EPSRC Centres For Doctoral Training (CDT) Outline Summaries

Introduction

Following the panel assessment of proposals submitted to the EPSRC Centres for Doctoral Training (CDT) outline funding opportunity the following proposals were invited through to the next stage and eligible to submit a full proposal.

In line with the published outline funding opportunity this document provides details of those outline proposals including the named investigators, lead organisation, and Joint Electronic Submission (Je-S) system summary sections. Other application content and assessment material will remain confidential.

These details are published to facilitate engagement with potential additional partners.

The panels commented on the high quality of proposals received. There were significantly more high quality proposals than we could invite to write a full proposal, given we only expect to fund around 40 CDTs. We saw a wealth of well-made cases for interdisciplinary cohort-based doctoral education to benefit the UK research and innovation system. While respecting the confidentiality of individual proposals, we will draw on this as evidence in developing the case for future doctoral investments.

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EPSRC Centre for Doctoral Training in Connected Digital Twins across Natural and Built Environments

Dr Thomas Beach Cardiff University

Beach, Dr T,Durance, Professor I,Kasprzyk-Hordern, Professor B,Kjeldsen, Dr TR,Rezgui, Professor Y,Rana, Professor O,Kassem, Professor M,Stirling, Dr RA,Ranjan, Professor R,Hofman, Professor J

The nature and climate emergencies require a step-change in how we interact with our life-support systems. The natural environment, comprising waterbodies and landscapes that support life on earth, is under pressure from increasing societal needs for goods and services. The built environment, comprising buildings, infrastructures and cities that support social and economic activities, adds pressure through pollution, disturbances, and depletion of resources. In turn, built environments are affected by degraded natural environments, that provide raw material necessary for their effective function (OECD, 2019). Thus, while mostly managed in isolation, natural and built environments are strongly connected, and both are at significant risk from climate change.

An improved understanding of the connections between the natural and built environments and the risks that impact them is key to achieving secure and resilient societies. The complexity of the challenge clearly requires novel, systemic, and integrated approaches across both natural and built environments.

Clearly a step-change is required, this requires a new generation of researchers who are trained in taking an interdisciplinary and systemic approach to tackling nature and climate emergencies. These researchers will be equipped to capture and integrate the built and natural environments, in a way that will allow equitable, transparent, holistic, and efficient decision-making. The TWIN CDT will take this step by fostering agile scientists, developed in cohorts, and guided by industry and government stakeholders, to develop the necessary Digital Twin architectures and their supporting sensing, intelligent processing, and actuation capabilities. This will build on existing strengths in digital twinning architectures, including UKRI investments, to expand the UK's global leadership to the nascent area of combined natural-built digital twins.

EPSRC Centre for Doctoral Training in Future Infrastructure and Built Environment: Unlocking Net zero (FIBE3 CDT)

Professor Abir Al-Tabbaa University of Cambridge

Al-Tabbaa, Professor A,Allwood, Professor JM,Lees, Professor J,Sheil, Dr B,Foster, Dr RM,Becque, Dr J,Brilakis, Professor I,Liang, Dr D

Civil infrastructure is the key to unlocking net zero. To achieve the ambitious UK targets of net zero by 2050, we require innovative and collaborative approaches to design, construction, and operation that prioritise energy efficiency, renewable resources, and low-carbon materials. Meeting net zero carbon emissions will require not only significant investment and planning, but also a radical shift in how we approach the design and management of our civil infrastructure. Reliable low carbon infrastructure sector solutions that meet real user needs are essential to ensure a smooth and safe transition to a net zero future. The UK must develop highly skilled infrastructure professionals who can champion this urgent, complex, interconnected and cross-disciplinary transition to net zero infrastructure. Cohort-based training will facilitate the required cross-disciplinary mix of technical and soft skills development. This FIBE3 CDT aims to lead this transformation by co-developing and co-delivering an inspirational cohort-based doctoral training programme with industry partners. FIBE3 will focus on meeting the user needs of the construction and infrastructure sector in its pursuit of net zero. Our successful 1+3 MRes+PhD model in FIBE & FIBE2 CDTs provides strong evidence of successful co-creation with clear pathways to real impact. Our goal is to equip emerging talents from diverse academic and social backgrounds with the skills, knowledge and qualities to engineer the infrastructure needed to unlock net zero, including technological, environmental, economic, social and demographic challenges. Achievable outcomes will include a dynamic roadmap for the infrastructure that unlocks net zero, cohort-based doctoral student training with immersive industry experience, a CDT which is firmly embedded within existing net zero research initiatives, and expanded networks and outward-facing education. These outcomes will be centred around four thematic enablers: (1) existing and disruptive technologies, (2) radical circularity and whole life approach, (3) AI-driven digitalisation and data and (4) risk-based systems thinking and connectivity.

FIBE3 doctoral students will be trained to unlock net zero by evolving the MRes year to include intimate industry engagement through the novel introduction of a fourth dimension to our successful 'T-shaped' training model and articulating the PhD with regular outward-facing deliverables. We have leveraged industry-borne ideas to align theory and practice, streamline business and research needs, and provide joint academia/industry led training activities. Cohort-based training in technical, commercial, transferable and personal skills will be provided for our graduates to become skilled professionals and leaders in delivering net-zero infrastructure. FIBE3's alignment with real industry needs is backed by a 30+ strong consortium, including client organisations, consultants, contractors, SMEs, technology providers, materials suppliers and knowledge transfer partners, who actively seek engagement for solutions and will support the CDT with substantial cash (~£2.5M expected) and in-kind (~£8M expected) contributions. This will enable us to recruit ~75 students. At Cambridge, the FIBE3 CDT will be embedded within an inspirational research and training environment, a culture of academic excellence and within a department with strategic cross-cutting research themes that have net zero ambitions at their core. This is exemplified by Cambridge's portfolio of internationally renowned centres and initiatives including Digital Roads of the Future initiative, Centre for Smart Infrastructure & Construction, Cambridge Zero and Cambridge Centres for Climate Repair & Carbon Credits, as well as our strong partnerships with UK universities and leading academic centres across the globe. FIBE3 will building on the success of our FIBE/FIBE2 to develop outstanding PhD graduates who will be net zero champions of the future.

EPSRC Centre for Doctoral Training in Sensor Technologies and Applications in an Uncertain World

Professor Clemens Kaminski University of Cambridge

Kaminski, Professor C,Owens, Professor R,Zeitler, Professor JA

The proposed EPSRC Centre for Doctoral Training in Sensor Technologies and Applications in an Uncertain World (Sensor CDT) will educate leaders who can effectively address the challenges of an increasingly complex, interconnected world. In recent years, society has faced a global pandemic, an energy crisis, the consequences of war, and natural disasters resulting from climate change. Sensor technologies play a vital role in addressing these challenges. They are essential tools for detecting changes in the world, protecting livelihoods, and improving wellbeing. Accurate sensory data are crucial for informing the public and providing evidence for government and policymakers to make evidence-based decisions.

The new Sensor CDT is designed to train and inspire future sensor leaders with interdisciplinary and agile thinking skills to meet these challenges. Our students will learn to collaborate and co-create solutions with various stakeholders, including other scientists, industry partners, the third sector, and the public. We will provide a fully integrated 4-year program that covers the entire sensor science value chain, from development over deployment and maintenance to end-of-life including middleware, and big data. The program will be led by over 80 leading academics, 40 industrial partners, and national research and policy agencies, equipping students with the expertise, skills, and leadership qualities needed to create beneficial and impactful sensor solutions.

Dealing with uncertainty is a major theme of the new CDT. It is more important than ever to train students to interpret data from uncertain sources, constantly changing data, and imperfect data. For example, according to the environmental sensor report published by UKRI in 2022, "data quality remains a major concern that hinders the widespread adoption of low-cost sensor technology". In addition, UK industries deal with uncertainties in supply chains, variable process conditions and feedstocks, and they are subject to changing regulatory guidelines. They need sensor data to minimise the effect of such uncertainties on the quality of products and services. Students will need to learn how to deal with uncertain data, to innovate on rapidly changing timelines, and to work increasingly in collaboration and synergy with stakeholders in commerce and the public. The required skillset needs a re-engineering of current engineering practices. The Sensor CDT will give students the skills needed to address uncertainty challenges effectively, for example through bespoke training in statistical methods and machine learning to interpret imperfect data and through the provision of training in systems thinking, leadership, and project management.

Whilst prevention of future disasters is important, we recognise an increasing need to create resilience in a world facing rapid, often irreversible, change. Solutions must be co-created with society. The CDT will equip students with the confidence to collaborate across a range of fields, including the humanities and social sciences, skills that cannot be acquired in traditional, single student / single discipline PhD programmes.

Finally, our programme will address a UK skills gap identified by industry and academia. They report a growing problem in recruiting suitably qualified candidates with the skills, disciplinary breadth and leadership qualities needed to drive innovation in the sensor field. In the UK alone, the sensor market contributes to ~ £6bn in exports, underpins at least 70,000 jobs and connects to a global market estimated at ~ £120bn (Sensor KTN UK). The global sensor market is expected to reach £400bn in 2030 (Next Move Strategy Consulting). Providing the skilled talent for the UK to succeed in this rapidly growing and competitive sector is a crucial objective of our programme.

EPSRC Centre for Doctoral Training in Catalysts Unleashed

Professor Duncan Wass Cardiff University

Wass, Professor D,Tredwell, Dr M,Melen, Professor R,Logsdail, Dr AJ,Edwards, Dr J,Maillard, Professor J,Slater, Dr T

The ability of catalysts to convert simple chemical building blocks into more valuable and useful products, and conversely to convert harmful chemicals into benign materials and control pathogens, means that they already account for more than 20% of UK GDP and 15% of exports. The importance of this technology, and the need for innovation and more fundamental understanding in this area, will only increase in the transition to a greener economy. The full potential of catalysts in propagating new technologies that will enable a sustainable global future can be realised through a multidisciplinary intersectional research led strategy. Examples of nascent application for catalysts include the production of sustainable liquid fuels, the conversion of carbon dioxide into valuable products, the storage and use of hydrogen as an energy vector, and the creation of reactive species from air/water (mitigating detergent use) to drive chemical and biological oxidation. These are all examples of the sustainable orientation of projects that will be carried out in this CDT. To deliver this research requires a workforce who have deep technical expertise of sustainable catalytic technology, but are also nimble, resilient, embrace multi-disciplinary science and engineering, and appreciate the complex and multi-facetted nature of the problems that must be solved. These graduates will be employed by both the traditional catalyst-using industries (energy, chemicals, pharma) but also industries for whom catalysis is a clean growth opportunity (water, cleaning and disinfection, consumer goods, cement). This EPSRC CDT in Catalysts Unleashed will provide the training and opportunity, delivered in partnership with industry, for graduates in this area to flourish. Training activities, such as 'PhD project hacks' in which students co-create their own PhD projects, will enhance the students' creative and teamworking skills and lead to better, collaborative and translational projects. This CDT will embrace all sub-disciplines of catalysis, from traditional areas such as heterogeneous catalysts to emerging areas including electrocatalysis, to deliver the best possible solutions and open-minded graduates. Catalysts are already used across many industries and are hugely important. But there are so many more opportunities, given a highly trained, expert and innovative future workforce. This is the workforce we will train, so that catalysts can reach the largest number of users and reach their full potential - catalysts unleashed!

EPSRC Centre for Doctoral Training in Advanced and Sustainable Biomedical Materials

Professor Sarah Cartmell The University of Manchester

Cartmell, Professor SH,Gough, Professor J,Roy, Professor I,Daly, Professor R,Shearer, Dr T,Wong, Mr J,Richardson, Dr SMA,Reilly, Professor G,Cameron, Professor RE,Hatton, Professor PV,Best, Professor S,Webb, Professor SJ

Biomedical materials have advanced dramatically over the last 50 years, driven by advances in biomedical materials manufacture and their characterisation, from materials that formed the basis of simple devices (e.g., hip joint or a wound dressing with a predominant tissue interface) to the development of smart and responsive materials that can adapt to changing physiological environments.

Medical products arising from novel biomedical materials and the strategies to develop them are key in dealing with the effects of the UK's increasingly ageing population, having the potential to promote more efficient and cost-effective healthcare interventions. This is evidenced by the growing global biomaterials market (valued at £112.7bn in 2021 with expected 15.4% 8-year CAGR) and mirrored by the thriving UK medical technology sector, which has doubled since 2009. The market's rapid growth is leading to a significant demand for highly-qualified professionals. In particular, the demand for biomedical engineers is projected to increase at the fastest-ever recorded rate (10%/year), generating an incremental professional gap. There is therefore a national need for a CDT to train an interdisciplinary cohort of students and provide them with a comprehensive set of skills so as to compete in this rapidly growing field.

Building from previous CDT success, the Universities of Manchester, Sheffield and Cambridge jointly propose a new CDT in Advanced and Sustainable Biomedical Materials that will directly address the sector's current employment growing needs and associated technical challenges. It will include a specific theme on cancer applications of biomaterials and will bring a new focus on sustainability, as key rising needs in the sector. In addition to the training of a highly skilled workforce, clinically and industrially led research will be performed that focuses on developing and translating smart and responsive biomaterials with a particular focus on higher throughput, greater reproducibility of manufacture and characterisation.

The consortium's combined strength and track record in biomaterials innovation, translation and industrial engagement aligns the UK need with resource, skills, industrial collaboration and cohort training. This is strategically underpinned by the Biomedical Materials axis of the UK's £235 million investment in the Henry Royce Institute, led by Manchester and partner Sheffield, with Cambridge's participation. To identify key thematic areas of need the applicants led national Royce scoping workshops with 200 stakeholders, including representatives from healthcare, industry and academia.

As a result, the CDT will onboard a total of 64 PhD students to contribute to 4 key research areas: bioelectronics, fibre technology, additive manufacturing and improved preclinical characterisation with the additional focus on cancer therapy and sustainability. All projects will have clinical, regulatory and industry engagement, which will allow easy translation through the consortium's access to well-established clinical trials units and will position the research to interface with opportunities arising from the biomedical industry.

EPSRC Centre for Doctoral Training in Net Zero Flight and Energy

Professor Graham Pullan University of Cambridge

Pullan, Professor G,Schafer, Professor AW,Ireland, Professor P,Carrotte, Professor J,Miller, Professor RJ,Wheeler, Dr A,Di Mare, Dr L,Walker, Dr AD

The vision of the CDT is to train the new generation of engineers needed to accelerate the aviation and energy sectors to Net Zero by 2050. There is a strong synergy between these sectors (Net Zero flight is dependent on Net Zero energy) with many examples of shared science and engineering. Both sectors are going through transformational change. This revolution needs a new type of engineer, one who can evaluate new technologies at a systems level (from energy resource to climate impact) and who also has the deep technical knowledge needed to develop new concepts rapidly into products. To meet the challenge, the CDT combines the expertise and facilities of the world-leading centres at the universities of Cambridge, Oxford, Loughborough and UCL with Industry Partners from across the sectors.

The CDT has been developed in close collaboration with our Industry Partners. This group of companies, ranging from established global businesses such as Rolls-Royce, Boeing, Siemens Energy and Mitsubishi Heavy Industries, to SMEs like Reaction Engines and new entrants such as Greenjets, are facing the same challenges and have identified the following 3-part requirement for training Net Zero doctoral engineers: 1) A broad systems perspective, allowing students to understand how new technologies can unlock change at a whole sector level; 2) Deep technical knowledge to enable development from ideas to viable technology in an environment with state-of-the-art methods, facilities, and a rapid-innovation culture; 3) Collaboration with industry to generate pull-through of new technologies into real products. The strong endorsement of our CDT, and the need for the Net Zero engineers that will be its key outcome, is evidenced by the 40 studentships that our Industry Partners intend to fund.

The scale of the CDT (in total, 90 students are expected to be trained) allows us to create a unique cohort-based training experience. The scope of the challenge is met by combining the expertise and cutting edge facilities of the four universities, and several of the industry partners, into a training experience that is beyond anything that could be delivered by a single institution. A new Master's course, based in Cambridge, will comprise: 1) taught modules, bespoke for this Master's course, including aviation and energy systems analysis, data science, and underpinning aero-thermal sciences; 2) 2-3 week hands-on 'Mini Projects' at the partner universities, and training courses on-site at our Industry Partners; 3) a dissertation containing an extended PhD project proposal to give students an accelerated start into the PhD-phase of the CDT.

The CDT has been designed to maximise the cohort experience. Building on learning from previous CDT programmes, we will: (1) Co-locate the cohort in the first year, both in terms of physical location and in activity. The time the cohort spends working (and relaxing) together creates a unique and mutually supportive community that endures throughout the CDT and beyond. (2) Harness the expertise and facilities from a range our universities and industries in the first year training programme and also during the PhD-phase with continued cohort events, connections and training. (3) Support students to develop their projects in an agile way in response to new information and findings - this is particularly important in the rapidly developing sectors of Net Zero Flight and Energy. A key component of this support is our 'Grandparents' scheme where each student has access to wise minds from across the sector throughout their project. This has been found to provide the small nudges necessary to make research far more impactful.

EPSRC Centre for Doctoral Training in Accelerated Medicines Design & Development

Professor Gareth Williams University College London

Williams, Professor GR,Marlow, Dr M E,Rawson, Dr FJ,Torii, Professor R,Zelzer, Dr M,Gaisford, Professor S,Hailes, Professor HC,Knowles, Professor JC,Alexander, Professor C,Stolnik-Trenkic, Professor SS

Medicines are inherently complex products. In addition to the drug (a molecule which causes a pharmacological effect in the body), they also contain a number of other ingredients (excipients). These are added for a variety of reasons - for instance, to ensure stability on storage or to target the drug to a particular part of the body. A very careful assessment is required to choose the right excipients and prepare a potent and safe medicine.

New therapies are being devised at an ever-increasing rate and have the potential to transform the lives of patients, for instance through the correcting of genetic defects. However, there is a long time-lag between the discovery of a new therapeutic entity and its translation into a medicine ready for patients to take. This means that patients are not able to benefit for many years. There are very significant benefits that would be realised from accelerating the medicines development process: this was made clear by the COVID-19 pandemic, in which the rapid development and roll-out of vaccines led to millions of lives being saved and allowed societies to emerge from lockdowns.

The UK traditionally has been a powerhouse for medicines discovery, and the medical technology and pharmaceutical sector is still a vital part of the economy. However, productivity has recently declined, and compared to peer countries the UK has a lack of high-innovation firms. If medicines development can be accelerated in the UK, there will be huge economic and societal benefits, in addition to the profound changes that can be made to the lives of individual patients.

To realise this ambition, the UK pharmaceutical sector needs highly-trained, doctoral-level, scientists with the advanced skills required to drive future research programmes in medicines development. The Centre for Doctoral Training (CDT) in Accelerated Medicines Design & Development seeks to directly meet this user need, by building a cohort of innovators and future leaders. We will do this between two universities and in collaboration with a network of industrial and clinical partners from across the UK pharmaceutical, healthcare and medical technologies sector.

Our students will receive comprehensive science training enabling them to overcome the major challenges facing medicines development. They will further receive extensive transferrable skills training, ensuring that they graduate with high-level teamworking, communication, leadership and entrepreneurial skills. We will foster an open and supportive environment in which students can challenge ideas, experiment, and learn from mistakes. Equality, diversity and inclusiveness (EDI), sustainability and responsible innovation will be at the heart of everything we do, and will be embedded throughout our training.

By liaising closely with our industry and clinical partners, we will ensure that the research undertaken in the CDT is directly relevant to the most significant current challenges in medicines development. We will further embed interactions with the "end users" (patients, clinicians) to ensure that these products are acceptable to patients and can be administered by clinicians. This will allow us to directly contribute to the acceleration of the medicines development process, and ultimately will deliver major benefits to patients as new products come on to the market.

Our graduates will join companies across the pharmaceutical, medical technology and healthcare fields, where they will innovate and drive forward research programmes to develop new medicines for a broad range of diseases. They will ensure that new therapies come to market and the health and well-being of individuals across the world is improved. Others will enter academia, training the next generation. Our alumni will seed a future landscape in which medicines are designed and manufactured in a manner which protects our environment, and in which there is equality of opportunity for all.

EPSRC Centre for Doctoral Training in Machining, Assembly, and Digital Engineering for Manufacturing (MADE4Manufacturing)

Professor Neil Sims University of Sheffield

Sims, Professor ND,Tiwari, Professor A,Harrison, Ms S,Crawforth, Dr P,Curtis, Professor DT,Ghadbeigi, Dr H,Marshall, Professor MBJ

This CDT will train the next generation of manufacturing researchers with unique capabilities to combine predictive models and in-process data, with a systems perspective, to enable faster, more flexible, and more sustainable high value manufacturing.

The UK's growth lags behind Europe and North America [1], and the chancellor, whilst celebrating our advanced manufacturing sector, also states [2] that 'poor productivity, skills gaps, low business investment and the over-concentration of wealth in the South-East have led to uneven and lower growth'. Digital technologies are widely recognised [3] as a key productivity enabler; in the advanced manufacturing sector this can achieve a fast and responsive approach by using sensors, communications, controls and informatics technologies that are coupled to the intricate physics underpinning complex manufacturing processes. This aligns strongly with the EPSRC's Digital Futures, Engineering Net Zero, and AI/Digitalisation priorities; the EPSRC Made Smarter programmes, and the UK Innovation Strategy's [4] digital and manufacturing priorities.

However, embedding Digital Manufacturing into the UK economy will require people with new doctoral-level skill sets dedicated to the four productivity challenges in manufacturing:

1. sustainability - an emerging underpinning theme in our stakeholder discussions.

2. speed - reducing production lead time;

3. quality - eliminating rework whilst achieving functional performance;

4. flexibility - adaptive production systems that eliminate intrusive setup/measurement;

The CDT will train cohorts that focus on cross-disciplinary research at the interface between these productivity challenges and key Digital Engineering themes identified by our industrial co-creators:

(1) mechanics, modelling, and intelligent control / optimisation of processes; (2) sensor networks and monitoring; (3) manufacturing informatics, system integration, and data security. We will focus on key manufacturing processes that are essential to the UK landscape: subtractive manufacturing (machining) and product assembly. We are uniquely placed to enable this approach: we lead the machining capability on behalf of the High Value Manufacturing Catapult, collaborate on the Manufacturing Made Smarter Research Centre in Connected Factories, (with a focus on assembly automation), and through Factory 2050 we host the UK's first state of the art factory entirely dedicated to reconfigurable robotic, digitally assisted assembly and machining technologies.

We will provide a unique opportunity for students to study alongside peers with a common application focus in machining, assembly, and digital engineering for manufacturing, leveraging the world leading environment provided by the Advanced Manufacturing Research Centre. This will enable the highest standards of subject-specific research training, underpinned by Sheffield's breadth of activity in engineering science. We will tailor the first year training to support their transition into the centre, and provide cohort experiences that reinforce system-level thinking and leadership skills, to ensure that our alumni's impact on society far exceeds that of a typical PhD student. Training will be undertaken individually, within a cohort, across the centre, and in combination with other centres and groups. Through this approach, we will achieve horizontal and vertical integration of the student experience within the centre and will support students in developing the specific skills required for their research. This will foster a collective culture in key training areas such as leadership, inclusion, innovation and communication, amply preparing students for their future careers.

[1] IMF, World Economic Outlook January 2023

[2] Chancellor Jeremy Hunt's speech at Bloomberg, 27/1/2023

[3] RAEng/IET Connecting Data Report 2015

[4] UK Innovation Strategy: Leading the future by creating it

EPSRC Centre for Doctoral Training in Future Telecommunications Systems for Sustainable Future Services

Professor Reza Nejabati University of Bristol

Nejabati, Professor R,Beach, Professor M,Bull, Professor D,Dawson, Professor M,Simeonidou, Professor D,Katsenou, Dr A A,Tavakkolnia, Dr I,Herrnsdorf, Dr JHL,Harbord, Dr EGH,Haas, Professor H

The telecommunications industry is undergoing major transformation motivated by the demand to extend services from the traditional connectivity to emerging digital and data-driven services. To fulfil the complex requirements of these new services (e.g., autonomous driving, metaverse), technologies such as AI, cybersecurity, cloud computing, content delivery and the utilisation of new spectrum are becoming fundamental part of the design of future telecoms networks. At the same time, there is an increasing expectation for solutions to address societal challenges, such as sustainability, inclusion, privacy and trust as part of the new digital services' offering. As a result, there is a growing gap of critical skills in the sector (e.g., AI/ML, cybersecurity, cloud, energy management, video and content coding as well as sociotechnical methodologies), owning to the fact that traditional telecoms training does not offer skills development fit for such future industry needs.

This CDT will make a holistic offering on skills needed for a transforming telecoms sector, spanning traditional topics (e.g., wireless and wired technologies) complemented by AI/ML, cybersecurity, cloud and sustainability topics and their relevance and applications in future telecom systems. It builds on complimentary excellence of the University of Bristol (UoB) and the University of Strathclyde (UoS) in the full breadth of the telecoms delivery chain, their long-lasting partnership, Bristol's previous CDT in Communications, flagship large scale strategic local and regional (Southwest and Scotland) investments by the two universities, government, and industry which are all directly relevant to this CDT.

The CDT will consist of 1 year taught modules, plus 3 years of research. The students will form a virtual cohort, including periodic participatory events in person along taught modules. The training program of the CDT will embed a layer of interconnectedness between the graduates, strengthening the telecom ecosystem with experts who have in depth awareness of the complex interaction of all system components within a telecom network. Furthermore, each cohort will form a support network, a community, giving the opportunity to develop team building skills, to form collaboration, to train alongside peers, to share experiences as well as to create relationships between PhDs and academics and industry through joint PhD supervision from the Strathclyde, Bristol and industry partners.

EPSRC Centre for Doctoral Training in "Diversity led, mission-driven research"

Dr Marie Muellenbroich University of Glasgow

Muellenbroich, Dr MC,Abbasi, Dr Q,Forgan, Professor RS,Gauchotte-Lindsay, Dr C

The EPSRC Centre for Doctoral Training in "Diversity led, mission driven research", which is submitted in the focus area of "supporting an innovative approach to CDT delivery", proposes a disruptive new model for building a CDT, where we will focus primarily on the diversity of our cohorts of postgraduate researchers rather than organising around a specific scientific topic. There is a large body of evidence that describes the significant positive impact of diversity on innovation yet, in academic science, researchers from marginalised and minoritised backgrounds face significant hurdles throughout their careers. The prevalence of genuinely disruptive, novel scientific research is also dropping as fields become condensed and researchers are siloed. There is therefore a compelling scientific and economic case that focussing on diversity will lead to more significant innovation and research impact. By putting the diversity of our researchers, supervisors, management teams, partners, and advisors at the forefront of the CDT, we will build a welcoming, inclusive safe environment to allow innovative science to flourish.

At the University of Glasgow, we have accumulated significant experience of developing a positive research culture through various initiatives to support underrepresented communities, including our award-winning investigations into our historic links with the slave trade which culminated in the founding of our highly successful James McCune Smith PhD Scholarships for Black British students. Our CDT will build upon these learnings to offer radical new pathways for the training of scientists and the generation of innovative multidisciplinary science around key institutional thematic areas including Net Zero, Artificial Intelligence, Healthcare Technologies and Quantum Technologies, drawing on our broad resource world-leading academic expertise.

We will apply evidence-led best practice alongside our longstanding institutional experience to ensure diversity permeates across our recruitment, project selection, training, supervision, mentoring, retention, governance and self-reflection processes. Through tailored, structured support of our researchers and academics, both individually and collectively as annual cohorts, we will foster an inclusive community where our members will be united by a sense of common purpose to effectively tackle mission-driven challenges.

Our CDT will be managed by a rotating group of four co-directors who will focus on our key pillars: (I) Talent and Skills, (ii) Impact and Engagement, (iii) Belonging, and (iv) Research Culture, a structure which will ensure diversity and innovation in practice with the added security of management continuity. Through innovative CDT management, such as (i) the development of a "catalogue of possibilities" that encompasses our scientific themes, supervisors, and other role models to ensure visibility across different marginalised communities, (ii) the use of sandpits to generate discipline-crossing projects, (iii) enhanced bespoke mentoring from industry and academia, and (iv) an inverted crucible exercise to allow students to select projects and supervisors, we will demonstrate the clear pathway from diversity to excellence. We will offer opportunities for scientists from under-represented demographics to thrive, and in doing so generate genuine scientific excellence while building a critical mass of role models and research leaders, as well as novel initiatives in applying the principles of justice, equality, diversity and inclusion to scientific research. The CDT will therefore be a catalyst for genuine, positive change, and act as a beacon for UK Higher Education both in our principles and practices.

EPSRC Centre for Doctoral Training in Innovation for Sustainable Composites Engineering

Professor Janice Barton University of Bristol

Barton, Professor J,Scarpa, Professor F,Hallett, Professor SR,Toumpanaki, Dr E,Matveev, Dr M,Belnoue, Dr JP,Ivanov, Dr D,Trask, Professor RS,Harper, Dr LT

The composites industry faces an imperative to prioritise sustainability. The urgent need to reduce impact on the environment and ensure the availability of resources for future generations is critical to securing a prosperous and resilient future. Composite materials are crucial for delivering a Net-Zero future but pose several unique technical challenges. Our proposed CDT in Innovation for Sustainable Composites Engineering will address these challenges by developing a workforce equipped with the skills to become leaders in the future sustainable economy and support UK industry competitiveness.

Our CDT is jointly created by the Bristol Composites Institute, the University of Nottingham and the National Composites Centre (NCC); it focusses on meeting a user need in the UK composites sector. In addition to the EPSRC funding, NCC will provide >£4M, combined with additional support from the wider industry (ca £1.3M), so that the CDT fits the Focus Area of Meeting a User Need. A letter of support has been provided to confirm the NCC contribution to the CDT. We are also seeking support from the wider industry and have so far received >20 expressions of interest from companies such as Rolls-Royce, Vestas Wind Systems, Siemens Gamesa Renewable Energy, Leonardo, Luxfer, JLR, Magma Global and EDF. We have contacted several SMEs and have expressions of interest from SHD Composites, Pentaxia, LMAT, Actuation Lab, ICOMAT and Lineat. Hence, we are confident that the CDT will attract a wide range of industrial support.

The CDT will provide a science-based framework for innovative, curiosity driven research and skills development to facilitate composites as the underpinning technology for a sustainable future. Critically, the CDT will offer an agile doctoral educational environment focused on advanced competencies and skills, tailored to industrial and commercial needs, providing academic excellence and encourage innovation. The ambitious goal of spanning Technology Readiness Levels (TRL 1-4) will be achieved by having a mix of university-based PhDs (TRL 1-2) and industrially-based EngDs (TRL 2-4):

* Fundamental industrial sponsored research will be carried out by PhD students based at University of Bristol and University of Nottingham.

* The EngD students will spend 75% of their time in industry conducting a research project that is defined industry.

Students will complete their doctoral studies in four years, with the taught component being studied flexibly. The doctoral research will run concurrently with the taught component, so students are immersed in the research environment from the outset. The bespoke training programme that we will create demands the critical mass of a cohort. A specific role on our Management Board focuses on maximising cohort benefits to students. The cohort continuity across years will be ensured by a peer-to-peer mentoring programme, with all new students assigned a student mentor to support their studies, thereby creating an inclusive environment to provide students with a sense of place and ownership. Methods for developing a cohort across different locations will be supported by our experience with our Industrial Doctorate Centres. The cross-year group cohort building activities will include: (i) Annual design, build and test competitions run by NCC, (ii) collaborative industry led 'hackathons', (iii) tailored hands-on immersive courses with key industrial partners, (iv) online and in person seminars and group meetings, (v) outreach activities, (vi) a student-led network, (vii) personal development activities.

EPSRC Centre for Doctoral Training in Photonic and Electronic Systems

Professor Alwyn Seeds University College London

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Photonics has moved from a niche industry to being embedded in the majority of deployed systems, spanning sensing, biomedical devices and advanced manufacturing, through communications, ranging from chip-to-chip and wireless access to transcontinental scale, to display technologies, bringing higher resolution, lower energy operation and new ways of human-machine interaction. Its combination with electronics enables the Digital Future.

These advances have set the scene for a major change in commercialisation activity where photonics, electronics and wireless converge in a wide range of information, sensing, communications, manufacturing and personal healthcare systems. Currently manufactured systems are realised by combining separately developed photonics, electronic and wireless components. This approach is labour intensive and requires many electrical interconnects as well as optical alignment on the micron scale. Devices are optimised separately and then brought together to meet systems specifications. Such an approach, although it has delivered remarkable results, not least the communications systems upon which the internet and our Digital Future depends, limits the benefits that could come from systems-led design and the development of technologies for seamless integration of photonics, electronics and wireless.

To realise such integrated systems requires researchers who have not only deep understanding of their specialist area, but also an excellent understanding across this interdisciplinary area ranging across the fields of photonics, electronics and wireless hardware and software.

We aim to meet this important need, building upon the uniqueness and extent of the Cambridge and UCL research programmes, where activities range across materials for future systems; higher levels of electronic, photonic and wireless integration; the convergence of wireless and optical communication systems; combined quantum and classical communication systems; the application of THz and optical low-latency connections in data centres; techniques for high capacity access networks; the substitution of many conventional illumination products with photonic light sources and extensive application of photonics in medical diagnostics and personalised medicine. Future systems will increasingly rely on more advanced systems integration, and so the proposed CDT includes experts in electronic circuits, wireless systems and enabling software. By drawing these complementary activities together, and building upon initial work towards this goal carried out within our previously funded CDT in Connected Electronic and Photonic Systems, it is proposed to develop an advanced training programme to equip the next generation of very high calibre doctoral students with the required technical expertise, responsible research and innovation, commercial and business skills to enable the > £100 billion annual turnover UK electronics and photonics industry to create the optimised, closely integrated systems of the future. The PES CDT will provide a wide range of methods for learning for research students, well beyond that conventionally available, so that they can gain the required skills. In addition to conventional lectures and seminars, for example, there will be bespoke experimental coursework activities, reading clubs, road-mapping activities, responsible research and innovation studies, secondments to companies and other research laboratories and business and entrepreneurship courses.

