ADVANCED MATERIALS RESEARCH & INNOVATION

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Advanced Materials Showcase

Growing the UK's critical capabilities in materials innovation

STRATEGY FRAMEWORK CONSULTATION

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Sir Peter Gregson

Royce Chair

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Pippa Sharma

Deputy Director Technology Strategy & Security, Department of Science, Innovation and Technology (DSIT)

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Caroline Hargrove

Chief Technology Officer, Ceres

Advanced Materials at Ceres

Henry Royce Institute for Advanced Materials Showcase

CLEAN ENERGY STARTS WITH CERES

21 April 2023

Caroline Hargrove

Ceres is a leading developer of clean energy technology, for power and green hydrogen.

Our licensing model enables us to partner with some of the world's most progressive companies to decarbonise at scale and pace.

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A leading developer of clean energy technology

600

experts in-house

Our values

We commit wholeheartedly

We are creative collaborators

We pioneer with precision

Our operating businesses

ceres power

Leading technology position in solid oxide fuel cells, being demonstrated in multiple applications and geographies through established global partnerships. Growing demand for higher-power systems and broadening applications in hard-to-abate sectors such as maritime.

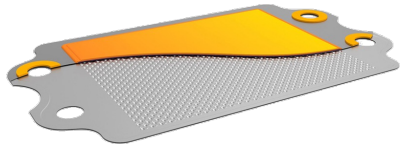
ceres hydrogen

Now addressing the potentially even greater market for electrolysis through a differentiated offering for hydrogen, with distinct advantages in efficiency, coupling with industrial processes that are high emitters of carbon dioxide today.

Our scalable technology

Solid oxide cell

Ceres' core cell is based on low-cost materials: a ceria ceramic electrolyte and a stainless-steel substrate and interconnect.



Solid oxide stack

Highly differentiated stack technology platform with strong and growing intellectual property and distinct advantages of robustness, efficiency and cost.

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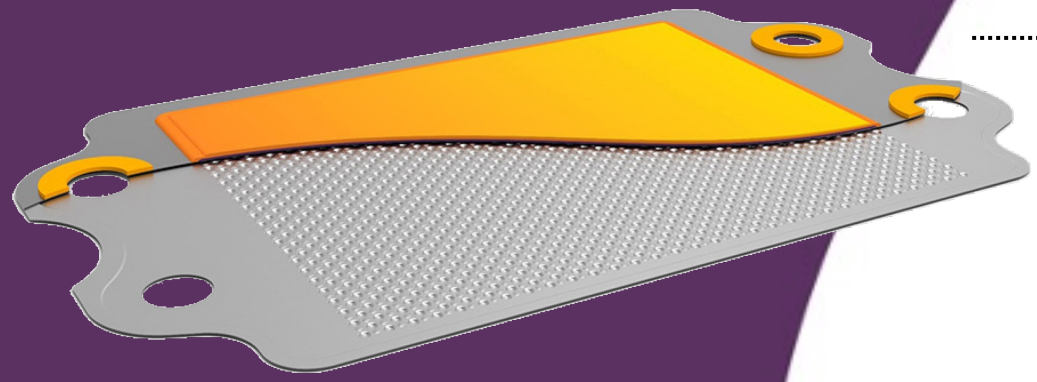
Our technology addresses our partners' applications

Common tech addresses multiple partner applications



Common technology licenced to grow

Stack

ceres power

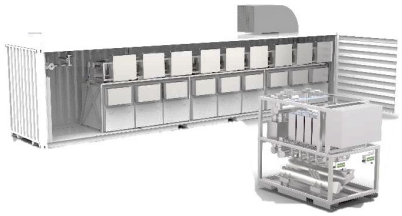
MIURA

BOSCH

DOOSAN

WEICHAI

ceres hydrogen



Engaging with global majors in, Industrial Gas, Clean Energy and Oil & Gas

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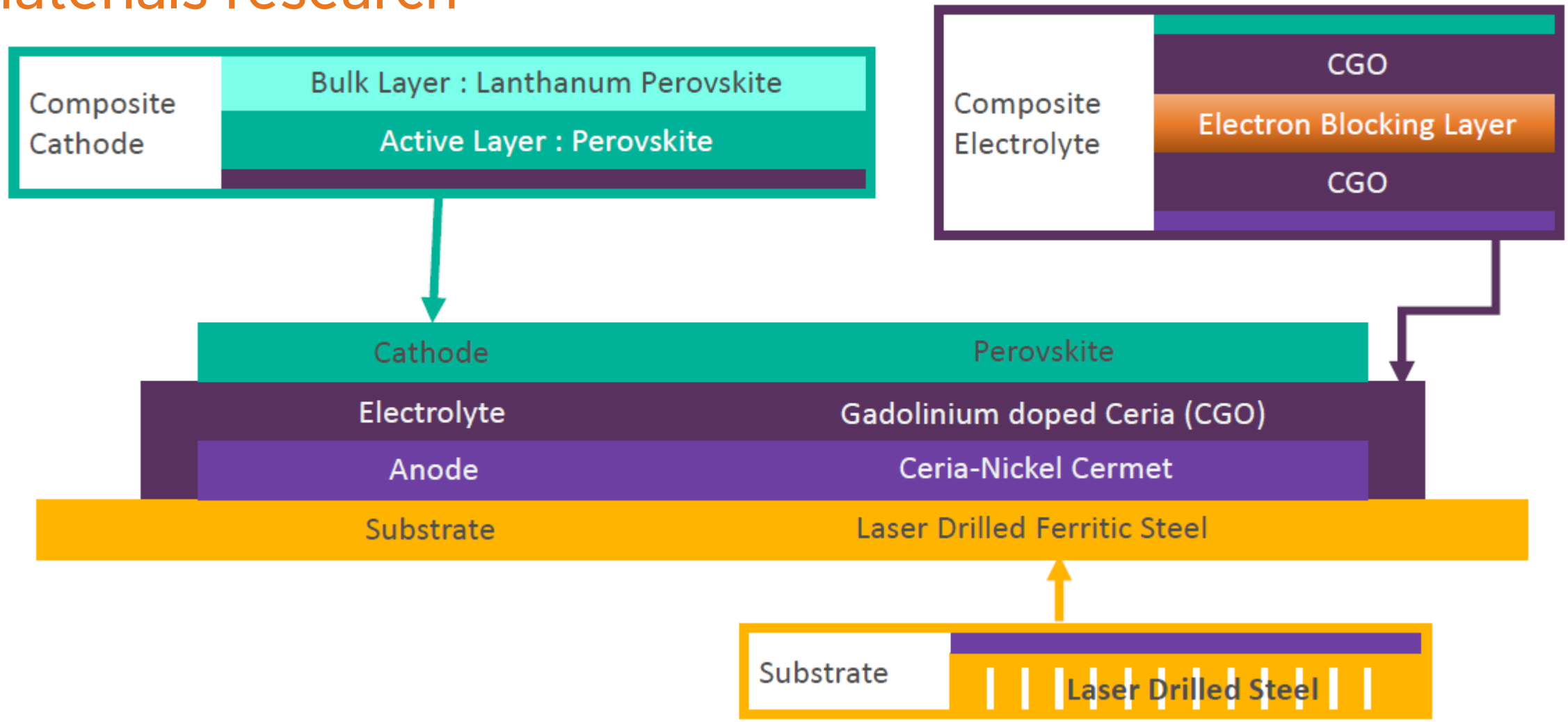
Ceres unique cell architecture comes from Advanced Materials research



