APEC 2019

SILENT SENSORS®

Making Flexible Materials Sentient

Industry Session 15: Energy Harvesting

Batteryless Monitoring System for Real-World Automotive Applications

Presented By –

Marcus Taylor, CEO

Silent Sensors Ltd

marcus@silentsensors.com

Wednesday, March 20, 2019

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Mission & Vision

Rubber Internet of Things

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Profile

- Embed electronics in rubber and elastomers
- Locations
  - London (HQ)
  - Sedgefield (design)
  - Swindon (product development
- 11 staff, growing rapidly
- UK SME supported with expertise from Government grant agencies
- Solution Engineering
  - Materials development
  - Antenna and sensor designs
  - Device manufacture
  - App and Cloud software
  - Support services
- Applications
  - Asset tracking with RFIDs
  - Development agreements

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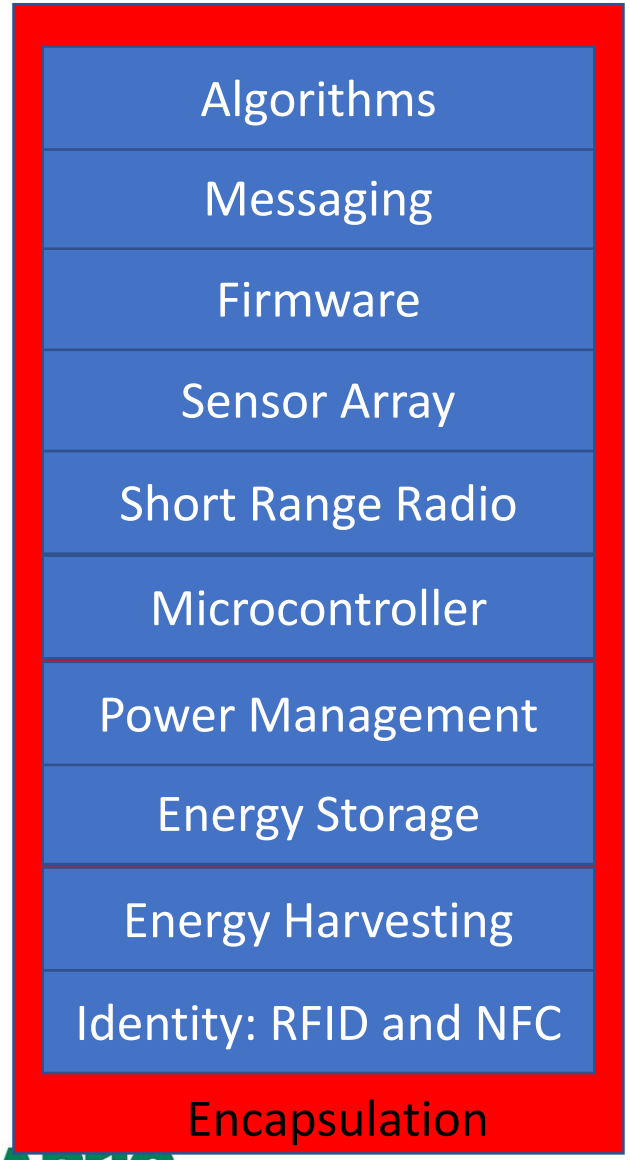
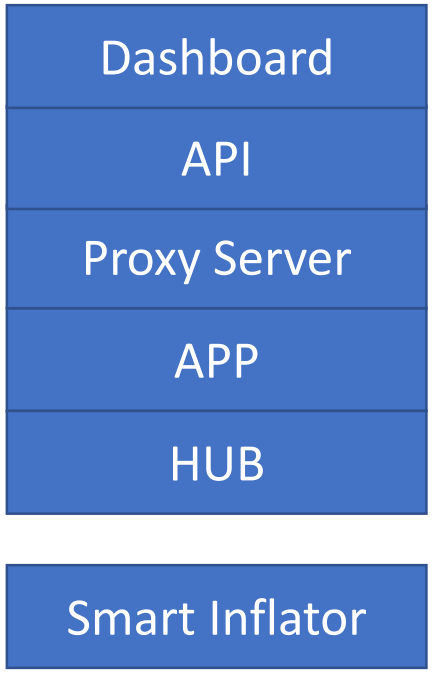
Smart Materials for Rubber, Elastomers and Polymers





- Encapsulation – ARTIS
- RFID (UHF and NFC) – Funded by EU H2020
- Piezo Energy Harvesting – CPI, UoBath funded by InnovateUK
- Vibration Energy Harvesting – Tyndall Institute
- Energy Storage and Triboelectric – Partnership with Comberry
- Power Management, Radio and TPMS Sensor
- Sensor Arrays - SSL
- Six Access motion
- Auto location
- Auto Configuration
- Solid State Microphone
- Atomic Mechanics
- nanoAI – Artificial Intelligence with Bragi GMBH

