



RESCU-M²

ANNUAL REPORT

2025



Executive Summary

Year One of the £34.6 million, seven-year Research Hub in Robotics, Automation and Smart Machine-Enabled Sustainable Circular Manufacturing and Materials (RESCu-M²) has been a year of engagement, discovery, and foundation-building. The Hub was established to help the United Kingdom (UK) transition to a more productive and sustainable circular economy by radically improving value retention processes (Re-X)—repair, reuse, refurbish, remanufacture, recycle and recover—through advances in AI, robotics and intelligent automation. This mission is critical nationally: demand for circular solutions is accelerating, with the UK alone expected to decommission 235,000 tonnes of EV batteries by 2040 and more than 52,000 tonnes of wind turbine blades annually by 2030. Yet today, remanufacturing accounts for only 2% of UK manufacturing, and the country remains heavily dependent on imported critical materials.

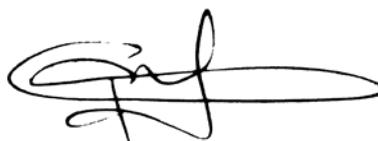
We initiated our scientific programme across seven research themes. These span cyber-physical inspection, collaborative disassembly, hybrid remanufacturing, autonomous sorting, testing and certification, design for minimal life-cycle impact, and circular business models. Research teams across all partner institutions have now been mobilised, with early outputs including accepted journal papers, consultations on emerging standards, development of prototype inspection and digital-twin systems, and new life-cycle case studies for designers. Together, these activities set the foundation for new smart, adaptive, and safe Re-X processes capable of delivering the step-change productivity improvements required for a viable circular economy.

Four sector-led flagship projects – Energy, Medical Devices, Electric Drives and Powertrains, and Large Structures – were developed through extensive engagement with industry partners. These flagships anchor the Hub's research in real, cross-sector challenges and represent some of the most complex sustainability and productivity barriers facing government, business, and society. They are designed to demonstrate

high-impact outcomes, from recovering critical materials to enabling safe, low-carbon de-manufacturing at scale. For example, the Medical Devices flagship addresses the circular processing of MedTech products and waste streams linked to the treatment of the UK's 4.6 million diabetes patients, offering substantial public-value impact.

We have seeded a wider community committed to advancing value retention, including the formation of regional clusters working with local government partners. Engagement has been deep and broad: more than 30 industry and civic partners are now actively involved, supported by an Industry Steering Board chaired by David Moule (ZF Automotive). Well-attended workshops, cross-sector forums and public events have strengthened shared understanding of challenges and built a cohesive national ecosystem that will support technology adoption and policy development throughout the Hub's lifetime.

In the coming year, RESCu-M² will focus on deepening the technical development within each research theme, progressing flagship demonstrators, expanding our regional cluster activities, and accelerating community-building initiatives. We will continue to develop foundation knowledge, work closely with industry to ensure challenge-led innovation, and with policymakers to shape national strategies for circular manufacturing and critical materials. With world-leading facilities across our Hub and spokes, we are now well positioned to deliver the breakthroughs needed to secure a sustainable and productive future for the UK's manufacturing economy.



Professor Samia Nefti-Meziani
Director of RESCu-M² Hub



Professor Samia Nefti-Meziani OBE is Director of The Birmingham Institute for Robotics and Chair in Robotics and AI at the University of Birmingham. With more than 25 years of pioneering research, she is internationally recognised as a leading authority in robotics, intelligent automation, and AI. She received the OBE in the Queen's Jubilee Birthday Honours for services to robotics and was named among Robohub Silicon Valley's Top 30 Women in Robotics Worldwide.

She has led major UK and EU-funded research programmes supported by Engineering & Physical Sciences Research Council (EPSRC), Innovate UK and UK Research and Innovation (UKRI), advancing robotic technologies across nuclear, aerospace, transport, food manufacturing and healthcare. She served as Academic Co-Chair of the UK Cross-Sector Robotics and Autonomous Systems Task Force.

Professor Nefti-Meziani combines technical leadership with a strong focus on the conditions required for the successful deployment and commercialisation of robotics and AI. She has long championed collaboration between engineers, industry leaders and policymakers to accelerate national adoption and secure economic and societal benefit.

One of her most significant contributions is the establishment of the National Committee on Robotics Regulations and Standards, created to bring coherence to the UK's regulatory landscape. The Committee unites regulators, standards bodies and major industry infrastructure organisations, representing 16 sectors, and has gained the support of influential figures including Lord David Willetts and ministers across successive governments.

Her collaborative ethos also shapes her leadership of major national initiatives such as the £34.6M RESCu-M² programme, which supports the UK's transition to a circular manufacturing ecosystem. She has extensive experience directing large-scale and multidisciplinary research efforts, including co-directing the EPSRC National Hub FAIR-SPACE, and has driven major investment in the North of England Robotics Innovation Centre by translating laboratory innovation into practical, industry-ready solutions.

Professor Nefti-Meziani remains dedicated to ensuring that advances in robotics and AI are developed with industry, government and communities, helping the UK realise its ambitions in smart automation and next-generation manufacturing.

Introduction

Welcome to RESCu-M²: We're the UK's Hub for Robotics and AI, Automation, and Smart Machine-Enabled Circular Manufacturing and Materials

RESCu-M² is a ground-breaking national programme designed to drive innovation and economic growth through the development and integration of smart machines, robotics, and AI in circular manufacturing and materials.

Aligned with the UK Government's Invest 2035 strategy, RESCu-M² addresses the urgent need for sustainable access to critical materials and minerals, and aims to reclaim billions in lost product value from End-of-Life (EoL) products.

We are building a future where circular manufacturing becomes the standard, minimising waste, reducing energy consumption, and extending the life of materials through innovative 'Re-X' processes: repair, reuse, refurbish, remanufacture, recycle, and recover.

"The first year of RESCu-M² has seen an exciting acceleration of scientific activity, with research teams across the Hub initiating groundbreaking work in AI-enabled inspection, collaborative disassembly, hybrid remanufacturing and autonomous sorting. These early developments are already demonstrating the transformative potential of smart, adaptive Re-X processes to reshape how the UK retains value from high-value products and critical materials. As we move into year two, the momentum across our research themes positions the Hub to deliver step-change advances that will underpin a world-leading circular manufacturing ecosystem."

Professor Niels Lohse
RESCu-M² Hub Deputy Director and
Director of Scientific Work Packages

"By forging deep partnerships with industry, academia and policy-makers, we're not only driving research excellence but creating tangible pathways to save millions of tonnes of CO₂ and unlock billions in resource efficiency gains. Our interdisciplinary Hub is proving that sustainable manufacturing is not a niche ambition but a transformative opportunity—reshaping how materials are used, products are built, and industry innovates for a low-carbon future. By integrating AI, robotics and smart machines into circular manufacturing and critical mineral reuse, we drive resource efficiency and secure supply chains, aligning with the manufacturing pillar of the UK industrial strategy and positioning the UK for global sustainable manufacturing leadership."

Professor Robert Richardson
Director of Impact



RESCU-M²

Positioning the UK as a global leader in sustainable circular manufacturing and materials

The Hub will address key challenges in radically transforming the sustainable use of critical materials and radically improve productivity of Re-X manufacturing processes.

Grand Challenge 1

Radically transform the sustainable use of critical materials

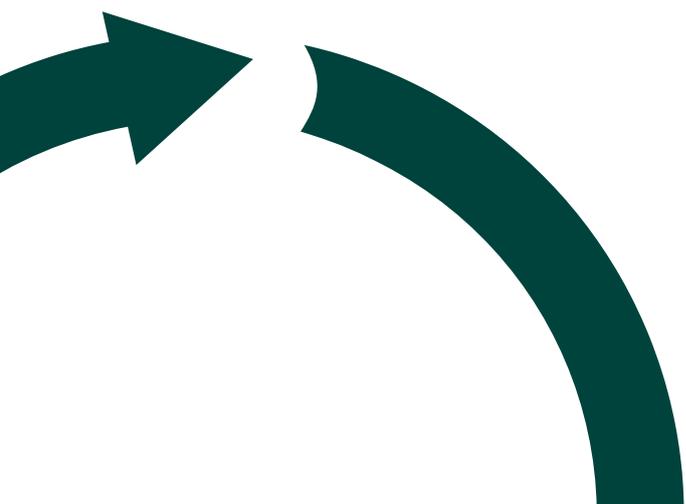
Grand Challenge 2

Radically improve the productivity of Re-X manufacturing processes on par with or exceeding traditional forward manufacturing processes

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Objectives

- 1** To establish Sustainable Circular Manufacturing as a recognised research discipline in the UK, with a critical mass of activity which shows global leadership.
- 2** To develop innovative manufacturing processes and technologies to improve the integrity and in-service reliability of high performance robotic arms.
- 3** To bring rigorous leading-edge and more effective Smart Re-X manufacturing processes and digital manufacturing research using robotics, automation and smart machines.
- 4** To embody the research findings in an array of hardware demonstrators to support scale up and wider industry/academic engagement.
- 5** To rapidly transition AI technology through to industrial application by pulling proof of principle or concept Re-X (repair, reuse, refurbish, remanufacture, recycle and recover) manufacturing systems through to manufacturing research demonstrators.
- 6** To create open and inclusive academic, industry and policy communities around the Hub providing supported access to the research outputs.
- 7** To enhance, improve and promote the UK skills base in the field of Sustainable Circular Manufacturing and Materials.
- 8** To support the UK manufacturing industry by developing smart systems that are robust to variation by supporting designers at the onset of the circular process.

Academic Partners

The University of Birmingham has a strong legacy in robotics, AI, and manufacturing innovation. The University of Birmingham Institute for Robotics unites engineering, computing, and AI to advance autonomous systems, medical, and rail applications. Major projects in nuclear robotics and circular manufacturing drive sustainable breakthroughs, while the Energy and Magnetic Materials groups develop sustainable battery technologies, spanning materials, manufacturing, and recycling.



**UNIVERSITY OF
BIRMINGHAM**

The Electrical Machines and Drives Group has a long track record of research in electrical machines and drives, with research income of >£25m over the last five years. It hosts five industry-funded research centres, including a Rolls-Royce University Technology Centre (UTC) in Advanced Electrical Machines, the Sheffield-Siemens Wind Power Research Centre (S2WP) and Romax Technology Centre.



**University of
Sheffield**

The University of Strathclyde's Digital Manufacturing Group (DMG), advances data-driven, "zero-setup/zero-measurement" manufacturing via digitalisation, instrumentation, in-process monitoring, real-time simulation, and digital twins for skill-intensive processes (e.g., wings, engine assembly). Based in MAC, DMG collaborates with industry across a number of UKRI-funded projects. The Scottish Institute for Remanufacturing advances Scotland's Circular Economy, while the CPM Centre pioneered a six-axis hybrid micromachine and a digital-twin smart micromanufacturing system.



**University of
Strathclyde
Glasgow**

The Advanced Engineering Centre at the University of Brighton works to develop truly sustainable solutions in transport, energy and manufacturing with practical wisdom at the heart of our approach. University of Brighton is setting up a regional Catalyst for Remanufacturing in the South East (CARE), which has already become a delivering partner for Brighton & Hove City Council's 2030's circular economy action plan.



University of Brighton



The Manufacturing Technology Centre (MTC) is a Research Technology Organisation and part of the Catapult Network. The MTC's mission is to generate rapid and sustainable industrial growth in the UK by delivering integrated manufacturing system solutions for customers, large and small, across sectors as diverse as Energy and Utilities, Defence and Security, Future Mobility, and the Built Environment.



Loughborough University is renowned for impactful research that strengthens industry, shapes policy, and improves lives. The Centre for Sustainable Manufacturing and Recycling Technologies (SMART), founded in 2004, develops strategies, methods, and technologies for sustainable product design, production, use, and disposal, supporting businesses in reducing waste and helping protect the planet's future.



The University of Leeds is a large, research-intensive public university founded in 1904, and is a member of the Russell Group. It is known for high-quality teaching and research, with over 39,800 students from around the world. The Institute for Design, Robotics and Manufacturing and Real Robotics have long-standing expertise in community engagement, bringing stakeholders into the research process and ensuring maximum impact.



Durham University Engineering is a Russell Group department ranked among the UK's top engineering schools, offering research-led education and strong industry engagement. Its £4.3 million facility investment supports advanced labs including wind tunnels, clean rooms, and geotechnical testing. Research is organised via eight technical nodes and three challenge areas such as Future Energy Systems and Sustainable Infrastructure.