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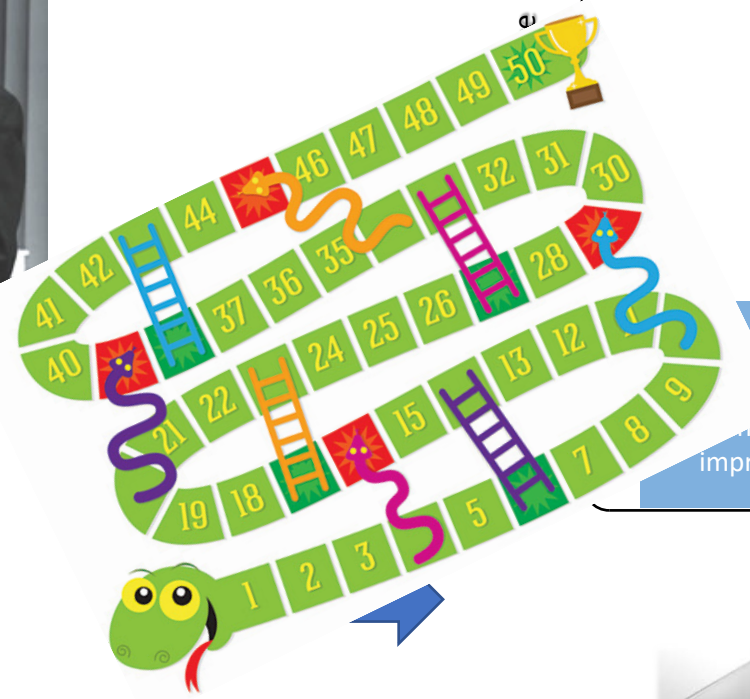
Electrochemical products have long development timelines

Credit: Imperial College

Professor Brian St
co-founds Ceres 20



2 X power improvement
3x life improvement (tested); 5X life (projected)
Increasing robustness to poisons

High volume production starts

ield trials
stness
ufacturing
improvements

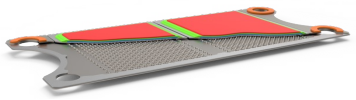
MIURA

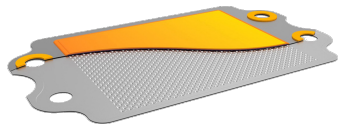
V5 – Tech Transfer
+15% Current density
>50% improved degradation rate

V6 - Launch-readiness
+25% Current density
Improved maturity
Industrialised processes

V7 (in R&D)
Improved Current density
Improved maturity
Improved robustness
New applications compatible
Digitalisation

2016 | 2018-2021 | 2021-2024 | 2023-2026





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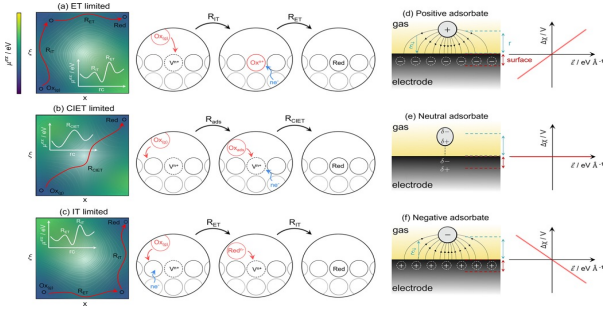
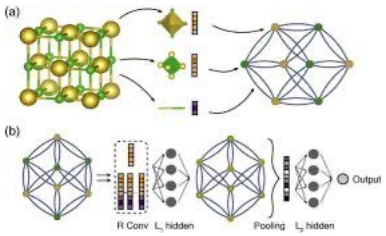
We don’t have 20 more years to provide climate change solutions!

