DER

Driving the
Electric Revolution
Industrialisation Centres

UK Research and Innovation

Driving the Electric Revolution

Racing Ahead…

CPE Conference 2023

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Driving the Electric Revolution

A UK Research and Innovation Industrial Strategy Challenge

Using PEMD to address climate change

- All UK cars to be zero carbon by 2035 (no 100% internal combustion engine vehicles from 2030)
- New aircraft to be electric/hybrid to meet next phase emissions and noise legislation by 2040
- Renewables (Wind, Wave, Tidal) to form an increasing % of energy generation (80% CO_2 reduction by 2050)
- High speed rail network to grow, no new diesels after 2040
- Marine transport target of 50% CO_2 reduction by 2050
- PEMD supports the realisation of the industrial digital technology (IDT) revolution – Industry 4.0

DER Driving the Electric Revolution Industrialisation Centres
North East | South West & Wales | Midlands | Scotland

UKRI UK Research and Innovation

Driving the Electric Revolution

The Vision

To make the UK globally recognised as the centre of excellence in Power Electronics, Machines and Drives manufacturing processes.

The Mission

To provide a UK network of open access facilities, growing world class design, manufacturing, test and validation capabilities.

A UK-Wide Network Addressing

- Gaps and lack of capacity in the UK supply chain
- Lack of UK skilled engineers
- Low levels of UK component content in existing UK manufactured products
- Limited number of UK manufacturing process development companies

Driving the Electric Revolution

£80M UK Government funding to

- Establish a UK-wide network of **Industrialisation Centres** (DER-IC)
- Provide open-access equipment in acknowledged centres of capability to support industry **build supply chain capability, and capacity**
- Collaborative Research and Development (CR&D)
  - Fast Start programme
  - Catalysing Green Innovation
  - Supply Chains for Net Zero
- Skills
  - Skills Hub
  - Building Talent for the Future 2

DER Industrialisation Centres (DER-IC)

DER Network

- £33M used to establish a UK network of PEMD capability.
- Accessed through four DER Industrialisation Centres (DER-ICs).

DER Industrialisation Centres

- £28.5M of open-access equipment to support UK companies
  - develop manufacturing processes.
  - accelerate and de-risk production plans.

- Open access to >£300M of technical capability **and skills** over 30 partner institutions.
- Leverage regional and devolved funding.
- Facilitate access to industry clusters and support

Network Partners

North East
AMRC
CPI
Newcastle
Northumbria
OREC
Sheffield
Teesside
TWI

Scotland
AFRC
Edinburgh
Glasgow
MSIP
NMIS
PNDC
Strathclyde
St Andrews

Midlands
Coventry
Loughborough
Manchester
MTC
NAMRC
NCC
Nottingham
NPL
Southampton
Surrey
UCL
Warwick
WMG

SW2
Swansea
Birmingham
Bristol
CSAC

DER-IC Locations & Capability

University of Strathclyde Glasgow

Propulsion and powertrain systems validation capability at MW scale with hardware in the loop.