RESCu-M² Hub Co-investigators

Ms. Agata Suwala is a Technology Manager for Automation and Robotics at the MTC. With ten years' experience in research and development, she specialises in automation and robotics implementation, particularly in the aerospace industry. She has co-ordinated and delivered a number of research and direct projects for automation in aerospace manufacturing, working in collaborative and multi-functional teams.



Professor Allan Walton has expertise in processing of permanent magnetic materials, solid state hydrogen storage materials, hydrogen processing of materials, coating technologies, hydrogen purification membranes and recycling of rare earth materials. Allan is Professor of Critical and Magnetic Materials and is the ex-chair of the UK Magnetics Society. He has published over 35 papers in scientific journals and has contributed to four patents held by the University of Birmingham.



Professor Ales Leonardis is Chair of Robotics at the School of Computer Science, University of Birmingham and Co-Director of the Computational Neuroscience and Cognitive Robotics Centre at the University of Birmingham. He is also Professor of Computer and Information Science at the University of Ljubljana and an Adjunct Professor at the Faculty of Computer Science, Graz University of Technology. He was a visiting researcher at the GRASP Laboratory at the University of Pennsylvania, a post-doctoral fellow at PRIP Laboratory, Vienna University of Technology, and a visiting professor at ETH Zurich and University of Erlangen.



Professor Ashutosh Tiwari is Deputy Vice-President for Innovation at the University of Sheffield and holds the RAEng/Airbus Research Chair. He is internationally renowned for research in digital manufacturing and works in partnership with industry to develop new techniques and solutions for digitalisation, instrumentation, in-process monitoring and real-time simulation of skill-intensive manufacturing processes, such as wing manufacture and engine assembly.



Professor Andrew Dove is a Professor of Sustainable Polymer Chemistry, leading the Dove Group lab (www.dovegrouplab.com), which is focused on addressing challenges related to sustainability and circularity in polymers, plastics and elastomers. Professor Dove is co-lead of the Birmingham Plastics Network, an interdisciplinary team of >100 academics working together to shape the fate and sustainable future of plastics. His work extends from polymer science and engineering into science policy in plastic sustainability and he is part of the UK Government Circular Economy Task Force.





Professor Clive Roberts is Executive Dean (Science) at Durham University. He was the Director of the BCRRE and previously Head of the School of Engineering. He also founded and led the national UK Rail Research and Innovation Network (UKRRIN). Clive has over 25 years' experience in Higher Education and a track record in attracting significant research income and in international growth, facilities and partnerships development. Clive's academic interests cover a range of interdisciplinary areas, including sensing and data analysis; complex system simulation; risk and safety assessment; AI and machine learning; cybersecurity and systems engineering.



Professor Duc Trouong Pham's research covers the fields of mechanical, manufacturing, computer and systems engineering. His academic output includes more than 600 technical papers and 17 books. He has supervised over 100 PhD theses to completion. He has won in excess of £30M in external research grants and contracts. In addition to pursuing and leading research, he has acted as a consultant to several major companies and has been active with knowledge transfer to industry, applying the results of his work to help multinational companies and SMEs generate wealth and create and safeguard jobs.



Professor Emma Kendrick is Chair of Energy Materials, in the School of Metallurgy and Materials at the University of Birmingham, co-director of the Centre for Energy Storage (BCES) and co-lead of the Energy Materials Group (EMG). She has been recognised for her research in sustainable batteries and her continued support to the research community through several awards: 2021 Faraday Institution (FI) Researcher Development Champion; Royal Society of Chemistry (RSC) 2021 Environment, Sustainability and Energy Division Mid-Career Award; and the 2019 Hothersall Memorial Award for outstanding services to Metal Finishing.



Professor Geraint Jewell is a Professor of Electrical Engineering at The University of Sheffield (UoS). He held an EPSRC Advanced Research Fellowship from 2000 to 2005 and a Royal Society Industry Fellowship with Rolls-Royce PLC from 2006 to 2008. He is Director of the Rolls-Royce University Centre in Advanced Electrical Machines and the EPSRC Future Electrical Machines Manufacturing Hub. He previously served as Head of the Department of Electronic and Electrical Engineering and Vice-President for the Advanced Manufacturing Group. His research interests include the design, modelling, and manufacture of a wide variety of electromagnetic and electromechanical devices.



RESCu-M² Hub Co-investigators

Dr Justyna Rybicka is a Technical Specialist at the MTC. Her research experience focuses on operational and strategic level decision-making in manufacturing and wider systems through modelling and simulation. In recent years, she has been developing capabilities around evidencing the sustainability of manufacturing innovation and circularity. She holds a PhD in production engineering from Cranfield University.



Mr Karol Janik is the Robotics and Automation Technology Manager at the MTC, where he leads the long-term strategy for deploying robotics, automation, and autonomous systems across manufacturing and challenging environments. With over a decade of industrial R&D experience spanning aerospace, nuclear, advanced manufacturing and other sectors, Karol plays a leading role in several European robotics initiatives and associations. He serves on multiple industrial advisory boards for CR&D programmes and is General Chair of the European Robotics Forum 2027, which will be held in Birmingham.



Professor Martin Freer is Chief Executive Officer of the Faraday Institution. He is Head of Nuclear Physics, Director of the Birmingham Energy Institute and the Birmingham Centre for Nuclear Education and Research at the University of Birmingham. His main research area is the study of the structure of light nuclei, using nuclear reactions. This research is performed at international facilities worldwide. In addition, he is actively engaged in promoting research and educational programmes to support the UK's investment in nuclear power generation. He received the Friedrich Wilhelm Bessel Prize, Humboldt Foundation, Germany, in 2004 and the Rutherford Medal (IoP) in 2010.



Professor Moataz Attallah is the Dean of the School of AACME at Loughborough University. He also holds a chair in advanced materials processing at the Department of Materials. Previously, he was the Director of Research and Knowledge Transfer at the School of Metallurgy and Materials, University of Birmingham. His research portfolio over the past 20 years has been focused on friction-based welding technologies and laser fabrication technologies, through research partnerships with Rolls-Royce PLC, MBDA, European Space Agency (ESA), ITP, Aero Engine Controls, BAE Systems, TWI, Messier-Bugatti Dowty, MicroTurbo, Meggitt, and Novelis.



Professor Niels Lohse is a Deputy Director of the Hub and Professor of Manufacturing Automation and Robotics at the University of Birmingham. He supports the Hub Director and leads the scientific work programme, drawing on his extensive experience in intelligent automation, robotics, and AI. A specialist in human-robot collaboration and smart manufacturing systems, Professor Lohse ensures that cutting-edge research is translated into practical, scalable solutions. He also provides a vital interface to the Co-AIMS research hub, strengthening cross-hub collaboration on sustainable, human-centred automation.



Professor Robert Kay is a Professor in Advanced Manufacturing at the University of Leeds with extensive experience in both academic and industrial research. He has pioneered disruptive manufacturing techniques, including a patented electroforming process founded to commercialise his innovations. His research spans additive manufacturing, materials, and electronics, supported by EPSRC funding and industrial partnerships. He also contributes to international additive manufacturing standards and is passionate about inspiring the next generation of engineers through teaching and outreach.



Professor Robert Richardson, Director of Impact, is a Professor of Robotics at the University of Leeds, leading the Real Robotics Lab. His research focuses on real-world robotic systems operating in the diverse environments of air, land, and underwater; supported by foundational research into manufacturing technologies, control and actuators. Between 2019 and 2023, he was Executive Chair of the EPSRC UK Robotics and Autonomous Systems (UK-RAS) network, with a strong focus on academic engagement and collaboration.



Professor Shahin Rahimifard is a Professor of Sustainable Engineering at Loughborough University and the Founder and Director of the Centre for 'Sustainable Manufacturing and Recycling Technologies (SMART)'. His research work is focused on sustainability issues throughout a 'Product Lifecycle', including projects on sustainable product design, resource efficient manufacturing, sustainable business models, and reuse and recycling technologies. These projects have benefited from involvement of a number of high profile global manufacturers and retailers, which include Rolls-Royce PLC, Jaguar Land Rover, GM, Nike, Clarks, Next, Unilever, PepsiCo, Marks & Spencer, and Tesco.



Dr Steve Davis has more than 25 years' experience in the field of robotics and is currently a Senior Research Fellow in Robotics at the University of Birmingham. Steve's research covers many areas of robotics with a specific focus on manufacturing, dexterous robot hands, end effectors, grasping and manipulation, human-robot interaction and collaboration, soft robotics and biologically inspired robot systems. He has worked with many industrial sectors, including automotive, energy (nuclear) and space and has received funding from UKRI, Innovate UK and the EU, in addition to industry-funded research.



RESCu-M² Hub Co-investigators

Professor Winifred Ijomah is a Director of The Scottish Institute for Remanufacturing, a pan-Scotland expertise Hub established to spearhead the Circular Economy in Scotland using product recovery. She is the Founding Editor of Springer's *Journal of Remanufacturing*, the first academic journal in the remanufacturing field. Professor Ijomah initiated and chaired the first International Conference on Remanufacturing, the first international academic conference for remanufacturing; and now a biennial event running in conjunction with Rematec, the world's leading remanufacturing exhibition and trade event.



Professor Xichun Luo is a Director of Research and Technical Director of Centre for Precision Manufacturing (CPM) at the University of Strathclyde. He is the founding Editor-in-Chief of *High-End Manufacturing* (a new SciLight Journal), an Associate Editor for *Proceedings of IMechE Part C: Journal of Mechanical Engineering Science*, and *Journal of Micromanufacturing*, and *Nanomanufacturing and Metrology*. His team established the world's first six-axis hybrid micromachine and developed a novel digital twin-driven smart micromanufacturing system.



Professor Yan Wang is a Professor in Circular Manufacturing, focusing on remanufacturing with case studies ranging from automotive, moulds and dies, machine tools, non-road mobile machinery, medical devices, etc. She was named as one of the "30 Most Inspiring Women" by KTN and *The Manufacturer* magazine in 2021. She chairs BSI standards for remanufacturing (TPR1/7/3), with her knowledge embedded in British Standards Institution (BSI) standards, e.g. BS8887. Working closely with industry, she has generated £6 million of economic benefits for businesses through two Knowledge Transfer Partnership projects.



Dr Yongjing Wang is an Associate Professor in the Department of Mechanical Engineering, School of Engineering, University of Birmingham. In the area of smart robotics for sustainable manufacturing, Wang is the Principal Investigator of the three EPSRC grants with a total value of £3.5M (ATARI, STAMAN and RoboTriage) and has over 60 publications. Wang's research work has been supported by world-leading companies in the aerospace, automotive and recycling industries in the UK, EU, US and China. He is on the advisory board of the United Nations Higher Education Sustainability Initiative, an editor of the United Nations guidelines on artificial intelligence for sustainability, and an invited member of a standard committee with the British Standards Institution (BSI), UK.



RESCu-M² Hub Operation team

Mr Peter Vitulli is the RESCu-M² Hub Project Manager. Bringing over 25 years of experience in high-tech industries spanning domestic, consumer, and industrial electronics, with the past decade focused on robotics research and innovation. He holds an honours degree in Computer Science and Artificial Intelligence, specialising in intelligent robotics. He led a £42 million EPSRC-funded project at the University of Birmingham and helped establish one of the UK's largest robotics labs for extreme environments. A champion of sustainability and inclusion, Peter actively promotes STEM outreach and serves as an EDI Ambassador for the School of Engineering.



Dr Osama Olaby is the Technical Manager of the Hub. Over the past two decades, he has accumulated extensive experience in research and teaching across four different countries. His diverse experience, spanning both academia and industry in the UK and abroad, has provided him with a unique perspective on Control Engineering, Mechatronics, Systems Integration and Automation. This perspective is enriched by his work in multidisciplinary areas like Medical Robotics, Health Care, and Rail Transport.



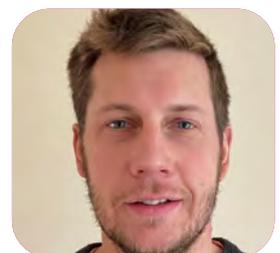
Dr Sarah Field is Community Engagement Lead and Project Manager at the University of Leeds. Sarah has held Technical Director roles in SMEs and Spin-Out companies, and recently led knowledge exchange and relationship development for multiple academic projects.



Aurelie Tolton is a Project Manager at the MTC, working primarily on government-funded projects such as Innovate UK (IUK), Department of Energy Security and Net Zero (DESNZ), and the Engineering & Physical Sciences Research Council (EPSRC) projects. Aurelie has over 15 years of experience managing projects in both R&D and production environments.