Simulations and AI are accelerating materials innovation breakthroughs

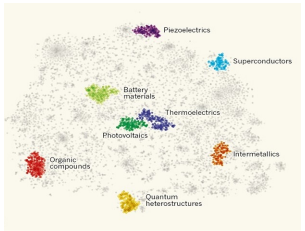


Simulations of fundamental mechanisms – deep specialist knowledge

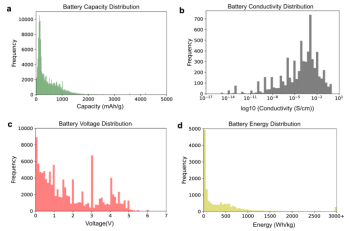


Structure-property relationship

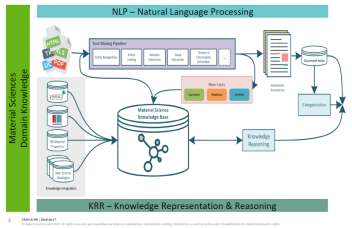
+



Latent knowledge embedding



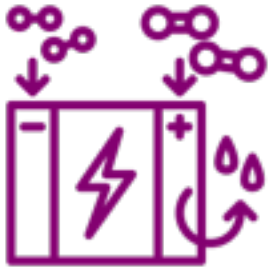
Automatic database construction



Knowledge bases

=

Reduce time for deep knowledge discovery



Accelerate new materials discovery

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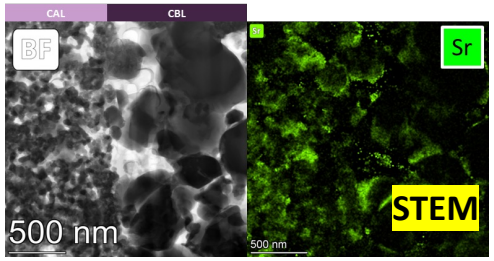
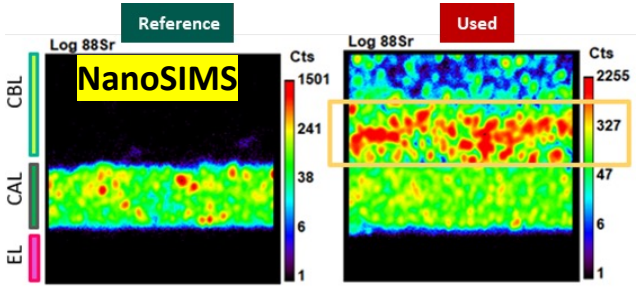
Ceres – Royce Institute Industrial Collaboration Programmes (ICP)

"Mechanistic understanding of solid oxide cell (SOC) electrode aging using multiscale characterisation"*

Core Objective 1: ***Understanding diffusion and distribution of elements in SOC following long term running.***

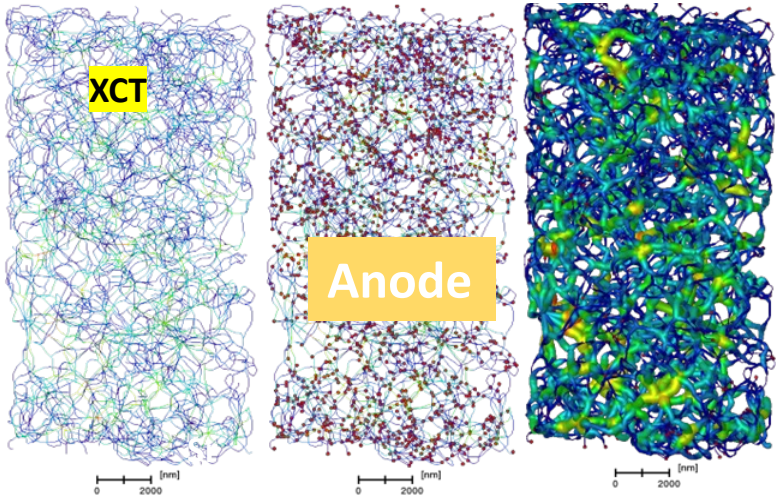
- ❖ STEM and NanoSIMS at Royce Manchester University revealed that Strontium (Sr) diffuses from active cathode layer and gets deposited along the grain boundaries at the cathode current collector (CBL), helping to explain Sr diffusion.





Core Objective 2: ***Understanding the pore network changes with time and its effect in the lifetime prediction of the SOC cell.***

High resolution XCT at Royce, University of Manchester revealed pore connectivity and evolution of pores.



Uni. Manchester Lead: Dr. Katie Moore; Ceres Lead: Dr Santanu Ray

"Understanding degradation and predicting lifetime in solid oxide cells"**

Core Objective 1: ***Understanding the stability of our standard and developmental air electrode materials in various environments***

- ***High partial pressure of oxygen***
- ***High partial pressure of steam***

Ordering, installation and commissioning of an in-situ XRD stage to expand capabilities at Royce/Imperial to enable this work

Characterisation of materials exposed to O_2 at SOC relevant temperatures in dry and humidified environment with XRD, SEM cross-section, LEISS and SIMS show that our air electrode materials are stable in all tested conditions

Imperial College London

Imperial College Lead: Prof. Stephen Skinner; Ceres Lead: Dr. Chandra Macauley

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THANK YOU

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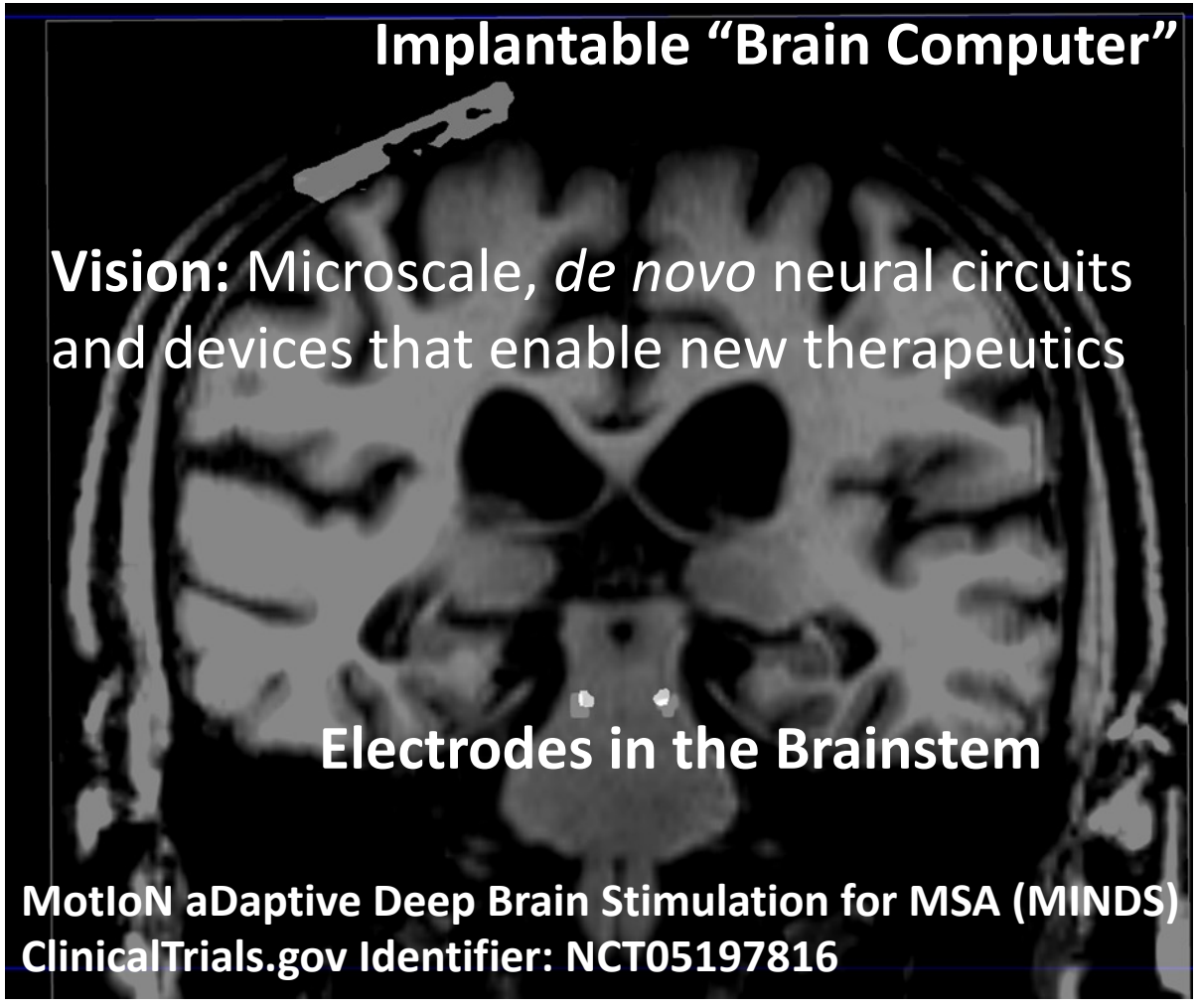
Tim Denison