UNIVERSITY OF BIRMINGHAM

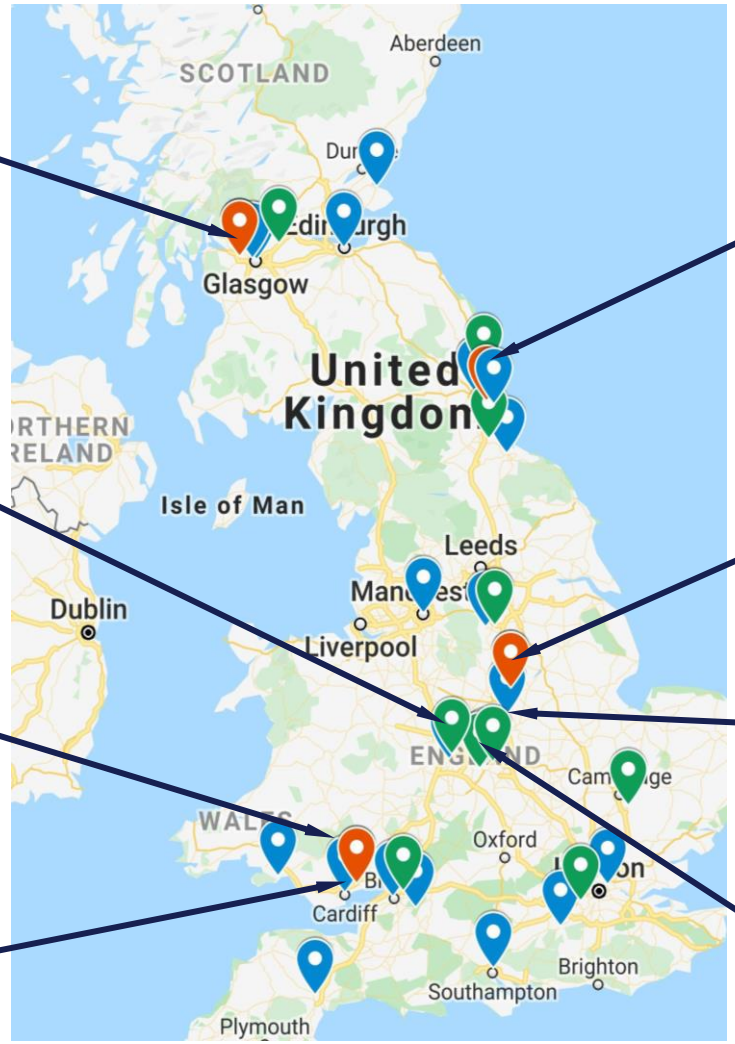
A production line to for recycled sintered magnets with ‘end to end’ supply chain to enable UK supply of recycled rare earth magnets from processed oxides for more secure UK supply.

CATAPULT Compound Semiconductor Applications

A facility to prototype ceramic and copper elements and sub-assemblies within highly integrated power electronic modules.

Swansea University Prifysgol Abertawe

A wide bandgap power electronics component industrial pilot line.



Newcastle University

Reconfigurable power electronics assembly line for semi or fully integrated high-power density drives.
Flexible electric machines assembly line which includes stator and rotor assembly, chemical dispensing, automated machine assembly line, and end of line test.

University of Nottingham UK | CHINA | MALAYSIA

A high-frequency coil manufacturing and magnetic test characterisation capability to develop and manufacture electrical machines to operate at higher frequencies.

WARWICK THE UNIVERSITY OF WARWICK

A power electronics reliability and failure analysis facility.

WMG THE UNIVERSITY OF WARWICK

A winding centre of excellence facility to manufacture all types of windings at production quality, specialising in hairpin stators.

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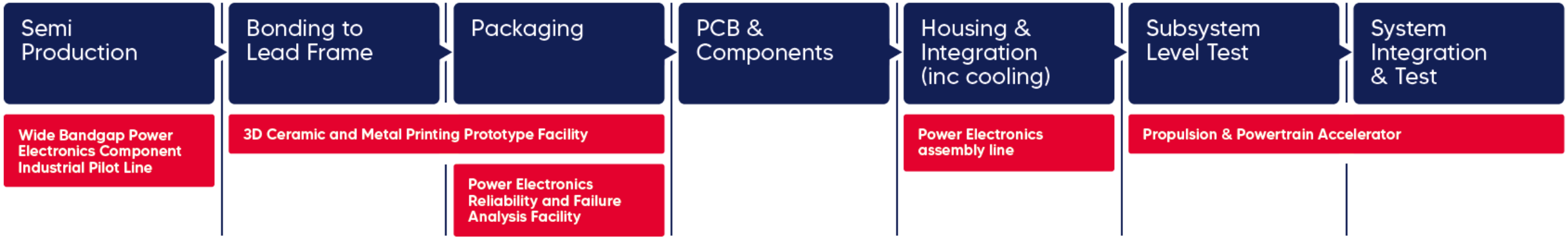
UKRI UK Research and Innovation

Supply Chain Mapping

Power Electronics



Electrical Machines

DER-IC Services

An Industry-Led Challenge

- Focus on mid-high Technology Readiness Level (TRL 4-8) industrial research
- Manufacturing and assembly process development
- Manufacturing process scale-up
- Small production runs (10s-1000 off) to prove out manufacturing processes
- De-risking capital investment
- Development of manufacturing equipment
- Diversification into lower TRL (1-3) research
- Prototype development
- Skills training
- Signposting and support of supply chain development