Students trained by the CDT will be equipped to expand the range of applications into which these technologies are deployed in key sectors of the Digital Futures and wider economy, such as communications, industrial manufacturing, consumer electronics, data processing, defence, energy, engineering, security and medicine.

Epsrc centre for doctoral training iN diGital heAlth technoloGiEs (ENGAGE)

Professor Rebecca Shipley University College London

Shipley, Professor RJ,Finlay, Professor DD,McKendry, Professor RA,Ryan, Dr AA,McLaughlin, Professor JA,Meenan, Professor BJ,Parker, Professor GJM,Dubis, Dr AM,Sebire, Professor N,Bond, Professor RR

Healthcare services in the UK and internationally are facing unprecedented strain and this is predicted to continue long-term. The situation has been exacerbated by the COVID-19 pandemic, which also shone a light on our existing challenges including the long-term burdens of infectious and chronic disease, ageing populations, vast inequalities in our societies, healthcare systems that are fragmented but challenging to integrate, and chronic healthcare worker understaffing. Yet, there are huge opportunities - not least a data revolution, which is providing access to health data (both for individuals and populations) like never before. We need to develop new technologies that harness the potential of these data and use digital solutions to enable a step change in health provision.

It is clear that an urgent barrier to this transformation is a lack of highly trained individuals who possess the skills to understand healthcare challenges and the needs of healthcare workers and patients - and use this understanding to design, test and implement the required digital health technologies. Currently, this risks the UK leadership in the digital health domain and, critically, our ability to tackle these challenges. Our CDT - ENGAGE - will address this deficit by creating a new research and training programme to tackle it directly. We will focus on digital health technologies that will enable a continuum of care from home-hospital, a nationally (and internationally) identified priority. We will also focus on training ENGAGE students in a diverse set of disciplinary skills spanning the mathematical, data and engineering sciences, avoiding traditional disciplinary silos and providing the broader expertise in how to deliver these technologies to patients - for example, commercialisation working with industry, medical regulation, and testing/ evaluation of technologies. The technologies we develop will be as diverse as wearables and apps for home-monitoring of health and disease, digitally-enabled sensors for surveillance of disease at the population level, or live algorithms to predict patient flows and treatments in a hospital.

ENGAGE partners two world-leading Universities - UCL and Ulster University - with a diverse set of NHS organisations and industry stakeholders, and distinct healthcare and economic environments. In this way, we ensure that we (a) tackle a diverse set of real-world healthcare challenges, (b) meet the needs of industry for skilled graduates, (c) deliver graduates with a portfolio of academic and broader skills to meet the digital health technologies skills gap. We have engaged 18 of our partners - including the NHS, major industry and SMEs - in creating ENGAGE, in particular defining our healthcare themes and training portfolio. This engagement will continue throughout ENGAGE - partners will help deliver our training (for example, in how to engage with patients, communicate research, and how to commercialise research), will define healthcare challenges, co-supervise projects and host student secondments. All students will avail of these opportunities, as well as our cutting-edge multidisciplinary academic training, positioning them uniquely as PhD graduates into the digital health technologies sector.

EPSRC Centre for Doctoral Training in Sustainable Energy Materials Innovation (SEM-CDT)

Professor Sian Dutton University of Cambridge

Dutton, Professor SE,Bronstein, Dr H,Grey, Professor CP,Driscoll, Professor JL,Udrea, Professor F,Sirringhaus, Professor H,Oliver, Professor RA,Stranks, Professor SD,Moya, Dr X

Averting dangerous consequences of climate change and transitioning to societies that use natural resources sustainably is the greatest existential challenge facing humanity, requiring far-reaching technological, economic, socio-cultural, and institutional change. At the technological level, advanced energy materials are needed to sustain incremental advances in performance and cost of existing zero-carbon energy technologies. Even seemingly mature energy technologies such as Li-ion batteries or wind turbines require incremental improvements in materials to sustain a roadmap for improvements in performance, lifetime or environmental impact, cost reduction or to address concerns about elemental scarcity or security of supply. There also remain significant open technology challenges in hard-to-abate sectors of the energy economy that require scientific and technological breakthroughs. At the same time there remain significant opportunities for disruptive innovation in energy materials, as evidenced by recent unexpected discoveries, such as defect-tolerant halide perovskite semiconductors for solar cells, that already surpass the performance of conventional silicon, novel transition metal oxides for higher capacity batteries that charge in minutes rather than hours and more efficient GaN materials and devices for power electronics and energy efficient control systems.

The Centre for Doctoral Training in Sustainable Energy Materials Innovation (SEM-CDT) at the University of Cambridge will provide world-leading, industry-focussed training in the fundamental science, design and discovery, development, scale-up, life-cycle analysis and system integration of advanced energy materials and devices that are needed for a successful energy transition to a zero-carbon society. It will overcome an issue of current training provision in this field which tends to be too compartmentalised and focussed on specific energy technologies and will provide cross-disciplinary training across different energy technologies as well as in systems aspects and the societal context of zero-carbon energy systems. The SEM-CDT will be industry focussed through delivery of industry co-developed courses and a "beyond-research" 3 -month internship programme in one of our industrial and non-academic partner organisations. It will prepare students well for diverse careers in net-zero energy systems in research, industry, government, non-governmental, or financial organisations. We also aim to provide an effective and supportive training environment that achieves a high level of student satisfaction and well-being and improves remaining diversity issues in the energy sector.

The SEM-CDT brings together a world-class team of > 30 investigators at the University of Cambridge working in a broad range of energy technologies, including but not limited to, photovoltaics, wind power, nuclear power, carbon capture and storage, energy storage and batteries, fuels cells, solar fuels, power electronics, energy efficient information processing, waste heat harvesting and low carbon heating and cooling. Our team includes an industrial network of > 20 small, medium and large companies with broad expertise across a wide spectrum of energy technologies and a wide geographical spread across the UK.

Integrated and Programmable Catalysis for a Sustainable Chemical Industry (IP-Cat)

Professor Igor Larrosa The University of Manchester

Larrosa, Professor I,Turner, Professor NJ,Hardacre, Professor C,Greaney, Professor M,Trujillo, Dr C C,Spallina, Dr V,Lovelock, Dr S,Cuellar Franca, Dr RM,Bures, Dr J

The UK boasts one of the world's leading chemical industries, characterized by exceptional growth, exports, productivity and international investment. This industry relies heavily on skilled researchers able to design and build molecules in a sustainable way, through the application of catalysis. Traditionally, training in catalysis focuses on either chemocatalysis, an approach where for example small molecules or metal complexes are used as catalysts, or on biocatalysis, where enzymes are used as catalysts. However, this compartmentalization hinders the discovery of new chemicals and improved chemical processes, where, the best route to a desired target molecule is likely to benefit from the use of both approaches.

IP-Cat, will train a next generation of interdisciplinary scientists with the ability to move seamlessly between chemo- and biocatalysis, and exploit the synergies between them. The CDT will provide training on the design of new catalysts and catalytic processes, sustainability and process engineering. This new generation will be able to apply their training to the development of sustainable chemical processes at both small and large scale, to facilitate the discovery and production of molecules our society needs.

The University of Manchester offers the ideal environment for this CDT, with world-leading research groups in chemocatalysis, biocatalysis, process engineering, and a proven track-record in the combination of chemo- and biocatalytic processes. The University has strong links with several key regional hubs for science and innovation, as well as with the chemical industry. Industrial partners to the CDT will provide guidance and help on training, research project co-creation, co-supervision of students, and placement opportunities, enriching the PhD student training.

The cohort-based training of IP-Cat will create a strong identity, with an embedded culture of responsible research and innovation (RRI) and equality, diversity and inclusion (ED&I). The shared experience of course attendance and organization, workshops, seminars and other training events, will promote cross-fertilization of ideas across the different research disciplines. On completion of their training, the PhD students will be highly employable experts on catalysis, with the advanced skills required by the chemical industry to help transition the UK economy to net zero.

EPSRC Centre for Doctoral Training in Data-Driven Healthcare (DRIVE-Health)

Professor Richard Dobson King's College London

Dobson, Professor RJB,roberts, Dr AR,Curcin, Professor V,Dregan, Dr A

Healthcare accounts for approximately 30% of the world's data and comprises clinical notes, images, test results, genetic information, data from smartphones, wearables and specialist medical equipment. These vast and varied data have the potential to predict individual risk of disease, pinpoint diagnoses, deliver personalised therapies, encourage healthy behaviours and drive improvements in the healthcare system. Despite this richness, the development of treatments for many common disorders such as diabetes, heart failure, multiple sclerosis and epilepsy do not exploit these data fully, and consequently, treatments are not as effective as they could be. Additionally, the growing, ageing population has complex healthcare needs, which creates cost pressures for the health system.

Addressing these challenges requires the development of new scientific skills, competencies and expertise. Healthcare data science and engineering skills are critical to the UK's future growth, jobs, and economic wealth. The UK is a major player in the global healthcare technologies sector, expected to be worth $1.5 trillion by 2030.

The EPSRC Centre for Doctoral Training in Data-Driven Healthcare (DRIVE-Health) has been designed to meet these future skills needs. Over the past three years, with King's College London seed funding and NHS and industry backing, our team has piloted the DRIVE-Health model and trained 28 diverse doctoral students in three cohorts. EPSRC funding, with additional contributions from King's and industry, will ensure a step-change for DRIVE-Health, enabling us to bridge the UK's health data skills gap.

The DRIVE-Health team will train 70+ doctoral students through a unique cohort-based approach, with shared challenges, peer-to-peer learning and multidisciplinary supervision (informatics, clinical and industry). Our PhD students will receive training in research skills through the following themes: (i) Creating healthcare data systems that are environmentally friendly and encourage new ideas (ii) Combining different kinds of health and non-health data from multiple sources and over time to get a fuller picture of a patient's health (iii) Using computer programs to study complicated systems, like hospital emergency rooms or how the human body works (iv) Making new tools that are easy to use and that doctors and patients can trust (v) Working with everyone involved in providing and using healthcare to make sure solutions are safe, fair, and ethical.

DRIVE-Health will offer students a comprehensive, structured 4-year PhD pathway with a formal programme of taught, assessed training and high-quality research, with access to specialist datasets, equipment, infrastructure, career development and mentoring. We have developed an inclusive recruitment programme to attract top candidates from ethnic minorities and disadvantaged backgrounds, supported by King's and our community partners.

EPSRC Centre for Doctoral Training in Nucleic Acids

Professor Michael Hannon University of Birmingham

Hannon, Professor MJ,Tucker, Professor JH,Booth, Dr MJ,Craggs, Dr TD,Turner, Professor NW,Waller, Dr Z

Overview:

This CDT in Nucleic Acids (NAs), led by three leading UK universities in the field, Birmingham, Sheffield and UCL, is co-created with, and will be co-delivered by, a bespoke academic-industry-public sector partnership, with representation from multinational companies to regional companies and stakeholders. It will use its combined expertise in nucleic acids, including synthesis and characterisation, therapeutics and delivery, diagnostics and sequencing, chemical biology and drug targeting, bioinformatics and computation, and scale manufacturing, to train a new generation of cross-disciplinary scientists with the necessary skills to secure the UK as a world-leader in nucleic acid science and technology.

The Need:

We are entering the age of nucleic acids. RNA-based vaccines have been administered to billions of people in response to the COVID-19 pandemic and are set to not only offer disease protection but also revolutionise disease treatment. Such advances, coupled with recent gene editing and gene silencing innovations, mean that nucleic acid therapeutics are projected to become a multi-billion dollar industry within the next decade. At the same time advances in rapid diagnostics and DNA sequencing technologies continue to strengthen the characterisation and analysis of nucleic acids for healthcare applications. These technological breakthroughs have transformed the academic and industrial landscape, providing a roadmap for a new generation of therapeutics and healthcare, based around nucleic acids and molecules that interact with them.

Through our dozens of conversations with industry, it is clear that while the UK is at the forefront of some areas of nucleic acid technology, in others it has yet to realise its full potential. As UK industries build and expand their nucleic acid capabilities over the coming decade, they have stressed to us the need for an ever larger and better supply of PhD-level specialists in this rapidly expanding area of technology. Our CDT will address this user need, producing a new generation of cross-disciplinary physical scientists with the appropriate skills that UK industry tell us they require. At the same time, it will also address a pressing need from academia, where more specialists are required to drive innovative research programmes in nucleic acid science, ultimately leading to further discoveries in nucleic acid technology.

Our approach:

Our co-created and co-delivered training from our academic-industry-public sector partnership will produce PhD graduates with a broad skill-base and knowledge across all areas of nucleic acid science, from blue-skies research to data handling and ethical practice. The cross-disciplinary supervisory pool will be diverse in gender, ethnicity and career stage, with a significant proportion of the PhD projects co-supervised with industry. All students will undertake a placement in the UK or overseas and take part in whole cohort-based activities and residentials, receiving training in both transferable and industry-led technical skills. We will adopt a "training for all" approach where postgraduate students funded elsewhere will benefit from our training. Much of our training content and our international seminar series will be open for all and publicly available online. A website dedicated to advocate and educate the public about nucleic acids, their uses and applications will form a critical part of our vision. The CDT will be overseen by a Steering Board, with representation from all academic and external partners, the EPSRC and professional learned societies.

This CDT in nucleic acids will become a global hub for training and innovation, driving the UK to the forefront of nucleic acid technology research and development, and ensuring we capitalise on the excellence already present across academia, industry and our public sector partners.

EPRSC Centre for Doctoral Training in Statistics and Machine Learning at Imperial and Oxford

Dr Sarah Filippi Imperial College London

Filippi, Dr SL,Rousseau, Professor J,Gandy, Professor A,Holmes, Professor C,Sanna Passino, Dr F,Pike Burke, Dr C,Cucuringu, Professor M,Rebeschini, Professor P,Cohen, Dr EAK

Data science, machine learning and AI are now part of our everyday lives, transforming areas such as healthcare, government, energy, business, finance, defense, security, transport and infrastructure. Their importance and influence will only grow, and at an ever increasing rate. The countries that lead the data revolution will be the ones that benefit most, extracting knowledge and value from the huge, complex datasets being harvested in all sectors, and meeting the big societal challenges of the future.

The techniques underpinning such analysis are founded in statistics and machine learning. The EPSRC Centre for Doctoral Training in Statistics and Machine Learning at Imperial and Oxford (StatML) will continue to train at the methodological core of these disciplines. Through close collaboration with a broad range of industry partners, our training will produce graduates possessing expertise in developing cutting-edge statistical and machine learning methodology and theory supported by industry know-how, empowering them to develop new foundational methodologies to harness these complex datasets and create real-world impact. It is well documented in government and learned society reports that the UK economy has an urgent need for these people to ensure future prosperity and security.

The StatML CDT will learn from and build on our previous successful experiences in cohort training of doctoral students (our existing StatML CDT funded in 2018 as well as other CDTs at Imperial and Oxford) to produce impactful, internationally leading research in statistics and machine learning.

This renewal will continue our excellence in research while innovating a brand-new training diploma in Industrial Statistics and Machine Learning (I-StatML), designed to equip our students with the practical skills required to transform how data is used in industry and society. It will be developed with and delivered by industry leaders alongside our academics and will be responsive and adaptable to ensure that students are receiving training in the most cutting edge technologies, along with the latest ideas in ethics, responsible innovations, sustainability and entrepreneurship.

StatML students will train and research at the methodological core of AI, where innovation must occur, thus delivering on the EPSRC Research Priority of a Mathematical and Physical Sciences Powerhouse. Imperial and Oxford with their world-leading research groups, together with StatML partners, are uniquely placed to deliver this training.

StatML will pioneer a comprehensive widening participation strategy to attract diverse cohorts of people from a range of backgrounds. We will work with our students and experts in equality, diversity and inclusion to participate in and develop initiatives aimed at eliminating discrimination and biases, helping change the face of the UK statistics and machine learning workforce, which currently suffers from a severe lack of diversity, including in terms of gender and socio-economic background.

Together, StatML and its partners will define the future statistical machine learning scientist, who will not only address the demands for transformative high-end skills, but also be ethical and responsible innovators who disseminate their expertise within the entire data science ecosystem. Our cohort-based training enables the breadth of industry engagement, range of data sources, and interdisciplinary culture needed for tackling an endlessly diverse set of real-world problems.

EPSRC Centre for Doctoral Training in Advanced Engineering for Personalised Surgery & Intervention

Professor Sebastien Ourselin King's College London

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Our EPSRC CDT in Advanced Engineering for Personalised Surgery & Intervention will train a new generation of researchers for diverse engineering careers that deliver patient and economic impact through innovation in surgery & intervention. We will achieve this through cohort training that implements the strategy of the government, UKRI, and EPSRC by working across sectors (academia, industry, and NHS) to stimulate innovations by generating and exchanging knowledge.

Surgery is recognised as an "indivisible, indispensable part of health care" but the NHS struggles to meet its rising demand. More than 10m UK patients underwent a surgical procedure in 2021, with a further 5m patients still requiring treatment due to the COVID-19 backlog. This level of activity accounts for a staggering 10% of the healthcare budget, yet still comes with a heavy human life toll: one third of all country-wide deaths occur within 90 days of surgery. The Department of Health and Social Care highlights "Innovation and new technology" as a necessity for the healthcare system. Our proposed CDT will contribute to this mission and deliver mission-inspired training in the EPSRC's Research Priority "Transforming Health and Healthcare". In addition to patient impact, engineering innovation in surgery and intervention has substantial economic potential. The UK is a leader in the development of such technology and the 3rd biggest contributor to Europe's 150 billion (euros) MedTech market (2021). The market's growth rate is substantial, for example an 11.4% (2021 - 2026) compound annual growth rate is predicted just for the submarket of interventional robotics.

The engineering scientists required to enhance the UK's societal, scientific, and economic capacity must be expert researchers with the skills to create innovative solutions to surgical challenges, by carrying out research, for example, on micro-surgical robots for tumour resection, AI-assisted surgical training, novel materials and theranostic agents for "surgery without the knife", and predictive computational models to develop patient-specific surgical procedures. Crucially, they should be comfortable and effective in crossing disciplines while being deeply engaged with surgical teams to co-create technology solutions. They should understand the pathway from bench-to-bedside and possess an entrepreneurial mindset to bring their innovations to the market. Such researchers are currently scarce, making bespoke training a key pillar of the UK Government's "Build Back Better - our plan for growth" and UKRI's "five-year strategy".

The cross-faculty and cross-discipline collaboration of King's School of Biomedical Engineering & Imaging Sciences (BMEIS, host), Department of Engineering, and King's Health Partners (KHP), our Academic Health Science Centre, will create an engineering focused CDT that embeds students within three acute NHS Trusts. Our CDT brings together 50+ world-class supervisors whose grant portfolio (c.£20m p.a.) underpins the full spectrum of the CDT's activity, i.e., Smart Surgical Instruments & Implants, Surgical Data Science, and Digital Surgical Twins.

We will offer MRes/PhD training pathway (1+3), and direct PhD training pathway (0+4). All students, regardless of pathway, will benefit from continuous education modules which cover aspects of clinical translation and entrepreneurship (with King's Entrepreneurship Institute), as well as core value modules to foster a positive research culture.

Our graduates will acquire an entrepreneurial mindset with skills in data science, fundamental AI, computational modelling, and surgical instrumentation and implants. Career paths, will range from creating next generation medical innovators within academia and/or industry to MedTech start-up entrepreneurs.

EPSRC Centre for Doctoral Training in Collaborative Computational Modelling at the Interface

Professor Timo Betcke University College London

Betcke, Professor T,Guillas, Professor SE,Cotter, Professor C,Kalise Balza, Dr DF,Ni, Professor H,Misener, Professor R,Betcke, Dr MM,Shahrezaei, Dr V

Since the advent of computer based numerical weather prediction in the 1950s, computational modelling and numerical simulations have been at the heart of scientific progress. From gravitational wave modelling to the design of cars and aircrafts, our technology is based on the ability to perform ever more complex physics based simulations. Over the last decade we have seen a parallel computational revolution, with models constructed from data, exemplified by the huge advances in machine learning. This has made possible quantum leaps in areas such as image recognition and natural language processing.

We know that the future is based on a convergence of data based and classical physics based models, using rigorous physical principles enhanced by machine learning and other data techniques, making possible simulations that react onto and feed back into the real world. Governments and industries across the world are currently creating huge investments into this growth area, often under the name "Digital Twins", which is a transformative evolution and convergence of the most advanced differential equation and data based methods.

But how shall we go on building this new simulation world? We are talking about complex interconnected simulations based on huge software ecosystems that need to bridge classical computational science and data science, integrated into ever more complex cloud eco-systems. We require a new generation of scientists and engineers at the interface of research software engineering, computational modelling, and data science, who understand the algorithms and mathematics behind both differential equation models and machine learning, and have the required software skills to build the massive software ecosystems required for these simulations.

This Centre for Doctoral Training has been designed to address this need to train a new generation of graduates who can move fluently between research software engineering, computational sciences, and data methods. Hosted by the UCL Centre for Advanced Research Computing we are developing an innovative novel training programme that puts research software engineering at its heart while at the same time giving students a rigorous education in the most advanced differential equation and data based simulation methods.

Core training in this CDT will not be based on classical model delivery but on topical collaborative working groups that are a combination of paper/book study, and software exploration to allow students to discover current computational topics through an integrated view of how software and research interplay. Students will engage in cross cohort open source activities, and actively contribute to open source software ecosystems across the computational and data sciences. Their thesis topics will combine rigorous software engineering with computational and data topics. In all these activities students will be supported by world class research groups across Mathematics, Statistics, and Computer Science at UCL and Imperial.

Students will benefit from a network of national and international partners, from world leading HPC Centres to innovative SMEs. Annual workshops, industry days, and many other cohort activities will ensure a cohesive experience across UCL and Imperial.

We are at the beginning of an exciting future that merges classical computational models, AI, and cloud-systems, into a new unprecedented digital representation of the world. This CDT will be front and centre in this revolution.

CDT - Energy Storage and Systems Integration (ESSI)

Dr Solomon Brown University of Sheffield

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Energy storage underpins the UK's cross-sectoral strategy for reaching its net zero targets. While the application of storage underpins the decarbonisation of the transportation sector through the mass roll-out of Electrical Vehicles, the planned deployment of renewables on the UK grid is dependent on matching of grid-scale storage to deliver system resilience at multiple spatio-temporal scales as laid out in the government's Powering Net Zero White Paper. Alongside this, the UK Heat and Buildings Strategy makes clear that Energy Storage is a cornerstone for the transition to low carbon heating, by providing the efficiency and flexibility required to secure the energy system. National Grid scenarios show storage capacity increasing by a factor of 4 - 6 by 2030, and by an order of magnitude by 2050. This trend is truly global, with an expected 15-fold expansion of grid scale batteries alone by 2030.

For the UK to meet this demand in this key technology, and to achieve a secure, sustainable and affordable energy system, it must address the need for individuals with an understanding of the full breadth of energy storage technologies, their applications and challenges in integration, and the complex system of markets and policy at regional and national-level. If the training and skills gaps in these areas continue to be addressed individually there is a great risk that storage integration will not only fail to achieve its full potential but also the UK will miss an opportunity to be a world-leader in the next generation of engineers and scientists that will deliver truly sustainable energy storage.

The CDT Energy Storage and Systems Integration (ESSI) will address this critical gap. ESSI will deliver a world-leading training programme, co-created stakeholders, covering the breadth of underpinning science and technology, whilst instilling critical depth of expertise in research projects that are co-developed with our industrial partners. These projects will encompass:

1. the development of storage technologies, including batteries, longer-duration energy storage and thermal energy storage, to improve their performance and reduce costs;

2. analysis of the environmental and resource impacts of energy storage technologies, from manufacturing to recycling, re-use and disposal;

3. understand how storage will help integrate power, transport and thermal systems, in domestic and business sectors;

4. the formulation of energy policies and markets to allow the system benefits of storage to be captured.

EPSRC Centre for Doctoral Training in Quantum Computation and Quantum Communications (QC2)

Professor Paul Warburton University College London

Warburton, Professor PA,Bose, Professor S,Browne, Professor D,Szymanska, Professor MH,Ruocco, Dr A,Beghelli, Dr A,Morton, Professor JJL,Malik, Dr S,Fisher, Professor AJ

Quantum computation and quantum communications will transform the global economy and society over the next fifty years, mirroring the transformation due to classical silicon information processing and optical fibre communications over the previous fifty years. UK government and industry has committed £1 bn to the National Quantum Technologies Programme (NQTP), creating a dynamic quantum computation and quantum comms ecosystem in the UK, with major corporations and around forty SMEs, supported by the National Quantum Computing Centre (NQCC). Quantum communications will play an increasing role in enabling networked quantum computation and the quantum internet. Convergence between the fields of quantum computation and quantum communications, enabled by distributed entanglement, will become increasingly important in the next decade.

The goal of QC2 is to train the next generation of quantum computation and quantum comms research pioneers, entrepreneurs and business leaders who will strengthen the UK's leading position in the sector.

QC2 will deliver high-impact internationally-leading research in all experimental, theoretical and software-focussed sub-fields within quantum computation and quantum communications, including: fabrication and characterisation of several hardware platforms; systems integration of quantum hardware and coherent quantum communications networks; algorithms for both medium-term and longer-term fault-tolerant approaches to quantum computation in both single-chip and distributed network implementations; quantum error-correction encoding and decoding; and fundamentals of quantum information.

QC2 will recruit sixty-five students in five annual cohorts, with each student working towards a PhD in some aspect of the engineering or computer science or physics of quantum computation and quantum comms. Of the sixty-five studentships, forty will be funded by EPSRC with the remaining twenty-five studentships funded by UCL and QC2's commercial partners.

UK commercial quantum computation and quantum comms activity was minimal five years ago and now has received around £200M in venture-capital and government funding. This rapid expansion has led to a chronic shortage of skilled people with the specialised doctoral-level scientific and engineering research training which is required - this shortage has been identified by a number of independent reports (see for example "Adoption of Quantum Technologies and Business Model Innovation", IfM White Paper, 2022). The QC2 CDT will leverage its internationally-leading research teams and an extensive network of partners to provide skills which are urgently needed for the UK to extend its leading global position in quantum computation and quantum comms.

QC2 will prioritise training in advanced manufacturing for quantum devices and systems, making use of the nanofabrication cleanroom and QUES2T cryolab suite at UCL. Software and quantum algorithm development skills become critical as systems begin to scale beyond their current lab-based environment into general-access facilities. Access to quantum hardware at scale through our strategic alliances with IBM (at the Hartree Centre in the northwest of England), Amazon Web Services (AWS) and OQC, coupled with expertise in the supervisory team, places QC2 at the vanguard of quantum software skills training.

EPSRC Centre for Doctoral Training in Sustainable Approaches to Biomedical Science: data-driven Drug, Device and Diagnostic Discovery (SABS:D4)

Professor David Gavaghan University of Oxford

Gavaghan, Professor D,Deane, Professor C,Robinson, Dr M,Marsden, Professor B

The EPSRC CDT in Sustainable Approaches to Biomedical Science: data-driven Drug, Device and Diagnostic Discovery (SABS:D4) will create a supportive learning environment within which 100 industry-sponsored computational and quantitative scientists can develop the research and leadership skills needed to drive the expansion of the UK Life Sciences sector and help meet the goals at the heart of EPSRC's priority area Transforming Health and Healthcare.

In 2020, the UK Life Sciences Sector employed 268,000 people across 6,330 businesses, generating a turnover of £88.9bn. It is one of the UK's most productive sectors, performs more R&D (£4.8 billion) than any other sector, and is characterised by rapid innovation and continual evolution. This constant development has been powered by the increasing application of quantitative and predictive mathematical and computational techniques to the biomedical research domain. Demand for researchers with both advanced quantitative and computational skills and the expertise to apply those skills to cutting-edge industrial biomedical research far outstrips supply. As the UK Government's 2021 Life Sciences Vision policy paper states: "Our ambition is to develop the highly skilled workforce needed to position the UK as the global hub for Life Sciences...[with]...digital, computational, and statistical literacy; translation and commercial skills" particularly needed.

Since 2009, a collaboration between the University of Oxford and a consortium of 28 leading industrial companies drawn from across the Life Sciences sector, and funded through EPSRC's CDT programme, has worked together to create the Sustainable Approaches to Biomedical Science (SABS) programmes to address this skills shortage. The SABS programmes funded to date have trained almost 200 future innovators and research leaders in precisely the predictive computational and mathematical approaches to biomedical research needed to maintain and build on the UK's position at the forefront of the Life Sciences sector, and to meet the UK Government's ambitious targets for 2030. Alumni from the SABS programmes already occupy senior and influential roles within industry, and several now act as industrial supervisors to current SABS students.

Building on the innovative cohort-based training that we have pioneered in our existing SABS programmes, SABS:D4 will have a particular focus on providing training in the data-centric approaches that are driving these rapid advances across biomedical research. At the same time, we will maintain our sector leading training in advanced research software engineering and responsible and reproducible research, as well as the necessary core training in mathematical modelling, scientific computing, molecular and cellular biology, computational structural biology, and biological and medical imaging. Learning from the approach taken to advanced software engineering in the current SABS:R3 programme, our data-centric training will take the form of multiple team-based projects to allow hands-on acquisition of key techniques, including data management, data wrangling, HPC and cloud computing, AI & machine learning, using data sets provided by our industrial partners. Working in cross-cohort groups supported by an industrial mentor and an academic mentor, each group will be led by students drawn from previous cohorts. This approach will also allow our students to develop professional skills identified as essential by our industrial partners, in particular team-based research, in a supportive environment, and will complement our existing extensive career development programme across all four years of study.

By embedding this strong focus on teams-based training and professional skills development, together with data-centric approaches, into all aspects of the new programme, our computationallyliterate scientists will be equipped to act as ambassadors to bring about a transformation of biomedical research.

EPSRC CDT in Resilient Chemistry to Underpin Net Zero: Feedstock to Function (CDT-F2F)

Professor Peter Licence University of Nottingham

Licence, Professor P,Antonchick, Dr A,Bennett, Mr N,Kovacs, Dr K,McKechnie, Dr J,Dynes, Miss L,Denton, Professor RM,Kays, Professor DL,Papadopoulos, Professor D,Cave, Dr GWV,Perry, Professor C,Lester, Professor E

Advanced economies are now confronted with challenges that requires us to approach problem solving in a completely different way. As our global population continues to rise we must consider several quite taxing philosophical questions, most pressingly we must address our addiction to economic growth, our expectation for longer, healthier lives and our insatiable need to collect more stuff! Societies demand for performance molecules, ranging from pharmaceuticals to fragrances or adhesives to lubricants, is growing year-on-year and the advent of competition in a globalised market place is generally forcing the market price downward, cutting margins and reducing the ability for some industry sectors to innovate. Feedstock to Function (F2F) is an exciting opportunity to forge a new philosophy that could underpin the next phase of sustainable growth for the chemicals manufacturing industry in the UK and further afield. An overarching driving force in the development of F2F was the desire to apply the knowledge and learning of Green and Sustainable Chemistry to the creative phases embedded in the discovery and development of performance molecules that deliver function in applications as diverse as pharmaceuticals, agrochemicals and food.

We propose a new multi-disciplinary CDT in sustainable chemistry which aims to achieve a sustainable pipeline of performance molecules from design-to-delivery. F2F will create an Integrated Approach to Sustainable Chemistry, promoting a culture of waste minimisation, emphasising the development of a circular economy in terms of materials and matter replacing current modes of consumption and resource use.

F2F represents a multidisciplinary group of 50 academic advisors spanning 2 Universities set less than a mile apart in Nottingham, a city defined by its status as a Science City and committed to a path to achieve Net Zero by 2028. Our group of CDT advisors covers 7 academic disciplines working together with a growing family of industrial partners spanning well-known multinationals including Unilever, GSK, Lubrizol and Croda, and niche SMEs, including Promethean Particles, Sygnature and Charnwood Molecular. Interestingly all partners have expressed a common desire to develop Smarter products using Better chemistry to enable Faster processing and Shorter manufacturing routes.

F2F will drive innovation by:

1 fostering a multidisciplinary, cohort based approach to problem solving;

2 focussing on challenge areas identified by our F2F partners such that sub-groups of our cohort can become immersed in research at the "coal-face";

3 embedding aspects of data-driven decision making in the day-to-day design and execution of high quality research either on paper or indeed in the lab;

4 nurturing a vibrant and supportive community that allows PhD candidates to think 'outside of the box' in a relatively risk-free way;

5 empowering the development of 'next generation' methods to drive efficiency, selectivity and productivity, underpinned by molecular modelling and the use of machine learning to extract additional value from experimental data;

6 developing sustainable processes that deliver efficiency and transition to scale-up from g to kg, under-utilised approaches, including electrochemistry, will be investigated increase atom efficiency and reduce reliance on precious metals;

7 enabling efficient scale-up of new processes using flow-chemistry and smart intensified process engineering to deliver the most efficient reactor system, maximising throughput whilst managing mass transport and thermal factors;

8 applying robust reaction/process evaluation metrics such that comparative advantages can be quantified, providing evidence for real process decision making.

Integration of outcomes from all F2F PhD projects, in combination with the expertise of all F2F partners, will deliver a major contribution to the health of the UK chemicals manufacturing industry.

