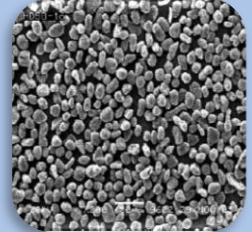
Seals &
Bearings



Molten Metal
Systems



High
Temperature



Lithium Ion

Key Markets – Energy

- Improving Efficiency

Wind turbine generators



- Power slip ring systems
- Brush-holders
- Improved generator lifetime

Solar



- Special grade insulation materials
- Reduce maintenance costs by 20%
- Reduce production costs by 50%

Key Markets – Energy

- Managing Efficiency

Smart Gas/Water Metering



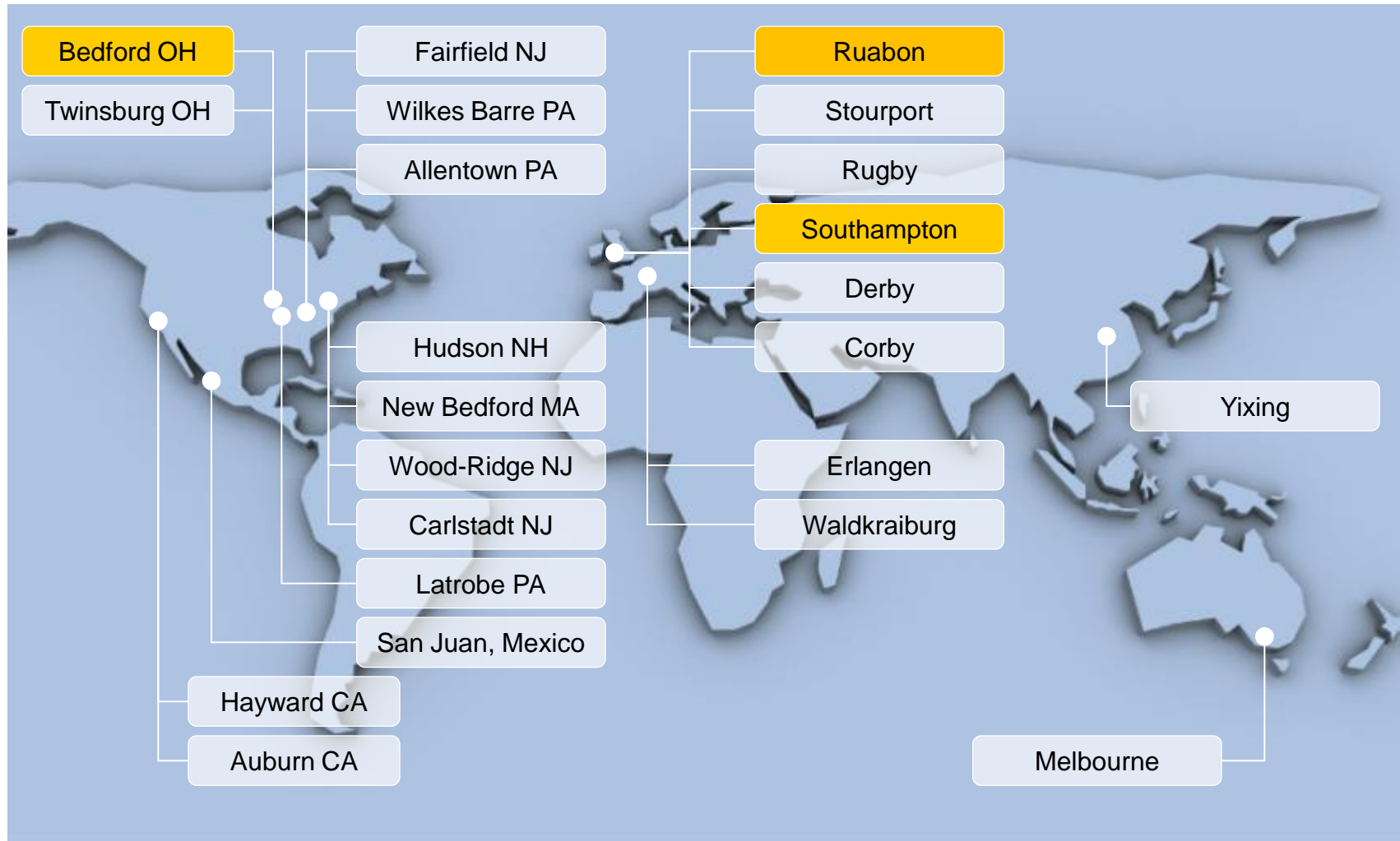
- PZT transducers for gas/water metering
- Being rolled out globally
- Saving of £14 billion to consumers