DER-IC Capabilities

Product and Manufacturing Process Equipment Design

Manufacturing Process Development and Optimisation

- Analyse existing processes, identify improvements, and implement enhancements

Prototype Manufacture and Scale-up Support

- Smooth transition from prototypes to full-scale production, optimising manufacturing parameters, and integration of new technologies or designs into production

Test and Validation

- Ensure reliability and performance to UK industry standards

In-Process and End-of-Line

- Streamline production workflows, improve quality control processes, and enhance productivity

Characterisation of Materials and Components

- Analyse and evaluate the properties and performance of materials and components

Electrification Skills Learning and Development

- Work with the ER Skills Hub, IESAM and WELD to enhance the knowledge and skills of PEMD professionals

DER-IC Thematics

Semiconductors – Wafers, Dies, and Fabs

- Silicon and wide band gap device processes for integrated circuits and discrete devices

Packaging and Devices

- Innovative packaging solutions, and device performance optimisation

Magnetics

- Design and optimisation of magnetic systems for efficiency, losses, and performance

Rotors and Stators

- Design optimisation and assembly processes

Windings and Busbars

- Innovative topologies, low-inductance interconnect and automated assembly

Drives and Integration

- System compatibility, control strategies, and overall performance

Thermal Management

- Thermal analysis, heat dissipation strategies, integrated cooling, and thermal interface

Passives, Non-Active Component Parts, and Light-Weighting

- Innovative materials and manufacturing methods

DER-IC Scotland, University of Strathclyde

Propulsion & Powertrain Systems Validation Capability

- Hardware in the loop and multi-MW capability (PNDC), and design and manufacturing (NMIS)
- MW-scale test bed for machines and drives
- University of St Andrews (Hydrogen platforms), University of Edinburgh (semiconductor device and converter capability), and University of Glasgow (Semiconductor R&D)

DER-IC Midlands, WMG at Warwick University

Winding Centre of Excellence

- Discrete and continuous hairpin winding
- Concentrated windings for radial and axial flux machines
- Robotic rotor assembly and magnetised magnet insertion
- Magnetiser
- Rotor assembly and stator insertion
- Trickle impregnation and curing
- In-process electrical, thermal and mechanical test

DER-IC Midlands, PEMC at Nottingham University

High-Frequency Coil Manufacture and Magnetic Characterisation

- Flexible hairpin and continuous winding manufacture, with adjustable, closed-loop coil shaping
- Asymmetric coil and adjustable conductor size
- End of line diagnostics for insulation monitoring

DER-IC Midlands, Warwick University

Power Electronics Reliability and Failure Analysis

- Semi-automatic flexible bonder
- Scanning acoustic microscope
- Environmental chamber for reliability testing
- Industrial data logging and hardware-in-the-loop
- De-capsulation
- Power cycling
- Fibre Bragg Grating system
- Thermal imaging

DER-IC South West & Wales, CSAC

Semiconductor Processing and Packaging

- Ceramic and metal printing
- Laser cutting and drilling
- Lapping and polishing
- Metrology - high-voltage test station

Wide Bandgap Semiconductor Power Electronics Component Industrial Pilot Line

- Deposition
- Etch - Synapse SiC deep etch tool
- Contacting - back contact laser anneal
- Grind
- Dice

DER-IC South West & Wales
University of Birmingham

Rare Earth Magnet Recycling Process Line

- Hydrogen reactor to strip NdFeB magnets from waste streams
- Integrated inert powder processing, including sieving, jet milling, and blending.
- Pulse magnetiser for alignment of powders and magnet magnetisation
- Uniaxial magnetic aligning press
- Inert sintering system
- Magnetic field mapping
- Milling equipment for SmCo magnets

DER-IC North East, Newcastle University

Fitzpatrick Drive, Sunderland SR5 3HE

- Combines new, unique open-access hardware capability with existing capability of NU EEE and partner institutions
- Houses 2 new facilities representing £6M of capital investment
  - Electrical Machines Assembly Line
  - Electric Drives Assembly Line