EPSRC Centre for Doctoral Training in: Plastics Shaken Up

Professor Stefan Bon   University of Warwick

Bon, Professor SAF,Lester, Dr D,Savage, Dr J,Calvillo Gonzalez, Dr N,Kremmyda, Dr G,Wan, Dr C,Peijs, Professor T

The central aims of the CDT Plastics Shaken Up (PSU) are: (1) to shake-up polymer science and revolutionise the way how polymers/plastics are made, processed, used, reused, unmade, remade and discarded, (2) to deliver on a rethink of how PhD students are trained and educated.

At Warwick University, the Warwick Cross Faculty Plastics Group (WCFPG, https://warwick.ac.uk/plastics) will train five cohorts of PhD students (80 positions in total, 24 international scholarships) in an exciting transdisciplinary way, in close collaboration with industry, UK government and non-government organisations. Gained knowledge, expertise and skills in Science, Technology, Engineering and Mathematics (STEM) will be enriched with the Arts, Humanities and Social Sciences, which will contribute theoretically and methodologically and encourage consideration of findings in their societal, political, and cultural contexts (STEM+ approach).

Research at PSU will take a holistic approach and involves five grand challenges: (1) Consumer trends and needs (eco-use, challenging habitual and behavioural choices), (2) Product and design (eco-design, properties, life cycle analysis, net-zero); (3) Sustainable chemical feedstocks (renewable, waste and recycled feedstocks); (4) Sustainable high value manufacturing (non-hazardous, cost-effective, green chemistry and processing, energy efficient, zero-waste); and (5) End-of-life (chemical, biodegradable and mechanical recycling).

Students carry out their research over a 4-years period, whilst having bespoke interdisciplinary supervisory teams with mentors from WCFPG and external partners. Each student is provided with a tailored STEM+ training and skills package which runs throughout the 4 years. Skills certificates are awarded upon completion. Students will be trained across a wide range of knowledge sets and skills, such as fundamentals of polymer science and engineering, coding, data processing, design thinking, IP and entrepreneurship, life cycle analysis, climate change, its ethics and justice, as well as the means of communicating findings to a wide variety of publics in accessible ways. They will be enriched and inspired by student-led annual getaways and engaged with our external partners at

Polymer Club consortium events. Each student will do secondments with our partners. Each student will produce an environmental and socio-economic impact assessment of their research findings.

Why this CDT, and why now? The plastics industry is crucial to the UK economy, being the 2nd largest employer in manufacturing. Plastics are a top 10 export (£9.6bn) and vital global materials, powering innovation and energy efficiency in key sectors such as food, transport, construction, sanitation, renewable energy, and health. However, plastic waste and pollution have reached globally alarming levels, and we believe that future thinking in plastics technology must be ethical, sustainable, interdisciplinary, and holistic.

At the same time, profound changes lie ahead for society, business and the UK labour market given the changing shape of the UK economy and our need to address our ambitions in for example climate protection and global technology leadership. STEM doctoral graduates need to be fit for this future. UK universities must equip them not only with outstanding scientific and technological expertise, but with interdisciplinary cognitive, digital, interpersonal, and self-leadership skills, as well as tools from social sciences and the humanities to deliver a just, sustainable workplace. Our transdisciplinary STEM+ approach will deliver this.

The next generation of scientists and engineers from PSU will be ambassadors of the UK green and sustainable plastics renaissance. These creative, critical, independent and accountable intellectual risk takers will serve wider society and deliver a UK workforce that can provide global leadership and innovation in tackling future environmental and sustainability challenges.

Henry Royce Institute and EPSRC CDT in Developing National Capability for Materials 4.0 (Mats4.0)

Dr Christopher Race The University of Manchester

Race, Dr C P,Pollard, Dr A,Walsh, Professor A,Bourne, Professor RA,Wynne, Professor BP,Oliver, Professor RA,Christofidou, Dr K,Liotti, Dr E

The job of materials science is to develop the materials that we need to make all of the things that we rely on in our daily lives. These range from the materials used to make large scale objects, like aeroplanes and buildings, right down to the smallest scales like the processors in the electronic devices we use every day. These materials are often complicated and need to be carefully designed with just the right properties needed to do their jobs for many decades in incredibly harsh conditions.

There are many current challenges that require us to develop new, better materials. We need to meet our net-zero climate goals and get better at designing products that can be fully recycled, for example. And there are some resources that we currently use in important materials that we would like to find alternatives for. These are difficult challenges and we need to overcome them quickly. But the way that materials scientists have worked in the past is too slow: it can take up to 20 years to develop a new material and we cannot wait that long.

Fortunately, recent developments in the computer simulation of materials, in robotics and sensor technology, in our ability to exploit large volumes of data through machine learning and in techniques for quickly making and testing large numbers of different materials can help speed things up. This idea, bringing digital technologies together to help us make better materials more quickly, is called "Materials 4.0".

If we are going to take advantage of Materials 4.0 then we need to make sure that materials scientists have the necessary digital skills. These skills, things like data informatics, machine learning and advanced computer simulation, are not usually covered in depth in undergraduate university courses in science and engineering. So, the Henry Royce Institute, the UK's national institute for advanced materials, in partnership with the National Physical Laboratory, is proposing to set up a Centre for Doctoral Training (CDT) that will take 70 science and engineering graduates and train them in the techniques of Materials 4.0. These students will work towards PhDs and become leaders in the field of Materials 4.0. They will undertake research projects in universities across the UK (Cambridge, Oxford, Imperial College, Manchester, Sheffield, Leeds and Strathclyde), tackling a broad range of materials science challenges and developing new approaches in Materials 4.0.

The need for these new approaches is widespread, throughout academia and in industry. In recognition of this, the training programme that we develop for the CDT will be made available more widely, in different forms, so that we can disseminate skills in Materials 4.0 to existing researchers in universities and industrial companies as quickly as possible. The training approach of the CDT will be to take our students from "Learners to Leaders" over the course of four years. Our students will be working across boundaries between materials science and computer / data science and between academia and industry. They will build new interfaces and help to develop a common language for communication. To strengthen our students' own learning and to disseminate their skills more widely, we will train our students as trainers so that the students are actively involved in designing and delivering training for fellow researchers and take the role of ambassadors for a cultural shift in materials science to modern ways of working.

EPSRC Centre for Doctoral Training in Fusion Power

Professor Roderick Vann University of York

Vann, Professor RG,Cecconello, Professor M,Khan, Dr A,Dickinson, Dr D,McKay, Dr K,Gandy, Dr AS,Armstrong, Dr D,Woolsey, Professor N

Fusion Power has the potential to solve one of society's greatest challenges: universal access to plentiful, safe & sustainable energy. A person's entire lifetime energy needs can be supplied from fusion energy using the deuterium taken from a domestic bath of water and the tritium that can be bred from the lithium in a single mobile phone battery. Fusion power plants cannot suffer any type of runaway and they do not produce any direct greenhouse gas emissions. However achieving fusion is technically challenging: it requires heating the deuterium & tritium fuel to millions of degrees. At this temperature, the fuel becomes a plasma - a gas of charged particles. The plasma must be confined for sufficient time at sufficient density in order to get more energy out than we put energy in. There are a number of approaches being explored but the most successful are (1) magnetic confinement fusion which holds the fuel by magnetic fields at relatively low density for relatively long times in a chamber called a tokamak, and (2) inertial confinement fusion which holds the fuel for a very short time but at huge densities.

The exciting news is that fusion is now entering a golden era. Since 2020, there have been substantial scientific breakthroughs, such as at JET in the UK and at NIF in the US. There has been dramatic expansion into the private sector with over 30 companies globally pursuing a range of approaches and many more establishing the fusion supply chain; governments around the world, but especially in the UK, are investing to accelerate fusion delivery.

A remaining critical barrier to making fusion a reality is the shortage of people who understand the inter-related operational constraints for both the plasma fuel and its containment materials, including the breeding of tritium from lithium, all of which must be satisfied simultaneously. The EPSRC CDT in Fusion Power will build on our existing success and international reputation to become the global beacon for training the next generation of fusion leaders. At the core of our CDT is the partnership between six leading research-intensive universities and more than 20 private companies, UK &

international labs and government agencies. Our students will benefit from a systems-thinking-based technical training in plasma physics and materials science including tritium breeding & handling. They will benefit from training delivered by non-academic partners in topics such as regulation & licensing, commercialisation & entrepreneurship, sustainability, financing & investment and project management. Through the CDT partners, the students will use internationally leading experimental facilities and high performance supercomputers. Initially through their supervisors and then increasingly independently, students will access international networks of institutions and fusion professionals. During their PhD, students will have the opportunity to build their track record through presenting work at conferences and leading their own "collaboratory" mini project. These scientists and engineers will go on to solve the technical cross-disciplinary challenges, moving fusion forward faster at a rate of 20 scientists & engineers per year. We will increase diversity in the fusion community through: positive recruitment & admissions practices; supportive, cohort-based training activities; undergraduate fusion internships for students from under-represented groups; outreach to the public and via sustained relationships with target schools. This supply of the best people will energise the UK fusion industry and enable a global ambition for fusion power plant innovation & development.

EPSRC Industrial Centre for Doctoral Training in Offshore Renewable Energy (IDCORE)

Professor David Ingram University of Edinburgh

Ingram, Professor DM,Masters, Professor I,Thomson, Dr RC,Allan, Dr GJ,Thies, Professor PR,Johanning, Professor L,Tao, Professor L,Wilson, Professor B,Race, Dr J,Williams, Dr AJ

A consortium of the Universities of Edinburgh, Exeter, Strathclyde and Swansea supported by the Scottish Association for Marine Sciences (SAMS) will run the Industrial Centre for Doctoral Training for Offshore Renewable Energy (IDCORE). This partnership offers a unique combination of experience in research, development and knowledge exchange with major industry stakeholders in the Offshore Renewable Energy (ORE) sector. This is complemented by the extensive experience of both SAMS, in the environmental and societal impacts, and the Fraser of Allander Institute (Strathclyde), in macro- and micro economics, of ORE projects.

The large scale deployment of ORE technologies is key to the UK achieving its net-zero carbon energy objectives while at the same time delivering secure, reliable and affordable energy. Both of these objectives must be achieved with minimal environmental impact. This requires the continuing development of new techniques and technologies to design, build, install, operate, and maintain energy generating machines in a hostile marine environment. Successful ORE projects must be affordable and minimise their environmental impact. Success will create green jobs at all levels in coastal communities across the UK and generate significant economic impact. The ORE sector, which includes companies ranging from world leading technology development SMEs (like Orbital Marine Energy and Mocean Energy) through to international energy companies as well as tier one suppliers, consulting engineers and project developers is creating a massive demand for highly trained scientists and engineers with a broad skill base.

The consortium is ideally-placed to support the industry in meeting these challenges through a conjoined infrastructure, which begins in some of the best academic research centres with leading test facilities and extends through a unique combination of demonstration facilities, ultimately to test and deployment sites. IDCORE will conduct internationally leading research, provide a vibrant training environment and deliver a body of high-quality post-doctoral staff for the sector. This proposal presents a revised training programme in response to changes in the sector (particularly the rapid growth of offshore wind, the commercialisation of tidal stream energy, and the drive to develop floating wind systems for deeper water). It also includes Swansea University for the first time, strengthening our links to developments in the Celtic Sea and brings significant expertise in computational modelling and aerodynamics.

IDCORE provides a solid background in professional, technical and transferable skills to a diverse cohort of students drawn from a wider variety of STEM backgrounds. IDCORE is designed to deliver a tightly knit cohort of highly skilled graduates forming a strong foundation for the future development of the sector. Our training is innovative and multi-disciplinary, using a variety of delivery methods, and utilising unique facilities including: the Kelvin hydrodynamics lab, FastBlade, the FloWave Ocean Energy Research Facility, offshore measurement systems (Wave and ADCP measurement array and surveying), the South West Mooring Test Facility, accelerated fatigue testing facilities (DMAC), survey vessels and field study areas. Through established links with partner organisations including the ORE Catapult, the European Marine Energy Centre (EMEC) students will be placed and, wherever possible site-trained in large-scale test facilities, prototype demonstration and small-farm demonstration sites. The training will also benefit from the extensive experience of the consortium in advanced engineering analysis and simulation, and access to UK-leading computational facilities. The training package offered by the centre provides our students with unparalleled engineering experience in applied offshore renewable energy R&D.

The EPSRC Centre for Doctoral Training in Use-Inspired Photonic Sensing and Metrology

Professor Derryck Reid Heriot-Watt University

Reid, Professor D,MacPherson, Dr WN,Turnbull, Professor GA,Jiang, Professor Dame X,O'Connor, Dr D P,Lavery, Professor MPJ,Flockhart, Dr GMH,Wilcox, Dr KG,Hands, Dr PJW

In a consortium led by Heriot-Watt with St Andrews, Glasgow, Strathclyde, Edinburgh, Dundee, Huddersfield and NPL, the "EPSRC CDT in Use-Inspired Photonic Sensing and Metrology" responds to the focus area of "Meeting a User-Need and/or Supporting Civic Priorities" and aligns to EPSRC's Frontiers in Engineering & Technology priority and its aim to produce "tools and technologies that form the foundation of future UK prosperity".

Our theme recognises the key role that photonic sensing and metrology has in addressing 21st century challenges in transport (LiDAR), energy (wind-turbine monitoring), manufacturing (precision measurement), medicine (disease sensors), agri-food (spectroscopy), security (chemical sensing) and net-zero (hydrocarbon and H2 metrology).

Building on the success of our earlier centres, the addition of NPL and Huddersfield to our team reflects their international leadership in optical metrology and creates a consortium whose REF standing, UKRI income and industrial connectivity makes us uniquely able to deliver this CDT.

Photonics occupies a unique space in UK research and innovation culture, with 20% of academic papers originating in the UK, and Photonics being the 5th most productive UK manufacturing sector, generating £14.5B annually across 1,200 firms with 76,000 staff.

UK companies addressing the photonic sensing and metrology market are vital to our economy but are threatened by a lack of doctoral-level researchers with a breadth of knowledge and understanding of photonic sensing and metrology, coupled with high-level business, management and communication skills.

By ensuring a supply of these individuals, our CDT will consolidate the UK industrial knowledge base, driving this high-growth, export-led sector whose products and services have far-reaching impacts on our society.

The proposed CDT will be configured with 40 EngD students, characterised by a research project originated by a company and hosted on their site. A complementary stream of 15 PhD students will pursue industrially relevant research in university labs, with more flexibility and technical risk than in an EngD project.

In preparing this bid, we invited companies to indicate their support, resulting in £3.5M cash commitments for 70 new students, exceeding by 27% our target of 55 students, and highlighting industry's appetite for a CDT in photonic sensing and metrology. Our request to EPSRC for £5.7M will support 35 students, from a total of 40 EngD and 15 PhD researchers. The remaining students will be funded by industrial (£2.43M) and university (£1.02M) cash contributions, translating to an exceptional 45% leverage of studentship costs.

The university partners provide 143 named supervisors, giving the flexibility to identify the most appropriate expertise for industry-led EngD projects. These academics' links to >120 named companies also ensure that the networks exist to co-create university-led PhD projects with industry partners. Our team combines established researchers with considerable supervisory experience (48 full professors) with many dynamic early-career researchers, including a number of prestigious research fellowship holders.

An 8-month frontloaded residential phase in St Andrews and Edinburgh will ensure the cohort gels strongly, and will equip students with the knowledge and skills they need before beginning their research projects. These core taught courses, augmented with specialist electives, will total 120 credits and will be supplemented by accredited MBA courses and training in outreach, IP, communication skills, RRI, EDI, sustainability and trusted-research training. Collectively, these training episodes will bring students back to Heriot-Watt a few times each year, consolidating their intra- and inter-cohort networks.

Governance will follow our current model, with a mixed academic-industry Management Committee and an International Advisory Committee of world-leading experts.

EPSRC Centre for Doctoral Training in Sustainable Chemical Technologies: a Systems Approach

Professor Matthew Davidson University of Bath

Davidson, Professor MG,Allen, Dr S,Guiso Gallisai, Mrs F,Buchard, Dr A,Mattia, Professor D,McManus, Professor MC

Chemical technologies underpin almost every aspect of our lives, from the energy we use to the materials we rely on and the medications we take. The UK chemical industry generates £73.3 billion revenue and employs 161,000 highly skilled workers. It is highly diverse (therefore resilient) with SMEs and microbusinesses making up a remarkable 97% of the sector.

Today's global chemicals industry is responsible for 10% of greenhouse gas (GHG) emissions and consumes 20% of oil and gas as carbon feedstock to make products. Decarbonisation (defossilisation) of the chemicals sector is, therefore, urgently required but to do so presents major technical and societal challenges. New sustainable chemical technologies, enabled by new synthesis, catalysis, reaction engineering, digitalisation and sustainability assessment, are needed. In order to ensure that the UK develops a resource efficient, resilient and sustainable economy underpinned by chemical manufacturing, developments in chemical technologies must be closely informed by whole systems approaches to measure and minimise environmental footprints, understand supply chains and assess economic and technological viability, using techniques such as life cycle assessment and material flow analysis.

Lack of access to experts in science and engineering with a holistic understanding of sustainable systems is widely and publicly recognised as a significant risk. It is therefore extremely timely to establish a new EPSRC CDT in Sustainable Chemical Technologies that fully integrates a whole systems approach to training and world leading research in an innovation-driven context. This CDT will train the next generation of leaders in sustainable chemical technologies with new skills to address the growing demand for highly skilled PhD graduates with the ability to develop and transfer sustainable practices into industry and society.

The new CDT will be a unique and vibrant focus of innovative doctoral training in the UK by taking full advantage of two exciting new developments at Bath. First, the CDT will be embedded in our new Institute for Sustainability (IfS) which has evolved from the internationally respected Centre for Sustainable and Circular Technologies (CSCT) and which fully integrates whole systems research and sustainable chemical technologies - two world-leading research groupings at Bath - under one banner. Second, the CDT will operate in close partnership with our recently established Swindon-based Innovation Centre for Applied Sustainable Technologies (iCAST, www.iCAST.org.uk) a £17M partnership for the rapid translation of university research to provide a dynamic innovation-focused context for PhD training in the region.

Our fresh and dynamic approach has been co-created with key industrial, research, training and civic partners who have already indicated co-investment of over £10M of support. This unique partnership will ensure that a new generation of highly skilled, entrepreneurial, innovative PhD graduates is nurtured to be the leaders of tomorrow's green industrial revolution in the UK.

Centre for Doctoral Training in Algebra, Geometry, and Quantum Fields

Professor Tara Brendle University of Glasgow

Brendle, Professor T,Szabo, Professor RJ,Jordan, Professor D,Dimofte, Professor T,Hollands, Dr L,Wemyss, Professor M

We will establish a Centre for Doctoral Training in Algebra, Geometry and Quantum Fields, joint between the Universities of Edinburgh, Glasgow and Heriot-Watt, and in the process deliver on the EPSRC priority area 'Physical and mathematical sciences powerhouse'.

This cross-boundary CDT will be simultaneously rooted in discovery-led mathematical abstraction and its vibrant scientific interfaces, and in the need to engage and intertwine these methods and power into the wider world and tech-based economy.

We will train a cohesive, dynamic, and diverse cohort of students in our world-leading interplay between algebra, geometry, and quantum fields where our overarching scientific aim is no less than the development of new foundations unifying all three disciplines. At the same time, we will move all students one step closer to applications through our placement programme, and by embedding bespoke, cutting-edge computing and AI training into our core.

The result will be a flow of PhDs with multiple skill sets, from abstraction to application, who will have the ability to be future leaders, to influence a wide range of people, and to creatively contribute to some of society's and technology's most pressing challenges.

EPSRC Centre for Doctoral Training in Aerosol Science: Harnessing Aerosol Science for Improved Security, Resilience and Global Health

Professor Jonathan Reid University of Bristol

Reid, Professor JP,Urbano, Dr LL,Stettler, Dr M E J,Boies, Professor A,Kumar, Professor P,Murnane, Professor D,Squires, Dr A,Miles, Dr REH,Pope, Professor FD,Topping, Dr D

Aerosol science, the study of airborne particles from the nanometre to the millimetre scale, has been increasingly in the public consciousness in recent years, particularly due to the role played by aerosols in the transmission of COVID-19. Vaccines and medications for treating lung and systemic diseases can be delivered by aerosol inhalation, and aerosols are widely used in agricultural and consumer products. Aerosols are a key mediator of poor air quality and respiratory and cardiac health outcomes: Improving human health depends on insights from aerosol science on emission sources and transport, supported by standardised metrology. Similar challenges exist for understanding climate, with aerosol radiative forcing remaining uncertain. Furthermore, aerosol routes to the engineering and manufacture of new materials can provide greener, more sustainable alternatives to conventional approaches and offer routes to new high-performance materials that can sequester carbon dioxide.

The physical science underpinning the diverse areas in which aerosols play a role is rarely taught at undergraduate level and the training of postgraduate research students (PGRs) has been fragmentary. This is a consequence of the challenges of fostering the intellectual agility demanded of multidisciplinary expertise in the context of any single academic discipline. To begin to address these challenges, we established the EPSRC Centre for Doctoral Training in Aerosol Science in 2019 (CDT2019). CDT2019 has trained almost 90 PGRs with ~40% completing industry co-funded research projects, leveraged £7.9M from partners and universities based on an EPSRC investment of £6.9M, and broadened access to our unique training environment to over 400 partner employees and aligned students.

CDT2019 revealed strong industrial and governmental demand for researchers in Aerosol Science. Our vision for CDT2024 is for a CDT focus that 'meets user needs' and expands the reach and impact of our training and research in the cross-cutting EPSRC theme of Physical and Mathematical Sciences, specifically in areas where aerosol science is key. The Centre brings together an academic team from the Universities of Bristol, Bath, Birmingham, Cambridge, Hertfordshire, Manchester, Surrey and Imperial College London spanning science, engineering, medical and health faculties. We will assemble a multidisciplinary team of supervisors with expertise in chemistry, physics, chemical and mechanical engineering, life and medical sciences, and earth and environmental sciences, providing the broad perspective necessary for equipping PGRs to address the challenges in aerosol science that fall at the boundaries between these disciplines.

To meet user-needs, we will devise and adopt an innovative Open-CDT model. We will build on our collaboration of institutions and ~70 industrial, public and third sector partners, working with affiliated universities and learned societies to widen global access to our training and catalyse transformative research, establishing the CDT as the leading global centre for excellence in aerosol science. Broadly, we will: (1) Train 90 PGRs in the physical science of aerosols, equipping 5 cohorts of graduates with the professional agility to tackle the technical challenges our partners are addressing; (2) Provide opportunities for Continuing Professional Development for partner employees, including a PhD by part-time study; (3) Deliver research for partners through partner-funded PhDs with collaborating academics, accelerating knowledge transfer through PGR placements; (4) Support the growth of an international network of partners working in aerosol science through subject-specific meetings, conferences and training. In addition, partners and academics will work together to deliver training to our cohorts, including in the areas of responsible innovation, entrepreneurism, policy and regulation, environmental sustainability and equality, diversity and inclusion.

EPSRC CDT in Neuromorphic Technology

Dr Antonio Lombardo   University College London

Lombardo, Dr A,Kazakova, Dr O,Branford, Dr WR,Kenyon, Professor AJ,Luk, Professor W,Heutz, Professor S,Cvetkovic, Professor Z,Rajendran, Dr B,Mehonic, Dr A,Moran, Professor R

Overview of the research area of the centre:

Taking inspiration from the human brain, neuromorphic systems use physical artificial neurons and synapses to process unstructured and noisy data directly, leading to a fundamentally new approach to computing. Similar to their biological counterparts, neuromorphic systems are very energy efficient and offer a solution to a global problem: the unsustainable power consumption of digital systems. Artificial intelligence methods such as deep neural networks are driving a technological revolution across almost every aspect of the society, however at the cost of an extremely high energy demand. Data centres already contribute to about 3% of the global carbon emission (roughly the same as commercial aviation) and consume about 2% of the worldwide electricity. This unsustainable energy consumption can be traced back to the inefficiency of digital computing, where data are shuffled between physically-separated processing and memory units. By rethinking computing architectures at the most fundamental level, exploring new materials and devices, co-designing hardware and software, establishing standards and protocols, neuromorphic technology provides a sustainable approach to computing, paramount to reach the UK and global strategic objectives of net zero carbon emission.

Need for doctoral scientists or engineers that centre will produce:

The multi-disciplinary nature of neuromorphic technology requires research and innovation leaders to possess skills and expertise spanning across traditionally-separated disciplines, such as material science, nanoelectronics, neurosciences, computer science and metrology. There is a clearly defined lack of appropriately trained cross-disciplinary scientists and engineers, which is holding the UK back from realising its technological and commercial potential, despite its leading position in neuromorphic academic research. Our CDT aims to fill this skill's need by providing a deeply multi-disciplinary programme and develop a new class of experts capable to fill present and future demand in this emerging industry and address the global challenge of unsustainable power consumption of digital systems.

Proposed approach to provide this training:

By bringing together complementary research and innovation excellence from UCL, King's College London, Imperial College and many industrial partners, this co-created programme will develop professionals with a set of skills and expertise spanning four key thematic areas and their intersections: materials and devices; systems and architectures; neuromorphic algorithms; and metrology. The programme will consist of one-year MRes followed by three years of doctoral training. Students will be exposed, across the four years of the programme, to a mix of bespoke and elective modules, practical training on experimental and computational techniques, individual and cohort projects, bespoke training on responsible research and innovation and entrepreneurship, complemented by professional and personal development activities. The supervisory team consists of over 50 supervisors and reflects the multi-disciplinarity of the programme. Industrial partners complement the academic team, providing training and research opportunities via projects, access to resources and facilities, workshops and internships. The Centre will engage with international centres of excellence to expand the training experience, and with programmes for underrepresented groups to access postgraduate research in order to widen the participation to doctoral training within and beyond the CDT.

EPSRC Centre for Doctoral Training in Chemical Biology: Empowering UK BioTech Innovation

Dr Laura Barter Imperial College London

Barter, Dr LMC,Vilar Compte, Professor R,Woscholski, Dr R,Ces, Professor O,Brooks, Dr NJ,Tate, Professor EW

Chemical biology is spearheading the development & translation of novel molecular tools and tech to study biology & develop biomedical understanding. By dovetailing these platforms with industry 4.0/5.0 breakthroughs in automation & robotics, Artificial Intelligence & Machine Learning the CDT will unlock the Lab of the Future paradigm. This will redefine the state of the art with respect to making, measuring, modelling & manipulating molecular interactions in biological systems & lead to novel R&D workflows, promoting efficient design-test cycles, driving sustainability.

These molecular technologies will enable biological & medical research revolutionising understanding of disease & create novel diagnostics, drugs & therapies, focusing increasingly on individual patient outcomes. They will also impact the agri-tech sector which faces huge demand to increase productivity by unlocking strategies to e.g. track agrochemicals in plants/soil, understand modes of action & drive precision farming. Similarly, advances in personal care industrial processes are critically dependent on development of molecular measurement technologies to gain insight into structured product design.

The application of novel molecular tools/technologies, Lab of the Future strategies & their commercialisation through the instrumentation science sector is thus critical to the UK economy, supporting >4,500 healthcare, personal care, agri-science & biotech companies. This will transform (i) therapeutic, agrochemical & personal care product discovery (ii) med-tech/biotech/healthcare instrumentation R&D pipelines & (iii) stimulate the creation of new SMEs.

Given the importance of Chemical Biology to UK plc there is a great demand but short supply of Chemical Biology PhD graduates able to match the pace of innovation across the physical/life science interface, at a time when industry & health sectors need these skills to accelerate productivity. The CDT in Chemical Biology: Empowering UK BioTech innovation with its unique 5 year programme: 1 year MRes + 3 year PhD + 1 year ELEVATE PDRA Fellowship directly addresses this skills gap by training a new generation of career-ready graduates, able to embrace the Lab of the Future concept and unlock its potential by fusing innovative molecular tools & tech with industry 4.0 & 5.0 advances to study molecular interactions & develop applications in the life science, agriscience & personal care sectors.

Working closely with civic partners including Hammersmith & Fulham Council and the NHS, the CDT's talent & research pipeline will act as an engine for one of the most rapidly growing Life Science ecosystems in Europe, the White City Innovation District.

CDT students will benefit from a research and training programme created with >100 industry/external stakeholders designed to meet future employer's needs. Our cohort-based programme with EDI at its heart, will allow students to contextualise their work within wider CDT activities & find novel solutions to their research, supported by one of the world's largest Chemical Biology communities: the Institute of Chemical Biology (>165) research groups.

Students will be trained in multidisciplinary blue skies/translational research, lean innovation, scale fast-fail fast approaches, creating scientists able to understand molecular technologies, sustainable product design, early-stage commercialisation, & industry's pace of change. To support this, our training includes Future Lab & HackEDU courses (prototyping training), a drug screening programme, Biz-Catalyst (a mini-MBA), Bio-Launch (SME accelerator), a Data Science course, Human Centred Design, Science Communication (with BBC) & Bio-ethics/RRI/Sustainability/Policy courses. Following PhD completion, students can enter the ELEVATE fellowship programme, bridging the gap between PhD & industry/academia. It will offer training, personalised workplace opportunities & enable students to kickstart new companies.

EPSRC Centre for Doctoral Training in Future Space Engineering

Professor Ralf Deiterding University of Southampton

Deiterding, Professor R,ryan, Dr c,Fear, Professor R,Brito, Dr M,Fliege, Professor J,Crittenden, Professor R,Walker, Dr SJI,Wittig, Dr A,Guan, Dr D,Ryden, Dr K

The proposed Centre for Doctoral Training (CDT) in Future Space Engineering (FuSE) brings together the Universities of Southampton, Surrey and Portsmouth to alleviate the current shortage of highly trained domestic engineers and scientists in the space field. The upskilling and inspiration of our future space workforce is one of the focus areas to support growth of this burgeoning sector. UKRI's Tomorrow's Engineering Research Challenges (TERC) document from July 2022 lists sustainable space research as the first and most imminent opportunity. This identified training need is echoed by the CDT's 15 industrial and government partners and aligned with EPSRC's strategic priority in Frontiers in Engineering and Technology as well as the National Space Strategy. Hence, the proposed centre will focus on training the next generation of engineers and scientists for advanced astronautical space system applications, space system design as well as the fundamentals of Earth observation. The scope is intentionally broad and addresses the key interdisciplinary engineering and sciences needs of the space field, including, but not limited to, fully reusable launch systems, autonomous in-orbit satellite technologies, active space debris removal, in-space manufacturing, space-based energy, space weather protection, remote sensing and AI-based data processing. There is presently no other CDT in this area, and FuSE will become a national beacon for space-related PhD education.

Supported by partner cash contributions of £2.44M to-date and in-kind of more than £4M, FuSE will train at least 80 PhD engineers and scientists over five annual cohorts. Over 45 research supervisors with space-related research activities have confirmed their participation. While spacecraft scientists and engineers need specialist knowledge within their own area of expertise, they also require an understanding of the key subsystem interactions and the higher level systems engineering trade-offs that are necessary to produce a space system that achieves the mission objectives. In order to upskill the future space workforce and to support the sector growth it is necessary to train cohorts of doctoral students with both specialist and contextual knowledge that can work effectively in a team. This is most successfully achieved through cohort training plus industrial engagement and the repeated interaction between the cohort and academic and industry experts. The technically diverse requirements and interdisciplinary nature of the space field will enable FuSE students to translate their acquired skills readily to other sectors, in particular those with forefront digitization and system engineering challenges.

The FuSE education programme combines the three universities' unmatched strength in space-related undergraduate and graduate education with the knowledge and commitment of 15 industrial and government partners. While >35 space-related graduate level modules are already offered by the three universities, FuSE cohort training will include compulsory courses in Space System Engineering, Data Processing and Business Creation, which will be co-delivered with industry experts. Company internships of at least 3 months duration for every student will ensure graduate training is directly aligned with user need, providing real world relevance and enhanced employability. FuSE will create a community and critical mass of expertise across graduates and stakeholders, which will act as a bridge between large companies/government and SMEs, and drive growth of the UK space sector. Regular FuSE space conferences, summer schools and outreach events will ensure wide sector and public impact.

FuSE will be led by the University of Southampton and include a sophisticated and modern governance structure that will ensure equal opportunities as well as student and staff well-being.

EPSRC Centre for Doctoral Training in Formulation Engineering: Formulation for Net Zero

Professor Mark Simmons University of Birmingham

Simmons, Professor M,Lopez Quiroga, Dr E,Greenwood, Dr R

Formulation engineering is concerned with the design and manufacture of products whose effectiveness is determined by the microstructure of the material. Formulated Products include foods, pharmaceuticals, paints, catalysts, structured ceramics, thin films and coatings, cosmetics, detergents and agrochemicals. In all of these, material formulation and microstructure control the physical and chemical properties that are essential to its function. For example, chocolate is sold in a crystal form that gives the properties consumers like, such as a shiny surface and a melt-in-the-mouth taste - if the chocolate melts and recrystallises, it forms a 'bloomed' material with a blotchy surface and a melting point about mouth temperature, so it tastes grainy and unpleasant.

Products are mostly complex soft materials; structured solids, soft solids or structured liquids, with highly process-dependent properties. Research issues that affect different industry sectors are common: the need is to understand the processing that results in optimal nano- to micro structure and thus product performance. For example, the same physics underpins the making and use of tablets in the the pharma and personal care industries, as well as food particles. To make products efficiently needs interdisciplinary understanding of chemistry, processing and materials science. Research has direct industrial benefits because of the sensitivity of products to their processes of manufacture.

Formulation engineering is not taught in first degree courses, so training is needed to develop the future leaders in this area. This was the industry need that led to the creation of the CDT in Formulation Engineering, based within the School of Chemical Engineering at Birmingham. The CDT leads the field; we won for the University one of the 2011 Diamond Jubilee Queen's Anniversary Prizes, demonstrating the highest national excellence. The UK is a world-leader in Formulation; many multinational formulation companies base research and manufacture in the UK, and the supply of trained graduates, and open innovation research partnerships facilitated by the CDT are critical to their success.