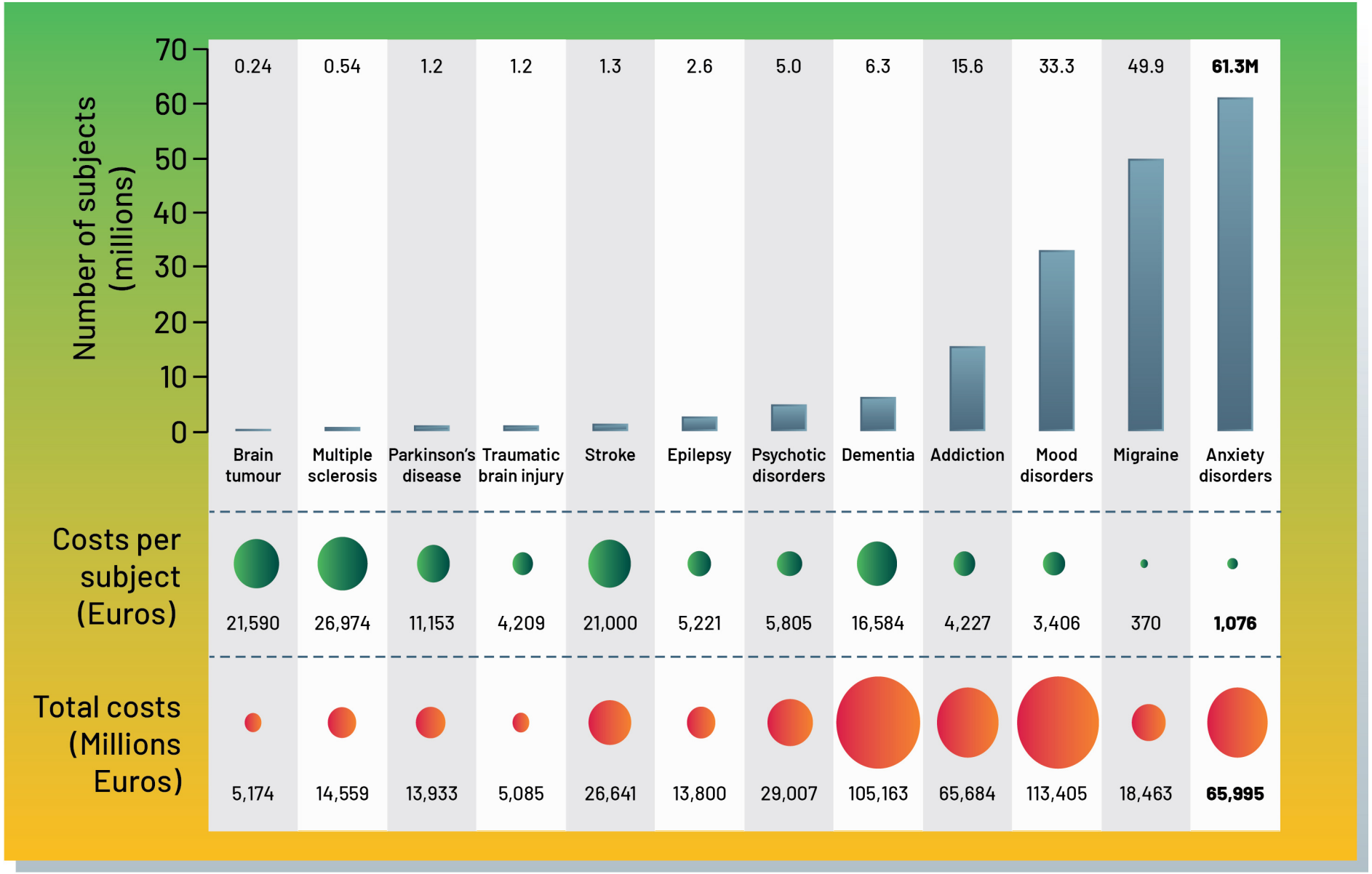
Professor of Engineering Science and Clinical Neuroscience, University of Oxford

Getting from Sci-Fi to the NHS

A FANTASTIC AND SPECTACULAR VOYAGE...
THROUGH THE HUMAN BODY...INTO THE BRAIN.