High Temp. Processing



- Superwool® lining materials reduce energy usage, costs and green house gas emissions.
- Thermal conductivity reduced by 20%.

Morgan Technical Ceramics Production Sites



Our products give us a leading position in the markets we serve

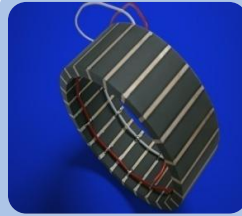
Piezoelectric Components



Sensors



Bimorph
Components



SONAR
Components

DC & RF Ceramic Capacitors



Encapsulated
HV Capacitor



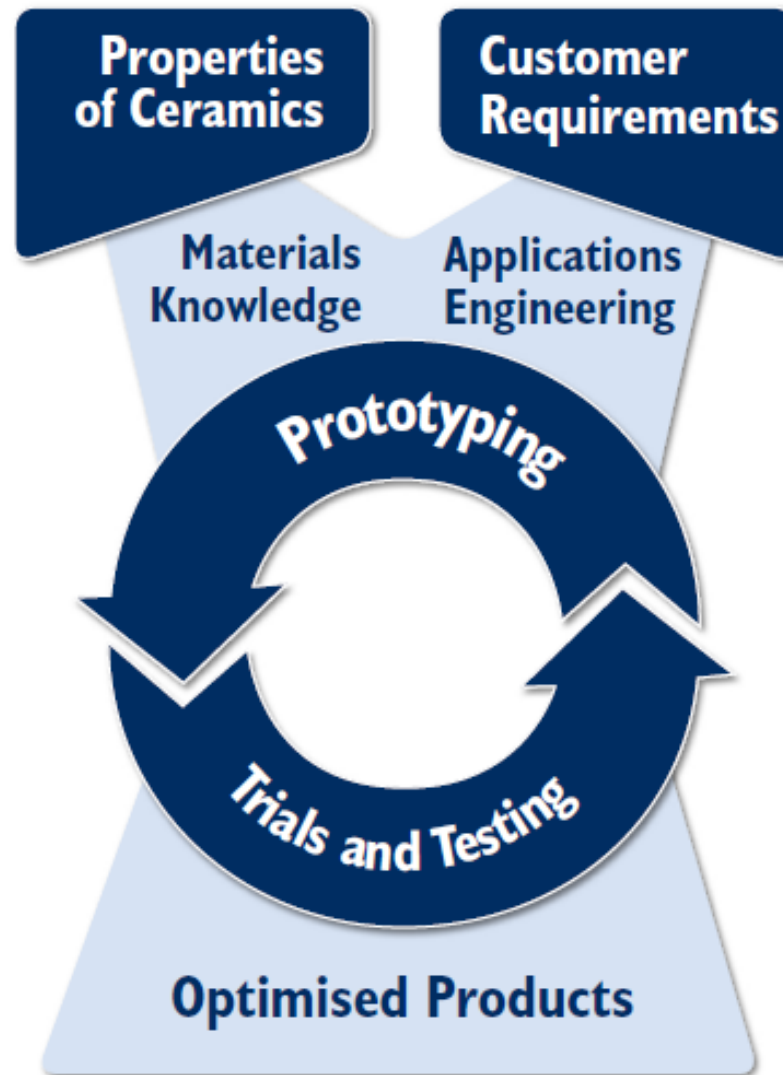
HV
Capacitors



Low Loss
Dielectric
Materials

- 3 Global facilities
- ISO 9001:2000 accredited
- ISO 14001, 18000 & 13485 accredited
- PPC environmental licence for using hazardous materials (lead) in manufacture.
- UK Site manufactures 17 different grades of Piezoelectric ceramic powders.