The CDT is user led and receives significant industry funding (>£500k pa). We have built deep links with major formulation companies such as Pepsico and Mondelez in foods, P&G and Unilever in personal care, AstraZeneca and Bristol Myers Squibb in pharma, BASF, Innospec and JM in fine chemicals, Imerys, and Rolls-Royce. We have embedded diversity and inclusion into all of our projects and processes, including blind CV recruitment, and having projects opened all year round rather than just in September; since 2018 our cohorts have been 50% female and >25% BAME.

A new CDT strategy has been co-created with our industry partners. We will address new user-led research challenges to train the next generation of formulation engineers to create products and processes to reach Net Zero. Our main theme will be Formulation for Net Zero ('FFN0), articulated in two research areas: 'Manufacturing Net Zero (MN0)', and 'Towards 4.0rmulation'. We will co-create training and research partnerships with other CDTs at Birmingham and elsewhere, Catapult Centres, and industry, and train at least 50 EngD and PhD graduates with the skills needed to enhance the UK's leading international position in this critical area. Cohorts will work together on new training courses in (i) Interdisciplinary Formulation Science, (ii) Data Science, Modelling and Experimental Design, (iii) Project Management and Personal/Professional Skills (iv) Responsible Research/EDI shared across the Birmingham CDT cohorts, including a course in Responsible Research in Formulation.

We have obtained promises of significant industry and University funding, with ca. 40 offers of projects already. EPSRC costs will be ca. 40% of the cash total for the CDT, and ca. £25% of the whole cost when industry in-kind funding is included.

EPSRC Centre for Doctoral Training in Statistical Applied Mathematics

Professor Paul Milewski University of Bath

Milewski, Professor PA,Cox, Professor AMG,Smith, Dr T,Ehrhardt, Dr MJ,Douglas, Dr S

In the last 20 years, there has been an explosion in mathematical innovation driving, and being driven by, the analysis and modelling of data running through every aspect of life. Methods and fields such as compressed sensing (recovering a signal from few data samples), stochastic optimization (optimizing complex problems under uncertainty), deep learning (large neural networks trained on data for tasks such as prediction), deterministic and stochastic modelling (writing mathematical equations with or without random fluctuations to reflect a phenomenon), numerical analysis (developing algorithms to solve equations on computers), network science (studying discrete interconnected objects), to name a few, have become interwoven and contributed to the delivery of modern data science. We named this interface between mathematics, computing, modelling, and data, Statistical Applied Mathematics. This era of data-driven mathematics requires mathematicians across the spectrum from theory to applications who can develop and apply new ideas and methods to harness the power of data to tackle challenges affecting society, the economy, and the environment. Academia and industry report a widening gap between demand and supply for such talent.

The Centre for Doctoral Training in Statistical Applied Mathematics at Bath (SAMBa, samba.ac.uk) will continue to deliver leading research and training in this space, more specifically in scientifically-informed mathematical data science. The focus of our research will be how to best synthesise data driven methods (such as machine learning) with science-based models (such as the physics of weather prediction). This synthesis is necessary because methods based on data alone often have potential pitfalls: they are "black boxes" which do not explain their result, may be inefficient and costly in the amount of data they require, and can only reflect the data they are trained with. In many applications these pitfalls can be countered by ensuring the data-driven methods also reflect fundamental laws and models based in science.

Our vision is to "Create internationally leading interdisciplinary statistical applied mathematicians in a world dominated by data. Our training will prepare them to lead in research and deliver impact in academia and industry through scientifically-informed mathematical data science."

SAMBa graduates move on to academia, providing sustainability to the UK's capacity in this field, and industry and government, providing impact through societal benefits and driving economic growth. Our graduates have gone on to advise vaccination strategy through SPI-M, develop methods for improved scoring of diagnostic X-rays, enhance safety simulations for nuclear reactors, and now hold permanent positions at leading UK universities.

Industrial partnerships are at the heart of SAMBa. Our long-term partners such as Novartis, NHS, Rolls-Royce, BT, Syngenta and the Environment Agency co-create our vision and our training, and many of our students will work directly on their challenges during their PhD either in their core research or with internships. Industry benefits from the high-quality research we deliver, enhancing their competitiveness, and they are enthusiastic that we address the huge need for talent in this key strategic area for the UK economy. Key to our industrial engagement are the unique Integrative Think Tanks. These are week-long events where SAMBa student cohorts, leading academics, and partners work together on industrial and societal problems.

The CDT will be delivered centrally from the Department of Mathematical Sciences at Bath where 98% of the research is world leading (57%) or internationally excellent. The department has over 50 academics supporting the CDT with similar numbers across the rest of the University. We will also partner with 5 other centres worldwide providing a vital international perspective and bringing international talent for co-delivered PhDs.

EPSRC Centre for Doctoral Training in Engineering Solutions for Antimicrobial Resistance

Professor Bart Hoogenboom University College London

Hoogenboom, Professor BW,Santini, Professor J,McKendry, Professor RA,Thomas, Dr M,Beckett, Mr R,Volpe, Professor G,Tiwari, Professor M,Ciric, Dr L

Infectious diseases come at a huge societal and economical cost. This has recently been shown by the COVID-19 pandemic. Looking forward, arguably the largest threat is antimicrobial resistance (AMR). As pathogens develop resistance against currently available antimicrobials (e.g., antibiotics) and as the development of new antimicrobials has stalled, we are risking an estimated 10M deaths per year globally and a US$100 trillion costs to the world economy by 2050.

We here propose a Centre for Doctoral Training on Engineering Solutions for Antimicrobial Resistance, with the overall aim of training physical scientists and engineers with the specialist research skills as well as broad contextual skills to create rapid impact targeting the AMR challenge. This includes different disciplines and wider aspects such as commercialisation/translation, public-health context, regulation and standardisation, implementation and adoption, public awareness and perception, and communication.

Identifying key research areas that depend on cutting-edge research advances in engineering and physical sciences, our Centre for Doctoral Training focuses on preventing the spread of infection, on surveillance and diagnostics, and on antimicrobial and vaccine development. By designing and delivering our training programme with public health institutions, multinational businesses, SMEs and charities, we maximise the impact of such research on addressing the public health threat of AMR and on exploiting business opportunities that are also associated with solutions to it.

EPSRC Centre for Doctoral Training in Engineering Biology: EngBio CDT

Dr Lucia Marucci University of Bristol

Marucci, Dr L,Carlisle, Dr R C,Turberfield, Professor AJ,Woolfson, Professor DN,Papachristodoulou, Professor A,Nair, Dr M,McManus, Dr J,Berger, Professor I,Gorochowski, Dr TE

Synthetic Biology is a growing field of science that combine Biosciences, Chemistry, Physics, Information Technology and Engineering, and involves the redesigning end engineering of organisms for useful purposes, for example to produce useful substances (e.g. medicines) or gain new abilities (e.g. sensing something in the environment). Synthetic Biology aspires to tackle grand challenges surpassing what is possible through traditional technologies: it has wide-ranging applications in healthcare, environment protection, energy, agriculture, computing, advanced chemicals and materials.

Synthetic Biology has grown significantly in the UK over the past decade, thanks to a >£400M investment via the Synthetic Biology for Growth programme. One of the key investments has been the SynBioCDT: the first UK CDT in Synthetic Biology funded in 2014 by the EPSRC and BBSRC and run by the Universities of Oxford, Bristol and Warwick. The SynBioCDT trained 79 excellent PhD students selected from >650 applicants, and attracted support from industrial, academic and public-facing partners. Our graduated students have gone on to work within the bioeconomy and have established disruptive start-ups.

The term "Engineering Biology" has been recently proposed to highlight the essential transition of Synthetic Biology into a mature Engineering discipline: Engineering Biology. The recent UKRI National Engineering Biology Programme (NEBP) sets the UK ambition for the field and encompasses the capabilities that can support the exploitation of Engineering Biology for economic and public benefit.

The Universities of Bristol and Oxford aim to establish a new CDT in Engineering Biology, the EngBioCDT, to train the academic and industrial Engineering Biology leaders of tomorrow, and to equip them with skills needed to contribute toward scalable, robust, and transformative engineering of biomimetic and biological systems.

The EngBioCDT builds on our experience with the SynBioCDT and will address the NEBP requirement for a new generation of biological engineers able to translate cutting-edge science into real-world impact; it will support the EPSRC focus area 'Frontiers in Engineering and Technology'.

The EngBioCDT will enable cohesive cohorts of students to gain expertise in the design, modelling and engineering of biological components and systems; to understand broad concepts ranging from biomolecular interactions to cell function; and to augment the Engineering Biology approach with robotic, automation and AI. Students will obtain advanced skills in programming and engineering; implement biological design across scales; place research in the context of both basic and applied science; and become cognisant of challenges such as process development and scale-up in biotechnology. Students will undertake both group and individual projects before starting their PhD project.

The EngBioCDT will take advantage of the expertise and opportunities provided by the two Universities and our industrial partners, which all will be catalysts for inter-University and inter-sector training and research. Students will also have superb opportunities to engage with leading international academics through an annual Summer School, and by participating in international conferences and workshops.

The environment at the two Universities is exceptional. Bristol hosted BrisSynBio, one of six UKRI-funded Synthetic Biology Research Centres, and now hosts the Bristol BioDesign Institute and the Bristol Centre for Engineering Biology (BrisEngBio). Oxford, which led the SynBioCDT, received three fellowships in Engineering Biology and offers vibrant translational opportunities. The applicants provide expertise in graduate training and many of them have previously worked together effectively. The Bristol-Oxford pool of >40 supervisors reflects the truly multidisciplinary nature of Engineering Biology, and includes internationally renowned researchers.

Centre for Doctoral Training in Ultra Precision Science and Engineering

Professor William O'Neill University of Cambridge

O'Neill, Professor W,Giusca, Dr C,Daly, Professor R,Davis, Professor JS,Piano, Dr S

The ability to process materials, manufacture components and characterise materials with uncertainties beyond 1 part in 10^6 is critically important to support discovery science and innovative engineering in areas such as plasma physics, life science imaging, molecular structures & dynamics, ultrafast laser spectroscopy, superconductors, particle physics, astronomy and drug discovery. Moreover, the CDT will support the creation of a new class of technologies across a wide range of fields including quantum instruments and devices, fusion energy, advanced space propulsion, defence technology, optics and photonics, autonomous systems, communications, medical devices, metrological instruments, and machine tools.

Exploiting innovations in these diverse fields promises great economic returns to the UK economy. Our national and university laboratories continue to deliver ground breaking advances spanning physics, materials science, chemistry and biology. They have a critical dependence on ultra-precision science and engineering skills in machine design, control systems, advanced metrology, test and measurement, materials processing and characterisation. Skills that must be transferred quickly to academic or industrial practice to stimulate the creation of world-leading ultra-precision products and services and to strengthen the competitiveness of the UK economy.

Over the 5 cohorts of the CDT, the four-way funding support of EPSRC, industry, universities, and government laboratories will train 50 graduate students. Our stakeholders wish to see a research skills and training programme designed to develop the following educational themes: Fundamentals of ultra-precision systems in the broad areas of machine design, metrology, optical testing, machine dynamics, ultra-precision processing, lasers, ion beams, micro engineering, control engineering, and digital technologies for advanced manufacturing; Concepts of, and strategies for, ultra-precision system design and implementation; Research experience via individual and group project placements in university research groups, national laboratories and industrial R&D facilities; and Aspects of Business, innovation, technology and business development. Responding to stakeholder needs, the new CDT will offer university-based PhD projects, and EngD projects where students conduct their research in national laboratories or partner companies. Our industrial partners will be engaged in: (a) intensively interacting and collaborating with their specified academic partner and in MRes, PhD, and EngD projects; (b) co-supervising student projects to monitor the progress of their dedicated student and provide feedback from an industrial and application perspective; (c) host industrial placements for their dedicated student; (d) contributing to the CDT training programme by bringing an industrial perspective to the academic modules; (e) contributing to the management and steering of CDT operations.

EPSRC Centre for Doctoral Training in Green Industrial Futures

Professor Mercedes Maroto-Valer Heriot-Watt University

Maroto-Valer, Professor M,Ma, Professor L,Pourkashanian, Professor M,Hardalupas, Professor Y,van der Spek, Dr M W,Krevor, Dr S,Whitmarsh, Professor LE,Fennell, Dr P,McManus, Professor MC,Andresen, Dr J

Skill shortages are limiting the opportunities of the green industrial revolution, adding significant risk of loss of economic and social value. Decarbonising energy-intensive industry sectors can secure the existing 2.6 million direct jobs as well as create new jobs in our industrial heartlands. For example, over 350,000 additional jobs (28% professional roles) are required to meet the demands of just the current UK industrial cluster projects in the period 2025 to 2040. Moreover, the UK's Net Zero Review identified industrial emissions (~16% of total) as some of the hardest to abate and requiring a whole systems approach to achieve net zero by 2050. Therefore, there is a substantial and pressing demand for training doctoral-level graduates to underpin research and development for industrial decarbonisation, and also more widely, to prepare future leaders for the net zero agenda.

The Centre for Doctoral Training in Green Industrial Futures (GIF) will deliver the next generation of global leaders in the energy transition, through a world leading interdisciplinary research and training programme that will systematically bring together key technological solutions to fully decarbonise industry and address national and global priorities. Four of the UK's leading institutions in industrial decarbonisation (Heriot-Watt University, Imperial College London, University of Bath and University of Sheffield) will deliver a cohesive cohort of 100 PhD graduates trained in a diverse and inclusive environment that engenders a culture of environmental sustainability, research trust and responsible research and innovation.

GIF will provide challenging and original research projects (hydrogen and low-carbon fuels; carbon capture, utilisation and storage; CO2 removal; resource and energy efficiency; and disruptive technologies), alongside training on how technologies are integrated into the industrial system. The training elements of the programme will run parallel to student's research projects and will be distributed throughout the four years to ensure cohesive learning within and across yearly cohorts. GIF students will complete a stimulating and flexible modular course programme, aligned to GIF's core themes as well as students' research projects. This programme will be anchored by two-week Summer and Winter Schools each year, as well as an Annual Conference, bringing students together from across the partners. During their first year, student teams will also undertake an Industry Challenge Project set and assessed by industry collaborators. Throughout the four years, all cohorts will participate in a biweekly student-led journal club and cross-institution peer-to-peer mentoring to support student's wellbeing, as well as student-led initiatives and career development activities.

GIF will offer a unique research programme, co-created with industrial collaborators, to discover transformative, responsible solutions to achieve net zero, whilst ensuring sustainability, economic prosperity and fairness. Research projects will be supervised by over 60 internationally recognised researchers with excellent track record of doctoral supervision, extensive experience in developing innovative and responsible research projects, and with outstanding industry relationships to ensure students have access to relevant end-users. GIF will also provide unrivalled transnational training in world-class facilities and unique enhanced training to maximise research impact.

In summary, GIF is uniquely placed to deliver the most comprehensive Centre for Doctoral Training to realise the green industrial revolution.

EPSRC Centre for Doctoral Training in the Advanced Characterisation of Materials (CDT-ACM)

Professor Martyn McLachlan   Imperial College London

McLachlan, Professor M,Howard, Professor CA,Thornton, Professor G,Conroy, Dr M,Labram, Dr J,Marquardt, Dr KT,Huang, Dr C,Regoutz, Dr A,Beale, Professor A

The advanced characterisation of materials underpins developments across engineering and the physical sciences, enabling research to support current and growing future UK needs. Over the coming decade advances in communications, mobility, energy, and healthcare will accelerate, providing a platform for the UK to be among the top global innovators. (1) Such ambitions must also be aligned with our commitments to clean and sustainable growth, such that we can become global leaders in the development, manufacture and use of low carbon technologies, systems, and services. Investment and innovation will collectively enable these ambitions to be fulfilled but alone are insufficient to ensure sustained growth. The CDT-ACM will create a new wave of talent by attracting, developing, and retaining diverse people with the correct skills, to build a nurturing working environment that gets the best out of everyone. (2)

To achieve these ambitions our CDT has, with significant industrial input, co-designed a formal training programme to support graduate students in the development of broad core-competencies in advanced materials characterisation, reinforced by detailed specialist knowledge of state-of-the-art characterisation techniques. Through a cohort-based model we will deliver a hands-on, practical learning programme using a suite of state-of-the-art instrumentation across our three partner institutions. The development of practical skills and cohort supported learning will be reinforced through an integrated 4-year taught programme delivered by academic experts and skilled industrial partners. To further enhance student development a tailored package of formal training in science communication, research ethics, responsible innovation and data science will be delivered throughout the training programme.

Professional and transferable skills designed to enhance and accelerate personal development will be interwoven into the 4-year programme, deployed at key stages to enrich the training experience and to augment the capabilities of our graduates. The framework of this content will be developed and delivered by the graduate schools of our university partners emphasising communication skills, including outreach and public engagement. Content co-created with our industrial partners will be used to support innovation, entrepreneurship and commercialisation. Throughout the technical and transferrable learning, we place an emphasis on curating a culture of responsible innovation and an ethos of environmental sustainability as core principles.

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EPSRC Centre for Doctoral Training in Sensing, imaging And diagnostics for Future Engineering structures (SAFE)

Dr Anthony Croxford University of Bristol

Croxford, Dr AJ,Peyton, Professor A,Drinkwater, Professor B,Clark, Professor M,Edwards, Dr RS,Huthwaite, Dr P,Macleod, Dr CN

The vision of the SAFE-CDT is to train a diverse generation of doctoral level engineers that will be at the heart of the sensing, imaging, and diagnostic aspects of the fourth industrial revolution. Recent years have seen rapid developments in sensor technology as well as huge progress in automated data processing and robotic deployment of sensors. Increasingly the future life of structures and components will be predicted by digital models seamlessly integrated with real-world sensor data, and this philosophy will underpin many aspects of net zero engineering. There is a clear opportunity to operate safety-critical structures in a much more autonomous way with enhanced safety, reliability, and cost-effectiveness. The SAFE-CDT will deliver this shift from human-centred operation to fully autonomous sensing and analysis. Meeting this demand requires a new generation of highly trained engineers that cover all branches of engineering, physics, applied mathematics, and data science. These engineers need a balance of breadth and depth of knowledge and the skills to work in interdisciplinary teams to drive forward this revolution in how engineering systems and structures are operated. By training the next generation of multidisciplinary engineers to deliver this vision, we will equip UK industry with the people and ideas to take a leading position in this area, vital to the UK's future competitiveness.

We have co-created the SAFE-CDT with industrial and academic partners to deliver an integrated cohort-based doctoral training approach. Our industrial partners span major companies with global reach (Rolls-Royce, BAE Systems, EDF Energy, Airbus, Jacobs, Shell), SMEs (PeakNDT, Theta Technologies, GUL, Baugh & Weedon), catapult centres (NCC and MTC) and public bodies (Nuclear Decommissioning Authority and HSE). With these partners we will work on major engineering challenges such as sensing imaging and diagnostics for new nuclear and small modular reactors; for hydrogen production, storage, and distribution; and for rail and water infrastructure networks.

We will use an innovative approach based around integrated project clusters that each address a major industrial challenge that has societal impact. The integrated project clusters will be interdisciplinary and will span across cohorts, creating a dynamic team environment. Our governing principles will be flexibility, supportiveness, and inclusivity so that all students thrive. The doctoral graduates produced by the SAFE-CDT will be used to working interactively, sharing data, and understanding the problems, in both technical issues and communication, of others. While building a novel, innovative, cohort-based training approach the centre will build on the core expertise developed and proven within the current FIND-CDT.

The CDT will be led by Professor Anthony Croxford at the University of Bristol, and to cover the range of disciplines inherent in our vision, will partner with groups at Imperial College and the Universities of Manchester, Nottingham, Strathclyde, and Warwick. This team will deliver internationally leading interdisciplinary doctoral training that covers sensors, connectivity and automation. Transferable skills training will be delivered through tailored modules co-created in a collaboration between the academic and industrial partners. Industry will co-deliver aspects of the taught modules as well as providing placements, facilities, funding, and steering of the curriculum throughout the centre's duration. Through these partnerships and our novel training approach we will ensure that our CDT delivers the breadth and depth of doctoral training required by industry, enabling our graduates to play major roles in ensuring future UK prosperity.

EPSRC Centre for Doctoral Training in Technology-Enhanced Chemical Synthesis (TECS)

Professor Jonathan Clayden University of Bristol

Clayden, Professor J,Fey, Dr N,Aggarwal, Professor VK,Willis, Professor C

Synthesis, the science of making molecules, is central to human wellbeing through its ability to produce new molecules for use as medicines and materials. Every new drug, whether an antibiotic or a cancer treatment, is based on a molecular structure designed and built using the techniques of synthesis. Synthesis is a complex activity, in which bonds between atoms are formed in a carefully choreographed way, and training to a doctoral level is needed to produce scientists with this expertise.

Irrespective of the ingenuity of the synthetic chemist, the complexity of synthetic endeavours means that they are often the 'pinch point' in the development of a new product or the advance of new molecular science. In addition, synthesis can no longer rely on intensive use of human, material, and time resources, and creative solutions to ways of making molecules faster, more efficiently, using less energy, and avoiding rare or toxic metals are urgently needed. Recent developments in digital chemistry (eg reaction technology and automation, data collection & analysis, machine learning & artificial intelligence, computation & molecular design, and the use of virtual reality) now make possible a fundamental change in the way molecular targets are identified and synthesis is carried out. The chemical and pharmaceutical discoveries which underpin a major sector of the UK's economy are almost entirely dependent on synthesis, and our industrial partners see an urgent need for a new generation of employees who combine cutting-edge chemical synthesis expertise with the state-of-the-art digital skills that are set to revolutionise the field.

We will therefore deliver a CDT that will train students to carry out world-leading chemical synthesis at the University of Bristol, the UK's top institution for chemistry research (REF2021), with their creativity and productivity being enhanced by an initial 8-month Digital Chemistry (DC) training focus that underpins a subsequent 3 1/4 year PhD project. The training will be delivered in the form of a set of modules that embody key aspects of DC such automation, algorithm-driven optimisation, photochemistry, electrochemistry and flow chemistry supported by training in the techniques of machine learning and data analysis. These activities will be applied to current synthetic challenges in two short immersive 'rotations' in research labs and will feed into a PhD research project in an area of synthetic chemistry that is underpinned by the application of digital chemistry methods. The focus of the CDT aligns with Bristol's global reputation in chemical synthesis and in its current investment in digital chemistry as a strategic research direction. Bristol Chemistry has had enviable success in spinout companies, and alongside ongoing training in professional development skills we aim to cultivate an entrepreneurial ethos by partnering with local start-up partners to provide immersive workshops, placements, network links and mentorship to nurture future spin-outs by CDT students.

We will build on lessons learnt from delivering previous successful CDTs in Chemical Synthesis, and we will continue to develop our recruitment, training & research opportunities in line with best practice for Equity, Diversity & Inclusion, applying more widely lessons from the evolution that has allowed the diversity of our applicant team to be reflected in the ~50/50 M:F and ~25% minority ethnic composition of our management committee.

Our evolved CDT that will train diverse cohorts of creative and entrepreneurial experts in chemical synthesis, skilled in modern aspects of technology & data science. Our graduates will be uniquely prepared to pioneer mould-breaking innovation in the chemical sciences that will underpin this country's future prosperity.

EPSRC Centre for Doctoral Training in Climate-Proofing Formulations

Professor Jerry Heng   Imperial College London

Heng, Professor JY,Kamaly, Dr N,Cabral, Professor J,Bayly, Professor A,Ward, Dr K,Muller, Professor F,Lee, Professor K,Salehi-Reyhani, Dr A,Georgiou, Dr TK,CAYRE, Dr OJ

This joint Imperial-Leeds Climate-Proofing Formulations CDT will create a unique, diverse network of 'multilingual' science and engineering post-graduate researchers, who combine a deep understanding of design, development, and manufacturing of formulated products with climate-proofing expertise in addressing industrial challenges posed by climate change and the need for sustainability.

There is an urgent, unmet need across multiple sectors (food, pharma, agrichemicals, fine chemicals, energy) for industry-ready PhD graduates with comprehensive knowledge of formulation science and technology, integrated with an understanding of sustainability challenges and climate impact. Advanced formulated chemical products are essential to daily life: to stay healthy, warm, dry, fed, clean and connected. Formulations underpin 2.1M British jobs across sectors, including food and drink (£30 bn output), pharmaceutical and biopharma (£21bn market value), agrochemicals, paints and coatings, and fast moving consumer goods. Innovating formulations will allow mitigation of climate change by enabling a more resource-efficient economy across all sectors (greater circularity of resources, reduced energy consumption, reduced water consumption, reduction in emissions), and will also enable reductions in consumer recourse use and emissions. The proposed CDT addresses gaps in the current university curriculum for engineering and physical science and will train a new generation of technical leaders and innovators with the skills to meet the challenges of climate proofing (mitigation and adaptation) to deliver net zero in formulations manufacturing.

Over 60 highly skilled, cross-disciplinary PhD researchers will uniquely combine a deep understanding of the design, development and manufacturing of formulated products with expertise in the enw challenges posed by climate change. Graduates will be empowered with the tools to tackle tomorrow's formulations challenges through agility and adaptability, mitigation, maximisation of co-benefits and minimisation of maladaptation - addressing industrial demands for business-ready graduates who are highly-skilled technical innovators, with sustainability knowledge and policy/regulation awareness.

Working closely with industrial and other partners, training will be provided through a combination of core cohort courses (foundation technical knowledge plus professional skills for future innovators), and tailored provision of advanced technical courses. The training framework is underpinned by four pillars: formulations and (nano)particulate science and engineering; systems thinking; life-cycle assessment; and sustainability and climate challenges. The CDT combines experimental and multiscale modelling techniques, coupled with optimisation, big data and machine learning, industry 4.0, agile crisis management, and sustainability metrics. Technical training is embedded within the professional skills and coaching programme, fostering innnovation, entrepreneurship and leadership qualities. Clustering of PhD projects in themes will drive cross-sector multi-disciplinary collaboration and innovation, and ensure horizontal and vertical cohort collaboration. In training our future technical leaders and innovators for these industries, potential EDI barriers to PhD will be addressed. Training in responsible innovation is embedded through the Anticipate, Reflect, Engage and Act (AREA) framework, and by integrating the approaches of social scientists, policy makers, enthicists and engagement practioners. Students engage with policy-makers and the public as an integral part of their research projects.

This CDT will support and accelerate the open flow and integration of data and knowledge within and between academia, industry, and translation hubs, which cannot be achieved through independent projects.

EPSRC Centre for Doctoral Training in "Applied Quantum Technologies"

Professor Andrew Daley University of Strathclyde

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Within the last two decades, Quantum Technologies have made tremendous progress, moving from fundamental science into applied research, and more recently, have seen the establishment of an industry base. Key to these new technologies are quantum phenomena, which govern physics on an atomic scale and can be used as a resource to produce technologies with far-reaching applications, including secure communication networks, ultra-sensitive sensors for gravity, acceleration and magnetic fields, and quantum computers. These devices will revolutionise measurements in fields such as geology and biomedical imaging, create fundamentally new paradigms of computation, and permit verifiably secure communications networks. In each of these applications, quantum technologies could result in transformative improvements in terms of capacity, sensitivity and speed, and will be a decisive factor for success in many industries and markets, such as engineering, medicine, finance, defence, aerospace, energy and transport. Quantum technologies are being prioritised worldwide through national or trans-national large-scale initiatives.

Our Doctoral Training Centre in Applied Quantum Technologies will train future quantum scientists and engineers for this emerging industry. The training program is a partnership between the Universities of Strathclyde, Glasgow and Heriot-Watt. In collaboration with industry, the Centre will offer advanced training in broad aspects of Quantum Technology, from technical underpinnings to applications, organised under the key areas of Quantum Measurement and Sensing, Quantum Simulation and Computing, and Quantum Communications. We will make quantum physics and technologies accessible to the general public through dedicated outreach activities, in which the students deliver presentations and exhibits at science centres and science festivals, schools, and during universities' Open Days.

The inclusion of supervisors from industry and engineering is a defining aspect of our Centre and key to ensuring the translation of fundamental physics to industry and practical technologies. We will train scientists and engineers who understand the fundamental physics exploited by quantum technologies, enabling them to develop devices and applications that fully harness quantum properties. Our programme is designed to create a diverse community of future leaders that will take on scientific and engineering challenges in the emerging industrial base, bring them to market, and work towards securing the UK's competitiveness in one of the most advanced and promising areas of the high-tech sector.

Quantum Information Science and Technologies Centre for Doctoral Training

Dr Jorge Barreto University of Bristol

Barreto, Dr J,Matthews, Dr J,Hensinger, Professor WK,Montanaro, Professor A,Linden, Professor N,Weidner, Dr C A,Skrzypczyk, Dr P,Clark, Dr A S

Quantum information science and technologies (QIST) are uniquely placed to disrupt and transform sectors from across the board. Quantum technologies, by exploiting the distinctive phenomena of quantum physics, can perform functions fundamentally unachievable by technologies based solely upon classical physics. For example, when applied to computing, calculations and operations that would take the best supercomputers hundreds of years to complete could be resolved within seconds using quantum computers; as another example, QIST can also be used in sensing and imaging to obtain enhanced precision in a variety of measurements ranging from gas concentrations to gravitational waves, supporting established industries in sectors like manufacturing, energy or healthcare. Furthermore, the application of quantum technologies will have significant implications within communications and security given their ability to break traditional encryption methods used to protect data within financial transactions or military communications while at the same time offering a range of novel, secure solutions largely compatible with the existing infrastructures.

The potential of quantum technologies is well demonstrated through its significant financial and strategic backing globally. Restricted to academic environments up until the start of the last decade, the worldwide investment into quantum initiatives has now reached $33 billion, with significant contributions made across China, the US, and Europe. In the UK, the strategic importance of quantum technologies is clear: with a combined investment of £1 billion, EPSRC has listed Quantum Technologies a mission-inspired research priority and the Department for Business, Energy & Industrial Strategy have named quantum technologies as one of their seven technology families within the UK's Innovation Strategy, and this is not expected to change when the new strategy is announced later this year. It is clear that, around the world, quantum technologies are flourishing.

While the technological potential and national importance of QIST to the UK is undeniable, a key challenge to realising our ambitions in this area is the ability to develop a quantum workforce of capable physicists, engineers, computer scientists, and mathematicians with both the requisite expertise in quantum information science, as well as expertise in the technologies that will realise it. In addition, the leaders of UK's quantum future must possess critical professional skills: they must be excellent communicators, leaders, entrepreneurs, and project managers.

To meet this key ambition, the programme offered by the Quantum Information Science and Technologies Centre for Doctoral Training (CDT) is uniquely positioned to deliver the diversity of skills and experience needed to supply the UK with internationally renowned QIST leaders across policy, innovation, research, entrepreneurship, and business. QIST CDT students will receive academic training delivered by world-recognised top educators and researchers; undertake industrially-relevant training modules co-delivered with industry partners; have hands-on experience within world-leading quantum research laboratories; receive one-to-one entrepreneurial mentorship; receive intellectual property and science policy training; have the funding to undertake on-site industry placements; and complete multi-faceted cohort projects designed to develop multidisciplinary teamwork.

EPSRC Centre for Doctoral Training in Cyber Secure Everywhere: Resilience in a World of Disappearing System Boundaries

Professor Awais Rashid University of Bristol

Rashid, Professor A,Joinson, Professor A,Owen, Professor RJ,Omoronyia, Dr I,Smith, Dr LGE

Digitalisation has generated a new era of technological innovations whose value can only be maximised with equally innovative cyber security. Our specific focus is on the cyber security of digitalisation and data in large-scale, intermeshed systems and infrastructures - where the boundaries between systems are blurred, data distributed with strong localisation and sovereignty claims, and there exist numerous, intricate inter-dependencies between service architectures. With the increasing shortage of cyber security professionals - both globally and in the UK - there is an urgent need for future research leaders who will have the capability to anticipate the challenges and develop innovative solutions to cyber security in a world where technology operates without concrete, clearly delineated digital boundaries. This capability is critical to ensure that digital infrastructures are secure and resilient and security professionals have suitable methods, tools, techniques and insights for securing the digital societal fabric.

The Centre for Doctoral Training (CDT) 'Cyber Secure Everywhere: Resilience in a World of Disappearing System Boundaries' will train at least 50 new doctoral-level graduates to address this capability gap. We will do this by educating PhD students in both the technical skills needed to study and analyse blended infrastructures, while simultaneously training them to understand the challenges as fundamentally human too. The training involves close involvement with industry and practitioners who have played a key role in co-creating the programme. The training also leverages state-of-the-art research testbeds and labs at universities of Bristol and Bath as well as partner industry organisations and international research centres. The programme builds on the best practices developed as part of our current CDT on Trust, Identity, Privacy and Security in Large-Scale Infrastructures (TIPS-at-Scale).

The first year will involve a series of taught modules providing core knowledge in cyber security (both technical and human & organisational aspects). There will be a programme of co-creation activities with industry as well as deep dives on particular research topics and industry challenges. This co-creation and collaboration ethos will continue throughout their research projects. Throughout the 4-year programme, they will also receive skills training on a number of fundamental computational and analytical techniques as well as intellectual property, entrepreneurship and commercialisation. They will work collaboratively with students in-year and across-years on shared problems and explore responsible innovation in real-world contexts. Through their projects and state-of-the-art experimental infrastructures, they will develop knowledge and expertise on rigorous, evidence-based research on cyber security.

The CDT is an exciting, novel way to develop future research and industry leaders who are not only able to tackle cyber security in emerging and future digital infrastructures but can do so in a way that is based on rigorous experimental work and a core ethos of responsible innovation.