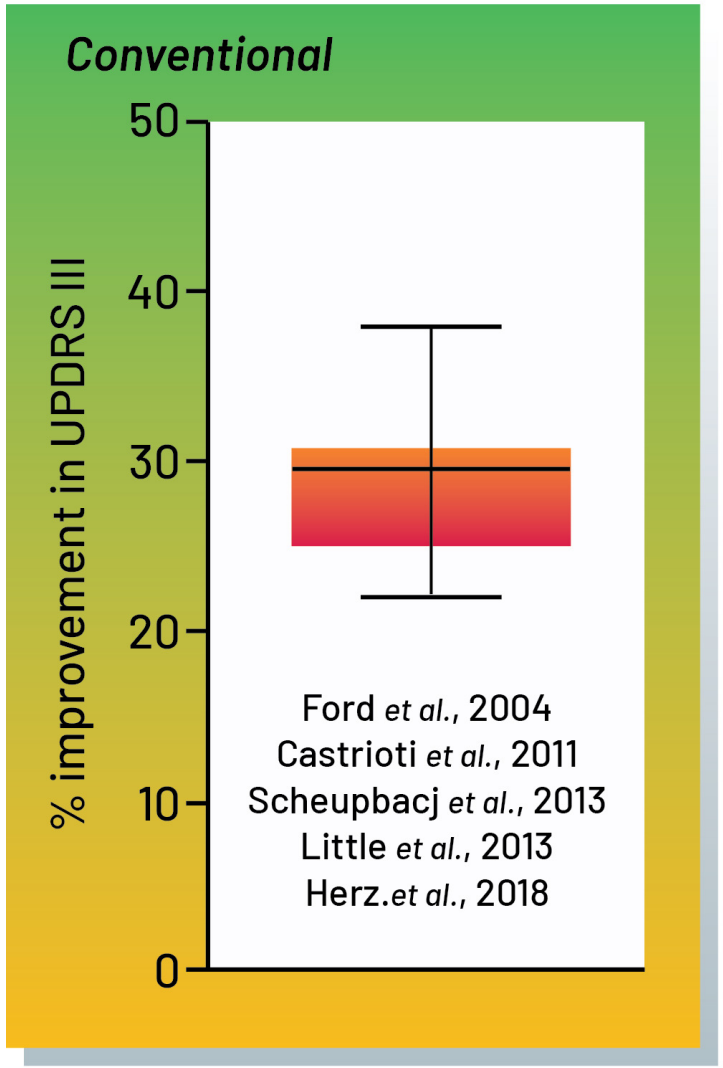
Why this journey matters: The burden of neurological disease



DiLuca, M. and J. Olesen, The Cost of Brain Diseases: A Burden or a Challenge? *Neuron*, 2014. 82(6): p. 1205-1208

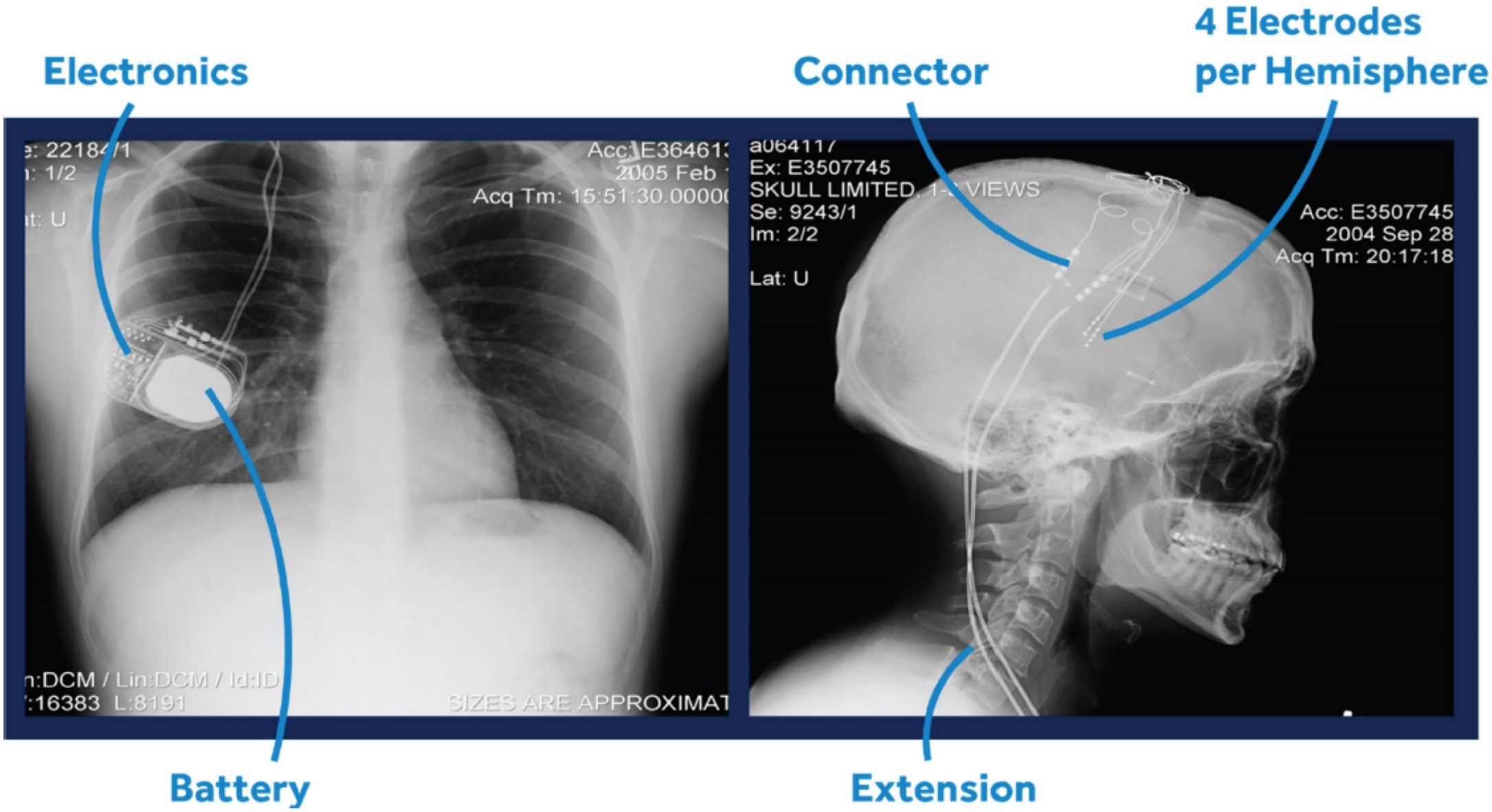
Where are we? Outcomes with brain stimulation