Mr Samuel King is a Senior Project Manager in the School of Metallurgy and Materials at the University of Birmingham. He manages the Birmingham Centre for Strategic Elements and Critical Materials (BCSECM) and the Magnetic Materials Group (MMG). Sam oversees major projects including RECREATE (EPSRC), REESilience (EU), and a commercial magnet recycling facility, focusing on REEs, permanent magnets, and collaboration with academic and industrial partners.



RESCu-M² Hub Researchers

At the core of the RESCu-M² Hub is a team of academics and highly skilled researchers working collaboratively across six sites. The team partners closely with industry to tackle critical challenges in circular manufacturing through the use of AI-driven smart machines and advanced robotics.



Dr Ali Aflakian
Research Fellow
University of Birmingham



Alexandra Rosioru
Research Engineer
Manufacturing Technology Centre



Dr Abdelmoez Hussein
Research Associate
Loughborough University



Dr Divya Tiwari
Research Associate
University of Sheffield



Mr James Owens
Senior Research Engineer
Manufacturing Technology Centre



Dr Jiaqi Ye
Research Fellow
University of Birmingham



Dr Leigh Kirkwood
Advanced Research Engineer
Manufacturing Technology Centre



Dr Michael Farnsworth
Research Associate
University of Sheffield



Michael Mendoza-Bollam
Graduate Research Engineer
Manufacturing Technology Centre



Minh Nguyen (Quang)
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University of Birmingham



Momen Negm
PhD Researcher
University of Birmingham



Dr Simon Ascher
Research Associate
Strathclyde University



Dr Steve Forrest
Research Fellow
University of Sheffield



Soravi Charoenwijitkul
PhD Researcher
University of Sheffield



Mr Windo Hutabarat
Research Associate
University of Sheffield



Yue Yao
PhD Researcher
University of Sheffield



Dr Yue Zang
Research Associate
University of Sheffield



Dr Ze Zhang
Research Associate
University of Sheffield

RESCu-M² Hub Independent Advisory Board

The Independent Advisory Board (IAB) brings together experts and policymakers across the fields of robotics, circular manufacturing, net zero and Re-X processes to provide oversight of the RESCu-M² research programme. They provide advice on the overall direction of the programme, support the strategic development of the research, offer insights into external developments which may benefit or influence the project, and act as a critical friend to leadership, with constructive challenge where appropriate.



Chair - Nabil Nasr
REMADE Institute
Founding Director,
Centre for Remanufacturing
and Resource Recovery

"The IAB, comprising experienced professionals from a broad spectrum of global industries, provides strategic guidance and calibration of the Hub's goals. It maintains oversight of the Hub's progress, offering recommendations informed by extensive industry practice. In an environment where large-scale initiatives depend on significant government and private-sector investment, and where ambitions are necessarily high, the IAB serves to ensure that objectives remain aligned, actionable, and grounded in sound professional judgement"



Fiona Charnley

UKRI National Interdisciplinary
Circular Economy Hub



Rehemat Bhatia

EPSRC Senior Portfolio Manager



Darwin Caldwell

Founding Director of
the Italian Institute of
Technology (IIT)



Liam Hogg

NHS Head of Net Zero Carbon
Waste and Resources



Niel Glover

Head of Materials Research,
Rolls-Royce PLC



Alois Christian Knoll

Technical University of Munich



Caroline France

Head of Robotics & Advanced
Materials at DSIT



Richard Walker

Board Member and Director
of Shadow Robot



Dominic Keen

Founder and CEO, Managing
Partner at Britbots
National Productivity
Campaigner

RESCu-M² Hub Industry Steering Board

Our Industry Steering Board (ISB) comprises members from across our industry partners. Chaired by David Moule (ZF Automotive), this board will ensure that the research activities undertaken within RESCu-M² align with industry priorities. Members will act as ambassadors, championing circular manufacturing and RESCu-M² outputs to ensure maximum impact.

If you are interested in joining our Industry Steering Board, please don't hesitate to contact us.



David Moule
(Chair)



Patrick Shroeder



Jack Lemm
Mike Hogan



Paviter Singh Phull



Ian Walker



Marco Chacin



Simon Swallow



Sarah Kelly



Anne Marie Hughes



Viola Vahle



Nick Lyt



Phil Winship



Adeel Aslam



Sara Ridley



Mark Gregory



David Fitzsimons



Lorenzo Gaspari



**Panagiotis Stavrakakis
Patrick McGinley**



Vaibhav Puri O.B.E.



**Chris Ballard
Andrew Begbie
Paul Mort**



**UNIVERSITY OF
BIRMINGHAM**

Jon Roberts

Enterprise



**West Midlands
Combined Authority**

**Charlie Hopkirk
Steven Heales**



John Mackie

Industry Partners

Our partners help us work towards our vision of putting the UK at the forefront of global scientific and technological advancement in sustainable circular manufacturing.

The Hub is supported by over 30 project partners from industry and local government, forming a strong and interdisciplinary foundation for delivering the project's ambitious goals.

Companies will work closely with the Hub team over the life of the programme to address industry pain points, develop demonstrable processes, methods, or tools to increase efficiency or reduce waste, and validate the impact of the developed solution.

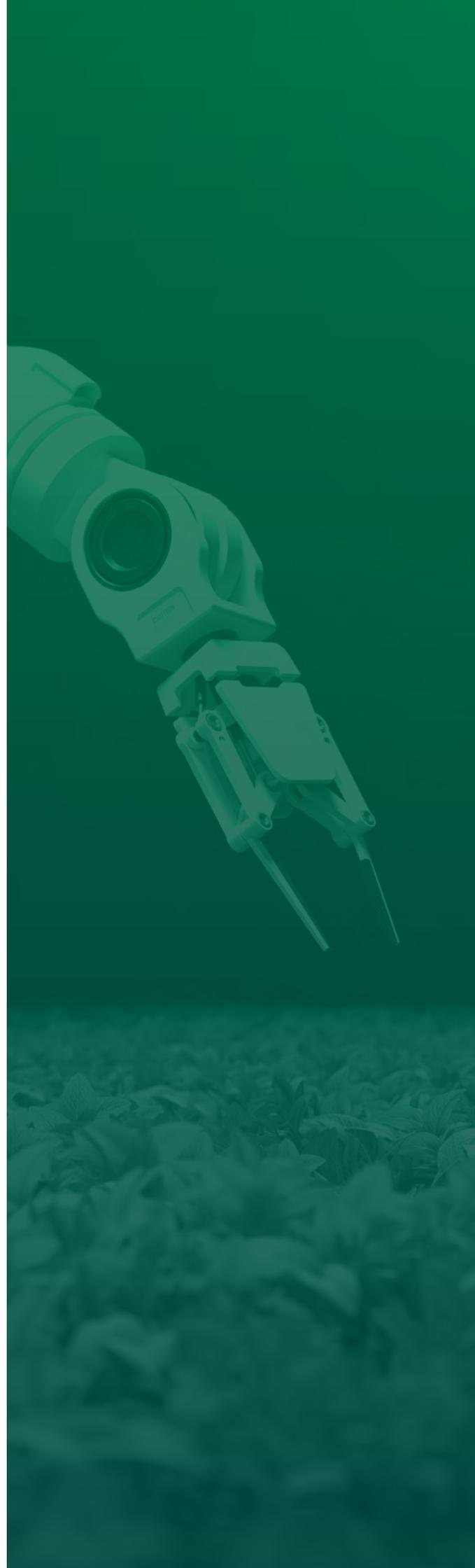
Going forward, we will seek engagement from the full spectrum of industry partners from large OEMs through to SMEs in the supply chain.



UNIVERSITY OF BIRMINGHAM

Enterprise







RESCU-M²

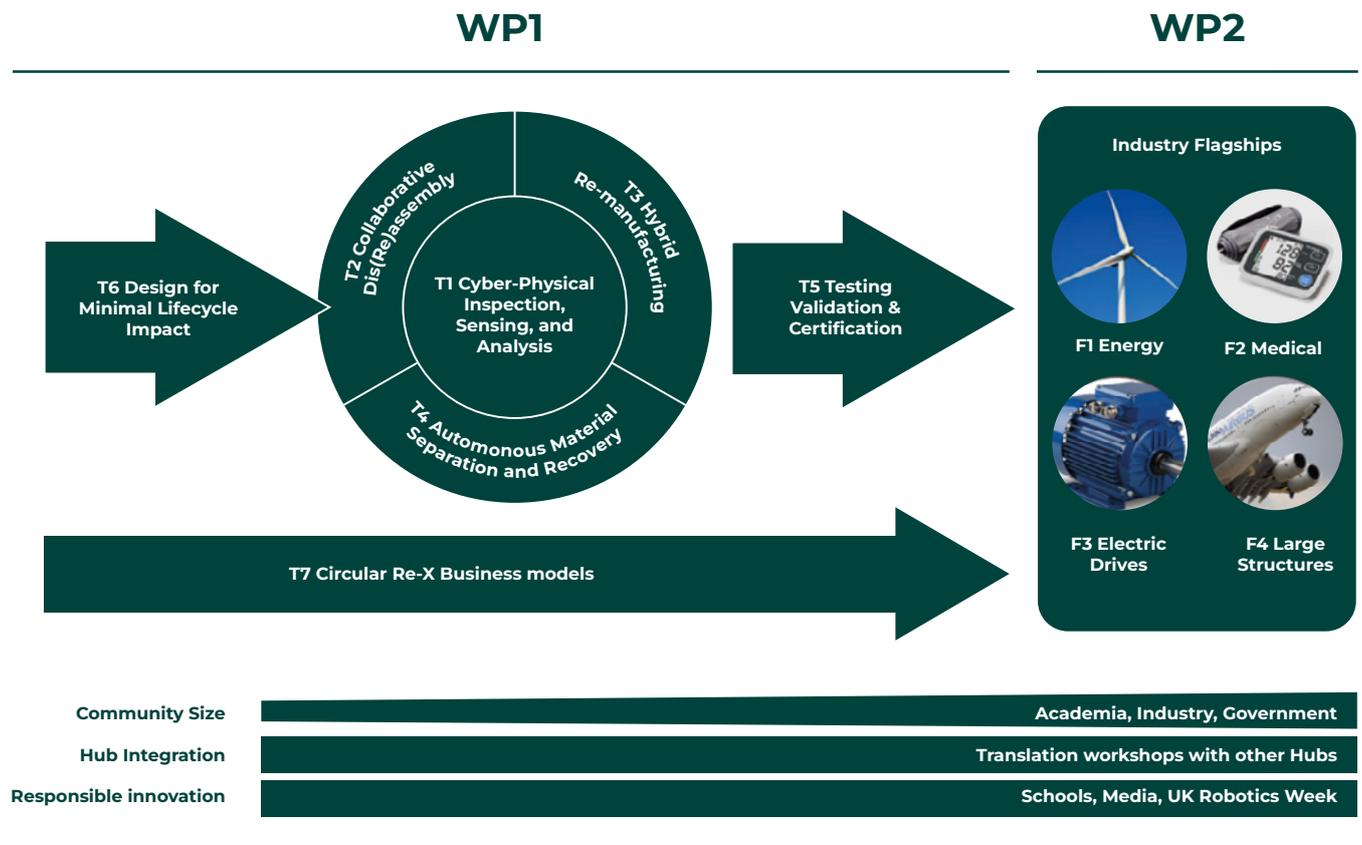
Hub Research Programme

The Hub's activities are organised into three main work packages (WP):

WP1 - Focuses on research and is split into seven themes. Technical themes will develop new tools, processes, and technologies to transform Smart Re-X processes, building more effective and applicable capability across different sectors. Alongside this, non-technical themes will ensure Re-X is embedded into the wider manufacturing ecosystem through new design approaches, testing/validation, and business models.

WP2 - Integrates the knowledge gained in WP1, demonstrating clear application to current challenges in the field of circular manufacturing. Utilising the expertise and experience within our industry partners, these initial flagship programmes will focus on four key sectors: Energy; Medical Devices; Electric Drives and Powertrains; and Large Structures.

WP3 - Builds the wider community, engaging academics, industry, policy makers and the public to ensure our research has visibility, awareness, and impact.