Working closely with our customers in order to provide optimised solutions

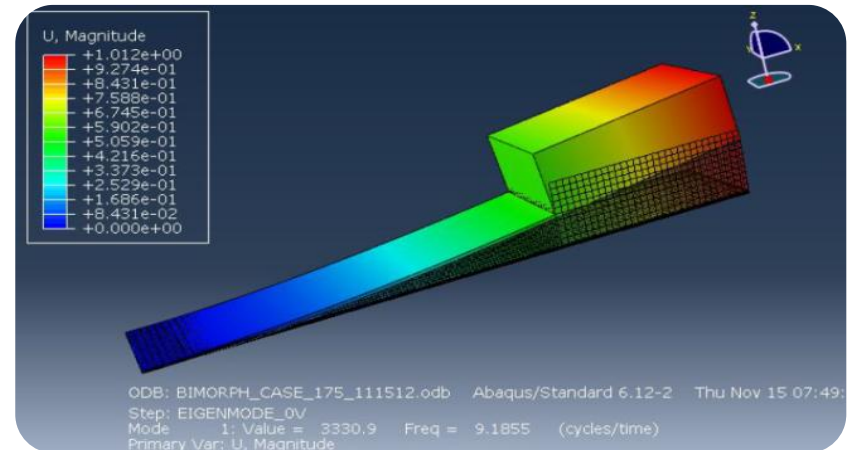
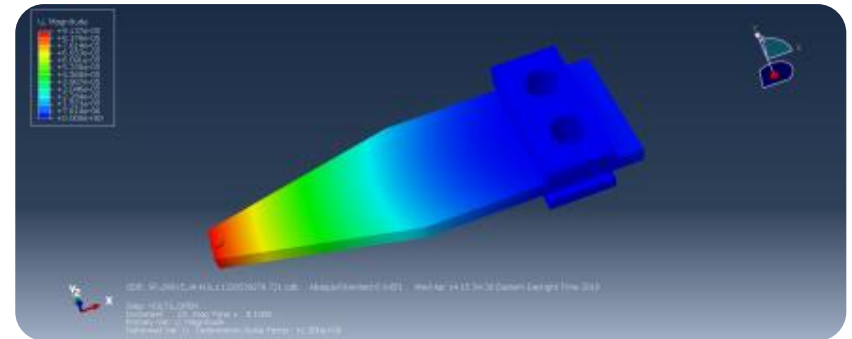


Manufacturing Expertise

- World class PZT formulations
- Uniform pressing process
- Improved firing techniques
- Tape casting and state of the art slicing capability
- Large scale manufacturing capability
- Component manufacturing can be used for EH:
 - Impact (PZT igniters)
 - Vibration (Bimorph)
 - Pressure (traditional ceramic components)

FEA Modelling Capability

- Choice of modelling software to model various structures and components
- Optimisation of design:
 - materials
 - adhesives
 - metallisation