Note: Blinded, which reduces DBS improvement estimates by ~20%

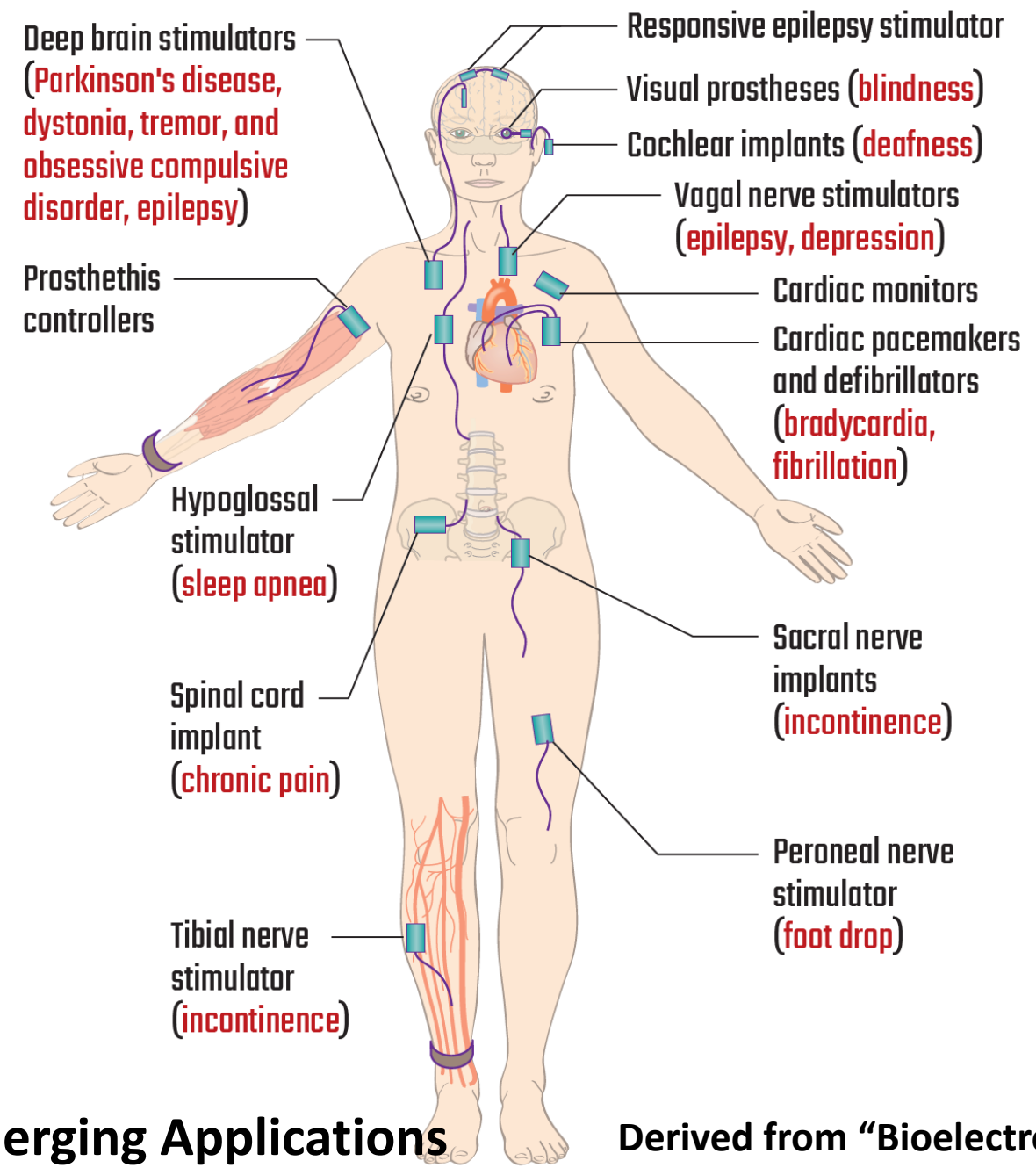


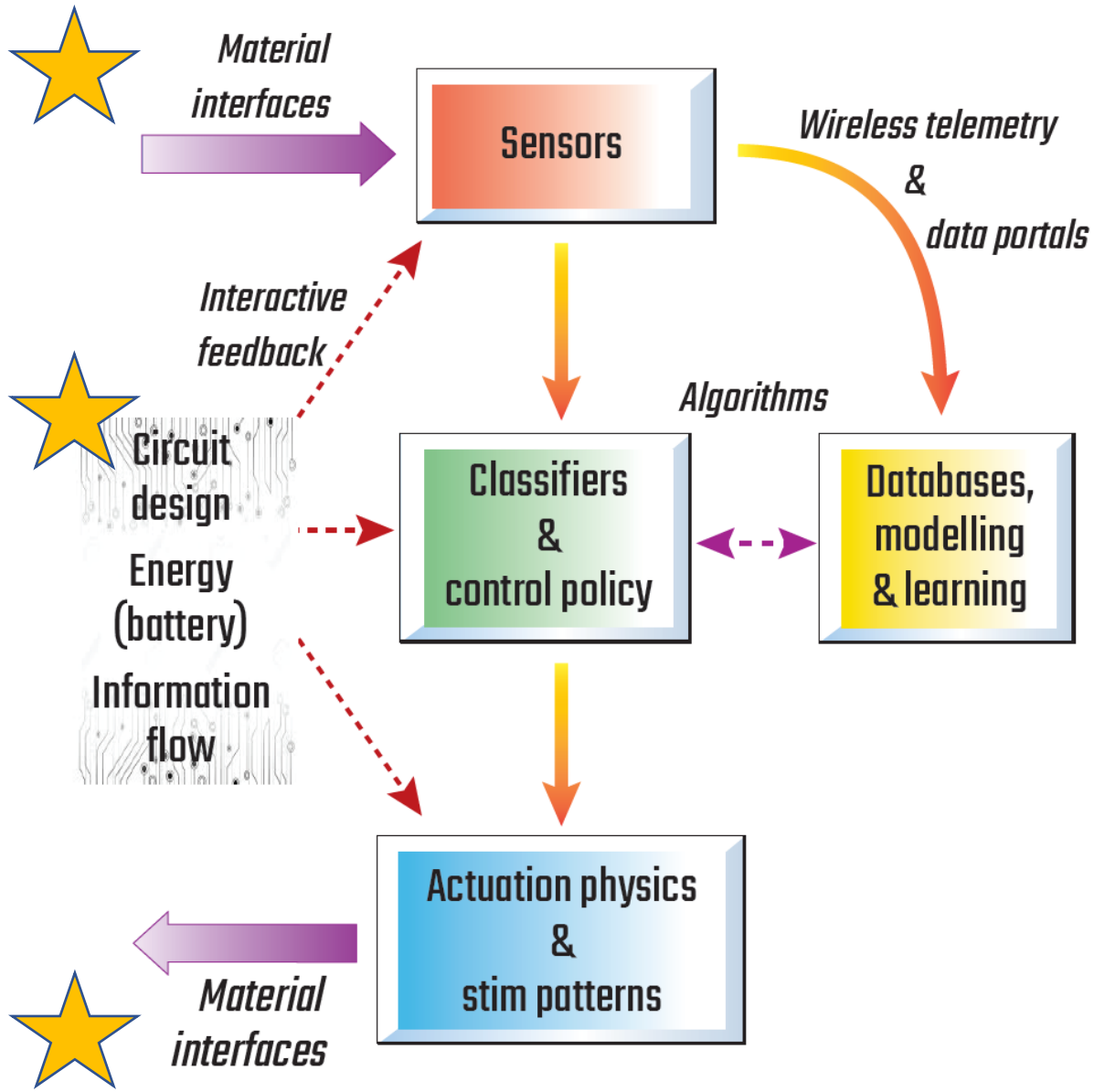
Treatment for intention tremor (Left system is off, Right it is on)