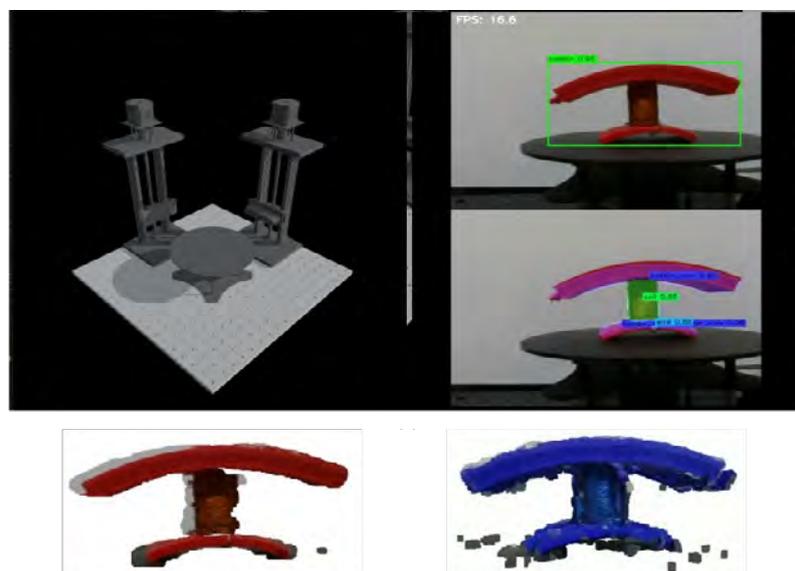
Theme: AI, Cyber-physical Inspection, Sensing, and Analysis

Professor Ashutosh Tiwari and Dr Michael Farnsworth

Investigating how lifecycle data, spanning design, manufacture, in-use operation, and end-of-life (EoL) can guide Re-X decisions (repair, reuse, refurbish, remanufacture, recycle and recover) and facilitate the engineering of circular manufacturing processes. Central to this effort is the embedding of the Digital Product Passport (DPP) as a secure, interoperable, and dynamic interface linking distributed sources. To this end, the research team has engaged with manufacturers of large structures as well as SMEs to review the current landscape, refine understanding of use cases, and prototype cyber-physical inspection rigs.

Scope of Work

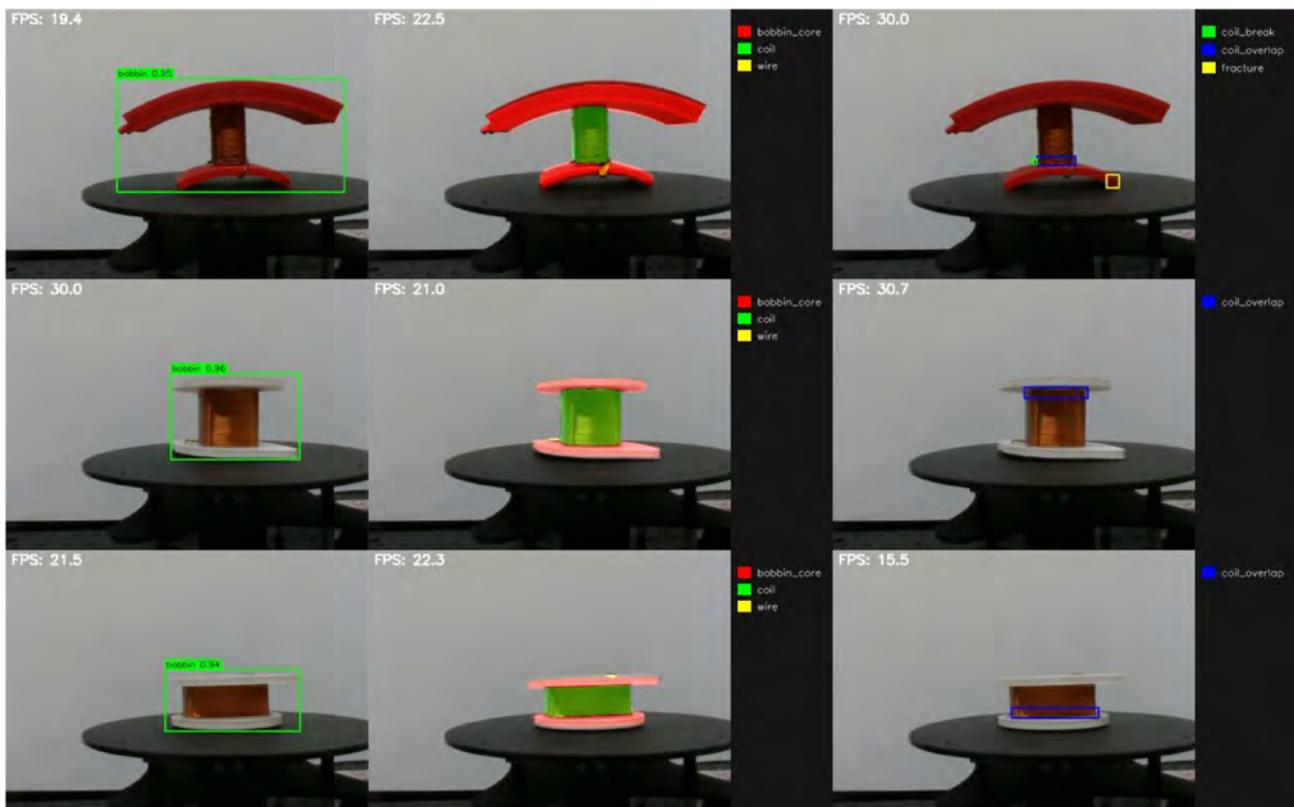
Contextualising inspection results, and informing predictive models of intervention, this work pairs the DPP with cyber-physical inspection platforms that integrate non-destructive testing (visual, acoustic, magnetic, tactile) to characterise assets adaptively while minimising disassembly and preserving whole-product integrity. It extends digital twins to 'Re-X process twins' that simulate prospective EoL interventions, such as disassembly, surface treatment, component recovery, while propagating uncertainty from inspection and history. Virtual trialling enables estimation of performance and material loss, cost, and certification implications, supporting comparisons of competing pathways to preserve value and avoid misclassification. These outputs feed decision-support systems for Remaining Useful Life (RUL) estimation and again Re-X pathway selection, combining statistical learning, physics-informed modelling, and uncertainty quantification. We further examine large, multimodal models (language-vision-structured data) to enhance generalisation and transparency, moving from fragmented, ad hoc EoL choices toward integrated, evidence-based reasoning across the full product lifecycle.



Research questions

1. How should Digital Product Passports be architected to provide secure, decentralised lifecycle data access and downstream interpretability for inspection and modelling?
2. How can multimodal NDT be actively guided by uncertainty and prior knowledge to minimise destructive testing and preserve whole-product integrity?
3. How can lifecycle data, condition assessment, and virtual intervention models be fused to deliver robust, transparent RUL estimates and end-of-life pathway selection?

Two demonstrator cyber-physical inspection rigs have been built to compare direct versus active inspection strategies and evaluate key non-destructive testing modalities. The Theme has been investigating the RUL and Decision Support pipeline, with a multi-modal large-language-model backbone identified for early fusion of text, vision and sensor inputs with links to the initial cyber-physical inspection rigs.



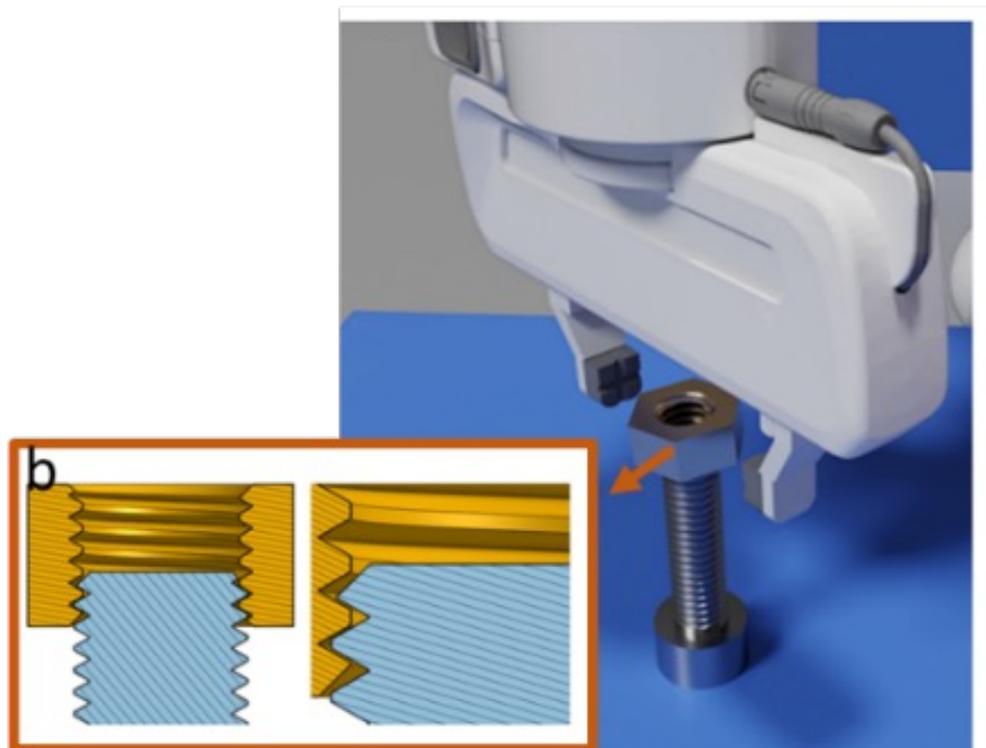
Theme: Collaborative Dis(re)assembly

Dr Yongjing Wang and Professor Duc Trouong Pham

A core capability for cost-effective advancement of circular manufacturing processes will be mechanisms to allow easy automation and up-scaling of contact-rich tasks. The deployment of robots in contact-rich tasks has been limited to date. Those that involve complex shapes, small clearances or deformable materials are particularly challenging to robotise due to the likelihood of jamming and wedging. Initial explorations into considerations for developing capabilities to overcome such challenges are reflected in four research papers accepted or published that acknowledge the RESCu-M² hub.

Scope of Work

This work package derives knowledge to design flexible, modular, cross-sector equipment for collaborative disassembly/re-assembly of products varying in size, weight, material, and conditions (e.g., electric vehicle drive motors, power electronics, batteries and water pumps), with a focus on the component level for their retrieval, assessment, reuse and remanufacturing. Creating collaborative disassembly and reassembly requires addressing the challenges in both hardware (e.g. sensors, actuators, compliance devices) and software (e.g. task generalisation, decision making, and system robustness).

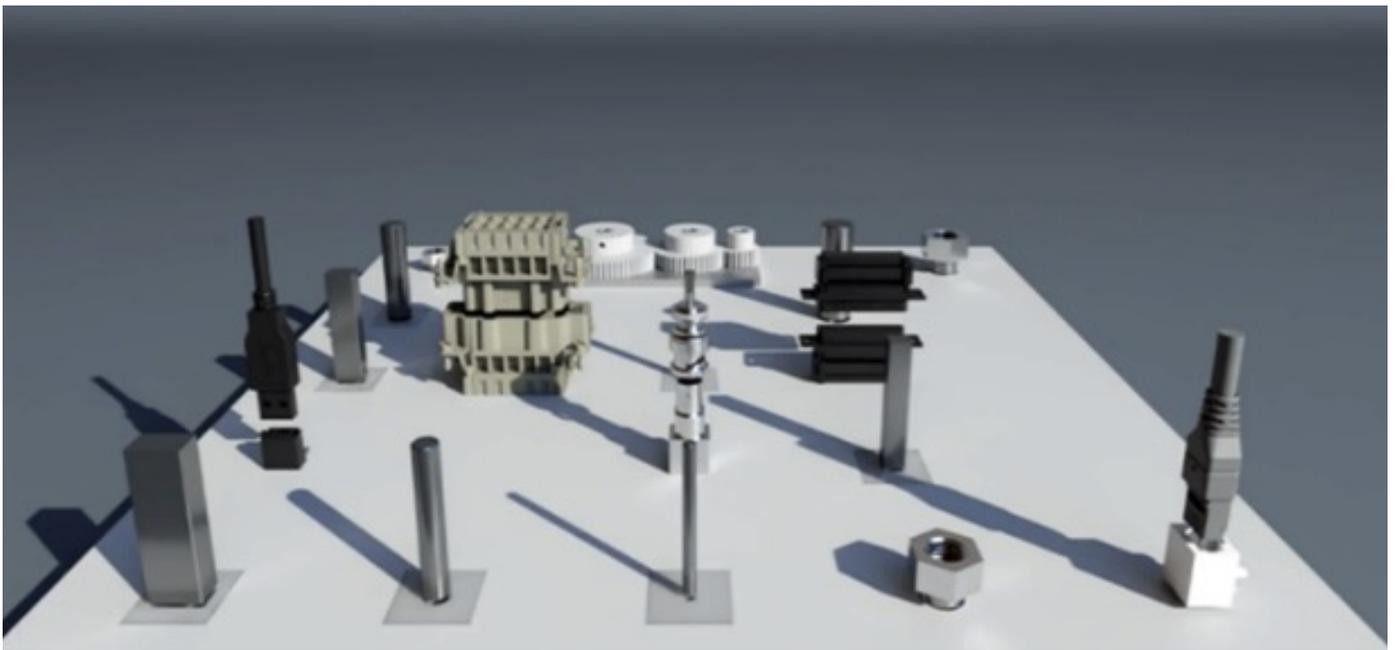


Many assembly and disassembly tasks in manufacturing have small clearances and limited accessibility, such as shaft-hole insertion/separation and bolt-nut assembly/disassembly. Using robots to complete these contact-rich tasks is more complicated than those having no physical contacts (e.g. computer visual inspection) or simple contacts (e.g. cutting, welding, pick-and-place). Some examples of contact-rich tasks in manufacturing include, but are not limited to:

- a robot removing a nut from a bolt;
- nut-bolt interactions involving multiple contact points and complex force conditions which can lead to jamming and wedging and;
- peg-hole tasks, shaft-ring tasks, gear-gear tasks, and socket-plug tasks.