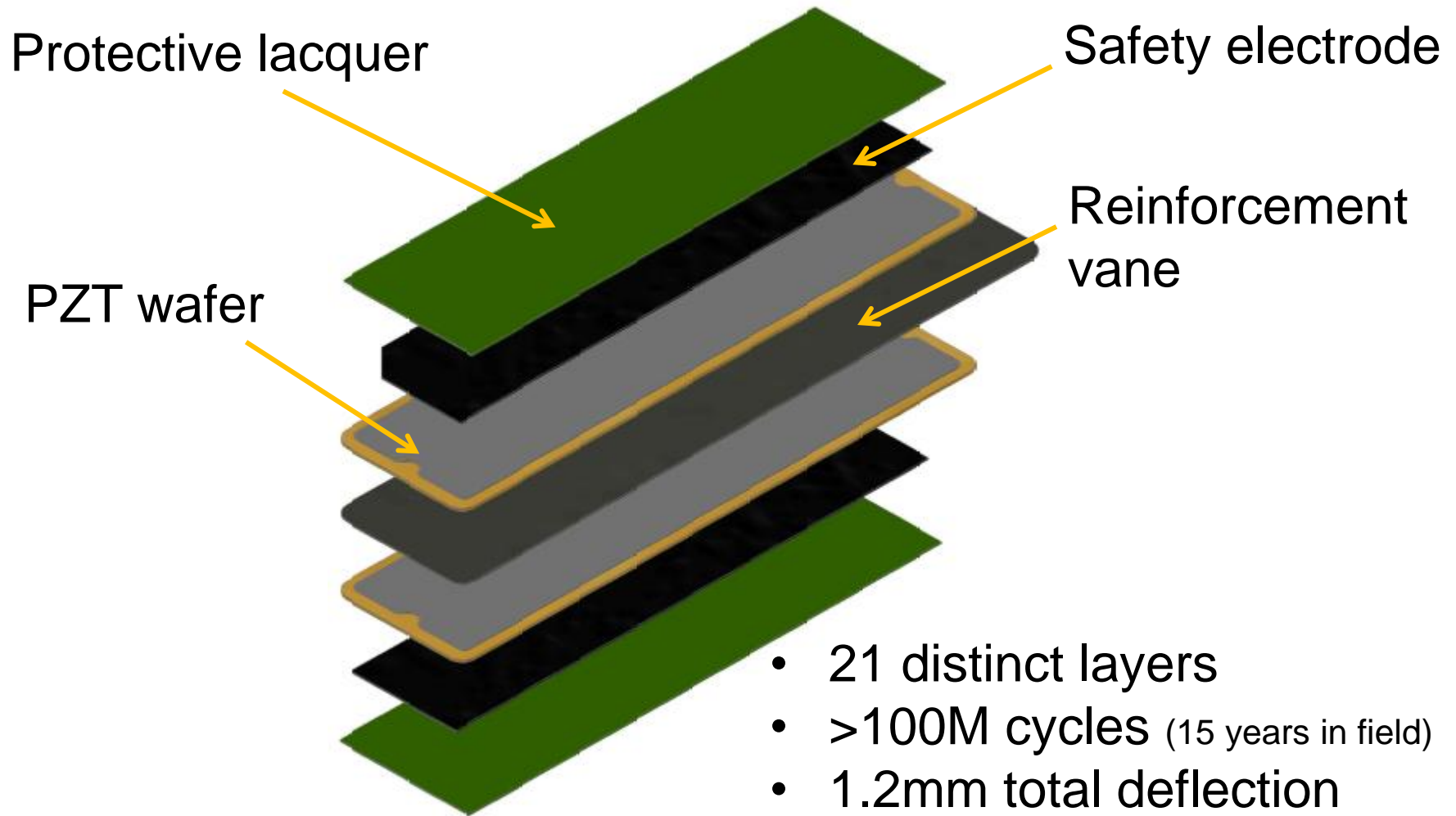


Piezoelectric materials available for EH

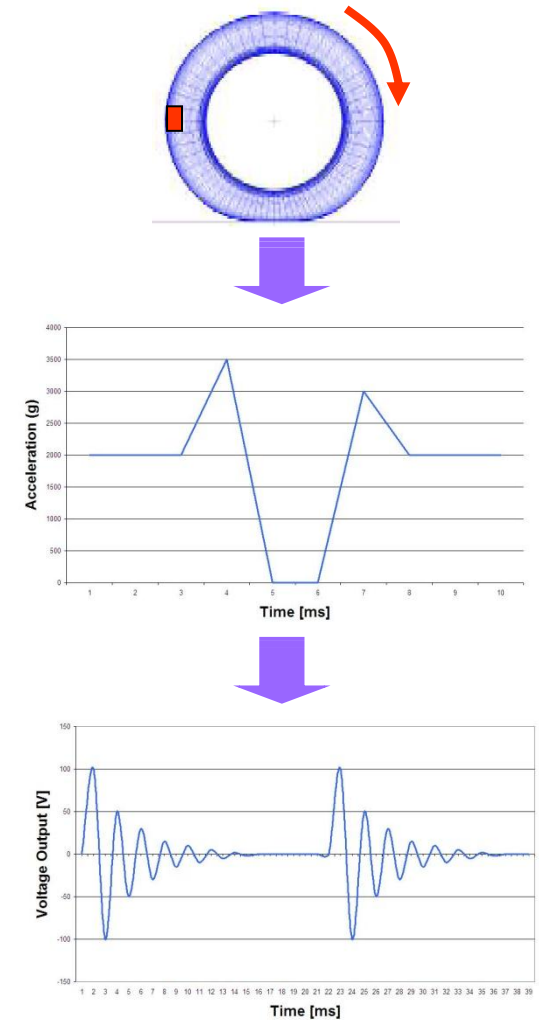
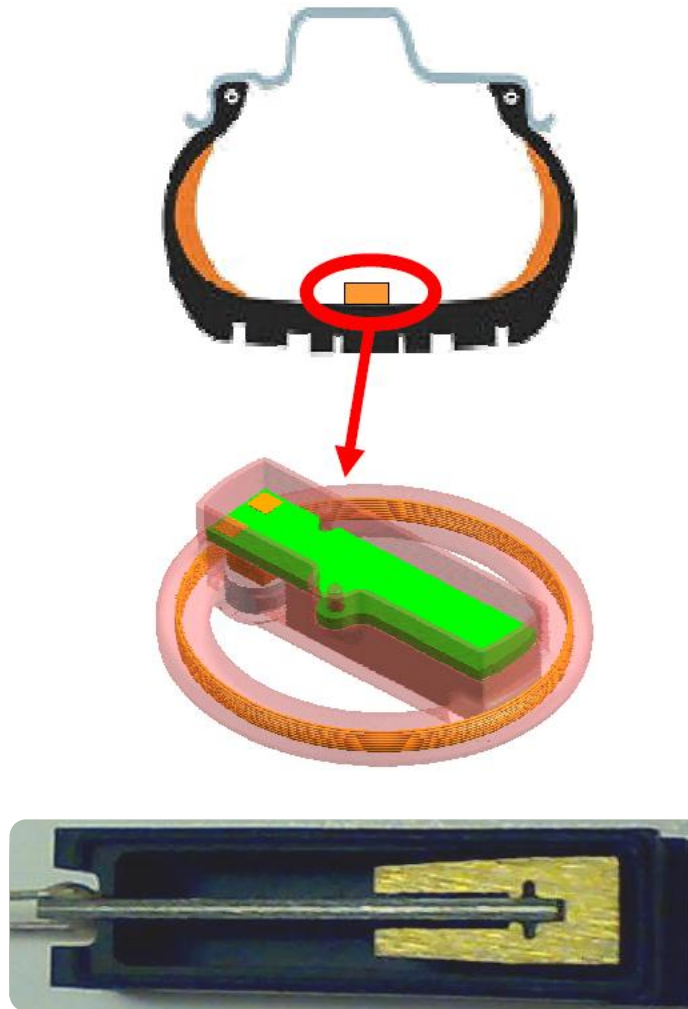
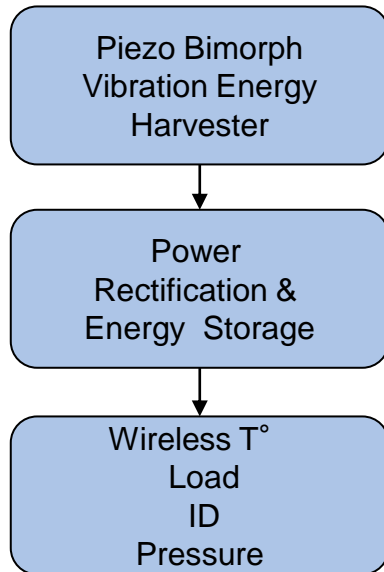
Parameter	5K1	507	505¥	503¥	5A4¥
K_{33}^T	6200	4400	2600	2100	1850
d_{33} [pC/N]	870	700	545	500	460
d_{31} [pC/N]	370	280	270	215	195
g_{33} [mV m/N]	16	20	24	24	28
g_{31} [mV m/N]	8	10	10	10	13
T_{\max} [°C]	-40 to 75	-40 to 80	-40 to 145	-40 to 145	-40 to 180
ρ [kg/m ³]	8200	7800	7800	7800	7900

(¥ Suitable for High T°)