How we got here? Gen-1 brain-interface system
Largely repurposed materials from cardiac pacemakers



Future: Expand Applications → Requires Materials Innovation





Emerging Applications Derived from "Bioelectronics" Ingenia, RAEng 2019 **Technology Stack**

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Robert Sorrell

Royce Hydrogen Challenge Lead

Materials Challenges for Hydrogen Deployment

Producing hydrogen by electrolysis of water has been known for years, the challenge is to address the materials challenges to enable us to scale it up to levels never seen before. Addressing the seven materials challenges outlined across the supply chain would transform hydrogen into a widely deployable source of energy for the UK, creating energy sustainability reducing emissions and creating tens of thousands of jobs.

Production

- Materials to radically improve performance and reduce cost of green electrolysis routes
- Materials solutions to enable waste heat use to drive up efficiency of hydrogen production
- Improved membranes to increase operational reliability and reduce environmental impact

Storage

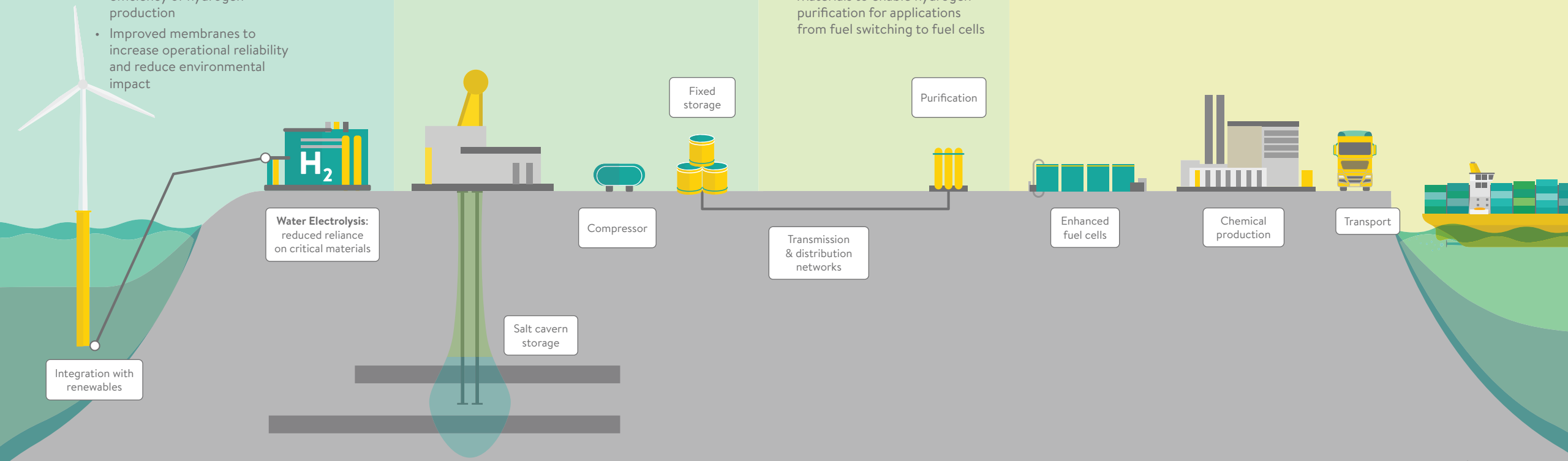
- Robust materials for hydrogen storage at scale for fixed and mobile applications

Distribution

- Compressor materials compatible with moving hydrogen at required volumes through repurposed natural gas network
- Materials to enable hydrogen purification for applications from fuel switching to fuel cells

End Use

- Materials capability to handle liquid hydrogen at extremely low temperatures for aerospace, to >1000°C for making glass, ceramics and powering ships, trucks, and planes



Monitoring

Smart materials for real time monitoring of critical infrastructure and ability to report, mitigate or resolve problems before or as they arise