EPSRC CDT in Sustainable Electronic Materials for Emerging Energy Technologies

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We propose to establish a world-leading doctoral training programme in sustainable electronic materials that captures the set of skills required for developing the emerging energy technologies for a transition to a net zero society. The supply chain (i.e., materials) needed for such emerging technologies must be free of critical raw materials. Achieving net zero and beyond requires truly sustainable approaches, which will be scrutinised by life-cycle analysis, and optimised via data-driven process engineering including machine learning. Emerging energy applications will focus on decarbonisation across sectors and include technologies such as hydrogen, e-fuels, solar fuels, sustainable batteries, printed solar cells, and integrated technologies and systems. The UK hosts leading start-ups and well-established companies in this field, meaning that demand for skilled graduates, as evidenced by the large number of companies that have shown interest and support in this Centre for Doctoral Training (CDT) programme, remains exceptionally high and is growing. Yet the supply of graduate students in this area is impeded by the lack of advanced training across engineering, (electro)chemistry, physics, and materials science that (1) exclusively exploits non-critical raw materials, (2) develops integrated systems approaches to predict and identify the most suitable materials and technologies from the start via life-cycle analysis, (3) symbiotically develops new technologies hand in hand with societal needs, and (4) uses data-driven optimisation to guide experimental synthesis, processing and device fabrication programmes, and end-of-life options. Our proposed EPSRC CDT in Sustainable Electronic Materials for Emerging Energy Technologies will address these challenges through a co-ordinated training programme that brings together three partner institutions (ICL, Swansea and QMUL) offering highly complementary training skills while supporting a diverse background of student intake across different regions of the UK. The partner institutions also bring different but inter-related industrial sectors together - for example the mainstream chemical and coatings sectors, the battery sector, and the advanced semiconductor manufacturing sector thriving in South Wales. As a collective, we have created an interdisciplinary, multifaceted learning experience that far transcends what could be delivered by any single institution or a standard doctoral programme. We are confident that the proposed CDT will deliver graduates with the depth and breadth of expertise to make the UK thrive as a net zero society.

EPSRC Centre for Doctoral Training in the Mathematics for our Future Climate: Theory, Data and Simulation

Professor Dan Crisan Imperial College London

Crisan, Professor D,Naveira Garabato, Professor A,Broecker, Dr J,Veraart, Professor AED,Scott, Professor JA

Global climate change threatens our future. Urgent societal action is demanded. However, crucial uncertainties regarding the future climate still need to be addressed. Extreme climate events are wreaking enormous environmental, societal, and economic tolls and they are becoming increasingly common and intense. The huge number of uncertainties related to our future climate combine with the sensitivity of the Earth's climate system to create extremely demanding challenges. Extending our understanding for deriving effective solutions demands effective interdisciplinary collaboration to determine the dominant factors in climate change. Currently, there is a lack of highly qualified mathematicians, statisticians and data scientists with the necessary training and experience to address the diverse problems and urgent challenges posed by climate change using computational and data driven research.

Our Centre for Doctoral Training (CDT) will train new cohorts of PhD students and build a scientific community to address the grand mathematical challenges raised by the significant levels of uncertainty in our future. The mission of our CDT will be to prepare graduates with strong mathematics, physics and engineering backgrounds to apply their skills in mathematical modelling, scientific computing, statistics and machine learning to key climate-related problems in oceanic, atmospheric and engineering contexts. By bringing together leading experts in mathematics, statistics, meteorology, oceanography, physics and engineering from Imperial College London, the University of Reading and the University of Southampton, our CDT will be uniquely placed to equip future mathematicians with the range of tools required to address global climate uncertainties.

Our CDT will achieve its goals by developing the mathematics and its applications that are required to understand, better predict and, ultimately, respond to impending changes in the Earth's climate and the associated risks. A particular emphasis will be the creation of a vibrant environment to integrate strong cross-disciplinary engagement and collaboration, both within and between cohorts and disciplines, in advancing the range of scientific techniques, fundamental theories, approaches and applications. This will include engaging with academics, government organisations, industry and the public. As a result, the development of outstanding skills in mathematics and science communication will be a priority. The collaborative and peer-to-peer interactions will help develop the complementary techniques and approaches that will underpin essential technical research and innovation and will be coupled with exciting opportunities to discover and advance fundamental mathematics to provide practical solutions in climate science and beyond.

Our CDT will act as a seed for growing the capability and capacity to inform decisions and efforts related to climate change on a rapid timescale. The technical focus of our CDT will be enhanced by activities to appreciate the social, political and economic dimensions of societal response to climate change. Furthermore, sustained effort to mitigate and adapt to climate change will be required during the coming decades. For this reason, along with building a professional community of graduates, the CDT will invest in imaginative outreach programmes involving high school pupils and undergraduate students, building on opportunities through the institutions partnering the CDT, including the Grantham Institute for Climate Change and the Environment, the National Oceanography Centre, the National Centre for Earth Observations, the UK Meteorological Office and the European Centre for Medium-Range Forecasts.

The EPSRC CDT in Sustainable Sound Futures

Professor Trevor Cox   University of Salford

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David Attenborough poetically talked about a Blue Planet, but from an aural perspective, Earth is a Noisy Planet. Human activity means that most places are infected with noise: from megacities to oceans, tranquillity is disappearing. This was starkly illustrated during lockdowns when transport and industry stopped making noise, and we glimpsed what a better-sounding future might be, as long as our neighbours weren't doing DIY.

Noise is a health problem for one in five EU citizens. At high levels it causes hearing loss. At moderate levels, it creates chronic stress, annoyance, sleep disturbance and increases heart disease. Noise makes it harder to communicate, harming learning in schools, and increasing withdrawal of older people from social situations. These problems are why the Lord's Science and Technology Committee has just begun an inquiry into noise pollution and human health. Moreover, as a pervasive pollutant, noise increases mortality in marine and terrestrial wildlife.

The Centre for Doctoral Training (CDT) focuses on the user need of businesses, society and government to create a more Sustainable Sound Future. This cuts across the Frontiers of Engineering and Technology. In EPSRC's Tomorrow's Engineering Research Challenges, the sound of drones and environmental noise are highlighted as needing innovative solutions. But the CDT is broader than that, contributing to seven out of eight Tomorrow's Engineering Research Challenges, because noise and vibration cuts across many sectors such as transport, energy, environment, construction and manufacturing.

We will address recruitment issues faced by the UK's £4.6 billion acoustics industry. Our partners tell us they struggle to find doctoral-level graduates who have acoustic expertise. Cohort training will give an unprecedented depth and breadth of knowledge to the CDT's graduates. This is needed because of the complexity of the challenge, from reengineering machines, systems and buildings, through to understanding how sound affects the health and well-being of humans and other animals. Current PhD training in acoustics is too piecemeal to tackle a problem that cuts across sectors, regulators and society. A CDT will create a unique cohort of future research leaders and innovators, with the ability to create a step-change in how noise is tackled by working across disciplines. A key part is a paradigm shift from simple noise and vibration control, to engineering positive sounds for a better aural future.

This CDT brings together four powerhouses in acoustics: the Universities of Salford, Bristol, Sheffield and Southampton; along with industrial partners, regulatory bodies, public and third sector. This will give CDT students access to an extraordinary range of laboratories and breadth of expertise for their training. This includes domain and application knowledge across many disciplines; state-of-the-art simulation, measurement and auralisation capabilities; datasets and case studies, and routes to impact. The CDT builds on EPSRC's UK Acoustics Network that already has over 1,500 members including 500+ early career researchers.

Challenging interdisciplinary research projects and cohort-based training will develop the much-needed postgraduates. A mixture of week-long residentials, group project and online activities are planned. These will develop technical skills for acoustics (simulation, measurement, machine learning, psychoacoustics, etc) and key skills for research (project planning, entrepreneurship, public engagement, policy influencing, responsible innovation, etc). Stakeholder placements will play an important role in ensuring the cohort learns about context and how to create impact from their research. The learning outcomes of the training have been co-created between academics and stakeholders, to ensure CDT graduates have the skills, knowledge and understanding to tackle noise and create a more sustainable sound future for all.

EPSRC Centre for Doctoral Training in Modelling of Heterogeneous Systems

Professor James Kermode University of Warwick

Kermode, Professor JR,Brommer, Dr P,Stansfeld, Professor PJ,Turner, Dr HL,Figiel, Dr LW,Hine, Professor NDM,Staunton, Professor JB,Hudson, Dr T,Bartok-Partay, Dr LL,Knight, Miss H

Meeting emerging science and engineering modelling challenges requires scientists who can master complex theory and simulation techniques, can assimilate data, and can collaborate in multidisciplinary teams with expertise across a range of modelling scales. Securing the UK's position as a world-leading research hub into the future therefore requires a well-integrated pool of researchers with a skillset that is both broad and deep.

HetSys is leading the way in addressing these needs by producing students with the tools necessary to meet the challenges of the future through our training programme. We are training the scientists who will develop the next generation of computational models, implemented in reusable software with robust error bars from uncertainty quantification (UQ), and who can learn from experimental and simulated data on an equal footing through advances in 'scientific machine-learning' (SciML). Linking heterogeneous materials models with UQ allows performance to be improved, enabling the technology needed to reach net zero through a step-change in design capability. The ongoing AI revolution has necessitated a redesign of our training programme to enable us to build on what we learnt during the first funding period and deliver our new vision. In particular, changes to our core training enable our students to (i) embed robust and sustainable research software engineering (RSE) in modelling; (ii) quantify modelling uncertainties through enhanced use of statistical methods; and (iii) exploit new trends in scientific machine learning.

The research focus of HetSys on new paradigms in the behaviour of heterogeneous materials remains vital for the competitiveness of the UK's high-value manufacturing and automotive industries. Prominent examples of challenges we are addressing include the design of (i) low dimensional and/or strongly correlated materials for quantum devices; (ii) high entropy alloys for fusion applications; (iii) biomolecules for combatting infectious diseases; and (iv) energy materials for future vehicles with reduced carbon footprints. Historically, the modelling pattern has focused on just one length- or time-scale; HetSys transforms this landscape by explicitly targeting the multiscale modelling of heterogeneous systems required by industry. The expertise we have accumulated opens up opportunities to capitalise on the transformative combination of mechanistic modelling with data-driven approaches (SciML). This requires a broader combination of disciplinary expertise, provided through our enhanced bespoke training programme.

Only a cohort approach can train high-quality computational scientists who can develop and implement new modelling methods in close collaboration with other scientists. The cohesive, interdepartmental cohorts and training programme we are creating lower many of the current barriers to interdisciplinary work and demonstrate our vision for the future of scientific endeavour, where teams of researchers work together to combine their skills and expertise. Only a critical mass of students and a large and highly collaborative team of supervisors makes this targeted and fully inclusive training approach feasible. HetSys supports the delivery of EPSRC's Physical and Mathematical Sciences Powerhouse strategic priority, helping to provide the platform on which research and innovation across the sciences is built.

EPSRC Centre for Doctoral Training in 2D Materials of Tomorrow (2DMoT)

Professor Irina Grigorieva The University of Manchester

Grigorieva, Professor I,Bissett, Dr MA,RAVEENDRAN NAIR, Professor R,Casiraghi, Professor C,Atature, Professor M,Ferrari, Professor AC,Falko, Professor V

The proposed CDT, a partnership between the University of Manchester and the University of Cambridge, will address the UK's need for a pipeline of highly skilled scientists and engineers who will be able to secure the country's position as the global leader in the science and technology of two-dimensional materials (2DMs). Having started with the discovery of graphene at the University of Manchester (UoM), this research field now encompasses a vast number of 2DMs, 2DM-based devices, composites, inks, and complex heterostructures with designer properties. Numerous proposals for applications have emerged from research groups worldwide, some of them already picked up and been developed by big established companies and a large number of start-ups (30+ spin-outs just from the two universities, Manchester and Cambridge). Many of the ideas put forward require further research and validation and many more are expected to emerge thanks to the unique properties of this new class of advanced materials and the ability to use modelling to predict new useful combinations of 2DMs or design conditions that bring about new properties. The CDT will support and enable new avenues of research and the development of 2DM-based technologies.

2DMoT will be an important part of the of the Graphene and 2D Materials eco-system centred on the UoM and UoC- based innovation networks. It will contribute to the plans by the local authorities, in particular, of the Greater Manchester Combined Authority to pilot Manufacturing Innovation Networks focused on graphene & nanomaterials, coatings and technical textiles. Industrial co-supervision of research projects will accelerate realisation of new products and technologies enabled by 2DMs, which is key to competitiveness.

The CDT will implement a new approach to PhD research training by incorporating individual research projects into several overarching, multidisciplinary research missions with 2-3 CDT students a year joining each research mission, either at UoM or UoC, and gradually forming 8-10 researcher teams incorporating CDT students at different stages of their PhD working collaboratively and sharing ideas and knowledge. All students will have opportunities to shape the overall projects, creating an inclusive environment, ideal for peer-to-peer learning and innovation.

A 6-months-long formal taught programme at the start of PhD will be complemented by transferrable skills training and research schools and workshops organised jointly with leading international research centres. Training in innovation and commercialization of research, project management, responsible research and innovation, equality and diversity, and dealing with the media will be mandatory for all CDT students. To ensure that the benefits of CDT training are available to a wider group of PhD researchers, a range of CDT events - residential conferences, seminars, research workshops, commercialisation training - as well as some of the courses, will be open to non-CDT students whose research interests are aligned with the CDT research themes. Outreach events will form an important part of CDT activities, in particular participation in Science festivals, British Science weeks, Bluedot, Science X, with exhibits showcasing the science of 2DMs and their developing applications.

EPSRC Centre for Doctoral Training in Space Manufacturing and Visualisation

Professor Bradley Wynne University of Strathclyde

Wynne, Professor BP,Wood, Professor BM

The UK space sector is a highly successful industry providing navigation, weather forecasting, power grid monitoring, financial transactions and TV and digital communications services. It supports military operations and underpins our national security and resilience. It is a highly innovative sector with emerging technologies providing new ways to tackle global challenges such as food security, climate change and biodiversity loss.

With the publication of the UK National Space Strategy [1] in September 2021, the UK government identified space as an important growth sector with the ambition to make the UK one of the world's most innovative and attractive space industries. The space sector is already a vital part of the UK's economy, worth over £16.4Bn per year and employing over 45,000 people and supporting over 125,000 jobs across the supply chain [2]. The space industry workforce is exceptionally highly skilled and an increase in people with the multidisciplinary skillset to lead innovation is essential to deliver the strong future growth predicted for the sector. Space is highly R&D intensive with the equivalent of 10.7% of direct industry GVA invested in R&D, space industry R&D is 6 times higher than the UK average of 1.71% [3].

The space industry is going through a period of transformational change. It is transitioning from expensive bespoke launch and payload systems towards lower cost launch systems, miniaturised satellite platforms and payloads, and optimising automation in manufacturing processes. This shift in affordability and technical capability has the potential for dramatic growth of new space-based applications and significant economic, societal, and environmental benefits for the UK. Space manufacturing research challenges include: automation of satellite manufacture to assist the transition from bespoke one-off to production-line satellites, development of new sustainable manufacturing technologies, application of simulation and visualisation for manufacturing optimisation, application of sensor and data capture technologies to form the basis of digital twins of manufacture and end-products, leading to maximum use and reuse at end-of-life, maximising the sustainability of the sector. There are also exciting opportunities to explore manufacturing and solar power generation in space.

In order to deliver this growth and support the UK's ambition to be a science and technology superpower, a pipeline of highly skilled space manufacturing research leaders of the future is required. The EPSRC Centre for Doctoral Training in Space Manufacturing and Visualisation will deliver these specialists by training over 70 doctoral students from a range of science and engineering disciplines. The CDT will be hosted by the University of Strathclyde, Glasgow Caledonian University and the National Manufacturing Institute Scotland who are ideally placed to take advantage of the hub of space manufacturing activity in the Greater Glasgow Area. Students will be recruited into a multidisciplinary cohort to be trained in the latest technologies and techniques (e.g. lightweighting strategies, manufacturing optimisation, emerging manufacturing technologies, simulation and visualisation techniques, industry 4.0, and data analysis techniques) before embarking on a doctoral research project in partnership with an industrial collaborator. Technical training will be complimented by a programme of research and professional skills activities including ED&I best practice and trusted research, co-designed with our industrial partners to equip our graduates will the skills and attributes needed to be research and innovation leaders in a world-class UK space manufacturing sector.

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ONSCDT in Cyber-Physical Risk

Professor Hervé Borrion University College London

Borrion, Professor H,Johnson, Professor SD,Hailes, Professor S,Carr, Professor M

The UK Government's Integrated review of security, defence, development and foreign policy highlights an evolution of the security landscape in which the ecosystems of socio-technical systems that support all aspects of society are subject to complex threats with social and technical components. NATO and the MOD have warned that hybrid threats, especially, are poised to increase in the next 25 years assuming many forms, such as misinformation campaigns, incitement to hate crime, online self-radicalisation, coordinated attacks against cyber, physical and social assets, and insider threats.

Cyber and physical spaces - including the emerging metaverse(s) - are domains in which we continue to find ourselves confronted with problems that we had not anticipated and that we are ill-equipped to deal with. There is a need for a new generation of experts capable of better understanding future, unknown risks of social-technological natures - especially those at the intersection between crime and national security - who can address the unprecedented challenges posed by the combination of cyber-physical disruption and disinformation in free hyperconnected societies, and develop novel techniques to pre-empt them.

To address this capability gap, we propose to co-create an ambitious Centre for Doctoral Training, drawing upon all of our experience and interdisciplinary approaches developed so far in physical and cyber security. We will recruit and train 5 cohorts of future leaders (10+ p.a.) to holistically manage threats in the ecosystems of systems upon which society depends for its services, commerce, and cultural life. The research programme will include three core research strands (Cyber-physical risk identification, analysis and treatment) as well as cross-cutting themes: Development and testing of futures methods (including the use of emerging technologies such as VR/XR and simulation approaches), Concepts of evolution, sustainability and resilience in cyber-physical risk management, Incorporating the perspectives of people in policy-governed ecosystems, Global concepts of harm, fairness and ethics in cyber-physical risk management, etc.

Note on EPSRC/MOD funding: Our vision is to develop a training environment that is open to the world (to attract high-calibre students and foster innovation) and offer secure spaces and mechanisms to carry out research on sensitive topics. We await for the publication of MOD requirements to examine if/how this can be delivered within the MOD funding framework, and detail the specific arrangements (e.g., partners, vetting process, use of our secure data lab) that will embedded in the CDT governance and delivery plan.

ESPRC Centre for Doctoral Training in Agri-Food Robotics (AgriFoRwArdS#2)

Professor Marc Hanheide   University of Lincoln

Hanheide, Professor MA,Iida, Professor F,Pearson, Professor S,Sklar, Professor EI,French, Dr AP,Mortara, Dr L,Watson, Dr N,Smith, Mrs K,Kucukyilmaz, Dr A,Forni, Dr F

Research Area:

Robotics and Autonomous Systems (RAS) technologies are transforming global industries. Agri-Food is the largest manufacturing sector in the UK. It supports a food chain which generates a GVA of £115bn to the UK economy, with 4m employees in a truly international industry, and over £20bn of exports.

However, the global food chain is experiencing unprecedented levels of stress and disruption from a range of geopolitical and climatic factors. Urgent challenges for the UK sector include labour shortages and sustainability, requiring a dramatic reduction in inputs such as synthetic nitrogen fertilizers, pesticides and fossil fuels, and development of robust crop varieties to combat climate change, while also increasing food chain resilience and industrial productivity.

Need for CDT Graduates:

Civic society and all supply chain actors urgently require novel, sustainable technologies that automate production and enhance workforce skills, whilst supporting the transition to net zero and an environmentally sensitive agri-food system. These challenges require new ways of working and thinking, in turn requiring professionals with new interdisciplinary skill sets at the leading edge of robotics and agri-food research.

The proposed renewal of the AgriFoRwArdS CDT will advance the state of the art by creating a new generation of research and innovation leaders focused on the delivery of RAS technologies to meet the evolving needs of the agri-food sector. This will include at least 60 PhD projects co-created with industry to give the UK global leadership across critical and essential sectors of the world economy, expanding the UK's science and engineering base, and transforming agri-food production.

Approach to Training:

The CDT team is uniquely placed to deliver this programme, comprising three institutions with complementary expertise located at the heart of the UK agri-food business. We will recruit students from diverse backgrounds and provide them with a year of formal, assessed training to underpin their research, and continuing professional development throughout the lifetime of the CDT. The approach provides computational training and develops systems thinking in the technical foundations, practical applications, and environmental, social and economic impacts of agri-food robotics research.

The programme will leverage expertise, cash and in-kind contributions from a world-leading group of stakeholders across the food supply chain. The renewed CDT will provide a dedicated Impact Fund, facilities and partnerships to ensure the translation of research to the agri-food industry, and an International Graduate Training and Collaboration Programme, to increase its attractiveness to the brightest talents and establish itself as a world-leading training centre in agri-food robotics.

EPSRC Centre for Doctoral Training in Uncertainty Quantification for Digital Twins

Professor Dirk Husmeier University of Glasgow

Husmeier, Professor D,Davies, Dr V,Kowal, Dr K,Penta, Dr R,McGinty, Dr S,Stewart, Professor PS,Miller, Professor CA,Illian, Professor J,Scott, Professor M,Hill, Professor NA

Mathematical modelling is changing the world. By building a complex mathematical model, aka digital twin, of a real-world physical process, scientists are now able to simulate its behaviour under different scenarios on a computer without having to carry out any expensive and time-consuming experiments. Applications range from healthcare and environmental monitoring to engineering and optimal process design. This will have a dramatic impact on society. For instance, instead of carrying out invasive clinical tests with potentially serious side effects, a digital twin of a patient's physiology has the potential to make fast and accurate assessments of alternative treatment options without any clinical intervention. However, a substantial challenge is model calibration. A digital twin typically depends on a variety of unknown physical parameters, many of which cannot be measured directly. For example, a digital twin of a patient's cardiophysiology requires detailed knowledge of e.g. the stiffness of the blood vessels or the flexibility of the heart's fibres. These can only be measured in a post-mortem study, while establishing their values in vivo is only feasible indirectly via statistical inference. This is a procedure aiming to systematically explore the parameter space, compare the digital twin's predictions with actual clinical measurements, and find parameter values that achieve a good agreement. However, the complexity of this task can lead to computer run times of days or weeks, rendering real-time decision support infeasible. An additional challenge is to quantify the intrinsic uncertainty of the parameter estimation itself, for reliable risk assessment and hypothesis testing.

The aim of our CDT is to train a new generation of cross-disciplinary scientists that have the skills to develop and calibrate digital twins of challenging real-world processes, apply powerful machine learning and statistical emulation methods for fast and computationally efficient calibration and uncertainty quantification, and integrate these calibrated digital twins into decision support systems that can act in real time with reliable risk assessment. This requires a systematic integration of established disciplines, most notably mathematics, physics, engineering, statistics, machine learning and data science.

Our CDT will provide a cross-disciplinary environment where each cohort of students will bring together these key backgrounds. The CDT will provide a training infrastructure based on a 3 plus 1 scheme, where 3 years of dedicated research studies are preceded by a year of taught courses, short projects and internships to ensure all student have a sound methodological understanding of the whole methodological spectrum mentioned above. The PhD research will benefit from a cohort approach, where collaborations within the cohort foster the acquisition of sound unifying methodological knowledge, while scientific innovation will be strengthened by the integration of a diversity of backgrounds and specific skills. These specific skills are directly related to end-user needs, e.g. defined by our external non-academic partners. We will introduce a peer support scheme, where students with different backgrounds are put into peer support groups, to provide a safe environment for scientific discourse, a sounding board for novel research and engagement ideas, a peer review platform for preparing conference presentations and scientific articles, and a discussion forum for sharing internship experience. We will run regular competitive method challenges to further facilitate the creation of a coherent student environment. In collaboration with and support from the Newton Gateway Institute, we will coach our PhD students to improve their presentation and engagement skills, and we will run an annual PhD-industry collaboration workshop, to encourage students to work together and apply their skills to societal and commercial challenges more broadly.

EPSRC Centre for Doctoral Training in the Mathematics of Information

Professor Sir John Aston University of Cambridge

Aston, Professor Sir JAD,Datta, Dr N,Altmeyer, Dr R,Kibble, Dr M,Fawzi, Dr H

The EPSRC Centre for Doctoral Training in the Mathematics of Information (MOI) will bring together some of the most exciting areas of mathematics, from analysis to statistics, from computation to information theory, to address problems in the mathematics associated with information, in its broadest sense.

Gaining reliable, trustworthy and actionable insights from data is now a cornerstone of operational strategies across societal, health, scientific, policy and industrial domains. This has caused the scientific area of the MOI to emerge, primarily because the complexities arising from these application domains lead to deep questions which require solutions that cross mathematical disciplinary boundaries. MOI includes key mathematical problems from data science, such as the fundamental underpinnings of machine learning and modern interfaces between topology, geometry and statistics, but can reach into fundamental mathematical or physical aspects of "information", such as in signal processing (Shannon entropy), quantum information (quantum entropies and entanglement), or even black hole physics (Hawking's information paradox). Tackling the most exciting challenges requires a generation of mathematicians who can work at cross-mathematical disciplinary boundaries and foster thinking well beyond their specialism.

The CDT will have a common first year, where students gain foundational knowledge in a breadth of MOI areas, including statistics, probability, computational analysis, and optimisation, to learn key research skills and also to work together and share ideas. Courses will be a mix between lecture-style and group-based courses with diverse assessment methods. Students choose a (provisional) supervisor and conduct independent research under their mentorship throughout the first year, embedded in an established research group, with a flexible system to find their final thesis interest. Students will also have the opportunity to take a placement or external project, which has been designed together with industry or third party partners, and this could potentially develop into a full PhD research project, if the student, partner and supervisor all agree.

Throughout the entire time of the PhD, there will be considerable interaction between different cohort years. Students will continue to experience a breadth of MOI research and ideas via weekly cross-cohort seminars. The cohort will come together regularly in a wide range of professional development courses and career development lunches, where partner members will informally discuss their career, facilitating interaction with a wide range of stakeholders. Students will have the opportunity for research visits to institutions worldwide to work with leading figures in their areas and to attend relevant conferences. Students from the CDT will move on to a wide range of sectors and we will equip them with a knowledge of many sectors as well as a grounding in the transferrable skills required in many fields. At the end of each year, there will be a student-organised and led conference for all members of the CDT, with an opportunity to showcase the work of the CDT to potential new partners. There will also be an annual retreat, which will be held outside Cambridge biennially.

The leadership team has been carefully chosen to bring a range of MOI research perspectives to and to, together with an extensive support team, maximise the potential of the CDT investment, and to ensure that wellbeing, equality, diversity and inclusion will be embedded in all aspects of the CDT. Supervisors are a diverse team of more than 40 mathematicians and statisticians of international research excellence, all with extensive PhD supervisory experience. The CDT has a wide range of collaborations and partnerships with organisations, commercial and third sector, both SMEs and large enterprises, in line with the ubiquitous demand and interest in MOI.

The UKRI Centre for Doctoral Training in Offshore Wind Energy Sustainability and Resilience

Dr Robert Dorrell University of Hull

Dorrell, Dr R,Dethlefs, Dr N,Coombs, Professor WM,Giulietti, Professor M,Munir, Professor F,Gilbert, Professor J,McLelland, Dr SJ,Smith, Dr M I H,Dervilis, Professor N,Shahbazi, Dr M

Offshore wind energy has seen remarkable growth over the past decade, and is now a central component of the UK energy mix that offers some of the lowest cost electricity. However, the pace of deployment needs to now accelerate rapidly. To increase national energy resilience the UK government targets 50GW of offshore wind by 2030, up from 14GW in 2022, requiring c£17bn investment per year. To enable transition to net zero, UK offshore wind must then increase to at least 120-170GW before 2050. In Europe a total capacity of 450GW is anticipated by 2050, of which 2/3 will be in the North Sea and North Atlantic. To achieve this growth, deployment of OW is now expanding beyond the relatively benign, shallow water sites of the southern North Sea to deeper waters, further from shore, which are a fundamentally different environment (e.g. due to seasonal stratification). In such areas the two-way effects of new OW development on physical processes, the biosphere and concomitant impact on other sea users are poorly understood.

Beyond specific technical challenges, a major barrier to achieving this pace of deployment is the time taken for consenting. The government aim of reducing typical consent time from 4 years to 1 year by 2030 is only achievable if new approaches to data collection, aggregation and modelling are validated and adopted. The volume and speed of deployment must increase 6-fold, requiring industrialisation of manufacturing and installation processes while ensuring that the use of materials (such as rare earth metals, copper and composites) and other resources (including energy) is sustainable. To achieve this growth and ensure increased UK content requires the development of a highly skilled and resilient workforce. The OW workforce is projected to reach 100,000 direct and indirect jobs by 2030, with >8,000 projected to be at HE Level 7+. In order to be achievable and sustainable, this workforce needs to be drawn from a diverse pool of talent and be built on equitable and inclusive cultures where safety and wellbeing are central.

The EPSRC/NERC funded Aura CDT in Offshore Wind Energy and the Environment (Aura CDT I) has successfully demonstrated the value to the sector of research and training at the interface of engineering and environmental sciences. However, to ensure sustainable growth of the sector as part of a resilient energy system, research and innovation needs to also address the social, societal and economic aspects of OW energy and so the proposed UKRI Centre for Doctoral Training in Offshore Wind Energy Sustainability and Resilience (Aura CDT II) will expand to address the full EPSRC/NERC/ESRC remit. Research and training will be focused around five challenge-based themes, which have been developed in conjunction with stakeholders including our Strategic Advisory Board and sector bodies including the Offshore Wind Industry Council, the Offshore Renewable Energy Catapult, The Crown Estate, Natural England and the Planning Inspectorate.

The CDT will be led by the University of Hull with partner Universities of Sheffield, Durham and Loughborough. PI Dorrell (Director of Aura CDT I) will be supported by nine CIs from the partner universities and a pool of >100 potential PhD supervisors who bring world leading expertise in the areas of engineering, environment and social sciences required to support the training and research elements. At least 70 CDT full and part time students will receive masters level training delivered collaboratively by all of the partners through an intensive 6-month multidisciplinary programme at Hull and subsequent targeted taught courses with partners addressing topics including leadership, public engagement, responsible innovation and EDIW. Clusters of PhD research projects will draw on expertise and facilities from across the four partner universities to provide holistic insights into sector challenges while building cross-cohort collaboration and multiplying impacts.

EPSRC Centre for Doctoral Training in Process Industries: Net Zero (PINZ CDT)

Professor Adam Harvey Newcastle University

Harvey, Professor AP,North, Professor M,Lee, Dr J,Boodhoo, Professor K,Sneddon, Professor H,Russo Abegão, Dr F,McDonough, Dr J R,Mutch, Dr GA,Farmer, Dr TJ,Velasquez Orta, Dr S

The future 'Net Zero economy' will be based on new forms of energy (e.g. renewable electricity and hydrogen), new feedstocks (sustainably sourced biological and waste materials), and a new depth of data.

These changes present particular problems for the process industries (chemicals, food, pharmaceuticals, utilities, and manufacturing sectors). To 'Engineer Net Zero' in these industries, they must undergo the most profound transformation since the industrial revolution. To accommodate these novel feedstocks, new energy types and new data, entirely new processes, process technologies and 'green' chemical routes will have to be developed.

The scale of the challenge is enormous; manufacturing alone accounts for ~10% of the total economic output of the UK (£203bn Gross Value Added) and ~7% of UK jobs (HMG, 2022).

THE RESEARCH CHALLENGES

The PINZ CDT will 'Engineer Net Zero' by developing new processes, green chemistries, and process technologies, via research at the interfaces of chemical engineering and chemistry, informed by and co-created with industry:

1. Energy: The use of renewable electricity and hydrogen, replacing fossil-fuel derived energy, will necessitate new ways of performing process steps (reactions, separations, heat transfer) and whole process design.

2. Feedstocks: Sustainable materials/solvents/auxiliaries (bio-based, CO_2, waste-derived, etc), will necessitate new chemistries, process pathways and technologies, and underpin the future 'circular economy'.

3. Data: Ever-increasing quantity, completeness, and quality of data (in-process data, energy use, carbon accounting, and life-cycle impacts etc) will change the way we design and operate processes.

THE TRAINING CHALLENGES

Build Back Better: Our Plan for Growth (HMT, 2021), and The UK Innovation Strategy: Leading the Future by Creating It (BEIS, 2021) highlight the need for a strategic focus on skills development, innovation, and Net Zero to transform the UK into a global science and engineering superpower. To meet this challenge and maintain the UK as a technology hub and global leader in innovation in the process industries, the UK requires pioneering, innovative, and knowledgeable chemical engineers/chemists. These world-class, doctoral-level graduates will not only be required to navigate these challenges: they will need to lead the change.

The PINZ CDT will create these 'Net Zero-enabled' future leaders via a nurturing, supportive and collaborative training environment, which will equip the researchers with the tools to develop, analyse, evaluate, and implement new technologies and processes during their projects and future careers.

Student-centred training will underpin everything we do, tailoring research training both at the individual and CDT level, alongside the provision of the management, entrepreneurship, and business skills that industry demands. Throughout the training, we will facilitate peer-to-peer interactions within and across cohorts to build a community and engender a broad exchange of ideas. This is especially important when working with students from diverse academic and personal backgrounds and recognises the contribution diversity makes to a challenge on the scale of Net Zero.

DELIVERY

PINZ will be led by the world's largest Process Intensification Group (PIG, Newcastle University), and the world-leading Green Chemistry Centre of Excellence (GCCE, University of York), leveraging >40 years of combined experience in technology transfer and >100 ongoing industrial partnerships. Only through this combination of the 'biggest and best' can the internationally-leading education, training, and research needed to produce the next generation of leaders and innovators for Net Zero be realised.