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** Smithers RAPRA The Future of Intelligent Tires to 2025*

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Tyre Industry

Mission

Design & Manufacture
High Quality and Safe Tyres
With Low Environmental Impact

Market Need

- RFID Tags & Inlays
- TPMS Sensor

Regulatory Requirements

Mandatory
RFID and Traceability

Competition

- Costly
- Bulky
- Battery

MESNAC

Silent Sensors

- Low Cost
- Thin, flexible, stretchable
- Self-powered
- Wide Temperature range

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Technology Contributions

Silent Sensors Limited (SSL)

- *System Integration / Smart Materials*
  - Speciality in Embedding in Elastomers & Polymers
  - Industrial Temperature Range Compliance
- *Ability to Harvest Ambient Energy (i.e. – Energy Harvesting or EH)*
  - EH-source Agnostic
  - Maximize Battery Life with Intermittent Energy Sources
- *Power Management / Optimization*
- *Intelligent Sensor Systems*
- *Radio Frequency (RF) Data Transceiving*
- *High-value Add-on Feature Enablement*
  - RFID, Intelligent Patches, Etc.

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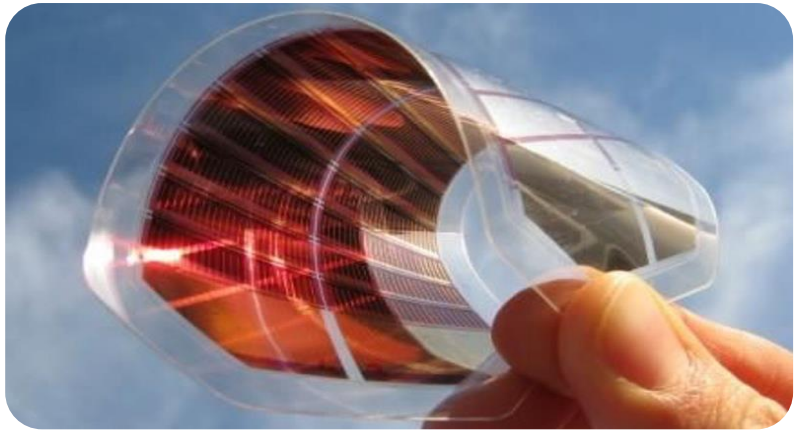
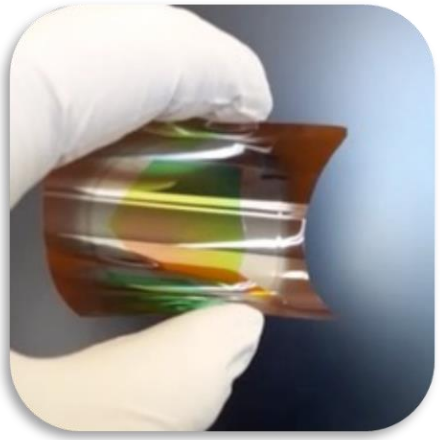
Technology Contributions

Silent Energy

- *Thin-film, Flexible Energy Storage*
  - Pseudosupercapacitor (Can Be Made to be More Supercap-like or More Battery-like)
  - Industrial Temperature Operating Range
  - Scalable
- *Joint Venture Between SSL & Comberry, based in UK*





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Technology Contributions

Ecosystem Partners

- *tesa*
  - Worldwide Leader in Specialized Adhesives Development
- *e-peas*
  - Differentiating Power Management IC (PMIC) & Microcontroller Supplier Specializing in Energy Harvesting Applications
- *Alta Devices*
  - Producer of High-efficiency, Thin-film GaAs Photovoltaic (PV) Cells

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Technology Contributions

General Energy Harvesting (EH) Comparison Matrix

- Comparing EH Technologies
  - Electrodynamic (**Dynamic**)
  - Photovoltaic (**PV**)
  - Thermoelectric (**TEG**)
  - Piezoelectric (**PZ**)
  - Radio Frequency (**RF**)
  - Vibrational (**Vibe**)
  - Triboelectric (**Tribo**)

EH TECH	Thin	Flexible	Energy Density	Raw Electrical Output
Dynamic			✓✓✓	AC
PV	✓	✓	✓✓	DC
TEG	✓	✓	✓✓	DC
PZ	✓	✓	✓	AC
FC			✓✓	DC
RF	✓	✓	✓	AC
Vibe			✓	AC
Tribo	✓	✓	✓	AC

NOTE: a check implies this EH tech is capable of that characteristic, but does not imply it applies absolutely.