Research questions

1. How can the robotic assembly/disassembly skills be generalised and augmented? This includes how to transfer the skill between machines and how contact-rich skills can be applied to a variety of tasks?
2. How can a robot collect information during disassembly and analyse end-of-life data to identify patterns that support decision-making?



Theme: Hybrid Re-Manufacturing

Professor Xichun Luo

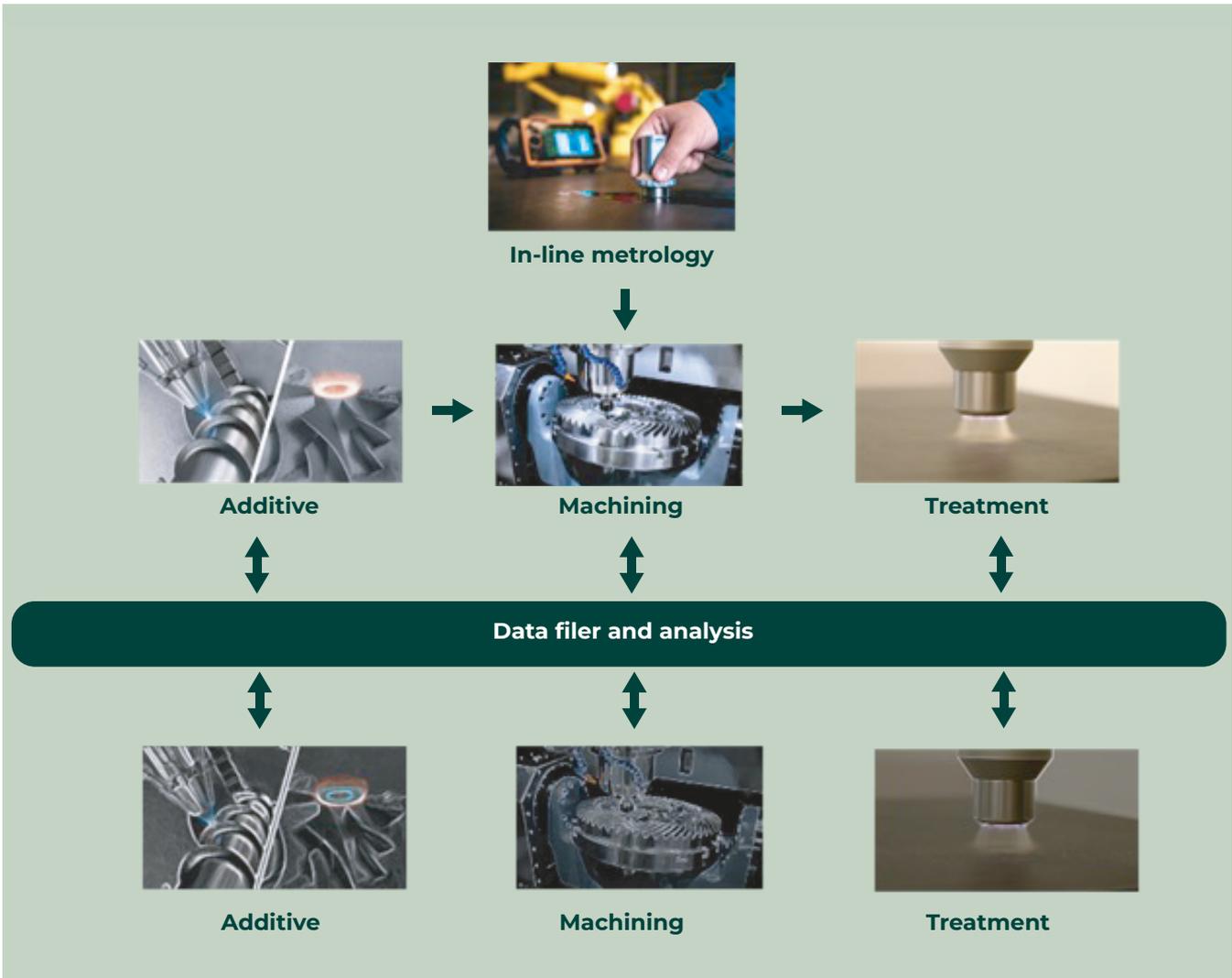
This work combines manufacturing processes with in-process metrology for developing targeted remanufacturing interventions and identifying the physical processes best suited to reconstitute materials to like-new conditions despite accidental damage, wear and tear, and material property changes, such as hardening or contamination. The first research paper has been accepted for publication.

Scope of Work

Researchers are developing a new digital twin-driven flexible hybrid remanufacturing process chain with an integrated in-line metrology system, assisted by a novel explainable AI (XAI) material model to reconstitute End of Life (EoL) products to like-new conditions in remanufacturing interventions. This process will directly inform developments for Industry Flagship 2 "Medical Device" and Flagship 4 "Large Structure". The team will investigate various Non-Destructive Testing (NTD) sensors for defect measurements and non-contact laser probes for geometry and form measurement, to research the Explainable Artificial Intelligence (XAI) enabled material fingerprint approach and the hybrid remanufacturing process chain.

Research questions

1. How to cost-effectively perform in-process measurement and assessment of micro-defects caused by stress-concentration;
2. How to model material properties as a function of variation of microstructures (including surface and internal defects) in different manufacturing processes;
3. How to develop a systematic approach to seamlessly integrate an in-process metrology system with remanufacturing processes to form a flexible remanufacturing process chain for different parts and achieve maximised sustainability.



Theme: Autonomous Material Separation and Recovery

Dr Steve Davis

This theme addresses the efficient and cost-effective recovery of value from End-of-Life (EoL) products, with the goal of preserving critical materials and reducing waste. The focus is on adopting the shortest possible circular feedback loops – reusing, repairing, refurbishing, or remanufacturing components whenever feasible, with recycling reserved for parts beyond recovery. Development to date has examined gaps and technical requirements for autonomous robotic sorting and the design of pipelines and platforms for circular processes.

Scope of Work

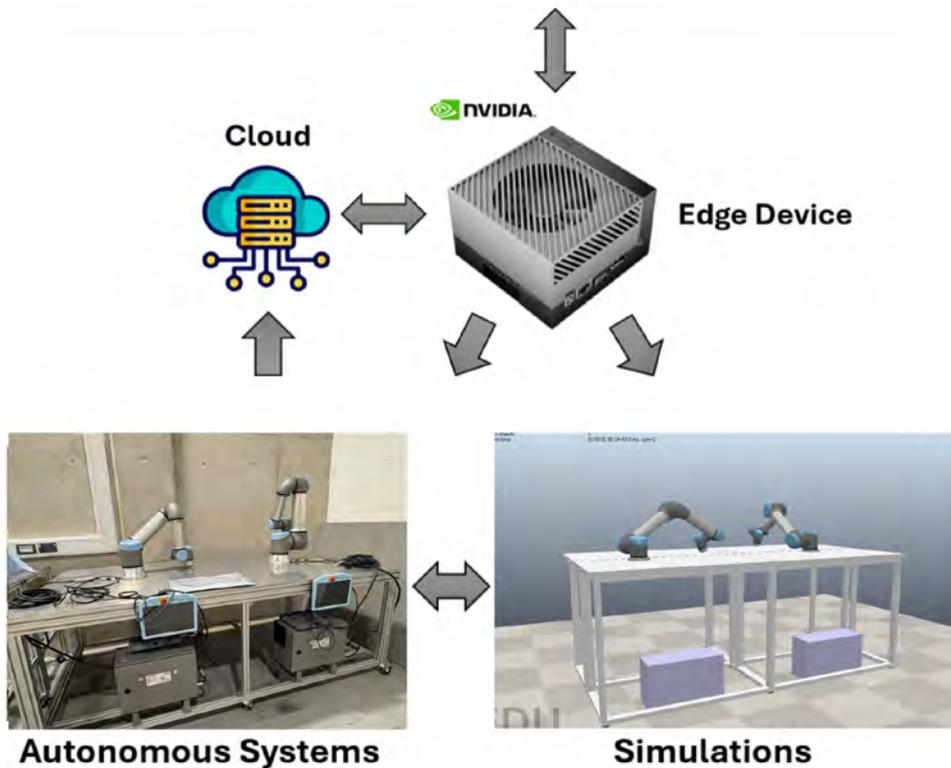
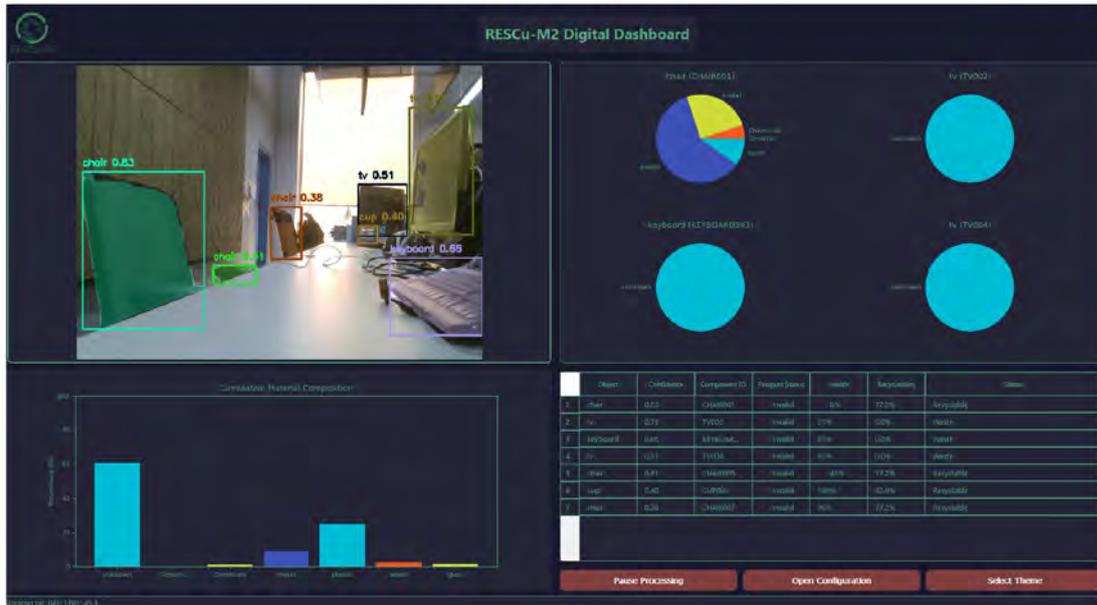
The primary challenge is to replace inefficient, labour-intensive manual sorting methods with robotic, AI-driven, and sensor-enabled solutions. These systems must be intelligent, modular, and adaptable to handle the wide variability of EoL products across sectors. Breakthroughs will require overcoming the high cognitive and motor demands of component sorting. Intelligent platforms capable of interpreting digital product passports (DPPs) and technical specifications will guide optimal Re-X pathways. In parallel, sensor-guided systems will be developed to recover components without relying on DPPs, enabling scalable, precise, and autonomous recovery of critical materials.

Research questions

1. How can integration of product passports and real-time multi-sensor data enhance the accuracy and efficiency of component sorting of EoL products?
2. How can AI-driven correlation between multisensor condition data and DPPs records enhance condition assessment, guide separation decisions, and support optimal Re-X pathway selection for EoL components?
3. How can modular, digital-twin-enabled autonomous systems recover valuable components from heterogeneous EoL products, while tracking material yield, energy use, and cross-sector performance?

A prototype digital dashboard has been developed to visualise sensor data and track recovery metrics. The design of an integration pipeline connecting the digital dashboard, cloud and edge devices and robotic actions have been initiated, forming the basis of a modular, scalable platform for autonomous separation and recovery manufacturing.