Typical Construction for a high reliability bimorph



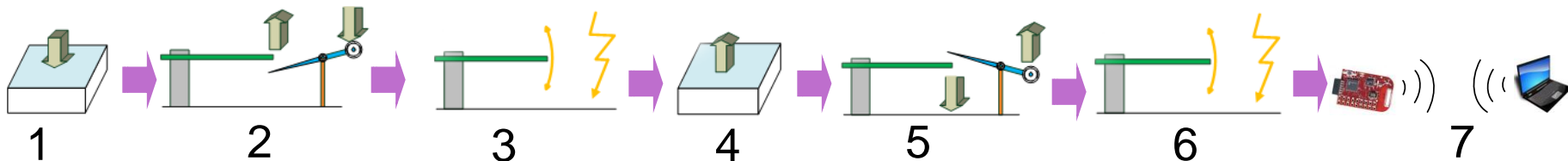
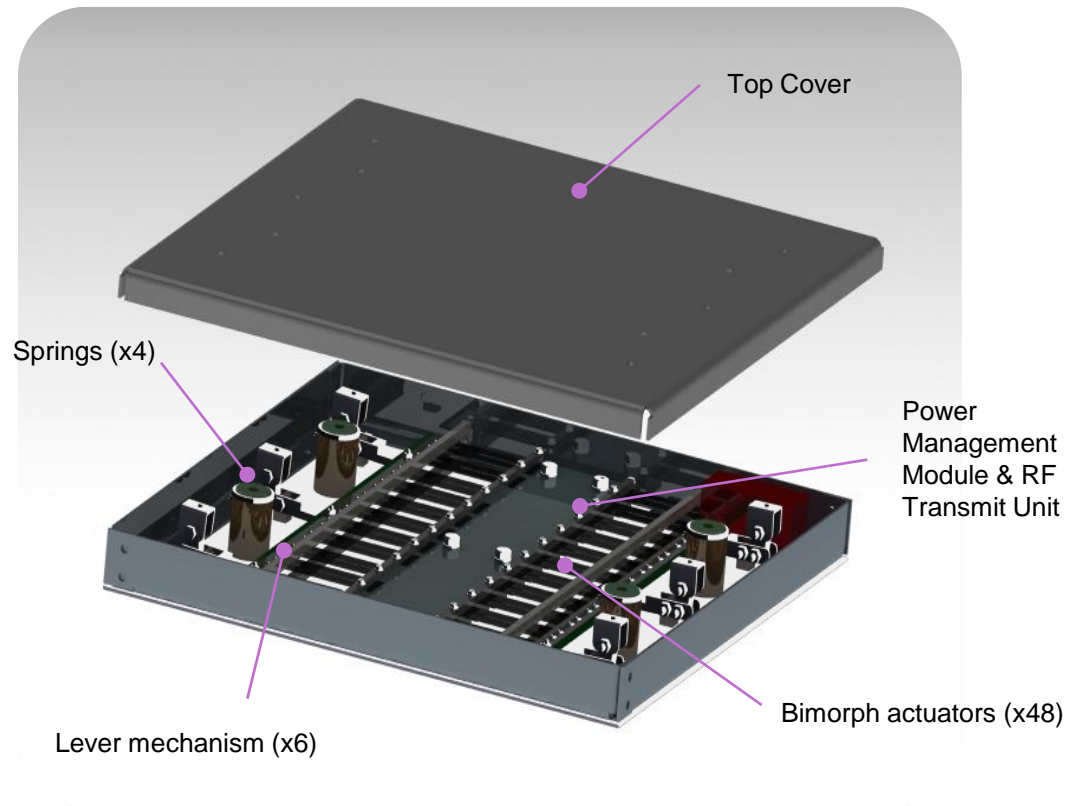
Energy Harvester for Automotive