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Technology Contributions

General Energy Harvesting (EH) Comparison Matrix

- Example Applications

APPLICATION	EH TECH	STORAGE	EXAMPLE LOAD (mW)*approx.
Tire Pressure Monitoring System (TPMS)	PZ	Supercap, Micro Battery	10
RFID / Security Tag	PV, RF, Tribo	Supercap	0.01
Asset Tracking	PV, TEG, PZ, RF	Supercap, Micro Battery	0.1-50
Smart Tape	PV, TEG, PZ, RF, Vibe, Tribo	Supercap, Micro Battery	0.05-5
Telematics	PV, TEG, PZ, RF	Supercap, Micro Battery	0.5-100
Smart Card	PV, RF, Tribo	Micro Battery	0.02-0.05
Industrial Monitoring	PV, TEG, RF, Vibe	Supercap, Micro Battery	1-100
Preventative Maintenance	PV, TEG, RF, Vibe	Supercap, Micro Battery	1-100

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Automotive Application Opportunities

- **Vehicle-to-Vehicle (V2V)**
- **Autonomous Vehicles**
- **On-Board Sensor Networks**
  - Tire Pressure
  - Oil/Water Temperatures
  - Fuel Level
  - Passenger Telemetry
- **Embedded PV External Paneling**
  - Roof
  - Windows
- **Kinetic/Vibrational/Thermal Energies EH**

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Automotive Application Challenges

- Weight
- Cost
- Power Consumption
- Amount of Data
  - **VALUE** of Data
- Security
- Slow Development / Qualification
- Mature Supply Chains

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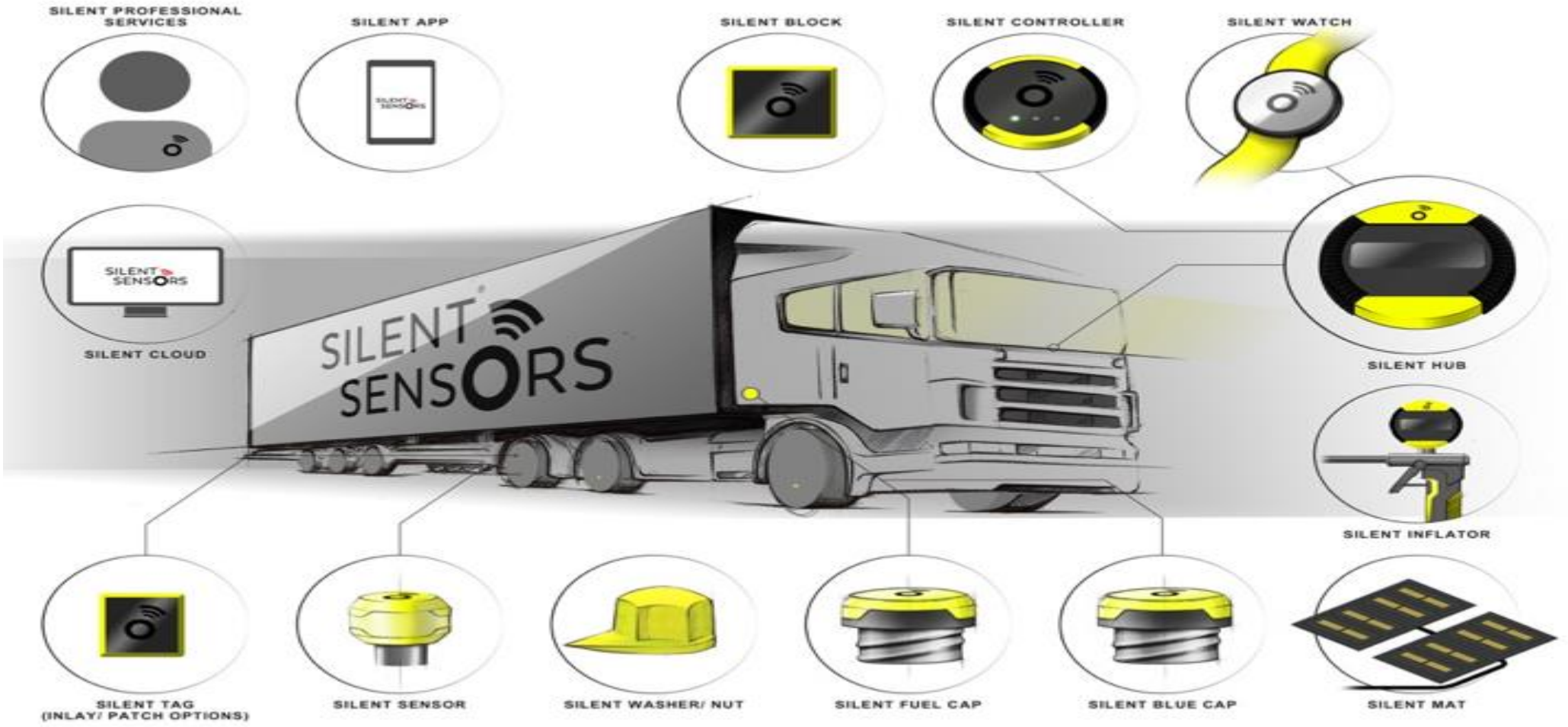
The Ecosystem



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What is an Intelligent Tyre?