Digital Dashboard



Digital Dashboard-centred Integration Pipeline for Separation and Recovery

Theme: Testing, Validation and Certification

Professor Yan Wang

This work investigates the strategy to test and validate (T&V) the developed solutions and their impacts on the quality and efficiency of Re-X processes. Work underway includes research into a methodology for decisions around when to remanufacture and consultations into quality standards for remanufactured products and lifecycle analysis.

Scope of Work

The work examines requirements for developing confidence in the use of regenerated products and materials and assuring the desired performance. Third-party certification for quality assurance will also be developed. Specific challenges to be addressed include: developing a strategy that is efficient and cost-effective to deploy and provides confidence Re-X solutions have the required accuracy, reliability, and functionality; and understanding how relevant data can be obtained and generalised for test and validation of Re-X solutions.

Research questions

1. How can testing and validation frameworks be designed to balance accuracy, reliability, functionality, cost and time of Re-X solutions?
2. How can uncertainty in data and model variability be addressed in the T&V strategy to maintain confidence in Re-X solution performance?
3. What metrics or Key Performance Indicators (KPIs) should be developed to quantitatively assess the success of T&V strategies for Re-X solutions?
4. What types of data are necessary and sufficient to effectively test and validate Re-X solutions while ensuring generalisability across different scenarios without compromising scalability or applicability?
5. How can certification frameworks be designed to verify the quality, safety, and performance of regenerated products and materials?
6. What certification processes most effectively build trust among manufacturers, regulators, and consumers in regenerated products and materials?

The methodology for when to remanufacture has been researched based on the service conditions and identification of deflections, alongside conditions assessment based on the image processing. The team is also undertaking a lifecycle analysis comparing the emission difference between reusable endoscope (Pentax) and single-use endoscope (Ambu).

Theme: Circular Re-X Business Models

Dr Justyna Rybicka

A key factor for successful circularity is recognising that business models and value must evolve with technology and digital tools. The first year of the project involved building an understanding of the transition ahead to a circular economy (CE) and the business model implications for manufacturers.

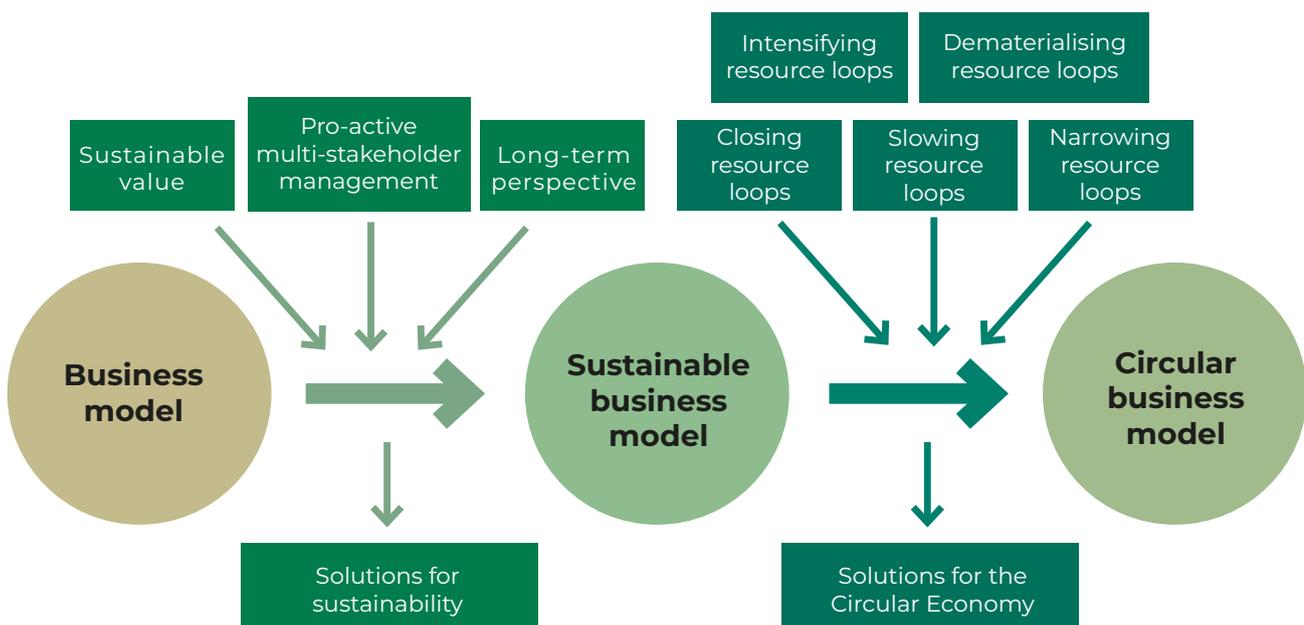
Scope of Work

The research includes a focus on understanding how business decisions change with technology-driven circular transitions, especially for manufacturers. It also involves creating a toolkit to help assess choices and show evidence of circular economy shifts using real examples as use cases. The planned work aims to use modelling tools to explore how innovation affects business and operations and provide proof and demonstrations of sustainable circular manufacturing using examples from the industry flagship projects.

Research questions

1. What are the business implications of transitioning to circular manufacturing?
2. How can we evaluate the evidence for a circular manufacturing transition?

The synthesis for understanding the role of manufacturers in circular economy transition has been consolidated, and a framework for mapping hotspots in circular economy transition has been conceptualised. Currently, the theme will be focusing on identifying use cases to test the framework for evaluating key elements of CE transition for different types of industrial challenges.



Theme: Design for Minimal Lifecycle Impact

Professor Winifred Ijomah

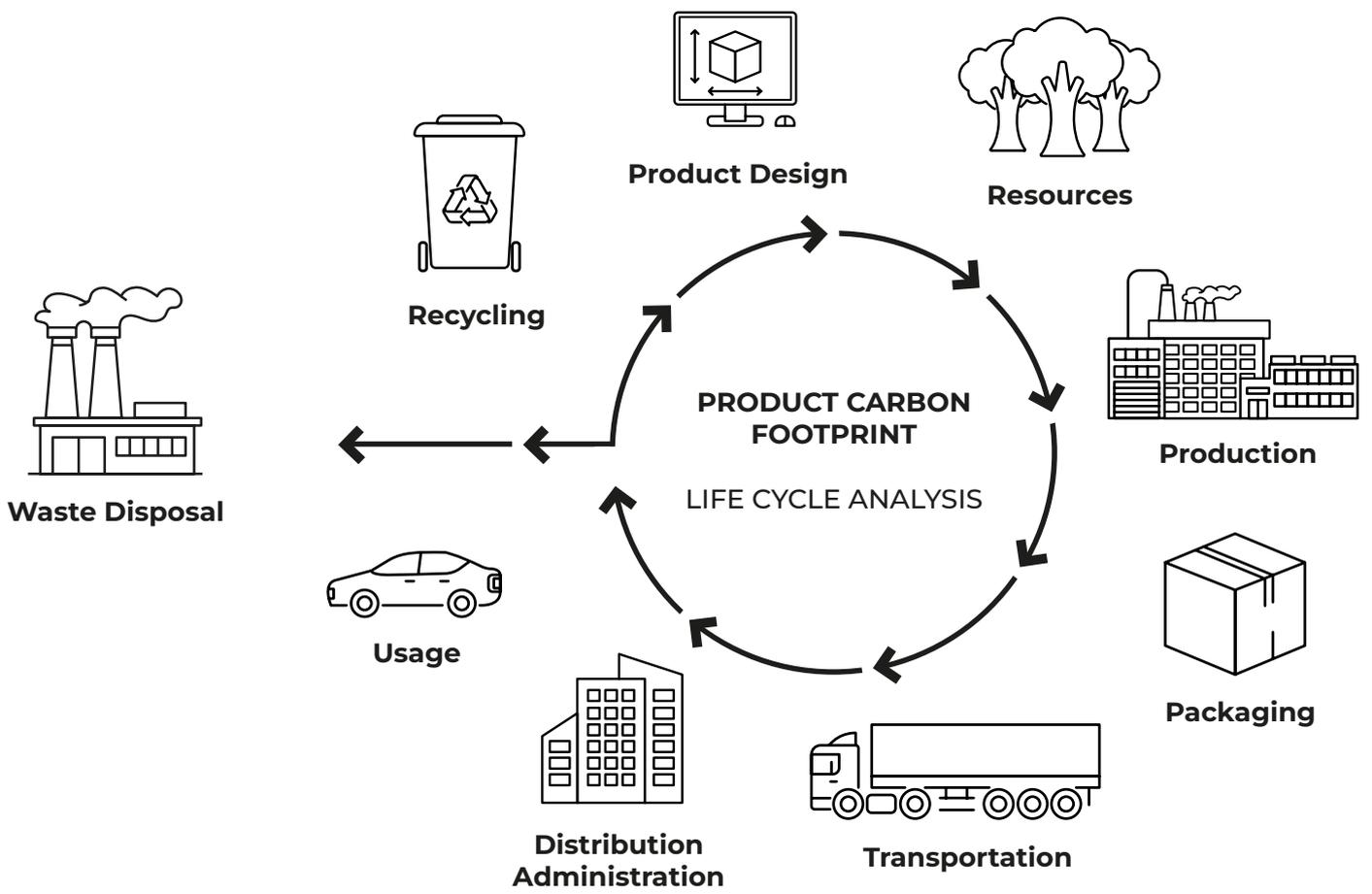
Many current methods of environmental impact assessment are considered to be too static, overwhelming and inadequate for embedding within design and manufacturing processes; for example, the best-in-class Life Cycle Analysis (LCA) guidelines are overwhelmed by the extent of information processed, and often lead to simplified scores that are difficult to keep up to date. Researchers are exploring opportunities across all the Hub industry flagships to assess potential utilisation of emerging technologies such as Chatbot to avoid the limitations of current design tools and approaches, and enable timely, effective decision making so that designers can develop product with significantly reduced environmental impacts throughout their lifecycle.

Scope of Work

The key challenges being addressed include knowledge provision to designers, given their lack of expertise in design for circularity, and approaches for data management, given the immensity of required information and levels of dispersion needed. The work includes preparation of a case study to deliver LCA information from a variety of sources and data partners; and development of an AI-driven Design For Minimal Life Cycle Impact (DfMLCI) advisory system to provide a proof of concept that will be trained on the LCA information obtained from the case study.

Research questions

1. How to increase understanding and practice in design for sustainability/circularity by more adequately addressing the challenges and by overcoming the limitations of current approaches of LCA and existing design guides.
2. Emerging technologies such as Chatbots and deep learning have been applied in many spheres with good outcomes, but have never been utilised in addressing design for sustainability challenges, creating a huge potential for novelty. This theme will address this gap by exploring the application of such technologies in decision-making to enhance DfMLCI.





RESCU-M²

Hub Flagship Programme



The Hub programme comprises four flagship projects that demonstrate and integrate the technologies developed within its seven core research themes.

Integrating the knowledge gained in the technical themes, our flagship programme aims to demonstrate clear application to current challenges in the field of circular manufacturing. Joining the expertise and experience within our industry partners with our research outputs, these initial flagship programmes will provide testbeds, translation pathways and real impact.

Flagship: Energy

Professor Moataz Attallah

Next-generation energy technologies such as nuclear fusion, small modular reactors (SMRs), and advanced modular reactors (AMRs) employ substantial quantities of high-value functional and structural materials with significant potential for recycling and resource recovery. These systems incorporate nickel, molybdenum, niobium, tungsten, copper-based alloys, zirconium alloys, advanced steels, and depleted uranium shielding, which are extensively used in pressure vessels, first-wall assemblies, heat exchangers, superconducting coils, and radiation shields. Following safe decontamination, many of these materials can be reclaimed, reprocessed, and reintegrated into new energy systems. Moreover, the modular and compact architectures of SMRs and AMRs facilitate disassembly, component reuse, and targeted recovery of critical elements, thereby advancing a circular materials economy within the nuclear energy sector.

Challenges

■ Radioactive contamination

Neutron irradiation makes nuclear components radioactive for decades, requiring remote handling by robots. However, the intense radiation itself damages robot electronics and weakens their mechanical parts, compromising safety and performance.

■ Operational degradation

Prolonged neutron exposure causes material's swelling, phase instability and embrittlement, which alter mechanical and magnetic/electrical properties. These make direct reuse of components unsafe, requiring reprocessing or downcycling rather than true recycling.

■ Complex alloy chemistries

The complex mix of elements in fusion reactor alloys makes them extremely difficult to recycle. After being exposed to radiation and heat, separating and purifying these elements becomes inefficient, often requiring energy-intensive chemical processes.