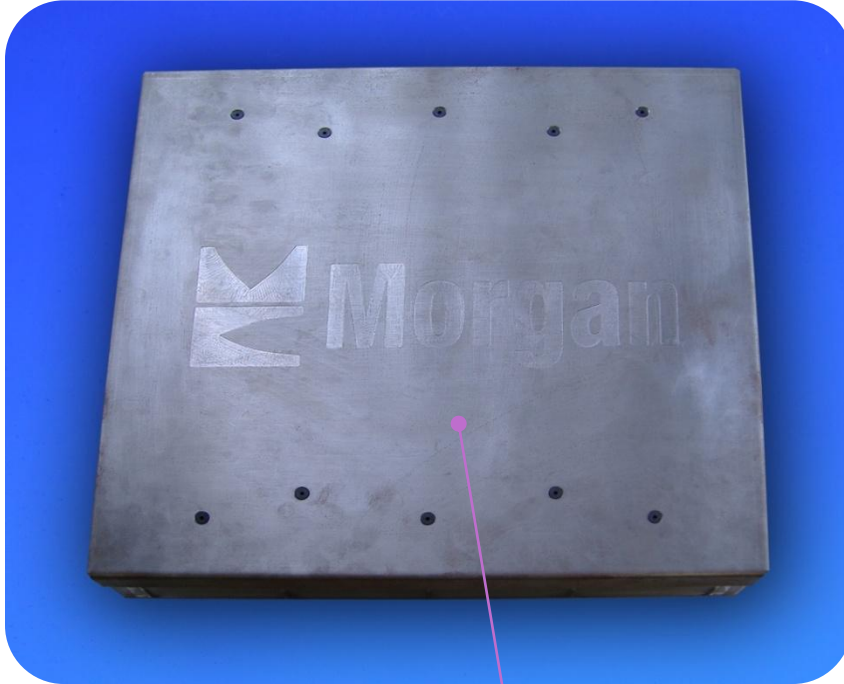
Energy Harvesting Tile

- Tile Specification

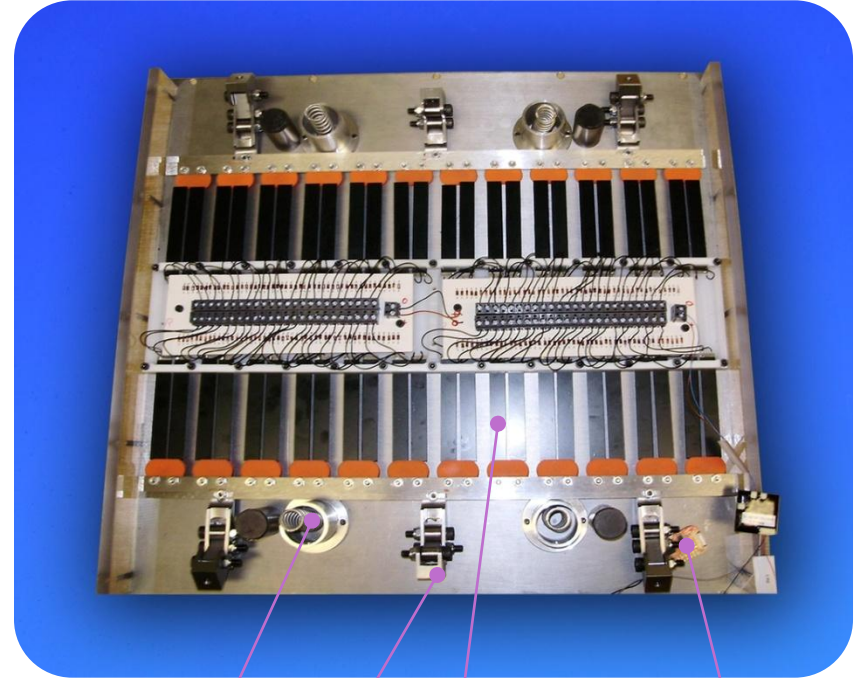
- Dimensions: 400x400x45mm
- Estimated weight: 12kg
- External Material: steel
- Weather resistant
- T° range: -10°C to 75°C
- Power Output: 180mW/step
- Output voltage: 3.6V
- Output current: 100mA