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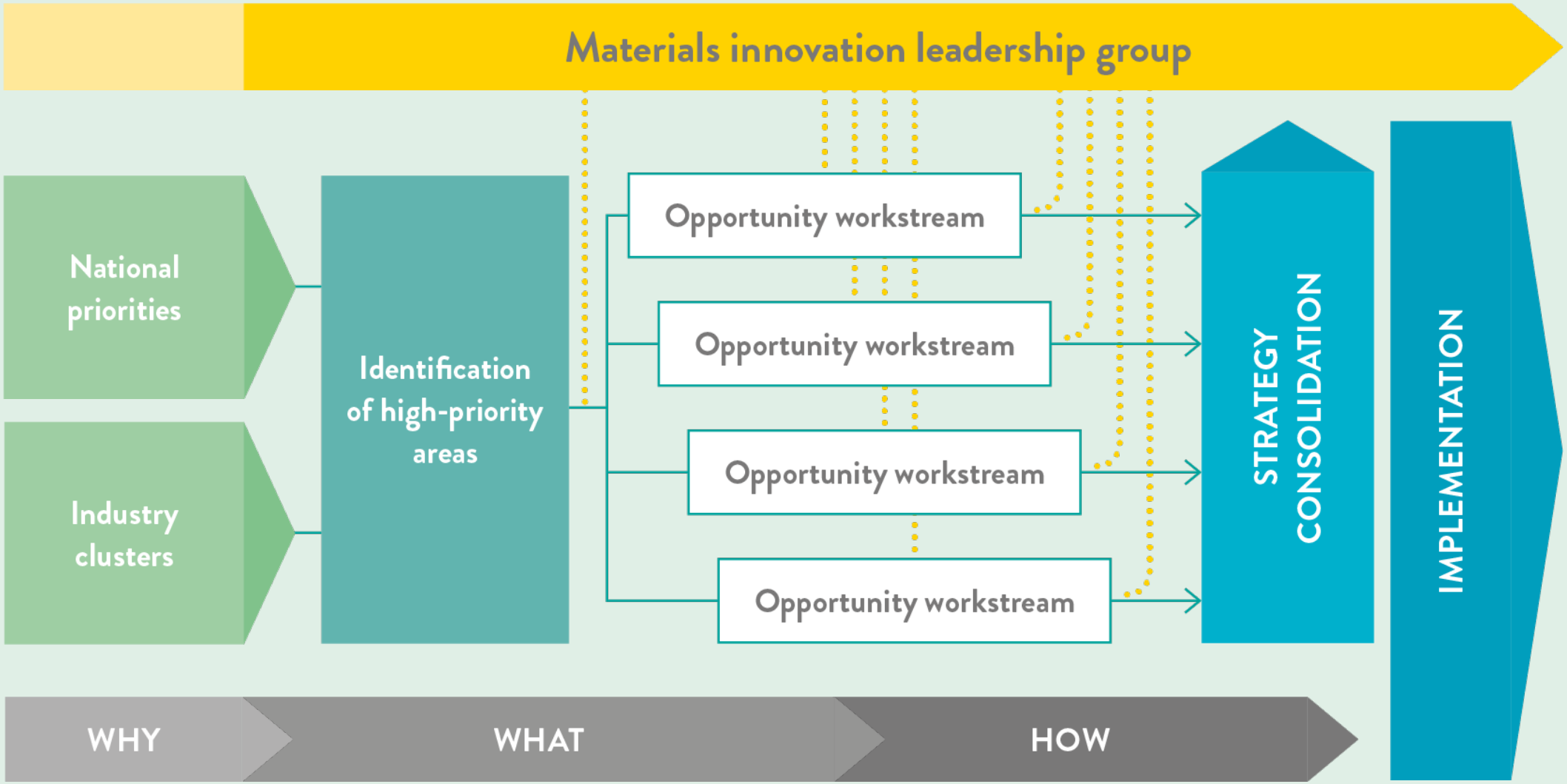
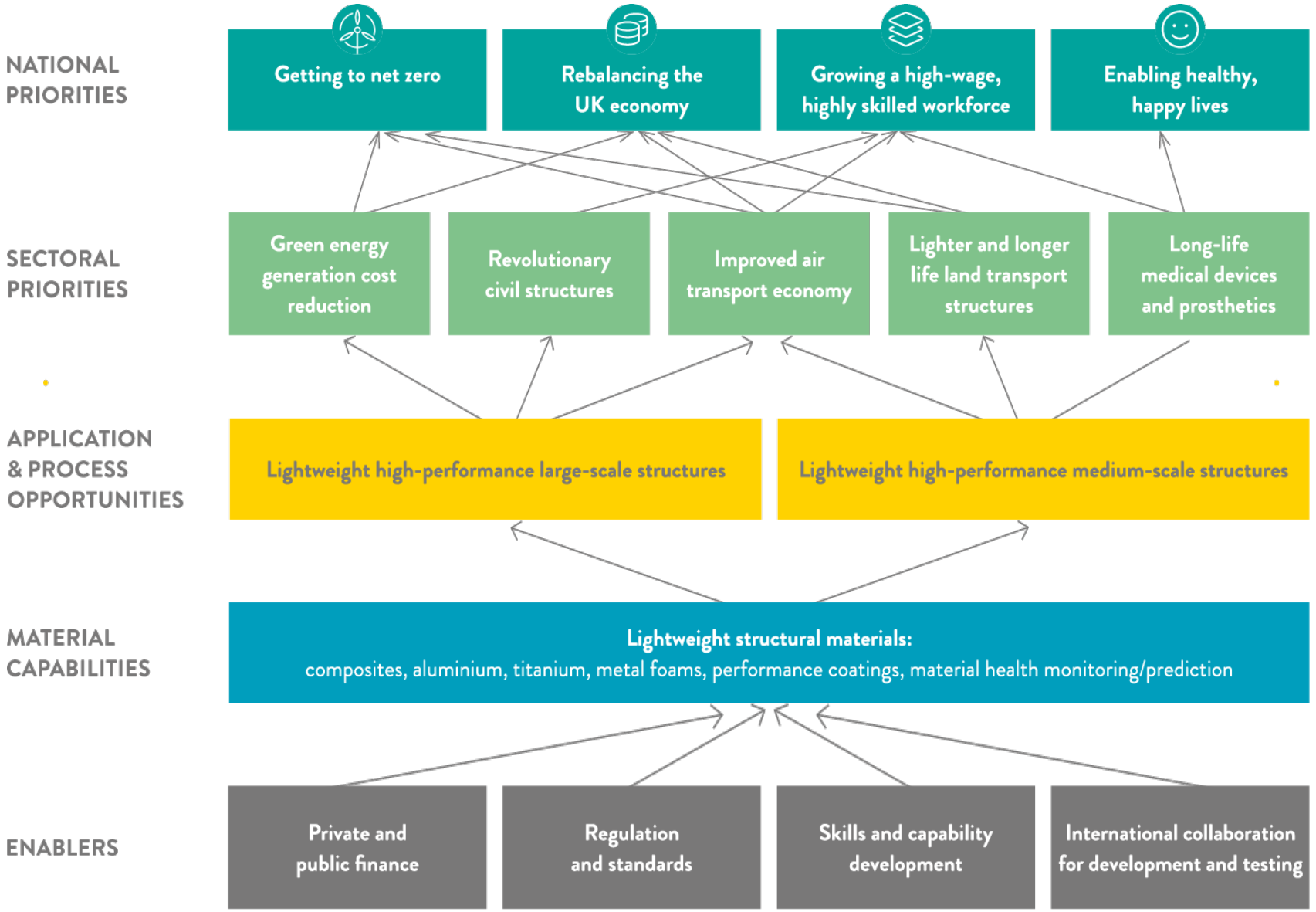
David Knowles

Royce CEO

A Vision for Action



Summary Landscape



A Vision for Action