Electrical Machines - Process

All sub-processes
- **are representative of actual 'stand-alone' industrial processes**
- **interconnect to form a complete process**

Components In

Component Measurement Machine
- Accurate characterisation of received and manufactured components
- Compare against design intent to verify processes

'Robopod'
- Assembly of laminated structures
- Press-fitting
- Mechanical component placement
- Chemical (glue and epoxy) dispense

Magnetiser and Magnetometer
- Magnetisation of magnets, pre- and post-assembly
- Magnetic field measurement of individual magnets and complete compound magnetic structures

Universal Balancer
- Address static and dynamic unbalance of rotating components

Rotor Out

Pre-wound Stator & Casing

Stator Hot Drop and Rotor Insertion
- Induction heating
- Shrink fit mechanical components
- Component lifting and placement

Mechanical Assembly
- Mechanical press
- Controllable hand tooling

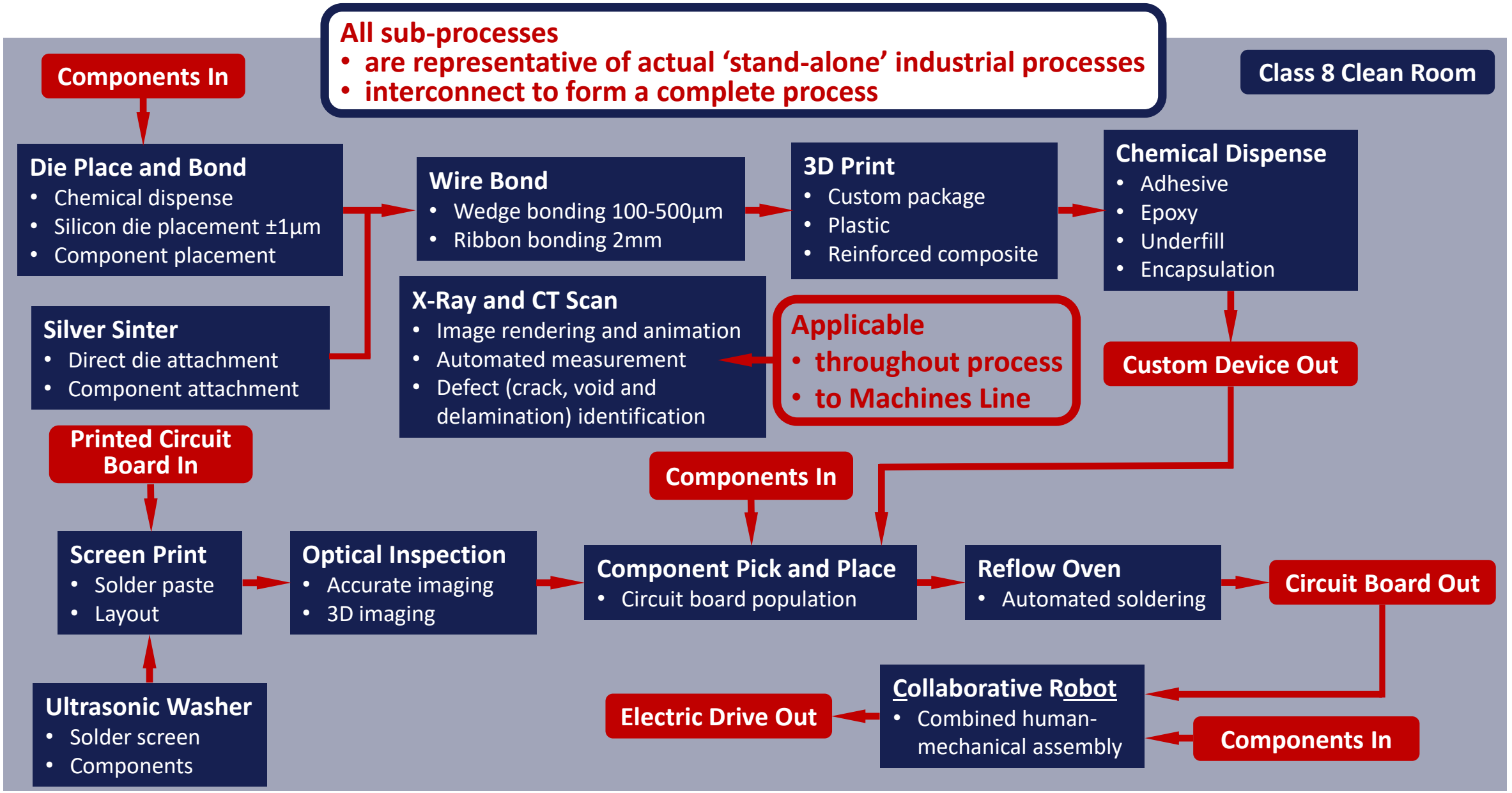
Collaborative Robot
- Combined human-mechanical assembly