EPSRC Centre for Doctoral Training in Design for Sustainable Electrification

Dr Glynn Atkinson Newcastle University

Atkinson, Dr GJ,Heidrich, Dr O,Miscandlon, Dr J,Deng, Dr X,Giesekam, Dr J,Lambert, Dr SM,Lane, Mrs AJ

The UK Net Zero 2050 policy has at its heart sustainable engineering solutions which can only be achieved through electrification; the replacement of mechanical and combustion powered systems with more efficient power electronics, machines and drives (PEMD), battery energy storage and smart systems to manage and optimise energy use.

Mechanical and combustion powered systems, such as the internal combustion engine, are generally reparable, replaceable, and recyclable, but their electrical replacements are less so. Over 50M Tonnes of electronic waste is generated worldwide per year and only 10% is currently recycled. At least 5% of this is recycled illegally in developing nations using unregulated cheap labour. Many nations, including the UK, are introducing regulations to ensure manufacturers are responsible for the reuse, upgrade, and recycling of their products, and to ensure recovered materials are easily separable and recycled at the end of the products life.

To date the main drivers for research in PEMD are improved performance and lower cost. As the volume of products such as electric vehicles, air source heat pumps and smart energy storage increase, the reduced dependence on materials with non-assured long-term supply and minimisation of environmental impact during manufacture and at end-of-life are becoming more important research issues. This requires a more holistic approach and wider technical skill set to address.

An understanding of the energy intensity of manufacturing processes and energy use over the products life is needed to ensure future problems are not created in the drive toward net zero. A more responsible and sustainable approach to the design of products for electrification is needed.

The technical skills and engineers to do this are however lacking. The existing workforce does not have the skills to design sustainable electrification products for reuse, repair, or recycling. Nor do they have a strong understanding of the legislative, geopolitical, and economic issues that will drive product change. Without enough engineers with these skills, UK industry will struggle to significantly contribute to Net-Zero.

Engineering generally, but especially the PEMD industrial sector is one of the least gender diverse parts of the economy, (in employment, leadership, research, and innovation). It needs to draw on all talents to grow and deliver a sustainable future.

Newcastle University, The National Manufacturing Institute Scotland/University of Strathclyde and 15 industry partners including Dyson, GKN Aerospace, Rolls Royce, Siemens, and Toshiba have partnered to offer our education, research, and technical expertise to develop this Centre of Doctoral Training. Our aim is to address the UKs skills shortage through high quality training and the diversity shortage through recruitment from a diverse cohort to develop the future leadership and role models able to drive a diverse future for the sustainable electrification industry.

EPSRC Centre for Doctoral Training in LOCation Unified Solutions (LOCUS)

Professor Jon Mills Newcastle University

Mills, Professor JP,Matthews, Dr J,Alvares-Sanches, Dr T,Peppa, Dr M M,Franklin, Professor R,Rodrigues, Professor LT,Marsh, Professor SH,Goulding, Dr JO,Barr, Professor S,Boyd, Professor D

"Everything happens somewhere" is a maxim oft cited in the geospatial industry to emphasise the significance of location. Be it to build resilience in national energy networks, track antimicrobial resistance through a river basin, or integrate the management of blue light responders to city centre emergencies; the challenges the UK faces every day necessitate system solutions that unify disparate, multi-scale, big datasets using the attribute of location across space and time. Effective solutions necessitate not only a technical understanding of modern data science (software development; big data, AI; cloud, edge computing; etc.), but also a deep-seated analytical appreciation of fundamental geospatial science (precision, accuracy, reliability; datums, projections; data fusion, error propagation; etc.). The EPSRC CDT in LOCation Unified Solutions (LOCUS) will train the next generation of experts to deliver a UK sovereign capability in exploiting the power of place. However, LOCUS will be more than a training pipeline for world-leading talent. "Locus", the place where something is situated or occurs, provides apt nomenclature for what will be the UK national centre of research and innovation excellence in the use of multifarious location-based technology, data and methods for sustainable futures and societal prosperity.

The Geospatial Commission, established by the UK Government as an independent body to "unlock the power of location", places strategic emphasis on "enhancing skills, capabilities" and "enabling innovation"; foci that are paralleled in the associated UK national space strategy. The UK is currently ranked 2nd globally in terms of "geospatial readiness". However, with >71k job postings necessitating geospatial expertise in the period 2014-19, the Geospatial Commission recognises that the UK needs "more people with the right skills to work with location data, across organisations and sectors, to meet the UK's future needs and support global development". As a nation, "we need to support the development of this specialised skills base to anticipate the changing skills requirements of the future", so the UK can "maximise the commercial opportunities of high-value emerging location technologies".

LOCUS will build on the relationships developed with 40+ partners from academia, industry and government involved in the EPSRC CDT in Geospatial Systems (intakes 2019-23). In Newcastle University Geospatial Engineering and The University of Nottingham Geospatial Institute, LOCUS builds on this successful CDT endeavour between 2 of the UK's internationally leading research groups in the use of location-based data. Co-created with key partners to ensure industry thinking is entrenched from the very embryonic stages of CDT development, LOCUS will be guided by an independent industrial advisory board and hybrid academia-industry programme management board to train 5 cohorts of 10+ PhDs in different thematic areas of identified national priority. To ensure a coherent, inclusive approach to co-delivery, all partners have agreed to sign up to a "LOCUS Declaration" of collaborative practice.

A 1+3 model will provide end-to-end geospatial data science training, incorporating at-partner co-delivery of tailored modules. Individual, yet interwoven, research programmes will be co-created with industry partners at an innovation festival and comprise blocks that coherently build towards award of each PhD. Bespoke horizontal cohort training in trusted research, entrepreneurial leadership, and environmental sustainability will similarly be co-delivered with/at partner organisations, with strong emphasis on innovation and translation. Wider activities, including a challenge week, annual assembly, and student-led retreat will engender vertical cohesion. Continuing the core ethos of the Geospatial Systems CDT, this will all be conducted in a diverse, supportive and inclusive environment where all are afforded equal opportunity to thrive.

EPSRC Centre for Doctoral Training in Smart Microsystems Integration

Dr Rishad Shafik Newcastle University

Shafik, Dr R,Peeters, Dr M,Trefzer, Dr M A,Johnson, Professor SD,Neasham, Mr JA,Yakovlev, Professor A,Krauss, Professor T,Duhme-Klair, Professor A,Zhao, Dr C,Freitag, Dr M

The Centre for Doctoral Training in Smart Microsystems Integration (CDT-SMI) aims to train the next generation researchers with the interdisciplinary skills and innovation outlook needed to upscale UK's capability in advanced microsystems design. Intensive cohort-based training is needed to equip researchers with a co-creational research, development, and enterprise mindset across the entire stack of new computing and sensing systems from conception to production, with a particular focus on diversification of technologies for smart microsystems design, integration, and translation into applications.

The UK is a major stakeholder in the global semiconductor and advanced microsystems ecosystem. The sector contributes £147B to our national economy accounting for 7.7% of our GDP. This has been possible through continuous, successful training of internationally excellent researchers and innovators, delivering novel architectural and technological solutions across industrial and academic workplaces.

The world is currently facing serious challenges in delivering scalable, reliable, and sustainable solutions for health and wellbeing, energy, food and shelter, and communication. Part of the solutions to these challenges relies on pervasive but non-invasive, high-performance but energy efficient, multi-technology sensing and computing devices and systems. Future electronics will tightly integrate with photonic, mechanical, and biochemical microsystems technologies, and continue to pervade challenging applications with considerably higher density and performance per unit of energy than what is possible today following a growth of 12.4% p.a.

These ambitions are, however, at odds with the slow pace of training a UK workforce with the necessary co-creational skillset of specialist technical know-how combined with a broader knowledge and appreciation of various microsystems technologies, as well as business and enterprise. There is a predicted significant shortfall of suitably trained engineers and scientists over the coming years. For example, only up to 8% more engineers are currently being trained to sustain prosperity as a digital society, against a demand of 9.6% annual increase of highly skilled IC designers. The absence of fabrication capability in the UK poses an additional challenge and emphasises the urgent need for individuals with fabrication knowledge and skills.

For the UK to meet the complex requirements of smart microsystems, e.g., incorporation of non-silicon technologies and devices, new data-driven microarchitectures, integration for multi-technology systems, metamaterials and design twinning tools, an organised cohort-based approach to doctoral training is paramount to fostering a skilled future workforce. This will have profound impact across domains, including technologies, devices, circuits, automation tools and applications. Currently, there is no such organised, cohort-based doctoral training in the UK delivering this.

The Centre for Doctoral Training in Smart Microsystems Integration (CDT-SMI) will close the capability gap and fast-track new solutions through training of 60 students over 5 cohorts, with significant industrial stakeholders and sponsorship, led by world-leading research groups at Newcastle University and the University of York - allowing us to cover a wide range of strength areas and disciplines, ensuring the UK's sustained global technological leadership.

EPSRC Centre for Doctoral Training in Digital and Automated Materials Chemistry

Professor Alessandro Troisi University of Liverpool

Troisi, Professor A,Slater, Dr AG,Vitaliy Kurlin, Professor V,Rosseinsky, Professor M,Reed, Professor M,Garcia-Tunon, Dr E

We will train a cohort of students at the interface between physical and computer sciences to tackle the urgent need of to introducing introduce digital methodologies in materials chemistry research. Through such training, each student will develop a common language across the areas of automation, AI, synthesis, characterization and modelling, preparing them to become both leader and team player in this evolving and multifaceted research landscape.

The lack of skilled individuals is considered one of the main obstacles to digitalization of materials research. This is demonstrated by the enthusiastic response from our industrial partners, who span sectors and sizes: already more than 430 wish to be involved and we have already received offer of financial support for well over more than 20 full studentships. This proposal will deliver the EPRSC strategic priority "Physical and Mathematical Sciences Powerhouse" by training in "discovery research in areas of potential high reward, connecting with industry and other partners to accelerate translation in areas such as catalysis, digital chemistry and materials discovery."

The Materials Innovation Factory (MIF) was established in 2017 at Liverpool with industrial partnership to deliver the vision of digital materials research: it now co-locates over 100 industrial scientists from over more than 15 companies with over 200 academic researchers. Academics from physical sciences, engineering and computer sciences with their industry partners have developed the intellectual environment, infrastructure and expertise to train scientists across these areas, which span traditional boundaries. More than 40 PhD projects had been co-designed with and sponsored by our core industrial partners in the areas of organic, inorganic, hybrid, composite and formulated materials since 2017. Bespoke training in data science, robotics, leadership and computational methods was developed. This opportunity needs now to be grown scalably and sustainably to match the rapidly increasing demand of from our core partners based on these experiences, and extended further across sectors to a larger number of partners, including late adopters of digital technologies and SMEs, which now have limited options to explore digitalization pathways without substantial initial investment.

The training of a series of cohorts with consistent size and composition of student background will exploit a unique and exciting training environment: peer learning and group activities within a cross-disciplinary team will accelerate the development of common language and the ability to use a combination of skills from different individuals with distinct domain expertise to solve complex problems. The professional training will reflect the diversity of career opportunities available to this cohort in industry, academia and non-commercial research organizations. Each component will be bespoke for scientists in the domain of materials research (IP & Commercialization, Entrepreneurship, Responsible Innovation, Health & Safety, Science Policy, Regulatory Framework) and the training will make extensive use of real-world case studies from the partners. External providers of training will bring different and novel perspectives (corporate, SME, start-up, but also charities, local authorities, consultancy firms). Cohort activities span the entire duration of the training, without formal division between "training" and "research" periods, exploiting the physical infrastructure of MIF and its open access area to foster a sense community of graduate students.

We will embed EDI principles in all aspects of the CDT (recruitment, day-to-day operation, student well-being, composition of sub-teams (management, supervisors, progression panels, external advisory board) to make it a pervasive component of the student experience and professional training.

EPSRC Centre for Doctoral Training in Net Zero Maritime Energy Solutions

Professor John Bridgeman University of Liverpool

Bridgeman, Professor J,Plater, Professor AJ,Whittle, Professor KR

The Government's commitment to increasing offshore and marine renewable energy presents significant technological challenges in designing, commissioning and building the infrastructure, connecting offshore generation back to shore, and in consideration of where these new developments are best placed to generate energy, whilst balancing the impact they have upon the environment. In tandem, it presents opportunities advance UK capabilities in cutting-edge engineering and technologies. The Centre for Doctoral Training in Net Zero Maritime Energy Solutions (N0MES) will develop a cohort of 51 highly trained researchers, skilled in the identification, understanding, assessment, and solutions delivery for pressing environmental challenges in offshore and maritime energy industries.

N0MES researchers will pursue new, engineering-centred, multidisciplinary research to address three important offshore net zero challenges currently facing the North West and the UK:

1: Generating offshore and marine environment renewable energy (offshore wind, tidal, wave, hydrogen, floating solar)

2: Addressing the short- and long-term environmental impacts of offshore and marine environment renewable energy generation, distribution and storage

3: Distributing energy from offshore to inland, including port-side impacts and opportunities

The problems to be addressed by N0MES researchers will be diverse, multidisciplinary and driven by scientific endeavour, national priorities and industry need. Extensive consultation with industry and policy partners undertaken in the development of this proposal (including major UK employers, as well as small local engineering firms, and the Liverpool City Region Combined Authority) has confirmed that there exist multidisciplinary science and engineering skills gaps, which required integrated solutions. The cohort approach of the N0MES CDT will enable graduates to communicate and research across disciplines, and will develop flexible, innovative workers who can move between projects and disciplines as employer priorities and scientific imperatives evolve and change.

EPSRC Centre for Doctoral Training in Engineering Hydrogen Net Zero

Professor Dani Strickland Loughborough University

Strickland, Professor D,Ozkan, Professor N,Giulietti, Professor M,Wijayantha-Kahagala-Gamage, Professor U,Leithead, Professor B,Dann, Dr S,Jackson, Professor L,Higginson, Dr R,Das, Dr DB,Lin, Professor W,Carroll, Dr J,Goddard, Dr P

The vision for the EPSRC Centre for Doctoral Training (CDT) in Engineering Hydrogen Net Zero is to develop the necessary networking, training and skills in future doctoral level leaders to enable rapid growth in hydrogen-related technology to meet the UK government's 2050 net zero targets. This CDT is a partnership of three world class Universities and around 60 Industrial and Civic organisations. The CDT aims to address the challenging aspects of rapid growth in hydrogen production and usage such as cost, supply and waste chain development, scalability, different system configurations, new technology, and social requirements through a blended cohort co-creation approach. The CDT will provide mandatory and optional training in Fundamental Knowledge, Thinking Innovatively, Business Acumen, Equity, Diversity, Inclusion, and Community (EDIC). A cohort based CDT is most appropriate for embedding skills in Engineering Hydrogen Net Zero due to the breadth of the training needs and the need for co-support and co-learning.

In addition to a tailored co-created skills training program, the CDT will engage with partners to address key research priority areas. The CDT research plans are aligned with the EPSRC's "Engineering Net Zero" research priority, aiming to engineer low-cost hydrogen for net zero. Decarbonisation is not just implementation of a single solution fits all but a complex process of design that is dependent on what is being decarbonised eg different types of chemical industry to whether or not there is future access to a hydrogen hub. This results in the requirement for many new solutions to ensure affordability, scalability and sustainability. This includes undertaking research on hydrogen into topics such as, design for scalability, hydrogen on demand, new low cost materials, new interfaces, new processes, new storage means, new energy interactions, new waste management, existing infrastructure adaption and lifespan monitoring and management and social acceptance.

The CDT will work with industry partners to generate impact through innovation through research. This will include direct financial benefits, improved policy outcomes through engagement with local authorities, government organizations, and standards bodies, enhanced public engagement and acceptance of hydrogen, and create employment opportunities for students with industry-ready skills. The CDT represents an excellent opportunity for students to work together, with industry and with world leading international experts on impactful projects for a common decarbonisation goal with multifunctional stakeholders.

This CDT will build upon the experience of the University partners and the lessons learnt from participation in 4 previous CDT's to bring forward best practice (e.g. buddy scheme and childcare funding) and remove roadblocks to opportunities (e.g. timetable clashes). We will co-create a CDT with international reach and access to over £55m worth of hydrogen and wind turbine demonstrator and research facilities. The team has excellent links with both Universities and Industry abroad including partners in Europe, Canada, Malawi, China, USA, Brazil and Australia. CDT students will have opportunities to learn from International experts at a summer colloquium, link with world leading experts to build international networks of contacts, CPD activities (such as partner site visits), national and international conferences & partners secondments, research sandpits and webinars. All activities undertaken with due care, diligence & best practice in EDIC.

The academic, industrial and civic team has the expertise to deliver the vision of the co-created CDT through the development of a unique research and training program.

EPSRC Centre for Doctoral Training in Next Generation Organ-on-a-Chip Technologies

Professor Hazel Screen Queen Mary University of London

Screen, Professor H,Tse, Professor Z,Iskratsch, Dr T,Norling, Dr L,Knight, Professor MM

Vision

We aim to deliver a paradigm shift in UK approach to accelerated delivery of safer, more reliable, and more affordable therapeutics, by engineering the next generation organ-on-a-chip technologies. We propose a CDT driving innovation in organ-chip bioengineering and will provide a world-leading doctoral training and research environment to deliver a cohort of future leaders in this multidisciplinary field.

User Need

The development pipeline for new therapeutics is failing. Our ability to carry out reliable, accurate early (pre-clinical) testing of new therapeutics is hampered by inadequate testing platforms which do not reflect human response nor human diversity. As a result, over 90% of drugs entering clinical trials ultimate fail, and each failure loses the economy an average of 10-15 years of work and over £1billion. The need for improved pre-clinical testing technology which addresses human diversity has been identified as a crucial healthcare challenge, with the potential to deliver affordable healthcare and revolutionise global health outcomes.

Organ-chips provide an answer to this challenge, offering more human-relevant technology to improve pre-clinical testing success. An organ-chip is a bioengineered microfluidic in vitro model, containing appropriate human cells and replicating key aspects of organ function and disease. Microfabricated using cutting-edge engineering approaches and combined with specialised materials, sensors and biomechanical stimulation, organ-chips offer innovative platforms to explore personalised medicine and response to therapeutics. Early adopters of this nascent technology have begun demonstrating the capability of organ-chips to better predict therapeutic behaviour in clinical trials. The race is now on to address the engineering challenges of designing next generation devices and bringing them into the regulatory pathway for therapeutic discovery.

Co-Creation of a Diverse, World-Leading Training Environment

Queen Mary University of London (QMUL) has an internationally leading reputation in organ-chip bioengineering. CDT directors, Screen and Knight lead the very successful UKRI-funded UK Organ-on-a-chip Technologies Network, in which over 1,000 members from academia, industry, NHS and other stakeholders, collectively promoted and advanced UK activity in the field.

The CDT will leverage the QMUL Centre for Predictive in vitro Models, providing over 50 academic staff actively working in organ-chip and associated technology, and access to state-of-the-art facilities including the Queen Mary+Emulate Organs-on-Chips Centre and CREATE microfabrication and 3D bioprinting lab. It will also leverage the combine expertise of our UK Network, with at least 2 EPSRC PhD students in each cohort allocated to collaborative projects with other network members, adding geographical diversity and additional experience.

We have worked with stakeholders from across industry and associated sectors, to co-develop a training programme targeting the skills gap, and will deliver 85+ PhD graduates with the essential skills to deliver next generation organ-chip technologies. Although the potential of organ-chip approaches is increasingly recognised, the UK still lacks bioengineers and scientists with the essential multidisciplinary technical skills to design and manufacture innovative models. Furthermore, underlying understanding of the industrial, regulatory and ethical framework is crucial to inform model design and must be integrated into a robust training programme. Alongside individual PhD research projects, students will undertake taught modules, internships, workshops, industrial-led case studies and practical training in cohorts, augmenting their skills and building their networks.

Collectively with our stakeholders, we will build the future community of organ-chip scientists and engineers, to transform the therapeutic discovery pipeline delivering better healthcare solutions.

EPSRC Centre for Doctoral Training in Heritage Science: Technology and Training Centre for Heritage Science

Professor Sarah Semple Durham University

Semple, Professor SJ,Turner, Professor S,Beeby, Professor A,Augarde, Professor C,Perry, Professor J,Williams, Dr EA,Al Moubayed, Dr N,Nicholson, Dr C E,Taylor, Dr G

TECH - Technology and Training Centre for Heritage Science - is a challenge-oriented doctoral training programme, designed to produce 50 heritage scientists to lead the discipline on a global scale. Heritage Science is an interdisciplinary research domain spanning the sciences and engineering disciplines, social sciences and humanities that is responding to modern demands with a focus on enhancing the understanding, care, use and management of both tangible and intangible cultural and natural heritage so it can continue to enrich people's lives, today and in the future.[1]

In 2019-21, during the Coronavirus pandemic, visits to cultural and natural heritage sites surged, as people (re-)connected with greenspaces, rivers, coasts and monuments, using heritage to enhance their sense of health, wellbeing, relaxation and accomplishment.[2] Yet this renewed global engagement is at a time of crisis; tangible and intangible cultural and natural heritage assets and collections are under intense threat worldwide from conflict, climate change, natural disasters, agricultural intensification, urban development and population increase/footfall. At the same time, cultural and natural heritage are recognised as having a key role in understanding the causes, impacts on, and designing responses to modern challenges as varied as drought management and irrigation, climatic warming and disaster resilience,[3] and are emerging as critical players in driving economic development from the local to the global.[4] Heritage Science research is developing at pace in response with the growing realisation that ancient and historic technologies and materials can often provide solutions in the present.

Combining the expertise of four University partners: Durham, Newcastle, Northumbria and Teesside, all with a track record in heritage science innovation, TECH is distinctive in our ability to mobilise core specialisms in the physical sciences, engineering and computing, in collaboration with the social sciences and humanities, to meet these sector needs. With ~40 regional, national and international partners from across the creative and cultural industries, TECH is informed by, and responds to, the modern challenges and opportunities of heritage, by working in partnership to create innovative, sustainable solutions for the future.

TECH puts emphasis on diversifying and internationalising participation with pre-application online workshops promoting project and training opportunities to multiple audiences. Each cohort of 10 students will take a skills training programme in their 1st-year, building knowledge and expertise, with case-study-led training in science, engineering and computing complemented by, for example, training in collections management, remote sensing, photogrammetry and visualisation. Project/ subject-specific skills training will be balanced with contextual learning on heritage in global context (management, law, ethics etc). We will involve our partner organisations in delivery to showcase particular challenges. Students will then select and develop their PhD projects and join their research cluster at Durham, Newcastle, Northumbria and Teesside, advancing strong cohort bonds through regular skills training opportunities. 100% of our student intake will access a 6-month professional placement in their 3rd/4th year with a UK or overseas partner organisation. TECH, in partnership, will realise a pipeline of heritage science innovators ready to support a vital, growing sector, widely recognised as a crucial driver for global economic development.[4&5]

[1] Heritage Science|ICCROM 2023; [2] HE 'Places of Joy' 2022; [3] ICSM CHC 'Global research and action agenda on culture, heritage and climate change' 2022; [4] Amirtahmasebi, R et al The Economics of Uniqueness. World Bank 2012; [5] Eg HE 'Skills gap/needs in the Heritage Sector 2019 & Heritage & the Economy 2020.

EPSRC Centre for Doctorial Training in Model-Based Systems Engineering (EMBSE)

Professor Michael Henshaw   Loughborough University

Henshaw, Professor M,Jackson, Professor L,Everitt, Dr M,Blay, Dr K B,Ji, Dr S,Cosma, Dr G,Lin, Dr Z,Jun, Professor G,Robertson, Dr DA

This CDT aims to address the UK capability and capacity needs in Model-Based Systems Engineering (MBSE) by graduating at least 70 Engineering Doctorates who are highly trained in MBSE and who carry out their research embedded within industry and public sector partner organisations.

MBSE is a transformational approach in which complex system requirements, design, analysis, and behaviour is captured using models, instead of documents. Many industries regard adoption of MBSE as a strategic priority as it enables more effective communication and collaboration among large teams, improved efficiency and accuracy in the design process, and complete traceability and transparency of system requirements and design decisions. The types of models used in combination by MBSE may include systems architectures, simulations, co-simulations, performance, cost, scenario, verification models, and digital twins, to name a few. The benefits are a reduction in cost (by up to 55%) and risk associated with complex system design and operation.

There are, though, many research challenges in MBSE (e.g. consistent and synchronised integration of models) and a significant shortage of high-end skills to meet the current and future demands of industry.

This programme directly addresses the EPSRC strategic objective to 'evolve our capability in UK Systems Engineering' (P18, of the Strategic Delivery Plan, 2022-25) and meets a strategic priority of industry to adopt sophisticated MBSE with the accompanying skills to lead the transformation.

All EngDs will co-create their PhD proposal with an industry sponsor to research MBSE applications in one or more of the four EPSRC mission-led priorities of:

- engineering net zero

- AI, digitalisation and data: driving value and security

- transforming health and healthcare

- quantum technologies

The current 20 confirmed industrial and public sector partners cover the health, defence, maritime, renewable energy, telecommunications, rail, nuclear energy, technical consultancy, and scientific research sectors. By addressing the range of sectors and mission-led priorities, and through cohort-based projects, cross-fertilisation of ideas will lead to general advances in the application of MBSE as an overall outcome, as well as sector specific outcomes. Furthermore, supervisors will be drawn from a range of disciplines (across 7 Loughborough University schools and departments), including engineering, science, business, and design in accordance with the multi-disciplinary nature of Systems Engineering.

Systems Engineering is the means through which complex systems are integrated; by addressing the mission-led priorities above, this programme will support EPSRC ambitions by providing the tools and skills for industry and the public sector to transform research concepts into viable products, systems, and services.

The programme will be proactive in its adoption of an inclusive approach and will enable full participation through a flexible approach to training, groupwork, and research environment.

EngD students will receive Master's level training in MBSE (leveraging the successful Loughborough Level 7 Apprenticeship in Systems Engineering) and leadership training through a collaboration between the university and industry partners.

As technical systems become increasingly complex, the competent adoption of MBSE has become a strategic imperative for UK industry. This programme supports that strategic imperative.

EPSRC Centre for Doctoral Training in Future Surgery and Perioperative Care

Professor Will Wenmiao Shu University of Strathclyde

Shu, Professor W,Lennon, Dr M,Wodehouse, Dr AJ,Connolly, Professor P,Kazakidi, Dr A,Maguire, Professor R,Mulvana, Dr H,Luo, Professor X,Reid, Professor S

Pre- and post-pandemic, the UK has had problems in delivering surgical interventions and care; more than 6.5 million patients are currently in long waiting lists for surgery, significantly compounding existing healthcare resources at unprecedented levels (~10% NHS costs, i.e. ~£20bn pa). Additionally, the UK Government's newly launched Medical technology strategy - GOV.UK (www.gov.uk) emphasizes the urgent need of developing resilience in future MedTech products, many of which underpin surgery and pre- and post-surgical care. Some 128,000 people are employed in MedTech in the UK across nearly 4,000 businesses with a turnover of £27.6bn. To deliver rapid transformation for long-term sustainability in the UK healthcare system and resilient MedTech products, we must act now to upskill and train the next-generation of researchers and the healthcare workforce. This need is also evidenced by the Future of Surgery Report (rcseng.ac.uk) of the Royal College of Surgeons (RCS). The advances in technology, therapies and devices envisaged by the RCS requires a multi-disciplinary, collaborative research approach across medicine, science and engineering. A key intervention to support this will be the training of cohorts of doctoral level skilled researchers. This CDT will produce future researchers in surgery and MedTech, delivering novel and emerging technologies such as; digital twins, AI, digital health and data analysis, human-centred design, advanced device and implant manufacturing, and in-silico trials. The researchers trained in this CDT will have impact across industry, medicine and academia.

EPSRC Centre for Doctoral Training in Complex Integrated Systems for Defence & Security

Dr Jordan Cheer University of Southampton

Cheer, Dr J,Sobey, Professor A,Clarkin, Dr CE,Scanlan, Professor J,Fliege, Professor J,Reed, Professor P,Karafili, Dr E,Dghaym, Dr D,Plant, Dr K

The EPSRC CDT in Complex Integrated Systems for Defence & Security (D&S) will train the next generation of leaders, researchers and technologists for the D&S sector, within the broad theme of complex integrated systems, but the technical focus of research and innovation will extend by design beyond individual technology domains. D&S is a core industry for the UK and ensuring that we have a highly skilled workforce that can provide leadership and innovation is key to its future success. This requires the development of new talent and, within an era of fast-paced technological advancement, the upskilling and reskilling of those currently employed in the workforce. Our CDT in Complex Integrated Systems for D&S aims to use a unique set of mechanisms to provide doctoral level training to students from all career stages, including those just graduating from university to those in work and those transferring from military to civilian job roles.

To support this, we propose an innovative approach to doctoral training, that will expose our candidates through a cohort-based structure to a truly multidisciplinary research environment and an understanding of the Defence and Security innovation landscape. The CDT will use a unique modular approach to provide this training in both part- and full-time modes of study, as trialled through our pilot Mobility DTP in D&S. The programme will provide foundational training, focused on building the students understanding of innovation, from both business and technical perspectives; interdisciplinary and collaborative skills development; understanding innovation within the D&S sector; and technical training, tailored to the individual student's training needs. Large parts of the foundational training will be delivered in short course format to improve accessibility for part-time candidates and to increase the sense of cohort. After this first year, the research programme will start with regular accumulation of credits, which will recognise industrial applications alongside traditional research. This will make the programme easier for part-time students to integrate into their current working practices and to meet the requirements of ever-changing career expectations. A series of on-campus and off campus inter-cohort events will develop the bonds required for part-time students to get the support they need, including seminars, mentoring and team building.

In addition to training our future leaders, we will position the CDT to make breakthroughs across the Science & Technology portfolio. The CDT will be centred around four key themes: digital, physical, human/biological and Policy and Political aspects, unified through their focus on complex integrated systems challenges. The first three of these themes cover the 25 MOD Science & Technology Portfolio Programmes while the Policy and Political Aspects theme addresses the need for this wider context within the training. The focused research topics will be guided by the sector but centred around University of Southampton core strengths in: maritime, aeronautical, astronautics, medical and electronic systems and will be linked to numerous cross-cutting disciplines. The CDT also builds on the significant doctoral level training we already provide across the D&S sector, including in particular our £1.5M EPSRC D&S Mobility DTP. Our CDT builds on these foundations and continues to innovate in the training we provide by recruiting from a diverse talent pool that enables a larger generational and experiential diversity within the cohorts. Through the more flexible ways of working, we will provide the D&S sector with the diverse range of highly trained innovators in complex integrated systems required for the success of the sector in the coming decades.

EPSRC Centre for Doctoral Training in Future Fluid Dynamics

Dr Oliver Harlen University of Leeds

Harlen, Dr OG,Tobias, Professor S,khodaparast, Dr s,Savy, Dr C,Noakes, Professor C,Ross, Dr AN,Jimack, Professor PK

The scientific discipline of fluid dynamics is primarily concerned with the measurement, modelling and underlying physics and mathematics of how liquids and gases behave. Almost all natural and manufactured systems involve the flow of fluids, which are often complex. Consequently, an understanding of fluid dynamics is integral to addressing major societal challenges including industrial competitiveness, environmental resilience, the transition to net-zero and improvements to health and healthcare. Fluid dynamics is essential to the transition of the energy sector to a low-carbon future (for example, fluid dynamics simulations coupled with control algorithms can significantly increase wind farm efficiency). It is vital to our understanding and mitigation of climate change, including extreme weather events (for example in designing flood mitigation schemes). It is key to the digitisation of manufacturing through 3d printing/additive manufacturing and development of new greener processing technologies. In healthcare, computational fluid dynamics in combination with MRI scanning provides individualised modelling of the cardio-vascular system enabling implants such as stents to be designed and tested on computers. Fluid dynamics also shows how to design urban environments and ventilate buildings to prevent the build-up of pollutants and the transmission of pathogens.

The UK has long been a world-leader in fluid dynamics research. However, the field is now advancing rapidly in response to the demand to address more complex and interwoven problems on ever-faster timescales. Data-driven fluid dynamics is a major area where there are rapid advances, with the increasing application of data-science and machine learning techniques to fluid flow data, as well as the use of Artificial Intelligence to accelerate computational simulations. For the UK to maintain its competitive position requires an investment in training the next generation of research leaders who have experience of developing and applying these new techniques and approaches to fluids problems, along with professional and problem-solving skills to lead the successful adoption of these approaches in industry and research.

The University of Leeds is distinctive through the breadth, depth and unified structure of its fluid dynamics research, coordinated through the Leeds Institute for Fluid Dynamics, making it an ideal host for this CDT. The CDT in Future Fluid Dynamics (FFD-CDT) will build on the 9 years of successfully running a CDT in Fluid Dynamics to address these new and exciting needs. Our students will carry out cutting-edge research developing these new fluid dynamics approaches and applying them across a diverse range of engineering, physics, computing, environmental and physiological challenges. We will recruite and train cohorts of students with diverse backgrounds covering engineering, mathematical, physical and environmental sciences in both the fundamental principles of fluid dynamics and new data-driven methodologies. Alongside this technical training we will provide a team-based problem-led programme of professional skills training co-developed with industry to equip our graduates with the leadership, team-working and entrepreneurial skills that they need to succeed in their future careers.

We build an inclusive, diverse and welcoming community that supports cross-disciplinary science and effective and productive collaborations and partnerships. Our CDT cohort will be at the heart of growing this capability, integrated with and within the Leeds Institute for Fluid Dynamics to deliver a dynamic and vibrant training and research environment with strong UK and international partnerships in academia, industry, policy and outreach.