■ High energy consumption and carbon footprint

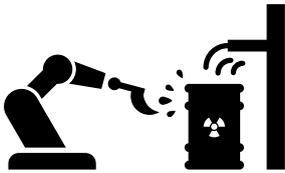
Current decontamination and reprocessing technologies such as smelting, electro-refining, or chemical leaching consume large amounts of energy and generate secondary waste streams. These processes contribute significantly to greenhouse gas emissions, partially offsetting the environmental gains achieved through low-carbon energy generation.

■ Operational hazards in dismantling and recovery

Reactor decommissioning requires the remote disassembly of radioactive components in hazardous, confined spaces. This process depends on advanced robotics and automated systems, which are still under development. The extreme conditions challenge safe access, accurate material handling, and efficient waste segregation.

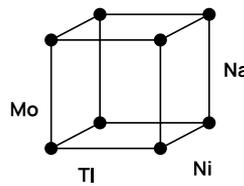
CHALLENGES IN NUCLEAR ENERGY TECHNOLOGIES

Radioactive contamination



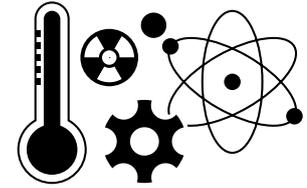
Long-term neutron irradiation transforms stable elements into radioactive isotopes

Complex alloy chemistries



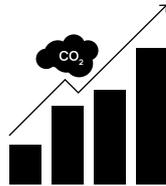
Fusion reactor alloys contain multiple high-melting and reactive elements

Operational degradation



Prolonged exposure to high neutron flux and elevated temperature

High energy consumption and carbon footprint



Decontamination and reprocessing technologies

Operational hazards in dismantling and recovery



Reactor decommissioning and segregation of activated structures in confined spaces

- Lack of efficient, low-carbon recycling technologies tailored to irradiated or transmuted alloys with complex chemistries.
- Insufficient automation and robotics for safe disassembly, sorting, and material extraction in high-radiation environments.
- Deficiency in advanced separation and purification methods capable of isolating critical or precious metals from activated matrices.
- Absence of standardised digital tracking systems for materials' activation history, composition, and recyclability across their lifecycle.

Flagship: Medical Devices

Professor Shahin Rahimifard

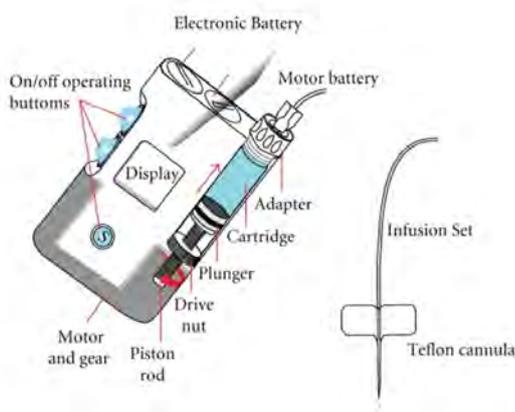
The proliferation of the range and number of medical treatments, their inherent reliance on the use of Medical Devices (MD) as well as an aging population and rapid growth in the number of patients seeking the most advanced treatments globally has resulted in a perfect storm which is threatening the long-term resilience of supply chains as well as fair and equitable access to such devices across the world. This highlights the urgent need for investigating the application of the Circular Economy (CE) in the MedTech sector.

There are many challenges in implementation of a CE approach for MDs including the decontamination of MDs before reuse, product redesign and complexity in recertification due to the wide range of national and international regulations and standards, new medical grade materials upgrade and substitution, new circular business models for supply and recovery chains, as well as many novel technologies required for the repair, remanufacturing and material recycling.

Three flagship projects are being scoped and defined to demonstrate the applicability of CE for MDs:

- Diabetes waste management: The project will investigate and develop sustainable strategies and practical solutions for minimisation, collection and recovery of medical waste associated with the treatment of 4.6 million diabetes patients in the UK, in particular those generated in patients' homes.
- Clinical e-waste recovery, which will focus on recovery and reprocessing of a range of electrical and electronic medical devices that come in contact with patients (ranging from embedded sensors and pain management devices to laser laparoscopic and shears) and should not be processed with general Waste Electrical and Electronic Equipment (WEEE) (e.g. NHS computers, monitors, kitchen equipment, etc).
- Servitisation models for complex medical equipment, which includes devices such as MRI and other scanning devices, surgical robots, etc. At the heart of making an economically viable business case for such a servitisation model is the challenges in remanufacturing and reuse of parts and components in such devices and similar products.

These timely and impactful flagship projects have the potential to showcase the research results in RESCu-M² research themes (sensors, product digital passport, design for remanufacturing, etc.) and will be undertaken in close collaboration with research teams in thematic 1-7.



Flagship: Large Structures

Professor Ashutosh Tiwari

Challenges in aerospace disassembly of high-value aircraft components and wind turbine aerostructures contain a high degree of geometric variations and composite components. The Large Structures flagship advances technical capacities for these challenges as it tackles the end-of-life (EoL) stage for the world's biggest engineered assets: commercial aircraft, wind-turbine blades and other large composite or metallic structures. Its goal is to turn retirement into a high-value, data-driven circular supply chain that:

- Feeds certified Used Serviceable Material (USM) straight back into aerospace and energy markets
- Recovers critical minerals for next-generation manufacturing
- Delivers the 10× productivity step-change targeted by the RESCu-M² Hub

Large, engineered assets such as wide-body aircraft fuselages and 80-metre wind-turbine blades are reaching EoL in ever-greater numbers. Each structure locks away tonnes of high-value titanium, aluminium, carbon-fibre and rare-earth magnets, yet today most retirements rely on slow, manual strip-down or landfilling. The result is a costly bottleneck for the fast-growing Used Serviceable Material market in aerospace and an emerging waste crisis in renewable energy, the very moment both sectors are scrambling for secure, low-carbon supplies of critical minerals. Manual disassembly also drives up labour demand: current remanufacturing tasks are already three-to-six times more labour-intensive than forward production, a gap the UK cannot close without new technology.

Converting this liability into a resource stream demands a leap in smart automation. Working with stakeholders like Air Salvage International (ASI) a UK-based aircraft disassembly and MRO business has brought to light many challenges in this domain. Large structures arrive in unpredictable states, for example, hidden fasteners, mixed composites, residual fuels or resins, and today's ad-hoc, siloed Re-X systems lack the flexible robotics, real-time data and decision support to cope. High-payload robots must collaborate safely with people, "digital passports" and live sensor feeds have to converge in trustworthy digital twins to guide EoL processes, and AI-driven grading plus rapid certification are needed so reclaimed parts can re-enter global supply chains at scale. Meeting these challenges is central to the Large-Structure Flagship, which aims to translate UK excellence in AI, robotics and circular engineering into a productive, low-carbon EoL pathway for aerospace, wind energy and the broader family of oversized assets.



Flagship: Electric Drives and Power Trains

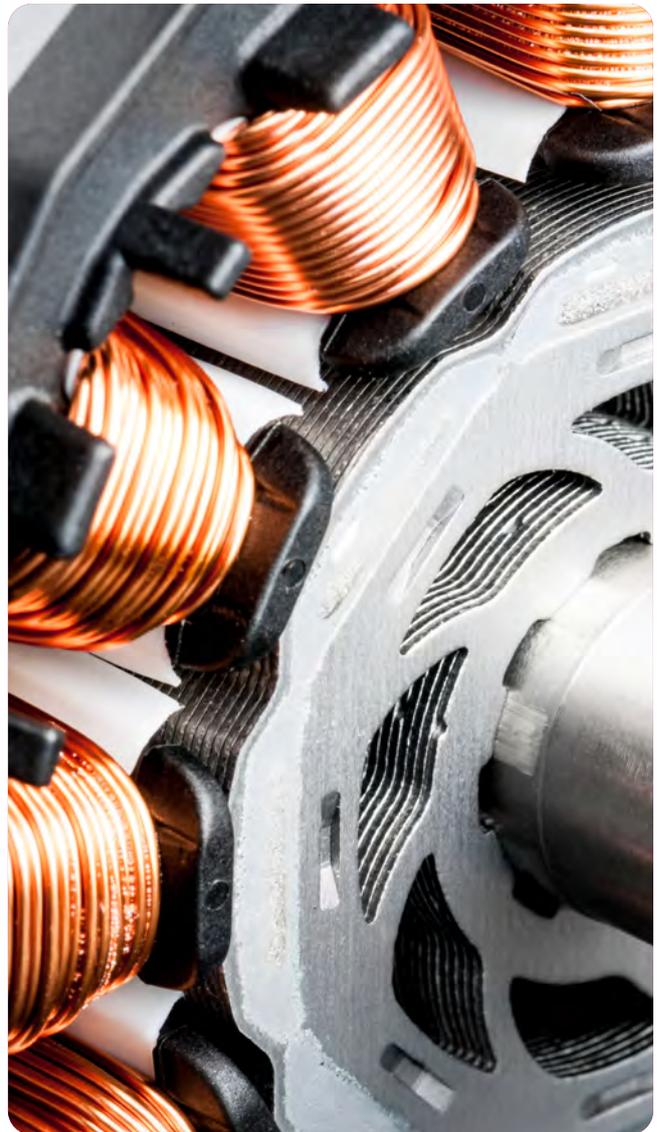
Professor Geraint Jewell

Electrical machines contain high-value functional materials such as copper, electrical steels, and rare-earth magnets, which are suitable for reuse and recycling, though often mixed with polymers and insulation. A rapidly growing volume of rare-earth permanent magnets in rotors of electrical machines which are reaching the end of their design life or being put into service in emerging mass-market products, notably hybrid and all-electric vehicles. The scope for remanufacture and repair of these machines has expanded significantly with automotive electrification, from established applications such as electrical power-assisted steering, now nearly ubiquitous, to the recent growth of hybrid and electric vehicles. However, the automated and cost-effective disassembly of permanent magnet machines poses many technical challenges, foremost amongst which are:

Challenge 1 - Disassembly of magnetised components (e.g. rotors with strong magnetic fields)

Disassembly is essential for repair, remanufacture, or recycling of electrical machines, requiring controlled separation of sub-assemblies without damage or degradation. In many machines that fail in service, the most common issues are bearing and stator winding failures, which do not usually affect the permanent magnet rotor beyond bearing removal. Consequently, intact rotor extraction for reuse or remanufacture is often the preferred approach. Many disassembly tasks mirror established practices in other rotating automotive and industrial components, such as turbochargers, compressors, and geared pumps, involving the removal of bolts, covers, structural end plates, and bearings.

However, in permanent magnet machines, strong magnetic forces exist between the magnets and ferromagnetic elements such as the stator core. When extracting a rotor for repair or remanufacture, the extraction method must be stiff enough to resist these forces and avoid damage to the rotor or stator. This is particularly challenging in high-variety operations where geometry-specific jigs are impractical. While robots offer adaptability and dexterity, the forces in many medium and large machines may exceed their payload capacity. In such cases, novel, reconfigurable end-effectors are needed to brace or guide the robot during rotor extraction.



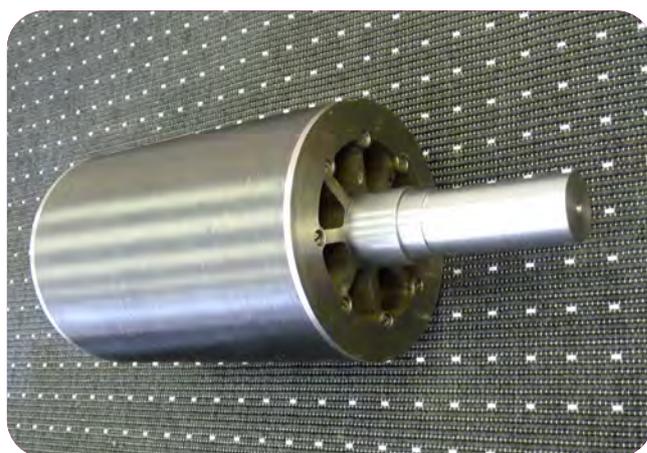
Challenge 2 - Varnishes and epoxies complicate automation

Electrical machines use varnishes and resins for insulation, mechanical support, and heat transfer, typically applied via wet processes with vacuum pressure impregnation and oven curing. While producing robust windings, these materials make removing damaged or end-of-life windings challenging, as cores can be damaged or residues left behind. Research in this area focuses on developing mechanical, chemical, and hybrid automated methods to extract stator windings efficiently and safely.



Challenge 3 - Composites hazardous to manual dismantling

Many high-performance electrical machine rotors use filament-wound carbon fibre composite sleeves with high pre-tension (>500 MPa) to keep magnets secured at rated speeds. During disassembly, this pre-tension must be carefully managed, especially when cutting the sleeve to access magnets. Ensuring that any automated process for magnet recovery can accommodate the sudden release of the tension in a rotor sleeve during cutting is a challenge in terms of both process design and variability of rotor sleeve response.