Are the future

- Unique Identity
- Measure and Monitor
- Communicate
- Act on information

Must be able to

- Self-power
- Survive super-heating
- Integrate with infrastructure
- Be on all the time
- Cover the last millimetre

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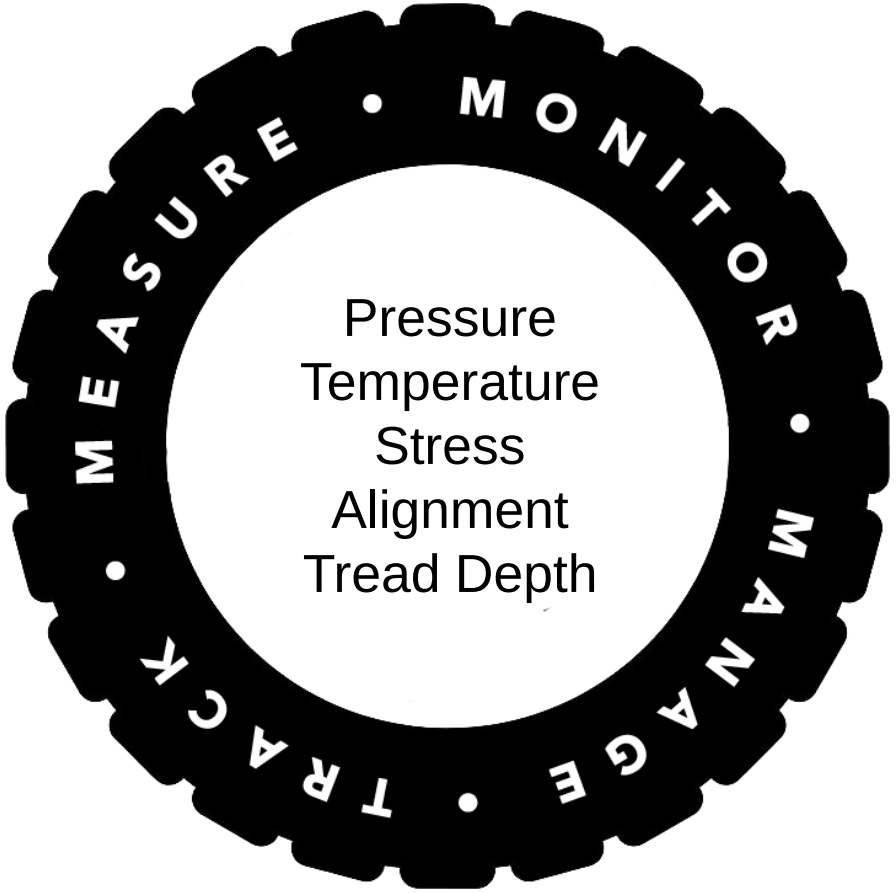
Reducing Lifecycle Costs

- Increased Safety
- Lower Costs
- Lessens Environmental Impact
- Requirements for autonomous vehicle operations (Intelligent)

Value-added ROI for today's Smart Tyres increases with tomorrow's Intelligent Tyres



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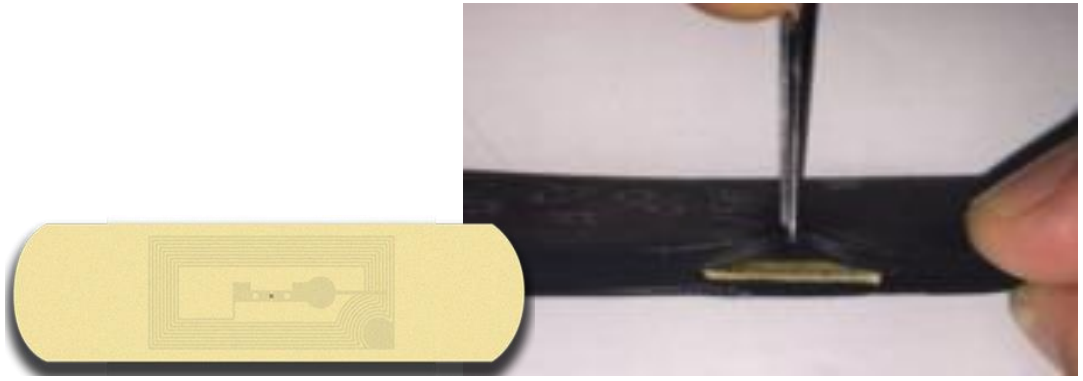
Structure of a Tyre