Centre for Doctoral Training in Heating and Cooling Net-Zero Cities (HC-Zero)

Professor Fleur Loveridge University of Leeds

Loveridge, Professor FA,Tait, Professor S,Jackson, Professor MD,Wang, Dr X,Burridge, Dr H C,Bale, Dr CSE,Radcliffe, Dr J,Mckay, Mr J,Schellart, Dr A

If we are to decarbonise heating and cooling in our homes and businesses, we need to radically reshape our infrastructure, adapt our housing stock, and find new approaches for supplying thermal energy to buildings. We also need to transform the planning system and our behaviour to enable these changes to take place. The challenge is huge - but addressing it is critical to tackle the climate emergency and the cost of living crisis. The UK needs low carbon, affordable, accessible heating and cooling for all its 28 million homes. Significant and rapid change is needed to transition to net zero: cities will need heat networks, shared ground loops, individual heat pumps, energy efficiency retrofit and flexible energy storage. Given the scale of the challenge, major technological innovation is needed, but a successful and equitable transition will only be achieved by understanding and addressing socio-economic constraints to adaption.

The Centre for Doctoral Training in Heating and Cooling Net-Zero Cities (HC-Zero) will deliver exceptional graduates with the skills to meet this challenge. Our strategy is to support interdisciplinary solutions for place-based whole-system heating and cooling. We will train at least 55 PhD researchers across four leading universities: Leeds, Sheffield, Birmingham and Imperial College London. The supervisory expertise in HC-Zero is highly multidisciplinary, covering engineering science and design, technology development, building physics, computational and data analysis, policy, social and behavioural science, environmental impacts, finance and investment, and change management. Following engagement with our diverse end-user community we are planning research projects involving geothermal resources, innovative thermal recovery and storage systems, policy and planning changes needed to unlock implementation of ground-loop systems, the integration of heat supply with other infrastructure, the interdependence of home heating and indoor air quality, and innovative utility business models for heat.

HC-Zero will offer PhD researchers high-quality research and training environments and excellent sectorial experience via place-based secondments with industry and public-sector bodies. Students will undertake whole-cohort training in areas such as ethics, stakeholder engagement, commercialisation and responsible research and innovation, and engage in interdisciplinary group challenge projects addressing complex partner-led assignments. The CDT will have support from a broad range of partners including SMEs, large engineering consultancies, energy companies, local authorities, regional and national government, and trade associations. Through a strong cohort approach, students will develop in-depth skills and expertise, as well as a shared understanding of real-world considerations of how to implement effective solutions in an evolving sector.

We are committed to delivering a demanding and engaging educational and training experience to a diverse cohort of students, responding to emerging sector needs while ensuring student inclusion. Equity will underpin all we do, from recruitment to training opportunities (e.g. alignment of project schedules and assessment with part-time and flexible study) and events (e.g. financial support for childcare). EDI is embedded in our team culture; the team includes academics from diverse backgrounds and individuals with non-traditional career paths and caring responsibilities.

Our graduates will deliver the UK's net zero transition in cities. They will support innovative SMEs, join engineering consultancies implementing large infrastructure projects, and become the visionary policy-makers shaping and developing new strategies in the civic sector. They will sustain and enrich the academic disciplines of engineering and energy whole-systems research with their strong educational background, diversity, and capability to show leadership in an ever-changing landscape.

EPSRC Centre for Doctoral Training in Quantum Technology Engineering

Dr Timothy Freegarde University of Southampton

Freegarde, Dr TGM,Motti, Dr S,Ledingham, Dr PM,TSUCHIYA, Dr Y,Fuentes, Professor I,Jiang, Professor L,Gates, Dr JC,Kuprov, Dr I,Carravetta, Dr M

Quantum technologies exploit the intriguing properties of matter and light that emerge when the randomizing processes of everyday situations are subdued. Particles then behave like waves and, like the photons in a laser beam, can be split and recombined to show interference, providing sensing mechanisms of exquisite sensitivity and clocks of exceptional accuracy. Quantum measurements affect the systems they measure, and guarantee communication security by destroying cryptographic keys as they are used. The entanglement of different atoms, photons or circuits allows massively powerful computation that promises complex optimizations, ultrafast database searches and elusive mathematical solutions. These quantum technologies, which EPSRC has declared one of its four Mission-Inspired priorities, promise in the near future to stand alongside electronics and laser optics as a major technological resource.

In this 'second quantum revolution', a burgeoning quantum technology industry is translating academic research and laboratory prototypes into practical devices. Our commercial partners - global corporations, government agencies, SMEs, start-ups, a recruitment agency and VC fund - have identified a consistent need for hundreds of doctoral graduates who combine deep understanding of quantum science with engineering competence, systems insight and a commercial head. With our partners' guidance, we have designed an exciting programme of taught modules to develop knowledge, skills and awareness beyond the provision of traditional science-focused PhD programmes.

While pursuing leading-edge research in quantum science and engineering, graduate students in the EPSRC CDT for Quantum Technology Engineering will follow a mix of lectures, practical assignments and team work, peer learning, workshops, and talks by our commercial partners. They will strengthen their scientific and engineering capabilities, develop their computing and practical workshop skills, study systems engineering and nanofabrication, project and risk management and a range of commercial topics, and receive professional coaching in communication and presentation. An industrial placement and extended study visit will give them experience of the commercial environment and global links in their chosen area, and they will have a funded opportunity to break their studies to explore the commercialization of research inventions. An SME Club will provide fresh, practical entrepreneurship advice, as well as a forum for start-up businesses to exchange experience and expertise.

The CDT will foster an atmosphere of team working and collaboration, with a variety of group exercises and projects and constant encouragement to learn from and about each other. Students will act as mentors to junior colleagues, and be encouraged to take an active interest in each other's research. They will benefit from the diversity of their peers' backgrounds, across not just academic disciplines but also career stages, with industry secondees and part-time students bringing rich experience and complementary expertise.

Students will draw upon the wealth of experience, across all corners of quantum technologies and their underpinning science and techniques, provided by Southampton's departments of Physics & Astronomy, Engineering, Electronics & Computer Science, Chemistry and its Optoelectronics Research Centre. They will be given training and opening credit for the Zepler Institute's nanofabrication facilities, and access to the inertial testing facilities of the Institute of Sound & Vibration research and the trials facilities of the National Oceanography Centre.

Our aim is that graduates of the CDT will possess not only a doctorate in the exciting field of quantum technology, but a wealth of knowledge, skills and awareness of the scientific, technical and commercial topics they will need in their future careers to propel quantum technologies to commercial success.

EPSRC Centre for Doctoral Training in Mathematics Applied to Challenges in Health and Medicine

Professor Amanda Turner University of Leeds

Turner, Professor AG,Frangi, Professor AF,Westhead, Professor DR,Lythe, Professor G,Barber, Dr S,Coleman, Dr S,Cutillo, Dr L,Mengoni, Dr M,Walwyn, Dr R

The recent pandemic highlighted the transformational impact of using powerful mathematical techniques in the medical sciences, from modelling the effect of interventions on virus spread, to evaluating treatments through clinical trials. Mathematics can play a major role in predicting and preparing for future health challenges, by harnessing the power of data, accelerating the development of health and medical innovations and the development and evaluation of precision medicine and individualised interventions. The vision for this CDT is to mitigate future health challenges by training a generation of mathematicians who understand the science underlying health and medicine. Students will acquire expertise in computational methods that combine modelling, simulation and data analysis, as well as the ability to establish the credibility of computer model predictions, which has thus far held back broader adoption of in silico approaches in health and medicine. Specifically, they will work towards developing the novel mathematics needed to progress the following three outcomes:

- Developing methodology for health data challenges;

- Using Mathematics to accelerate medical innovations;

- Medical, health and social care interventions tailored towards individual users.

This CDT will build a long-term collaborative relationship between the mathematical sciences and healthcare communities by ensuring a sustainable pipeline of researchers with a deep knowledge in applying mathematical modelling to health, a quantitative appreciation of the risks and uncertainties within these models, coupled with the ability to inform and educate health professionals. The vision for the CDT was conceived following a consultation with healthtec companies on barriers to successful innovation in digital health which identified a pressing need for researchers who understand the mathematical foundations underpinning algorithms. It will train 50 PhD students through an integrated MSc/PhD programme. In addition to subject based teaching, they will receive skills and professional training, and benefit from opportunities for peer-to-peer learning and stakeholder engagement with external partners. To encourage and enable recruitment from as diverse a pool as possible, strong students without a mathematics degree will be offered a one-month intensive conversion course. A summer research internship program will be available to enable potential applicants, particularly those from non-traditional backgrounds, to learn about what research entails.

The University of Leeds is uniquely placed to deliver this CDT, with extensive experience of running CDTs and world-leading capability in mathematics, medicine and data science. This CDT brings together the School of Mathematics, ranked top-10 for research power in REF2021, Leeds Institute of Clinical Trials Research (LICTR), one of the longest established clinical trials units in the UK and based within Europe's largest teaching hospital, and Leeds Institute for Data Analysis (LIDA), a core university partner of the Alan Turing Institute and hosts of a CDT in "AI for Medical Diagnosis and Care". The Leeds City Region represents the UK's largest economic area outside London and the South East with 22% of digital health technology jobs in the UK, including the headquarters of NHS England. This gives access to an extensive network of partners who will provide students with funding, data, training and placements, and will gain benefit through opportunities to work closely with experts from the University, build links with a cohort of bright, ambitious PhD students seeking subsequent employment, and influence training and skills development. This extensive breadth and depth means that Leeds has all the capability required to run this interdisciplinary CDT on a single site, which will hugely facilitate a sense of community and collaboration amongst the students.

EPSRC Centre for Doctoral Training in Microwave and Terahertz Technologies for a Connected and Sustainable Future (TESLA)

Professor Edward Wasige University of Glasgow

Wasige, Professor E,Norouzian, Dr F,Liu, Dr B,Delfanazari, Dr K,Li, Dr C,Wang, Dr Y,Gashinova, Professor M,Moran, Professor DAJ,Cumming, Professor DRS,Feresidis, Professor A

TOPIC: Higher frequency microwave bands, namely millimetre-wave and terahertz (THz) will enable very high capacity mobile or wireless communications and connectivity to meet the ever-increasing hunger for communication bandwidth, both at local level within an office or apartment, and at nodes within data centres and server farms; and high-resolution radar imagery for, for instance, autonomous driving which, in addition to wireless connectivity, requires vehicles to be situationally aware through high-resolution 3D images of the road ahead and of the surroundings; as well as sensing. Other new applications including virtual/augmented reality, digital twins, and holographic telepresence will be underpinned and enabled by new and advanced microwave and THz technologies that are the topic of this CDT.

CDT research will involve developing semiconductor and related technologies at the higher microwave frequency bands, where large bandwidths are available for communication and sensing. Individual research topics will cover semiconductor devices, integrated circuits and waveguide components and their integration, antennas, metamaterials, packaging, and demonstrator systems, with much of the design work underpinned by new AI (artificial intelligence) techniques. Students will address and invent new ways to exploit the larger spectrum available in the higher microwave frequency bands and generate novel integrated functionality for sensing, data processing and communication. In doing so, they will be trained in core skills such as device or component design, semiconductor manufacturing, micromachining, and in advanced characterisation and measurements.

NEED: The critical need for cohort training in the proposed CDT topic has been identified in discussions with a wide range of industry partners who face significant recruitment challenges. This is aptly captured in the recent report by Filtronic Broadband [https://filtronic.com/blogs_challenges-of-recruiting-rf-engineers/] and is echoed by regular calls for upskilling programmes on semiconductor manufacturing [https://iuk.ktn-uk.org/events/skills-education-manufacture-innovation-for-semiconductors/]. This is further evidenced by the significant support and funding of studentships for this CDT from the UK industry.

This CDT is therefore both timely and impactful and will help position the UK at the international forefront of high capacity wireless communication, and high-resolution radar and sensing technologies. It will help re-establish the UK's sovereign capability in advanced communication systems and in semiconductors as identified in the "Telecommunications (Security) Bill (2019-2021)" and "The semiconductor industry in the UK, 5th report of Session 2022-23, House of Commons", respectively.

APPROACH: A 1+3 programme where Year 1 will feature new MSc level modules on advanced measurement techniques, hands-on training on communication systems measurement and design tools, as well as AI techniques. It will also feature new team design mini-projects on microwave systems for communication, radar or sensing to engender system concepts and foster teamwork. These will be augmented by existing MSc modules on the technology theme at Glasgow and the communications/radar theme at Birmingham, and transferable skills training.

Years 2-4 will consist of a PhD project co-created with industry, hosted at one of the two universities with specialised whole cohort training and events covering communication, responsible innovation, entrepreneurship, co-innovation techniques and innovative outreach, as well as focused summer/winter schools designed to expose students to the latest developments in the field. Students will go on industry placements to experience design, manufacturing, and/or testing in the work environment. A few students may be fully based in industry (as dictated by the research project) and, in this case, will be awarded an EngD degree.

EPSRC Centre for Doctoral Training in Water Infrastructure and Resilience II (WIRe II)

Professor Peter Jarvis Cranfield University

Jarvis, Professor P,Coulon, Professor F,Walsh, Dr C,Amezaga, Dr JM,Birdi, Dr KS,Boxall, Professor J,Kilsby, Professor C,Alibardi, Dr L,Smith, Dr H,Shucksmith, Dr JD

The water sector is facing unprecedented challenges from the impacts of climate change, population growth, pollution discharges and increasing demand for limited resources. In response to these challenges, the EPSRC Centre for Doctoral Training in Water Infrastructure and Resilience II (WIRe II) aims to deliver collaborative discovery science and a cohort-led training programme, equipping graduates with the interdisciplinary skills and enthusiasm for innovation to elicit change and transformation to ensure a more water-secure world. The CDT is a collaboration between three leading universities in water research who host world-leading urban water experimental facilities: Cranfield University, the University of Sheffield and Newcastle University. We will enrol and train 60 PhD students in an inclusive environment underpinned by responsible research principles, fostering strong community connections within and across cohort groups. We have co-created the scope and ambitions for the WIRe II CDT with our end user partners from the water sector, which comprises the majority of the UK water companies, including the UK Water Industry Research group, consultancies, small and medium sized enterprises and the UK Collaboratorium for Research on Infrastructure and Cities (UKCRIC). With a critical mass of over 60 experts and strong international networks, we will develop the world-leading science and the people with the necessary interdisciplinary science and engineering skills to accelerate change and combat the challenges our water systems are facing. There is therefore an urgent need for transformative research to support the key civic priority of securing resilient and sustainable water resources and services, ensuring: 1) safe drinking water; 2) wastewater services that don't pollute the environment; 3) affordable and equitable water; and 4) the sector is net beneficial to the environment, while critical infrastructure is protected from the impacts of climate change. Our enriched training programme, developed in partnership with our end-users, will prepare graduates to be highly effective communicators and mindful practitioners of equality, diversity and inclusivity and responsible research and innovation. We will use the UKCRIC urban water facilities to deliver transformative experimental science and training that will advance the water sector's net-zero goals and mitigate against the effects of climate change on infrastructure and water resources. Our experimental science and training will be interdisciplinary and connected, spanning chemical and civil engineering, microbiology, hydrology, urban planning and social science. Through the UKCRIC Doctoral Skills Network, we will collaborate with other CDTs and access shared facilities, training, and dissemination opportunities. This will enable our students to work with other CDTs and gain exposure to a wider range of research and expertise.

EPSRC Centre for Doctoral Training in Compound Semiconductor Manufacturing

Professor Peter Smowton Cardiff University

Smowton, Professor PM,Elgaid, Professor K,Hou, Dr B,Boland, Dr JL,Beggs, Dr DM,Brasher, Mrs S,Ponnampalam, Dr L,Ng, Professor J,Liu, Professor H,Hopkinson, Professor M,Missous, Professor M

"Semiconductors" are synonymous with "Silicon Chips". After all Silicon supported computing technologies in the 20th century. But Silicon is reaching fundamental limits and already many of the technologies we now take for granted are only possible because of Compound Semiconductors (CS). These include The Internet, Smart Phones, GPS and Energy efficient LED lighting!

CSs are also at the heart of most of the new technologies expected in the next few years including 6G wireless, ultra-high speed optical fibre connectivity, LIDAR for autonomous vehicles, high voltage switching for electric vehicles, the IoT and high capacity data storage. CSs also offer huge opportunities for energy efficiency and net zero.

CSs are often made in small quantities and using bespoke techniques and manufacturers have had to put together functions by assembling discrete devices. But this is expensive and for many of the new applications scale-up and integration, along the lines of the Silicon Chip, are needed

CDT research will involve the science of large scale CS manufacturing, manufacturing integrated CS on Silicon and applying the manufacturing approaches of Silicon to CS; it will generate novel integrated functionality and all with a new emphasis on finding environmentally sustainable manufacturing methods.

CIVIC PRIORITY: This CDT is a fundamental part of the strategic development of the CS Cluster centred in South Wales, and in linking it to activity across the UK. It is part of a wider training strategy including apprenticeships, MScs and CPD, to train and upskill the entire workforce. The latest skills requirements have been identified by partner companies and through working with Welsh Government, Cardiff Capital Region City Deal and the CS Applications Catapult

The partners support the CDT financially and with their time. This is because the limiting factor to rapid cluster growth is skilled people. The expected PhD level jobs increase for the existing cluster companies alone would mop up all the students trained by this CDT. We provide a £2k stipend top-up to maximise recruitment from all backgrounds.

However, the CDT does more - clusters are about cross-fertilisation of people and ideas and the CDT combines academics from 4 universities with leading and complementary expertise in CS. We form teams of two academics from different universities, one industry supervisor and the PhD student to create and carry out each PhD. The CDT also ensures the whole cohort regularly works together to exchange new knowledge and ideas and maintain breadth for each student.

The UK and Welsh administrations see CS as an opportunity to boost the economy with high technology jobs and the UK government uses the CDT as part of its pitch to overseas companies to locate here.

APPROACH and OUTCOMES: a 1+3 program where Year 1 (Y1) is based in Cardiff, with provision via taught lectures and transferable skills training, hands on and in-depth practical training and workshops led by University and Industry Partner staff. Following requests from Y2-4 students the industry workshops are presented in hybrid format so all Y2-4 students can further benefit from this program and where we now cycle presenters, companies and specific topics over 3 years.

A dedicated nursery clean room allows rapid practical progress in a supportive environment, learning from doing, experts and the rest of the cohort and then an industry facing cleanroom, co-located with industry staff and manufacturing scale equipment, where students learn the future CS manufacturing skills. This maximises exchange of ideas, techniques and approach and the potential for exploitation. Both students and industry partners have praised the practical skills this produces.

Y2-Y4 consist of an in depth PhD project, co-created with industry and hosted at one of the 4 universities, and specialised whole cohort training and events, including energy audit, research ethics and innovative outreach

EPSRC Centre for Doctoral Training in Robotics and AI for Net Zero (RAINZ CDT)

Dr Simon Watson The University of Manchester

Watson, Dr SA,Flynn, Professor D,Hawes, Professor N,Dennis, Dr L,Herrmann, Professor G,Zhao, Dr G,Mohjazi, Dr L L,Maiolino, Professor P p,Fallon, Professor M,Sharmina, Dr M

The EPSRC Centre for Doctoral Training in Robotics and AI for Net Zero (RAINZ CDT) is a new CDT in Robotics and AI (RAI) which will train and develop, in both research and commercialization, the next generation of multi-disciplinary robotic systems engineers who will help revolutionise lifecycle asset management of critical infrastructure in support of the UKs Net Zero strategy. The focus will be on how RAI can be used for inspection, maintenance and repair (IMR) of new infrastructure in renewables (wind, solar, geothermal, tidal, hydrogen) and nuclear (fission and fusion), and to support the decarbonization of existing maintenance and decommissioning of legacy assets, expanding to include, but not limited to, the Oil & Gas, Aerospace, Transport and Utility sectors. It addresses the focus area "Meeting a user-need or supporting civic priorities". The fundamental and applied research being conducted through the CDT aligns with the cross-cutting priority "Engineering Net Zero".

The RAINZ CDT is a partnership between three of the UKs leading Universities and represents an unparalleled critical mass of complimentary end-to-end robotic systems research capabilities, facilities and sustainability expertise. It has been co-created with leading industrial partners in the Net Zero sector to address the national challenge that "advanced robotics requires highly skilled workers such as engineers, leading to a need to train new workers". New industrial partners will also be actively sought throughout the lifetime of the CDT.

RAI used in the energy sector are often deployed into complex, hazardous and high-value environments, but significant barriers, both technological and cultural, are limiting its estimated economic yield to £0.6B gross value added (GVA) by 2035 instead of a potential £23B GVA. Overcoming these barriers is a key focus of this CDT. In addition to addressing a vital national need, it will support local initiatives, such as the Botley West Solar Farm in Oxford. It will also support the levelling-up agenda across the three host cities, as well as in West Cumbria through the Robotics and AI Collaboration (RAICo) facility, which has been established to build an innovation pipeline for new RAI solutions in both the nuclear and other sectors.

The RAINZ CDT will adopt an innovative cohort training and research model to ensure graduates are not only subject matter experts, but have highly valuable skills in teamworking, multi-disciplinary systems integration, industrial engagement and commercialization. Each newly enrolled cohort will be recruited (with appropriate EDI considerations) to conduct research directed towards a different industry defined cross-cutting challenge which will change for each new cohort. The Year 1 challenge is "Autonomous Maintenance in Confined Spaces". Challenges in later years will be co-created with industry and could include areas such as "Long-Term Autonomous Inspections" or "Scalable Fleets of IMR Robots". PhD projects for each cohort will be co-created with industry to address gaps in enabling science and technologies for these challenges through both fundamental and applied research. Whilst RAINZ students will undertake their own individual research, it will be significantly enhanced through collaborations with others in the cohort. There will be annual research sprints where the cohort will come together to demonstrate elements of their research on industry defined demonstrator scenarios. The CDT will create an innovation pipeline that will produce high-quality, highly skilled and employable Robotic Systems Engineers with an aim that at least 50% - 75% of the graduates are employed in robotics industries. It has an ambition to have supported the creation of 5 spin-out companies and the submission of at least 5 Fellowship proposals.

EPSRC Centre for Doctoral Training in Inorganic Materials for Advanced Manufacturing (IMat)

Professor Simon Aldridge University of Oxford

Aldridge, Professor S,Williams, Professor CK,Grobert, Professor N,Vincent, Professor KA,Clarke, Professor SJ

Our CDT in Inorganic Materials for Advanced Manufacturing (IMat) will provide the knowledge, training and innovation in Inorganic Chemistry and Materials Science needed to power large-scale, high-growth, current and future manufacturing industries. Our cohort-centred programme will build the skills needed to understand, transform and discover better products and materials, and to tackle the practical challenges of manufacturing, application and recycling.

IMat CDT addresses the 'Meeting a user need' CDT focus area, while also addressing 3 EPSRC strategic priorities: 'Physical Sciences Powerhouse', 'Engineering Net Zero' and 'Quantum Technologies'.

'Inorganics' are essential to many industries, from fuel cells to electronics, from batteries to catalysts, from solar cells to medical imaging. These materials are made by technically skilful chemical transformations of elements from across the breadth of the Periodic Table: success is only achievable via in-depth understanding of their properties and dynamic behaviour, requiring systems-thinking across the boundaries of Chemistry and Materials Science. The sector is characterized by an unusually high demand for high-level (MSc/PhD) qualified employees. Moreover, wide-ranging synergies in manufacturing challenges for 'inorganics' mean significant added value is attached to interdisciplinary training in this area. For example, understanding ionic/electronic conductivity is relevant to thermo-electric materials, photo-voltaics, batteries and quantum technologies; replacing heavy metals with earth-abundant alternatives is relevant to chemical manufacturing from plastics to fragrances to speciality chemicals; and methods to manufacture starting from 'natural molecules' like water, oxygen, nitrogen and CO2 will impact nearly every sector of the chemical industry.

IMat will train graduates to navigate interconnected supply chains and meet industry technology/sustainability demands. To invent and propel future industries, graduates must have a clear understanding of scientific fundamentals and be able to quickly apply them to difficult, fast-changing challenges to ensure the UK's leadership in high-tech, high-growth industries. A wide breadth of technical competence is essential, given the sector dominance of small-to-medium enterprises employing <50 people. The 'inorganic' sector must also meet challenges associated with resource sustainability, manufacturing net zero, pollution minimization and recycling; our cohorts will be trained to think broadly, with awareness of environmental, societal, legal and economic factors. Our creative and highly skilled graduates will transform sectors as diverse as energy generation, storage, electronics, construction materials, consumer goods, sensing/detection and healthcare.

IMat builds upon the successful EPSRC 'inorganic synthesis' CDT (OxICFM) and (based on extensive end-user/partner feedback) expands its training portfolio to include materials science, physics, engineering, medicine and other areas needed to equip graduates to tackle advanced materials challenges. It addresses local, national and international skills gaps identified by our partners, who include companies spanning a wide range of business sizes/sectors, together with local enterprise partnerships and manufacturing catapults.

IMat offers a unique set of training goals in 'inorganic' chemistry and materials - a key discipline encompassing everything made which is not an organic molecule: from salts to composites, from acids/bases to ceramics, from organometallics to (bio)catalysts, from soft-matter to the toughest materials known, and from insulators to conductors. A unifying training spanning this breadth is made possible through the strength of expertise across Oxford Chemistry and Materials, and our national partner network. Our goal is to empower future graduates by equipping them with this critical knowledge ready to apply it to new manufacturing sector.

EPSRC Centre for Doctoral Training Superconductivity: Enabling Transformative Technologies

Professor Antony Carrington   University of Bristol

Carrington, Professor A,Speller, Professor S,Durrell, Professor JH,Coldea, Professor AI,Grosche, Professor FM,Hayden, Professor S

The aim of this CDT is to train students with the essential multidisciplinary skills needed to feed the growing needs of our UK superconductivity industry and develop the transformative technologies needed to engineer Net-Zero, improved healthcare, and quantum devices. The CDT brings together graduate superconductivity training in the Universities of Bristol, Oxford and Cambridge across their Physics, Material Science, Engineering and Chemistry departments. The CDT has partnerships with several major companies which use superconducting technology. The CDT will form a nucleus for the UK superconductivity community offering training and networking opportunities to those outside of the CDT.

Two fundamental properties of superconductors which drive applications are: i) their ability to transmit large electrical currents without energy loss, and ii) their macroscopic quantum properties. The first property enables technologies which underpin our transition to Net-Zero (EPSRC priority engineering net zero). Examples include generation of high magnetic fields for plasma confinement enabling nuclear fusion reactors, motors and generators enabling electrically powered aircraft, high efficiency generators for wind turbines, and low loss electrical power transmission. This property also facilitates an important contribution to healthcare, as superconducting magnets are an essential component of magnetic resonance imaging (MRI) systems. Development of improved superconducting materials will transform MRI both in terms of reduced cost and availability to less developed countries and the higher resolution enabled by higher magnetic field strengths which will in turn lead to enhanced diagnostic abilities. The second fundamental property of superconductors facilitates their use in quantum-devices, such as superconducting qubits used in quantum computers. In many cases, the unique properties of superconducting materials do not just provide a cost-effective alternative to existing technologies but fundamentally enable these technologies. For example, the high magnetic fields needed for small size Tokamak fusion reactors, which are being developed in the UK and world-wide, can only be provided by high temperature superconducting materials.

Our CDT will enable a step change in superconductivity training in the UK by providing our researchers of tomorrow with an education spanning fundamental science to applications. The cohort approach to our CDT training programme is critical to our vision and will allow students to benefit from each other's knowledge and insights, understanding and taking interest in problems outside of their specialism. For example, engineers who are using superconductors to make large scale machines and devices will understand the limits imposed by the fundamental science and be able to interact with the materials scientists who are optimising the materials. Students working on the fundamental science will gain a better understanding of the technological implications of their work and what is needed to improve the eventual applications. Our training programme includes lecture-based learning, extensive practical training in relevant techniques and experimental methods as well as real-world experience at implementing the knowledge gained within projects based at one of our many industrial and scientific facility partners.

CDT in Satellite Technologies for Non-Terrestrial Networks (SPACE)

Professor George Goussetis   Heriot-Watt University

Goussetis, Professor G,Donaldson, Dr R J,Worrall, Dr K,Imran, Professor MA,Sellathurai, Professor M

The explosive demand for e.g. mobile broadband connectivity, navigation and climate monitoring, has in the past ten years changed our daily use of space more than in the previous five decades. We are experiencing the dawn of a new space era marked by several thousand new satellites in low and middle Earth orbits driving new services at reduced costs. Satellites as small as 100 grams or less are now a reality and launches are now accessible with as low as £25,000 and below. Yet satellite systems remain largely siloed from the remaining terrestrial infrastructure; they require bespoke terminals, operate with distinct protocols and support dedicated services and markets.

The next milestone will be to fully integrate satellite networks as part of the global infrastructure to e.g.; receive satellite signal on handheld device in the absence of cellular signal with a seamless transition to terrestrial network when available; obtain real-time information on radio signals emitted on the Earth to optimise spectrum usage and regulation; offer robust options for position and navigation that will enable integration with terrestrial infrastructure in e.g. smart cities or autonomous driving; connect billions of IoT devices, particularly in remote areas, to the global infrastructure; image the Earth not only at optical and infrared but also exploiting the backscattering of GPS/GNSS signals.

For this evolution, individual satellites will not operate as a monolithic piece of infrastructure delivering a dedicated service, but instead as an orchestrated element of a multi-orbit network that delivers improved and new capabilities. For example, connectivity to handheld devices requires spaceborne antennas that are impractically large for a single satellite; future spaceborne antennas may be distributed across multiple satellites. Such distributed antennas will provide high resolution in spectral emission localisation or may operate as distributed receivers for backscattered GNSS signals. To optimise future spaceborne resources, satellites flying over areas of reduced interest (e.g. over oceans) may reconfigure their payloads to avoid idleness; future software defined payloads shall, for example, reconfigure between antenna processing over areas of interest on the Earth and elsewhere as nodes of a distributed edge processing system that reduces the bandwidth requirements to the ground. Constellations could eventually deploy spaceborne AI to become truly autonomous. Meanwhile protocols and waveforms will be shared with terrestrial networks.

For this vision to materialise, it is important that future space systems are designed in their entirety. For example, distributed antennas will need to be designed in light of the orbital control and orientation capability of the satellite bus. Energy consumption of each satellite should be adjusted to the demand for a given node and the available power; wireless power transmission may be used. Optical links are needed to provide very high-speed low-latency links between satellites and should be accommodated on small satellites with limited orbital control. The demands of digital and radio electronics should be considered in light of the heat dissipation; new device technologies, RF & active architectures and power efficient algorithms & waveforms should be co-developed with thermal management systems. Efficiency and miniaturisation calls for deployable multifunctional subsystems, e.g. solar panels that also act as antennas. "Fractionated satellites", whereby functions of a single monolithic platform are spread across a swarm of swarms may well provide cost efficient and easy to maintain solutions with capacity tailored to the current needs; Model Based System Engineering (MBSE) and digital twins for small satellites as very valuable platforms to design those systems.

SPACE will create the environment that will catalyse the co-development of solutions that will enable this vision to materialise.

EPSRC Centre for Doctoral Training in Sanitation and Water Services in a Net Zero Future (SWANZ)

Professor Barbara Evans University of Leeds

Evans, Professor BE,Tyrrel, Professor S,Parker, Professor D,Wilby, Professor RL,Bartram, Professor J,Scott, Ms R,Hutchings, Dr P,Parker, Dr A,Mckay, Mr J

Cities around the world are rapidly developing; by 2050 70% of the global population will be urban, and significant investments in sanitation and water services are required to meet their needs. Addressing the climate crisis requires a rapid transition to net zero carbon for cities as a whole and for sanitation and water services in particular. Ground-breaking new research has indicated that in addition to greenhouse gas emissions from transport, agriculture and buildings, those from sanitation and water services are globally significant (accounting for nearly half of emissions in many cities) and thus need to be addressed as an urgent priority.

Trillion dollar investments in sanitation and water services in cities must be made in order to deliver on the Human Right to Water and Sanitation (WHO-UNICEF, 2022). The marginal additional costs of ensuring that these investments are net zero is relatively small, and therefore represents good value for money compared to decarbonisation routes which require significant behaviour change (e.g. eliminating beef consumption) or are highly politicised (e.g. reducing fossil fuel use).

However, research in this area is so new that the challenge is neither well-known nor a priority for most industries, including water utilities. Industrial partners tell us of an urgent need for a cohort of highly-skilled researchers with the ability to work both across disciplines and at the interface between academia and industry, to effect fundamental changes to approaches to innovation in the sector. To create this cohort, we propose a Centre for Doctoral Training in Sanitation and Water Services for a Net Zero Future (SWANZ), involving three universities - Leeds, Loughborough and Cranfield. This builds on a successful existing partnership via the current Water-WISER CDT (EP/S022066/1) which has been instrumental in the initial scoping of research in net zero for sanitation and water. Much further specific and detailed research is required, and this will be the focus of SWANZ.

In addition, flagship research by students in the Water-WISER CDT has shown that the workforce and leadership in the sanitation and water services sector lack diversity and that structural inequality persists, hampering innovation. The Water-WISER CDT has one of the most diverse student bodies amongst its peers and has been highly commended by EPSRC, thus we have a strong track record to build on to create the diversity of lived experience, perspectives and skills that we regard as essential for the sector.

SWANZ CDT graduates will combine a solid grounding in fundamental water, waste and sanitation engineering and science with a broader training and development programme focused on climate and the net zero transition. They will develop the skills needed to collaborate with sociologists and political scientists, and with professionals in city planning, digital design, business development, health, international development and finance to address the climate crisis.