Flagship Engagement

Flagship leads have been engaging with relevant industry professionals, trade associations and regulatory bodies to understand the issues which are preventing the transition to a circular mode. Incorporating theme leads, each meeting has had a focus on hearing the industry voice and ensuring that the RESCu-M² research aims align with the needs of the sector.

Energy

Circularity of Critical Materials in Batteries Workshop 2025

Delivered jointly with EPSRC Hub RECREATE and Faraday funded project ReLib, this event took place Wednesday 29th October and consisted of a stakeholder engagement day on circularity of critical materials in lithium-ion (Li-ion) batteries. This event brought together three major UK research initiatives focused on lithium-ion battery recycling and critical materials recovery.

This event was carefully designed to foster an open dialogue between industry, academia and funding bodies with the aim of understanding real-world challenges faced by industry in Li-ion battery manufacturing and recycling, and how research can support and engage with industry to identify further opportunities for collaboration, innovation and impact.



More than 30 stakeholders from across the battery value chain were present, including representation from recyclers, processors, active material producers, cell manufacturers, automotive OEMs and funding bodies. Attendees gave short presentations followed by roundtable discussions throughout the day with a focus on industrial challenges and research needs. The event was a highly collaborative and candid forum, delivered in a way to foster ongoing engagement between industry, academia and funders with the aim of shaping the future of battery recycling in the UK.

Medical Devices

Professor Shahin Rahimiford engaged with the workshop on Circular Economy of Medical Devices (MDs) hosted by NHS Scotland in Golden Jubilee Hotel in Glasgow in October 2025, and brought together research groups, NHS staff, and industrialists actively leading initiatives in this area. There were two site visits to medical device reprocessors, and also to Queen Elizabeth Hospital in Glasgow, to survey the current best practices and size of clinical waste problems within a very busy hospital. There was a presentation by a Department of Health and Social Care (DHSC) representative to highlight progress made against a number of actions included in their Design for Life Roadmap (<https://assets.publishing.service.gov.uk/media/679ca015a9ee53687470a2ed/design-for-life-roadmap.pdf>). Forty-five attendees discussed a number of key barriers and research challenges in the transition towards Circular Healthcare. These included waste collection and sorting, digital technologies in support of circular use of MDs, challenges in data collection and measurements, and embedding and sustaining behaviour changes. These areas (barring behaviour changes) significantly overlap with various research themes in RESCu-M². Several actionable tasks were identified throughout these breakout sessions, which are being collated and circulated among attendees by the organisers, and have formed the basis of key use cases for demonstration of RESCu-M² capabilities.

Electric Drives & Powertrains

In October 2025, Professor Geraint Jewell held an online workshop with industry representatives spanning several key sectors including aerospace, automotive, renewables, machine recycling and industrial machinery. The workshop was centred on technical discussions on the research challenges identified by the RESCu-M² team, and more specifically, the opportunities and benefits that automation could bring. This included a review of previous work in non-electrical rotating machinery and discussion of the very different requirements and opportunities for different business models, e.g. an OEM curated narrow product range feedstock versus a high-variety input. It was recognised by the participants that the notion of repair and refurbishment was well embedded in the electrical machines sector through the longstanding "motor rewind" industry. This sector continues to thrive and is particularly well suited to repairs driven by obsolescence and lead-time considerations. However, it was also noted that the threshold of the rating of machines that are deemed repairable has crept up over recent years due to cost pressures and also that the extent of automation is limited.

The proposed focus of this flagship research on electrical machine-specific automation research challenges was endorsed not least since several of the tasks involved in disassembly can lean into existing experience and expertise drawn from non-electrical machinery such as removal of fixings. Specific topics of interest were the removal and handling of magnetised components and establishing an understanding of means for accommodating the extensive use of polymer resins to impregnate and encapsulate coils. The discussion also extended to the critical role of machine condition assessment as a precursor to identifying the most appropriate route for a given machine and the learning that can be drawn from the body of knowledge of in-service condition monitoring. It was universally acknowledged that incorporating disassembly requirements had featured very little in electrical machine design to date, and whereas industry will need to deal with this legacy for many years to come, there is a pressing need to consider disassembly in future design and process selection.

The workshop concluded with identification of some specific aspect of research on disassembly around magnetised component handling and coil extraction which will be taken forward in collaboration with industry.

Large Structures

Between July and September, the team conducted several industry on-site visits followed by a workshop with MTC in October:

- July and September 2025. Visit to Airbus. Discussions with Airbus Engineers led to a list of possible use cases where RESCu-M² could provide research input. Use cases are being evaluated internally to identify initial target opportunities.
- July 2025. Visit to Air Salvage International. RESCu-M² team members visited the ASI Cotswolds site to tour the facilities and share the RESCu-M² focus. ASI shared their challenges and business/research opportunities and ended with a discussion for collaboration.
- October 2025. A joint workshop was held between Dr Michael Farnsworth (University of Sheffield) and Justyna Rybicka/Aurelie Tolton (MTC). The workshop focused on the end-of-life challenges faced by large, complex and high-value assets such as aircraft components, wind turbine blades and industrial pressure vessels. These structures share persistent barriers at the End of Life (EoL), including multi-material construction, incomplete service histories, high mass and geometry complexity, and demanding safety and certification requirements.

Around ten participants from industry, academia and national innovation centres joined members of RESCu-M² to discuss how these challenges could be shaped into cross-sector research use cases. Through a series of collaborative mapping activities, attendees identified areas of shared importance, such as the need to bring designers into the fold to address EoL challenges, better methods for certification and more policies to incentivise circularity.

A particularly strong theme to emerge was the critical need to better understand material and feedstock flows across the circular economy. Participants noted that uncertainty in the availability of recovered materials can significantly affect small and medium-sized enterprises operating in repair, remanufacture and recycling, with consequences for business continuity and regional resilience.

The insights generated will directly inform RESCu-M²'s ongoing work in the Large Structures flagship, aligning with the Hub's four core research themes that span cyber-physical inspection, collaborative disassembly, hybrid repair and remanufacturing, and autonomous material recovery. The discussions will help refine research priorities and define cross-sector demonstrators aimed at improving integrity preserved, time-to-decision and value recovered at EoL.

Community Engagement

Community engagement is an essential part of the RESCu-M² Hub programme. A host of engagement activities to bring together researchers, industry specialists, policy makers and the public will drive the conversation around circular manufacturing to increase the profile and prestige of the manufacturing ecosystem and engineering within the UK.

Key aspects of the Community Engagement work package include providing a collaborative research environment for different areas of the circular manufacturing ecosystem to interact, creating opportunities for collaboration and communication through task groups and knowledge exchange, and raising the profile of RESCu-M² research across the spectrum of specialities and general public.

In the first year of the programme, efforts have focused on cementing connections between Hub partners, building the wider connection network through targeted workshops, and raising the profile of RESCu-M² at academic and industry meetings.

Hub Community

In the first year of RESCu-M², we have cemented relationships between the Hub partners and created a highly collaborative environment to drive the research forward. Forums such as our launch event in November 2024 and our internal research workshops in October/November 2025 facilitated discussions between the theme and flagship leads. This has led to mutual support, knowledge exchange and the development of synergies, thereby strengthening both their own activities and those of the wider Hub teams.



Hub Researchers and Industry Partners at the RESCu-M² launch event.

Wider Academic Engagement

Hub team members have been sharing the vision and ethos of RESCu-M² at various academic events throughout 2025, including:

- Manufacturing: AI, Robotics and Digitalisation Showcase
- The Hazards Forum
- The 5th Atari Workshop
- ICMR 2025
- UKOMAIN Multimodal Workshop
- UK-RAS Network Showcase
- BCS Artificial Intelligence 2025
- Manufacturing Data Summit

These engagements provided valuable opportunities to raise awareness of the Hub's objectives and strengthen links with industry and academia. Collectively, they enhanced the Hub's visibility within key UK research and industrial networks.

Regional Stakeholder Engagement

The RESCu-M² Hub represented by University of Brighton hosted two workshops (Nov 2024 and March 2025) to engage regional stakeholders including Brighton & Hove City Council, Sussex Chamber of Commerce (600 members), Gatwick Diamond Network (400 members), manufacturing 1066 (regional manufacturing network), the manufacturing, engineering, Technology Alliance (MATELL) to develop strategy to co-create and co-develop the South East Spoke of RESCu-M². This has generated significant impacts: The South East spoke has become the delivery partner of Brighton & Hove City Council for their Circular Economy Action Plan 2020-2025. £350k co-investment is leveraged (contract drawing) from the South East such as West Sussex City Council, Green Healthcare Hub.

The University of Brighton chaired the BSI standard for remanufacturing on 2nd September to discuss two potential initiatives: classifications of quality of regenerated products and standardised approach for Lifecycle analysis for value retention processes (remanufacturing, refurbishment, reuse, repair).

Policy Engagement

RESCu-M² has been actively pursuing policy engagement opportunities within 2025, with input into the below policy documents.

Smart Machines Strategy 2035: In February 2025, The Smart Machines Strategy 2035 was launched. An output from the Robotics Growth Partnership, with RESCu-M² Hub directors Professors Samia Nefti-Meziani and Robert Richardson providing academic leadership, the strategy provides a bold roadmap to position the UK as a global leader in robotics and Smart Machines, emphasising their potential to address societal challenges and to revolutionise diverse sectors by integrating seamlessly into the physical world with people to increase economic productivity. The 10-year plan builds on the UK's strengths in research, innovation, and entrepreneurship, laying out strategic goals and actionable steps to establish leadership in a rapidly evolving technological landscape, and to unlock the full potential of Smart Machines by 2035.

Space: 2075: Professor Samia Nefti-Meziani contributed to a Royal Society report published in June 2025. As part of a broad strategy, this report explored the need for autonomous and robotic monitoring, dismantling and recycling of space debris as part of novel in-space manufacturing processes, recovering critical materials and reducing the need to transport new materials via expensive launches. Such maintenance robots would reduce the requirement for astronauts and result in fewer satellites being launched, increasing the value and yield of each satellite whilst reducing overall costs and mitigating any potential risks of heavy metals impacting the upper atmosphere as they burn up.

Why doesn't the UK make more Robots?

(white paper, Nov 2025): RESCu-M²'s Director of Impact Professor Robert Richardson, with Professor Samia Nefti-Meziani and Dr Sarah Field, launched a white paper exploring why the UK is research-rich but manufacturing poor for robotics and autonomous systems. Circular manufacturing and modularity were discussed, with RESCu-M² featured as a key UK initiative to drive growth in the sector. Poised to influence the UK Government's implementation of the National Robotics Adoption Hubs, this important white paper is set to generate long-lasting impact for the sector.



Dr Yongjing Wang attending the 5th September 25 ATARI Workshop.

Hub Publications

Deng et al. "Learning from new products: A robust end-of-life object detection model for robotic disassembly using the dual constraints of anchors and corners." *Journal of Cleaner Production* (2025)

Parnada et al. "Towards cost-effective and safe contact-rich robotic manipulation with reinforcement learning: A review of techniques for future industrial automation." *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering* (2025)

Puthanveetti et al. "A Review of Explainable Artificial Intelligence in Smart Manufacturing". *International Journal of Production Research Engineering* (in press) (2025).

Qu et al. "Contact-Based Digital Twins Modelling for Reinforcement Learning of Robotic Disassembly Operations." *IEEE Transactions on Industrial Cyber-Physical Systems* (2025).

Zang et al. An augmentation mechanism that allows the generalisation of contact-rich skills, *IEEE IROS 2025* (accepted)

Summary

The first year of the RESCu-M² Hub has been a pivotal period of foundation building, strategic alignment, and collaborative mobilisation, setting the stage for a transformative seven-year programme that will redefine the role of robotics, automation, and smart machines in sustainable circular manufacturing. Over the past twelve months, the Hub has successfully established its core governance structures, launched its seven interdisciplinary research themes, and confirmed the participation of major industrial, academic, and policy partners. This integrated ecosystem now provides the operational, scientific, and strategic backbone through which the Hub will deliver lasting impact.

Overall, Year One has been characterised by momentum, collective ambition, and a strong sense of shared purpose across all Hub partners. With our research architecture established, demonstrators defined, and partner engagement secured, the RESCu-M² Hub enters its second year with clarity, confidence, and the infrastructure required to deliver meaningful change. We are now well positioned to accelerate innovation, deepen collaboration, and begin delivering the technological, economic, and societal impacts at the heart of our mission.



RESCU-M²

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