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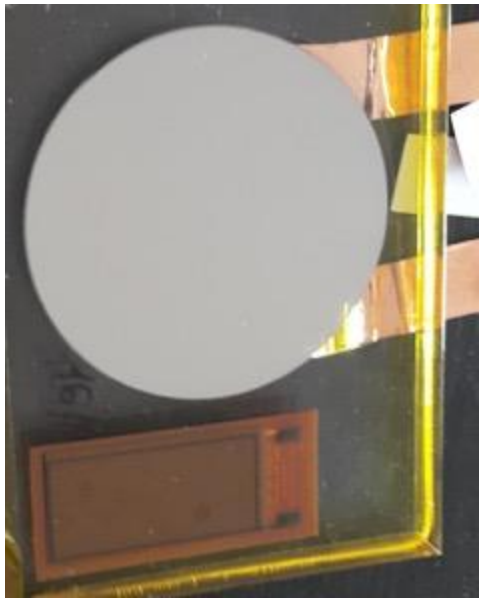
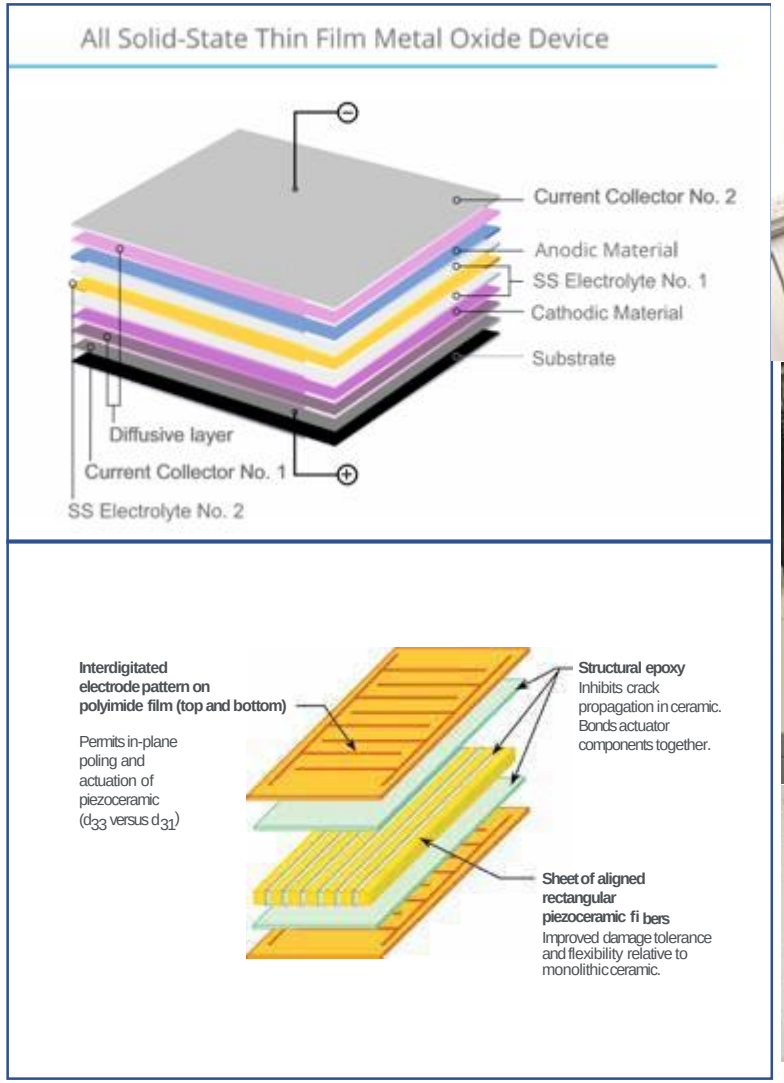
Project “Tyreless” – *Power Generator and Storage*

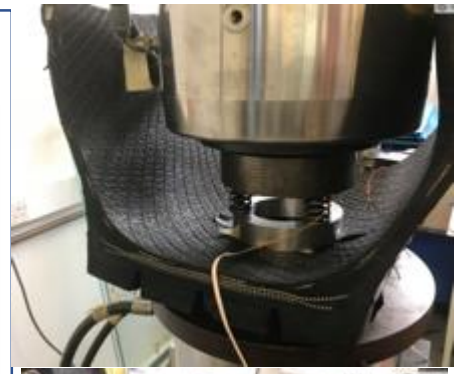
InnovateUK Grant – *Completed*

The new RFID design will enable us to produce PZT piezoelectric materials on same PE substrate with same process.