Electrical Testing
- Partial discharge, short circuit and electrical characterisation
- Verification of received or assembled components

Environmental Testing
- Dynamometer: 400kW, 12000rpm
- Mechanical vibration, variable axis, g-shock and custom profiles
- Thermal chamber -70 to +180 °C
- Combined vibration, thermal and humidity
- Thermal shock -70 to +180 °C
- Combined thermal and pressure

Machine Out

Electric Drives - Process



Case Study 1

Ricardo

Ricardo has spent ten years developing magnet free, sustainable, synchronous-reluctance, traction motor technology, which retains the attributes of magnet-rich motors.

Alumotor 1

DER-IC supply chain development project to deliver manufacturing learning for

- Aluminium windings
- Low wastage stator manufacture
- Composites in rotors with additive manufactured flux guides

Alumotor-2

Partners: Aspire, Brandauer, GTR, PSI, WMG and the **DER-IC Midlands** Winding Centre of Excellence

- Application of Alumotor 1 concept to increase a commercial vehicle motor MRL.
- Deliver a ‘design for manufacture’ pre-production, highly sustainable motor, removing 12kg of rare-earth magnets.
- Phase 1 develops DFM solutions, and procures, assembles and tests first iteration motors, to validate the digital-twin model
- Phase 2 optimises manufacturing processes using feedback from LCA, and performance and durability tests
- Parallel development of DFM and manufacturing processes for a higher performance rotor that includes novel composites from the UK-Alumotor 1 project
- Widens the attractiveness of the motor to higher performance Defence and passenger car applications

Case Study 2

H2Gear

Led by GKN Aerospace in partnership with **DER-IC North East** (Newcastle University)

Aim

To lead technological development needed for the future of more sustainable aviation

- The Newcastle University team is developing an ultra-high efficiency liquid hydrogen power and propulsion system
- The propulsion system, designed for short-distance aircraft, can be scaled up to larger aircraft
- Liquid hydrogen is being converted to electricity within a fuel cell system, eliminating CO_2 emissions

- H2GEAR will reinforce the UK's position at the forefront of aerospace technology research and development
- The collaboration between Newcastle University, GKN Aerospace, Intelligent Energy, Aeristech, and the Universities of Manchester and Birmingham will create more than 3,000 jobs in the next decade
- The programme is supported by £27M of Aerospace Technology Institute funding, matched by GKN Aerospace and its industrial partners to make a total investment of £54M.

Case Study 3

RIFT Technology Ltd

'RIFT-10', the RIFT 10-30kW integrated machine and power electronics converter, is an innovative approach to an ultra-efficient Electric Vehicle (EV) motor, with ~50% weight reduction, lower cost and up to 75% increase in range

Aim

- Advance RIFT-10 manufacturing readiness level to MRL7
- Refine the supply chain to enable initial sales of trial units to fund future development and facilitate further investment

Achieved by

- Making Design for Manufacture advancements
- Reshoring the supply chain to the UK
- Advancing UK production capacity to 300 units p.a. at cost of £2,000 per unit.

- **DER-IC Midlands** (Warwick Manufacturing Group) is active in improvement of the supply chain and manufacturing competitiveness
- The collaborative partnership of RIFT and WMG bring together innovation, supply-chain and production expertise, customer knowledge and route to market

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