Energy Harvesting Tile – Prototype Demonstrator



Top Cover



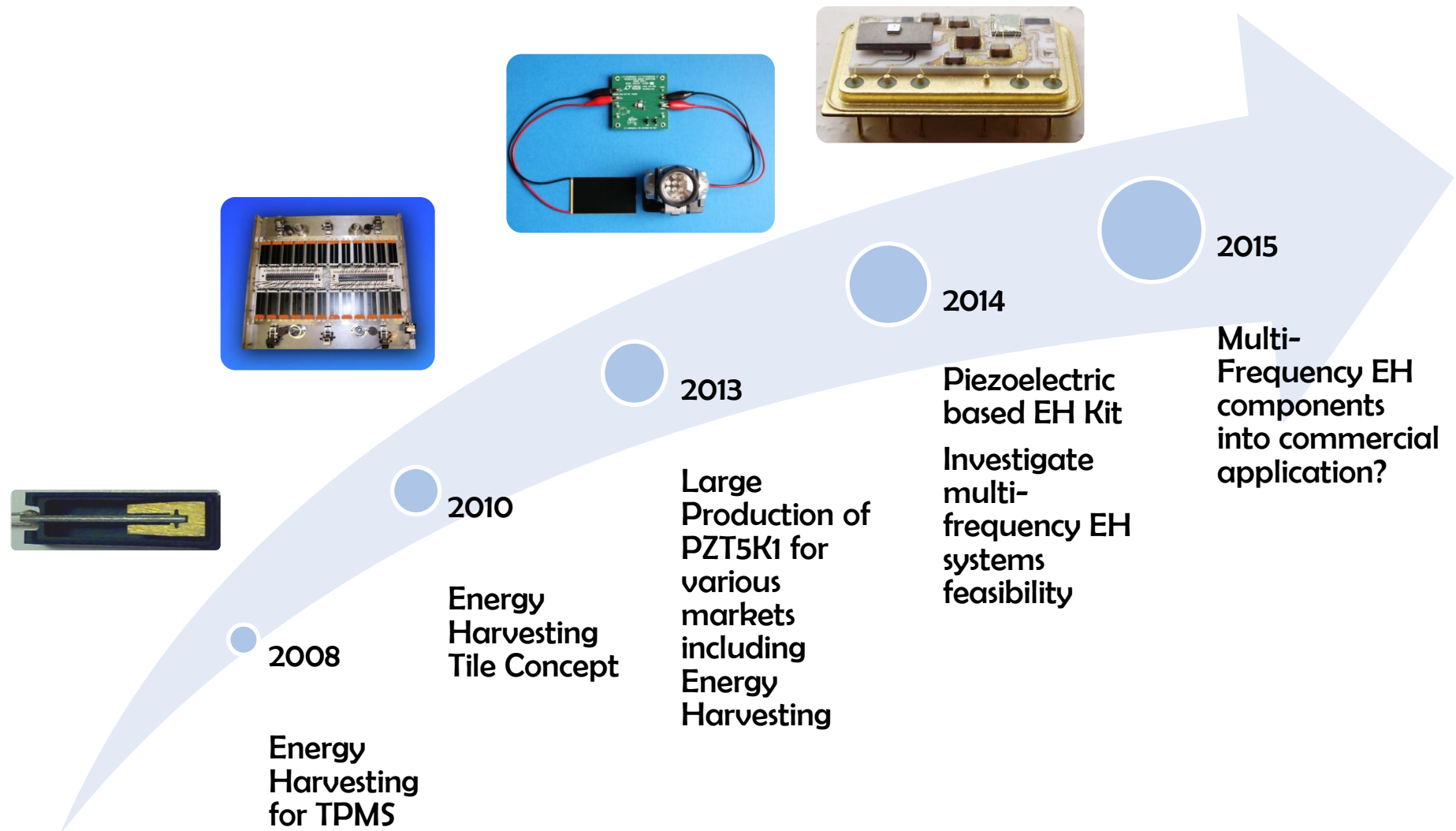
Springs (x4)

Lever mechanism (x6)

Bimorph actuators (x48)

Power Management Module & RF Transmit Unit

Innovation/Development : Niche Bimorph



EH Development Strategy

- GOAL: Gain understanding of design space based on:
 - Review academic literature
 - Discussion and collaboration with potential customers
 - Develop analytical and FEA modelling for MTC components
 - Prototype to validate the models
 - Deploy a commercial solution