Thin Film Energy Storage material

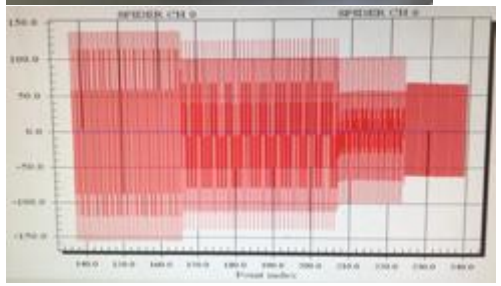






Material being tested

Material attached to tyre



Graph showing output varying at different frequencies

Tyreless Piezoelectric Harvesting material

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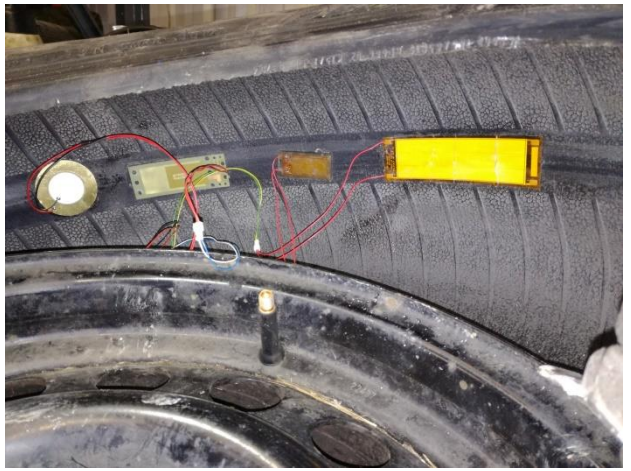
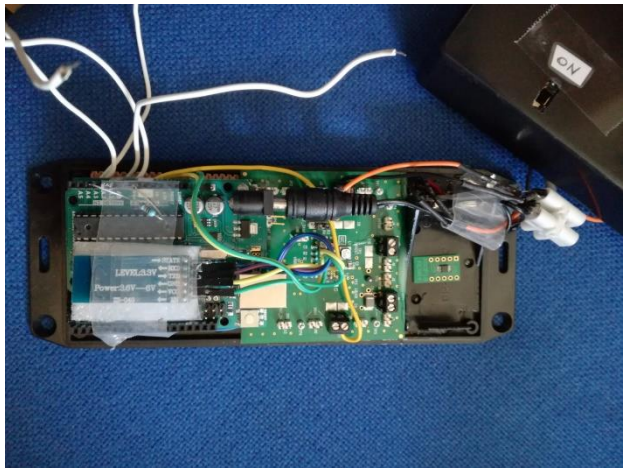
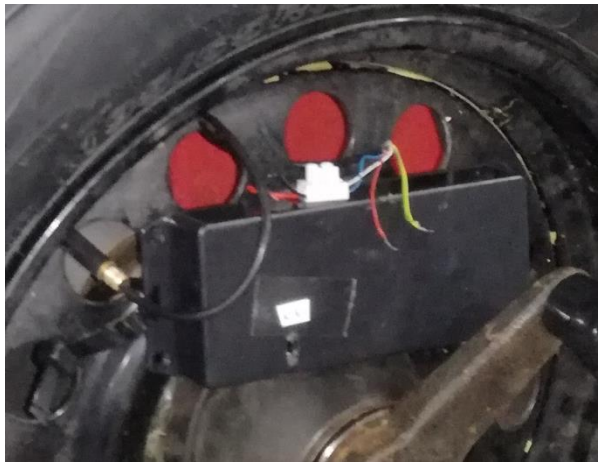
Wheel and Tyre Installation and Monitoring

- 4 off PZT Harvesters attached to inside of wheel using cyanoacrylate adhesive (after preparation of tyre surface)
- Multicore cable brought through steel Volvo wheel to provide connection to 3 of the PZT using miniature connectors
- PZT types were:
  - MFC
  - Murata disc
  - MIDE
- Tyre part assembled to rim; connections to PZT made; and final assembly of tyre onto rim
- Cable connection to Monitoring unit which is strapped to centre of rim







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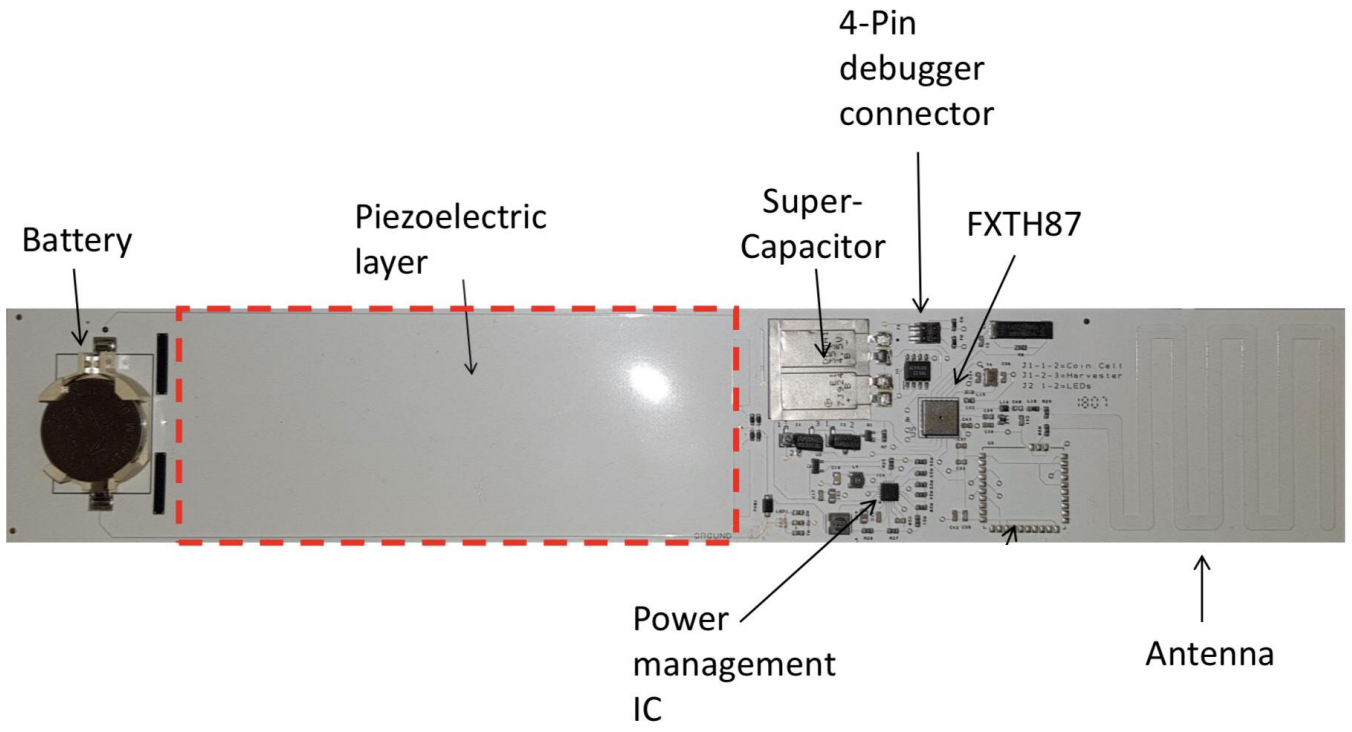
Sensor Module Prototype

- Tire Pressure Monitoring System (TPMS)
  - Self-Powered
  - Thin, Flexible
  - Industrial-Grade Temp



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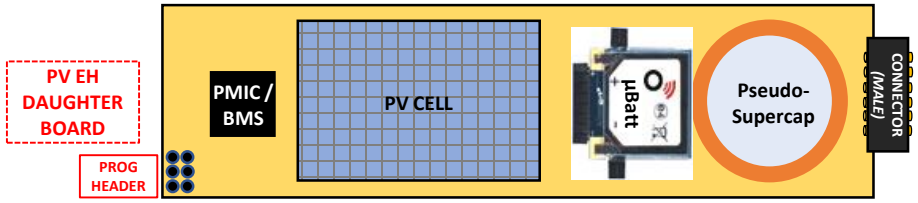
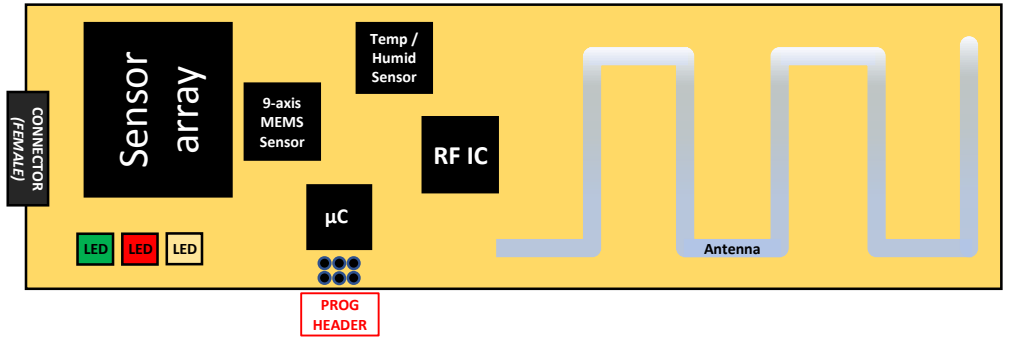
Demonstration Concepts

EH-agnostic Sensor System

- Wireless Sensor System Disaggregated from Power Source
  - Separate Power & System Planes
  - Same System Plane Can Service Multiple Applications
  - Printed Circuit Assemblies (PCA) Integrated with Connectors





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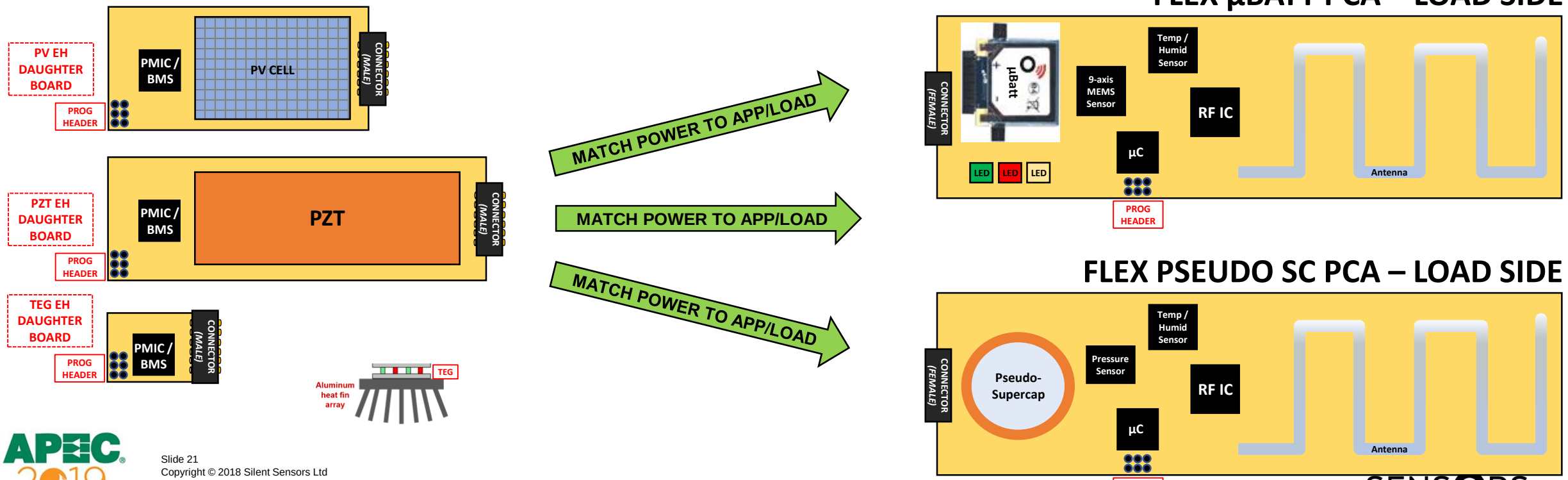

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Application Tools

Design Calculator/Tool

- Cloud-based Tool to Facilitate Customer Design/Brainstorming Process
  - Database of Characterized Components
  - Options/Guidance for Matching EH to Application
  - Web Interface for Easy Access
  - Supply Chain Integration

Model Library

- Part/Assembly Models for Assorted CAD Usage
  - Mechanical
  - Electrical
  - Physics-Based Simulation

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The Future

- Transformative business models, from supply to service
- Sentient Tyres for autonomous driving, information on road conditions
- 3D printing of rubber combined with embedded electronics
- Securely integrated sensor platform and Cloud based data sharing

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SILENT SENSORS

Making Flexible Materials Sentient

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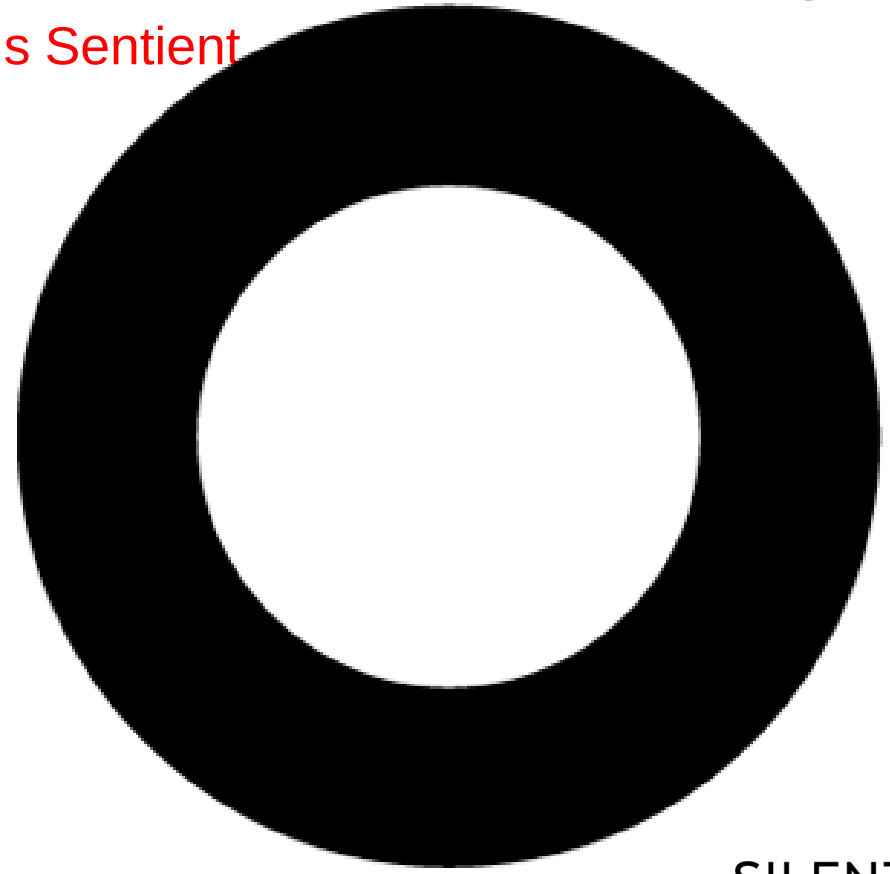

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