Students will study at one of the three Universities but be embedded in a vibrant cross-University CDT cohort, with regular opportunities for networking and joint training. To prepare and support them in developing a challenging PhD project, they will undertake a rigorous formal assessed training programme of MSc-level modules, cross-CDT Research Skills training (including Responsible Research & Innovation), and a portfolio of cohort-building activities focusing on successful peer-to-peer learning, creativity, leadership and engagement with end-users. This programme will be co-created in partnership with end-users such as water utilities, government bodies, and development agencies such as the World Bank, UNICEF or WaterAid.

Innovations in SWANZ will open opportunities for the creation of new industries and jobs through innovative manufacturing businesses, new sanitation and water technologies and associated systems for energy and food production through reuse.

EPSRC Centre for Doctoral Training in Diverse Data Visualization (DIVERSE)

Professor Jason Dykes City, University of London

Dykes, Professor JA,Cohen, Dr RL,Wilson, Professor S,Begum, Dr M,Gibbs, Mr I,McInerny, Dr GJ,Turkay, Professor C,Wood, Professor JD,Jones, Dr SV

Visualizations of data can present information in ways that amaze, engage and inform users. However, there is a need for diverse approaches to enable human-centred visualization to more fully unlock the potential of data and this is the focus of the DIVERSE-CDT.

The Centre for Doctoral Training in Diverse Data Visualization (DIVERSE-CDT) offers an ambitious and innovative programme that will deliver cohort-based training to 60 PhD students to become critical, multidisciplinary leaders at the forefront of data visualization research and will tackle key barriers to doctoral education for under-represented groups.

DIVERSE-CDT responds to three needs. First, research in data visualization needs new, diverse approaches that will enable people to perceive and interact with data to address complex scientific, societal and industrial problems and it needs approaches that cut across domains such as healthcare, financial and the environment. Second, students from ethnic minorities and students who identify as female are under-represented in doctoral education and this is a concern given the need for diversity in data visualization. Third, the UK does not have sufficient capacity to respond to the demand for data visualization skills in the workforce.

We address these needs through three important innovations:

1. Enriching and inclusive processes for recruitment, training, and research environment.

2. A new structure for the PhD programme where students progressively create and reflect upon a series of artifacts that will form the basis for examination.

3. Cohort-based training and collaborative work.

We offer a four year doctoral training programme with a significant internship component and we replace the traditional linear thesis with digital visualization "notebooks". These structured digital documents contain narrative text, graphics, and computational elements that allow analysis to be performed, documented and discussed. Students will use these documents to progressively capture and reflect on their research.

Students will follow an MRes programme in year 1. This will cover core topics in data visualization, specialist topics delivered in elective modules, a research project and an innovative Visualization Design Labs module where students will address real-world data visualization problems. PhD research in years 2-4 will be structured as two 1-year phases of research and reflection, followed by a final year of synthesis. The research and reflection phases will be grounded in internships where students will identify challenging research topics in collaboration with academic and industrial partners.

The training programme will equip students with a unique blend of interdisciplinary skills. A rounded programme of complementary training across the 4 years will provide them with wider research and professional skills based on regular needs analysis, e.g. training in responsible innovation, EDI, entrepreneurship and other topics from the comprehensive doctoral researcher development programmes at City and Warwick.

We will develop communities of practice across and between cohorts through activities including an annual inter-cohort 'Data Challenge', 1-day retreats and an annual residential reflection retreat. Partners will provide industry mentors and we will host a series of engagements with EDI role models. Students will actively contribute to a vibrant and inclusive research environment through co-creation and roles in delivery of these activities. DIVERSE-CDT also has an exciting international perspective. We are collaborating with international research labs and all students will have the opportunity for a research visit to enhance the doctoral experience.

EPSRC Centre for Doctoral Training in High-Efficiency Next-Generation Photovoltaics

Professor S Silva University of Surrey

Silva, Professor SRP,Lidzey, Professor D,Herz, Professor LM,Haque, Professor SA,Stranks, Professor SD,Zhang, Dr W,Cameron, Professor PJ,Snaith, Professor HJ,Dunbar, Dr ADF,Walker, Professor AB

A more secure, resilient and sustainable energy future is the prerequisite for the development of a modern, thriving and dynamic nation. The impact of Covid-19 pandemic on the global supply chain in conjugation with the recent sharp increase in energy prices have sparked rising discussion on the role of renewables in improving energy security and sovereignty by replacing fossil fuels. To meet Net Zero Target by 2050, the UK government has set out policies for decarbonising all sectors of the UK economy. Globally, Solar PV and wind power continued to dominate new renewable energy investment, with solar PV accounting for 56% of the 2021 total and wind power for 40%. The UK has set a target of a 5-fold increase in the current solar electricity capacity by 2035 (up to 70GW), which offers at least 10,000 new jobs in the associated industry. Despite UK's leading role in PV research, its global presence in PV industry pales into insignificance (beyond top 10 countries). In the meantime, supply chain disruptions in late 2021 also highlight the importance of domestic production of PV modules: US and Europe have reinitiated PV manufacturing, and the UK can't be left behind. To secure the leading position of the UK in PV research and supply chain, a coordinated and focused training programme to incubate emerging leaders in a fast moving and uncertain future PV landscape, is in urgent demand.

The aim of this CDT is to provide necessary training to develop highly skilled scientists and engineers, capable both of leading development and of contributing growth in a variety of aspects of high-efficiency next-generation PV technologies. The emerging PV materials (halide perovskites, chalcogenide perovskites, etc.) have a great potential to complement and extend Si materials, because they are made from earth-abundant materials and processed by simple techniques, which have already demonstrated 25% boost in device efficiency over the crystalline Si cells without considerable increase in cost, thus representing a disruptive technology for the future renewable energy market. UK research institutions have a strong track record in the development of next-generation photovoltaics and there are companies seeking to significantly grow this area. This CDT brings together leading academic teams in the solar PV area in the UK (Surrey, Sheffield, Oxford, Bath, Cambridge, Imperial College London) and encompasses all the disciplines relevant to PV, including materials physics, solution chemistry, device engineering and modelling, design, synthesis and processing, scale up, as well as relevant industrial experience. Our graduates will service the UK's growing solar energy industry with potential change in PV face in Europe/US in coming decade.

We will create a doctoral training environment in which students benefit from leading academic expertise and world-class facilities to develop their knowledge as well as the tools to innovate and create within their selected research theme. The training programme will comprise a) comprehensive training in specific fundamentals and skills for PV (year 1);

b) training and participation in challenging, collaborative and industry-led research projects (year 2-4);

c) transferrable skills for research and collaboration, and accredited qualifications in intellectual property, entrepreneurship and management (all years).

We emphasise that the Equality, Diversity and Inclusion will be embedded in the PhD recruitment and management process. Our cohort of students will have the opportunities to gain an exposure to a wide range of skills in a variety of environments to enable a smooth transition from the doctoral training to leadership roles.

EPSRC Centre for Doctoral Training in Future Open SecuRe NeTworks (CDT in FORT)

Professor Rahim Tafazolli   University of Surrey

Tafazolli, Professor R,Schneider, Professor SA,O'Neill, Professor M

In the coming years, our communication systems are set to become even more advanced with the development of 6G and beyond. These systems are expected to be open, secure, and resilient, while combining various networks to help bridge the digital divide. They will also contribute towards the UK's goals of diversifying its 5G supply chain and promoting environmental sustainability.

The 2022 National Cyber Strategy outlines the need to 'ensure ... the next generation of connected technologies are designed, developed and deployed with security and resilience in mind and as part of a concerted effort to embrace a 'secure by design' approach'. Future networks will underpin Critical National Infrastructure in various sectors as they go through digital transformation, gradually becoming a Network of Networks (NoN) that integrates space and terrestrial networks that, in addition to mobile broadband, will deliver sensing, timing and positioning information. Due to the unprecedented complexity of NoN, new solutions that take advantage of AI/machine learning (ML) solutions are needed. Currently, there are insufficient people with the skills and experience to address these challenges.

Alongside the demand for these skills from our industry partners, the Huawei Cyber Security Evaluation Centre (HCSEC) provides security evaluation to the UK government for a range of products used in the UK telecommunications market and in their most recent report (2021), NCSC stated that it is critical that HCSEC recruit appropriate technical cyber security specialists and with demand outstripping supply, they were likely to see hiring challenges. The £80M DSIT-funded UK Telecoms Lab (UKTL) recently established to boost the security, resilience and performance of the UK's telecommunication networks, will also be looking to the FORT CDT to help address its recruitment pipeline. Given the numbers of people required, cohort training is particularly beneficial in this context. As well as being the most efficient way to upskill a significant number of individuals simultaneously, it offers opportunities for team-working and peer-to-peer learning. Further, it creates a network of professionals that will persist when the individuals graduate.

The FORT CDT will create a community of industry-conscious thinkers and leaders with a unique range of expertise across wireless communications, cybersecurity, networking and AI. Graduates from the Centre will be capable of thinking about the complex challenges involved in delivering future open, secure and resilient communications systems and leading innovations to address those challenges, ensuring that the networks are secure by design. To deliver this vision, partners with key strengths in hardware security, cyber security and wireless communications are needed. Hence, FORT will be jointly hosted by the University of Surrey and Queen's University Belfast (QUB) and will bring together the 5/6G Innovation Centre (5/6GIC) at Surrey (a UKRI World Class Lab), the Surrey Centre for Cyber Security (SCCS) and QUB's Centre for Secure Information Technologies (CSIT) (both NCSC-accredited Academic Centres of Excellence in Cyber Security Research).

EPSRC Centre for Doctoral Training in Modelling, Uncertainty Quantification and Decision Support for Real-World Complexity

Dr Sarah Heaps Durham University

Heaps, Dr S E,Willcocks, Dr CG,Caiado, Dr CC,Shum, Dr H,Gosling, Professor J,Bencomo, Dr N,Cristea, Professor AI,Wilkinson, Professor DJ

Important decisions are typically based upon mathematical and computational models. News briefings during the COVID-19 pandemic brought into living rooms evidence of the critical role played by epidemiological models on public health decisions. Meanwhile, digital twins of cities are created to enable policymakers and business leaders to plan transportation, reduce emissions and experiment with urban planning. The computational models at the heart of such examples in areas like engineering, health and physics are necessarily complex. However, they can only provide an approximate and uncertain reflection of the real world: their use in supporting robust decision-making relies on identification and quantification of the uncertainty in the models as well as the data used to calibrate them. This demands a synthesis of disciplines like statistics, model development, numerical analysis and scalable computing technologies. There is a severe data skills gap in the UK workforce with a recent policy paper estimating that 178,000 hard-data roles needed to be filled. These problems are magnified in careers that demand inter-disciplinary training with research suggesting industry is struggling to recruit specialists to meet the demand for digital twin technologies. A CDT in Modelling, Uncertainty Quantification and Decision Support is essential as a step towards filling this shortage. As a pioneering and globally recognised institution for uncertainty analysis of computer models, Durham University is well-placed to host this centre.

Many surveys highlight the sharp rise in the number of students experiencing mental health problems over the course of the pandemic, with 81% of students now affected by such difficulties, compared with 60% in 2021. It is more vital than ever that universities create an environment that fosters student wellbeing. As a single-centre host, we will utilise Durham's unique college system with students within a cohort guaranteed an offer of accommodation in the same college. In turn, this will provide students opportunities to work and socialise together outside the classroom and take part in college and community outreach projects. Community-building will be further enhanced by team-building activities, including an annual residential retreat with training to support mental health and cross-CDT training during Durham's mini-MBA summer schools.

Our vision is to create a single-host multidisciplinary centre that: (i) brings together students from the mathematical and computer sciences to learn the skills needed for robust decision-making under uncertainty across various domains of application; (ii) facilitates student wellbeing by placing the development of peer support networks at its core.

Recruiting students primarily from the mathematical and computer sciences, the training will capitalise on Durham's existing provision of interdisciplinary programmes and established connections with industrial and public sector partners who will help shape the curriculum. Depending on background, students will be introduced to foundational topics in statistics or computer science. They will come back together for core modules in advanced statistics and machine learning, introducing them to the pre-requisites for a new module: "Uncertainty Quantification". Emphasising the importance of domain understanding, students will also be introduced to applications of uncertainty quantification from areas such as engineering, earth sciences and biology in an "Applications Taster" module delivered by domain experts. The students will take part in a 2-week industrial internship at the end of Year 1 working in groups to address a problem introduced during the internship and presenting back to industry at a showcase event. Formal training will continue in Years 2 and 3, with a mini-MBA coordinated by the Durham Business School, comprising two 2-week summer schools that cover entrepreneurship, responsible research and commercialisation.

EPSRC Centre for Doctoral Training in Resilient Net Zero (RESNET0)

Dr Frances Wood The University of Manchester

Wood, Dr FR,Ford, Dr AC,McLachlan, Professor CE,Dawson, Professor RJ,Mander, Dr SL,Blenkinsop, Dr S,Nicholls, Professor RJ,Minns, Mr A,Jenkins, Dr K,Parkes, Dr B

The EPSRC Centre for Doctoral Training in Resilient Net Zero (RESNET0) will provide the next generation of technical experts and leaders that are essential for the UK to deliver a successful transition to net zero that is resilient to climate change. The delivery of net zero by 2050 is a key government commitment. During this timeframe the climate will change and continue to do so over the course of the century. The delivery of net zero requires transformational change in the way energy, transport and material resources are provided. The infrastructure and changes to the built environment required to deliver net zero have a normal design life of at least 50 years and will be operating in a different climate to today's by the 2070s. The level of climate change will depend on global efforts to reach net zero - which is difficult to predict. Net Zero changes must therefore be built with alternate climate futures in mind. Increases in extreme weather events associated with climate change threaten the reliability of critical infrastructure and the acceptability of net zero measures such as passive cooling and active travel. The electrification of energy services, increased use of smart control and wider interdependencies between networked systems introduces new vulnerabilities in the event of power and ICT outages together with risks of cascading failures. Although there is an increasing awareness of flood risks, other climate impacts and sequences of weather events (e.g. drought followed by heavy rain) are often not considered when designing net zero actions. This could undermine the success of net zero, for example through failure of critical technologies (power cuts), mal-adaptation (e.g. installation of mechanical ventilation, or carbon intensive flood defence systems), or limit behavioural changes (e.g. avoidance of public transport during heatwaves, or active travel due to surface water flooding). Adaptation and resilience measures must be integrated into the net zero transition to avoid undermining its success and creating costly failures.

The available UK skills base to address integrating adaptation into net zero planning is limited. RESNET0 will train engineers and physical scientists in climate science, mitigation, climate data analysis and impact assessment to enable them to analyse a range of present and potential climate-related problems and design appropriate net zero solutions that are resilient to climate impacts. It will bring together the 22 year experience of the Tyndall Centre for Climate Change Research partnership, integrating the respective strengths of the partner universities: at Manchester on net zero; Newcastle on climate impact assessment and East Anglia on climate science to provide world-leading training and research opportunities. We will work with our partner organisations to provide high quality, co-developed and co-delivered transdisciplinary training, supervision, and coaching. The CDT is designed to create a supportive and positive environment for our Post Graduate Researchers (PGRs) to thrive, fulfil their academic potential and develop the skills needed for effective science-based leadership.

The key outcomes of the CDT will be:

- A large (50+) cohort of high-calibre engineering and physical science graduates with the skills, experience and cross-sectoral understanding to lead and deliver transformative change to a resilient net zero future for the UK and the world.

- A thriving and diverse PGR community and associated graduates who are academically engaged and stretched to achieve their full potential.

- Development of methods that embed climate adaptation and resilience needs within the net zero transition to satisfy national and international needs.

-New innovative solutions to the challenges of delivering resilient net zero in the real changing world, co-produced with our industry, policy and third sector partners.

Net Zero Chemicals

Professor Eileen Yu   Loughborough University

Yu, Professor EH,Wagner, Dr J L,Kovacs, Dr K,Pinfield, Professor V,Cowan, Professor AJ,Cai, Dr Q,Zimmermann, Dr A,Buckley, Dr BR,Sadhukhan, Professor J,Winzer, Dr K,Carnell, Dr A

The UK's £63b chemical manufacturing sector contributes £18b GVA (gross value added) to the UK economy, employs over 150,000 people directly (2019 figures) and exports £54b-worth of goods (2021). However, the sector is the largest energy user and produces ~15% of the UK's industrial emissions. The UK has committed to net zero carbon by 2050 and therefore new innovative processes and working practices are urgently required for this critical sector to move away from its conventional fossil fuel feedstocks and petrochemical products produced by energy-intensive, carbon-emitting processes. A Net zero Chemicals vision relies on the transition of 1) feedstocks from petrochemicals to sustainable sources and repurposing waste with circular approaches, 2) energy consumption from fossil fuels to renewable energy, 3) processes from a linear economy to circular economy to minimise environmental impact. A successful transition requires the development of innovative technologies (green chemical processes, biotechnology, carbon capture and utilisation and novel materials, and digitalisation), non-technical social economic enablers (policy, business, finance) and next generation professionals and talents who can innovate and lead the transition. To meet UK's 2050 Net zero target, 300k jobs requiring "green skills" are anticipated by 2050 in all industry sectors.

The proposed CDT for Net Zero Chemicals consists: Loughborough University (the lead), University of Nottingham, University of Liverpool and University of Surrey, capitalises on the world-leading expertise in the UKRI Interdisciplinary Centre for Circular Chemical Economy. The CDT will provide training to equip a new generation of scientists and engineers with the multidisciplinary expertise that is needed to lead the transformation of the chemical sector to net zero and deliver environmentally sustainable manufacturing. The interdisciplinary nature of the CDT has been co-created with industry sector partners. Our students will not only develop cutting edge technologies, but a multidisciplinary skillset and a deep appreciation of the whole systems approaches and the policy and business environment to ensure discoveries have a commercial and societal impact at scale. The cohort approach of the CDT allows ideas from fundamental feasibility studies to reach to real world applications with industrial partners, with relevant techno-economic analysis and influence on business strategy and policy, exposing our cohort to the extensive range of net zero challenges faced in the chemical sector. Students will undergo broad multidisciplinary training across the three core research strands technologies, digitalisation and whole systems approaches, socio-economic non technical enablers, as well as professional skill development. In addition, they will undergo deep training in their particular research specialism. Appreciating the importance of digital futures, we ensure that every student develops a thorough level of knowledge and skills in digital technologies. A distinctive feature of our centre is the embedding of skills in commercial awareness, enterprise and entrepreneurship to enable future leaders in the technological business world to support the net zero transition.

Our holistic interdisciplinary cohort training and cutting edge research has been co-created with key stakeholders to ensure our centre delivers 65 the highly skilled doctoral graduates required to enable and lead the technological, digital and politico-socio-economic changes to drive the chemical sector to net zero.

A Strategic Advisory Board will be established to inform the CDT Management team on the strategic direction of the CDT, reviewing the training programme and monitoring progress against project objectives. We will invite Project partners, leading academics, industrial sector leaders, EPSRC and regional development agencies.

EPSRC Centre for Doctoral Training in Transformative Integration for Engineered Systems (TIES)

Professor Adrian Murphy   Queen's University of Belfast

Murphy, Professor A,Mahon, Mrs L L,Schwingshackl, Dr C,Eakins, Dr D,Bennett, Dr C J,Robinson, Professor TT,Cotton, Professor S,Eastwick, Professor CN,Bowman, Professor R,Sorel, Professor M

A sustainable, resilient, & prosperous future requires complex systems, designed & manufactured in the UK in a new way, where users & operators continue to see improved functionality, performance, & reliability, while at the same time, our planet sees an overall reduction in the carbon released & the virgin resources used. This is true for all complex engineered systems, from mass data storage & mass connectivity through to mass transport. The greatest opportunities & challenges are aligned with systems which have predicted & demonstrated long term growth, which society needs to be cheap, ultra-reliable & fast, but today are energy intensive & reliant on fossil fuels. Key examples for the UK are aviation, data storage & communications (which are core parts of today's ICT sector). For example, driven by an insatiable desire for ubiquitous access to data, our telecommunications infrastructure, associated data centres & the number of network users are growing exponentially. In fact, the ICT sector is now responsible for 3 to 4% of global CO2 & if left unaddressed, emissions are expected to reach 14% of global CO2 emissions by 2040. In 2021 aviation accounted for over 2% of global energy-related CO2 emissions and is one of the fastest-growing sources of emissions. Aviation is an essential pillar of transport, enabling social connections, facilitating access to goods & services, including trade, jobs, health care & education, but is recognised to be the most challenging form of transport to decarbonize. Especially for the UK, air transport which is efficient, rapid, creates interconnectivity & is accessible by all is necessary to enable shared prosperity, but also as an island nation aviation provides our connections with most other countries. While these sectors are diverse, they face the same challenges in designing for the future.

For aviation, data-storage and telecommunications there is a need for a new talent pipeline of technical leaders who are capable of enhancing our fundamental understanding of industrially relevant problems, and capable of producing new understanding, tools & technologies that are the foundation of future commercial solutions. These future solutions will be intrinsically linked by the technology used, which share many common cross-cutting research challenges, dictated by the coupled physics at the heart of their operation. Therefore, there is a transformational need for doctoral scientists & engineers who are transformative thinkers, capable of leading cross- & interdisciplinary teams & projects, who are able to work with & across industry sectors, & who can foster new innovative approaches, deliver innovations & business capabilities which will deliver a better world.

This new centre will build on the proven 'anchor-tenant' model of a current CDT by expanding to include two global multinationals, allowing more cross & multi-disciplinary training, & a more diverse cross-section of the UK manufacturing supply chain to engage & benefit. Training will be cross & multi-disciplinary, but will be collaborative, cross-geographic, outward facing, with a tailored mix of instructor-led, placements, group projects, peer-to-peer learning opportunities, delivered or enabled by industrial & academia, exposing students to new disciplines, skills & tools across different organisation scales. The centre brings together previous large consolidated partners, with significant EPSRC investments, & together we have co-created a unique training environment, with world leading companies with a mass of intellectual property & knowhow and facing significant technology challenges, a cohort of academic excellence with state of the art research & research facilities, supported by institutions willing to invest in this vision.

EPSRC Centre for Doctoral Training in AI for Creativity & Creativity for AI (AICCAI)

Professor Ricardo Climent The University of Manchester

Climent, Professor R,Jay, Professor CE,Bilbao, Professor SD,De Roure, Professor D,Elliot, Professor MJ,Kingston, Professor RP,Salem, Dr O,Freitas, Dr A,Allmendinger, Professor R,Arvanitis, Dr K

This Centre for Doctoral Training will bring together Scientists and Humanities academic experts to train students on the fundamentals of science and engineering behind artificial intelligence (AI) and data-driven technologies and their applications on human society, arts and culture. What would it mean for a heritage organisation to introduce AI in their collections and processes? What if the success of a film could be predicted by an AI? Can orchestras expand their goals and digital ambitions through AI?

From online shopping, to healthcare, to food delivery, these are all examples of every-day services driven by artificial intelligence trained to deal with large amount of information faster and more efficiently than humans. The democratisation of AI technology and its positive impact across a broad range of industries has also impacted the arts and cultural sector. Museums can invite visitors to draw portraits in the style of Van Gogh, and concert producers can bring Frank Sinatra's voice back to stage, as AI can now mimic the voice of singers from a bygone era. In turn, creative research has also informed AI research, for instance, translating AI code into sound has been used by scientists to better understand how machines deal with information and 'think', hence supporting the development of more efficient AI algorithms.

Despite these inspiring innovations, AI is also generating agitated academic and public debate across generations, demanding an increase in public trust on AI technology.

As a result, it is becoming increasingly important to train people to make best use of existing AI technologies which can bring together the best of humans and machines. These new generation of students will be the ones reinventing the way people interact with services and with each other, and how AI is ethically used.

To train an AI model requires vast amounts of data, and the quality of such data will determine how effective it is in achieving given targets. Humans programme AI models to extract certain features from this data and classify them for a specific measurable goal. However, some advanced levels of AI may not even require human intervention to extract and classify features. What are the implications of machines that can think for themselves? Potential biases in decision-making and not seeing the human in-the-loop have raised important ethical questions that need to be addressed.

How the programme works? This is a 4 PhD programme where in year 1, students acquire advanced skills that will increase their preparedness for the following three years of research. The training in year 1 will include three components:

- Programming skills for AI: machine learning and data analytics, generative and natural language models.

- Research methods: ethical and responsible innovation, industry placement methods and inclusivity.

- Free choice course in the humanities or sciences from a pool of 50 courses. For example: music and media, business strategies for the arts, text mining, digital media crafting and urban planning.

Students will also undertake a year-long CDT project to develop a real case study of an AI with specific applications in the Humanities. This may include 3-week placement with industrial partners from the creative industries and public organisations.

During the 3-year research period, students will focus on laboratory work supported by custom research methods training, PhD supervision sessions and biannual progress review panels. Every student will also receive a personal development plan to meet their needs. Students will help organise a seminar series across the 4 years, yearly symposia and a AI & Creativity Summer school at which invited speakers from industry and academia will provide ongoing feedback. As a cohort, students will meet regularly to attend further training workshops, events and socials.

On completion of their PhD, students will be highly employable experts in Creative AI.

EPSRC Centre for Doctoral Training in Net Zero Aviation

Dr Panagiotis Laskaridis Cranfield University

Laskaridis, Dr P,Norman, Dr P,Lawson, Dr CP,Mobbs, Professor S,Featherston, Professor C,Burt, Professor GM,Navaratne, Dr R,Xie, Professor Y,Cipcigan, Professor LM,Wijayantha-Kahagala-Gamage, Professor U,Gratton, Dr GB

The EPSRC CDT in Net Zero Aviation in partnership with Industry will collaboratively train the innovators and researchers needed to find the novel, disruptive solutions to decarbonise aviation and deliver the UK's Jet Zero and ATI's Destination Zero strategies. The CDT will also establish the UK as an international hub for technology, innovation and education for Net Zero Aviation, attracting foreign and domestic investment as well as strengthening the position of existing UK companies.

The CDT in Net Zero Aviation is fully aligned with and will directly contribute to EPSRC's "Frontiers in Engineering and Technology" and "Engineering Net Zero" priority areas. The resulting skills, knowledge, methods and tools will be decisive in selecting, integrating, evaluating, maturing and de-risking the technologies required to decarbonise aviation. A systems engineering approach will be developed and delivered in close collaboration with industry to successfully integrate theoretical, computational and experimental methods while forging cross theme collaborations that combine science, technology and engineering solutions with environmental and socio-economic aspects. Decarbonising aviation can bring major opportunities for new business models and services that also requires a new policy and legislative frameworks. A tailored, aviation focused training programme addressing commercialisation and route to market for the Net Zero technologies, operations and infrastructure will be delivered increasing transport and employment sustainability and accessibility while improving transport connectivity and resilience.

Over the next decade innovative solutions are needed to tackle the decarbonisation challenges. This can be only achieved by training doctoral Innovation and Research Leaders in Net Zero Aviation, able to grasp the technology from scientific fundamentals through to applied engineering while understanding the associated science, economics and social factors as well as aviation's unique operational realities, business practices and needs. Capturing the interdependencies and interactions of these disciplines a transdisciplinary programme is offered.

These ambitious targets can only be realised through a cohort-based approach and a consortium involving the most suitable partners. Under the guidance of the consortium's leadership team, students will develop the required ethos and skills to bridge traditional disciplinary boundaries and provide innovative and collaborative solutions. Peer to peer learning and exposure to an appropriate mix of disciplines and specialities will provide the opportunity for individuals and interdisciplinary teams to collaborate with each other and ensure that the graduates of the CDT will be able to continually explore and further develop opportunities within, as well as outside, their selected area of research. Societal aspects that include public engagement, awareness, acceptance and influencing consumer behaviour will be at the heart of the training, research and outreach activities of the CDT. Integration of such multidisciplinary topics requires long term thinking and awareness of "global" issues that go beyond discipline and application specific solutions. As such the following transdisciplinary Training and Research Themes will be covered:

1. Aviation Zero emission technologies: sustainable aviation fuels, hydrogen and electrification
2. Ultra-efficient future aircraft, propulsion systems, aerodynamic and structural synergies
3. Aerospace materials & manufacturing, circular economy and sustainable life cycle
4. Green Aviation Operations and Infrastructure
5. Cross cutting disciplines: Commercialisation, Social, Economic and Environmental aspects

75 students across the UK, from diverse backgrounds and communities will be recruited.

EPSRC Centre for Doctoral Training in Next Generation Rehabilitation Technologies

Professor Ruth Goodridge University of Nottingham

Goodridge, Professor R,Logan, Professor PA,Roach, Dr P,Morgan, Prof. S,Bibb, Professor R,Lewis, Professor M,Caleb-Solly, Professor P,Booth, Dr V,CAPEL, Dr A,Clark, Professor D

THE NEED FOR REHABILITATION: Advances in medicine have increased both life expectancy (ageing population) and survival rates from trauma and disease. However, this has led to significantly increased rehabilitation demand, involving patients with complex conditions and co-morbidities. Currently in the UK, ~34% of people are living with a condition that requires rehabilitation, with ~15m suffering from a chronic condition. In diverse and vulnerable populations, the requirement for rehabilitation is often greater, for example over half of older people (>50) have multi-morbidities. Rehabilitation is commonly associated with traumatic injury, but it is much wider than this, covering a broad range of physical and mental health conditions (e.g., cancer, addiction, respiratory disorders, anxiety, heart conditions, depression, stroke).

THE NEED FOR ADVANCED TECHNOLOGY & SPECIALIST SKILLS: Technology has an increasingly vital role in rehabilitation: to support a limited number of skilled healthcare professionals; prevent hospital admissions (and re-admissions); speed up discharge from primary, secondary and social care services; improve engagement with rehabilitation programmes; increase independence and improve outcomes. Virtual reality-based therapies, rehabilitation robotics, wearable sensors, interactive media applications and direct neural control of prostheses are just a few recent technologies that have shown promise for more effective rehabilitation. However, the UK urgently needs more highly skilled researchers with the ability to not only develop these advanced engineering solutions, but also be able to collaborate effectively with multiple stakeholders and across disciplines. This will ensure the solutions that they co-create are sustainable, meet the needs of the UK's diverse population, and are adoptable by industry and healthcare organisations.

A LEADING NATIONAL AND INTERNATIONAL CENTRE: To support this skills gap, this CDT will be directly connected to the new NHS National Rehabilitation Centre (NRC), a £105 million state-of-the-art facility located in the East Midlands. The NRC is designed to be a centre of excellence, combining clinical rehabilitation, research, training and innovation, under one roof, not only leading the national agenda but also influencing international activity in this area. The close proximity of the NRC facility, and aligned Defence Medical Rehabilitation Centre (DMRC), to the University of Nottingham and Loughborough University, provide the perfect incubator for cohort-based training, and give students a unique opportunity for their research to impact national and international rehabilitation programmes. This will be augmented by our strong links to other NHS Trusts and healthcare settings (inc. care homes), as well as links to industry through our partnerships with the Association of British Healthcare Industries, Medilink and numerous relationships with companies in the HealthTech and manufacturing sector.

AN INNOVATIVE, INTERDISCIPLINARY, COHORT-BASED TRAINING PROGRAMME: An innovative delivery model will be used that exploits the connection of this CDT to a state-of-the-art national healthcare facility (and connected community rehabilitation teams) and applies inclusive, pioneering pedagogical practice to maximise learning across diverse groups. CDT students will be part of the NRC academy alongside other training professionals, such as nurses and apprentices, in a combined clinical, research and training facility. This will provide a unique opportunity for reciprocal peer learning between disciplines and professions, developing exceptional researchers and innovators who can create transformative solutions for rehabilitation.

EPSRC Centre for Doctoral Training in UK Semiconductor Industry Future Skills (UK-SIFS)

Professor Paul Meredith Swansea University

Meredith, Professor P,Jennings, Dr M R,Wood, Dr CD,Ritchie, Professor D,Davies, Professor AG,Linfield, Professor EH,Guy, Professor O,Armin, Dr A

Recent geopolitical events have starkly demonstrated the criticality of the semiconductor sector to all advanced manufacturing supply chains, with the development and consolidation of 'sovereign capability' now being urgently pursued in the EU and USA. Although the UK is no longer a global player in silicon chip manufacturing, we have a vibrant emerging sector in advanced semiconductors, with the largest cluster of companies and R&I activity based in South Wales (the CSconnected Cluster). Critical supply chains are also evolving across other UK regions, for example in Scotland (Clas-SiC), North of England (Coherent, Nexperia and INEX), Lincolnshire (DYNEX), and the Torbay Hi-tech Cluster. Sustainable growth of our national industries that depend on semiconductor technologies will require the creation of indigenous industrial heartland talent through high quality, coordinated cohort training across all technical levels.

To address this, Swansea University and the University of Leeds will create a new, practice-based CDT to deliver the critical underpinning skills and talent needed to grow the UK's semiconductor sector. Our CDT will be co-delivered with industry and is intimately connected to other vital skills pathways including company graduate training programmes and apprenticeships - creating resilient and informed links up and down the technical levels. We intend to implement a flexible and innovative approach to the training which allows for a spread of career stages, retraining from industries and fields outside of semiconductors, and intakes from across engineering disciplines, physics and chemistry. We will accommodate part-time study and trial continual professional development recognition through micro-credentials. The CDT will utilize state-of-the-art new facilities at Swansea and Leeds for semiconductor research and training. Our skills and infrastructure package will enable frontier TRL-spanning research to be advanced by our students from project inception in a wide variety of technology areas including power electronics, clean energy, healthcare and bioelectronics, telecommunications and the internet of things.

Our UK-SIFS aligns with the long-anticipated UK Government's Semiconductor Strategy and the need for substantially expanded practice-based training in semiconductor science and engineering. Our current institutional efforts are not at the scale or ambition required. UK-SIFS is vital to expand the current training portfolios of SU and UoL, but more importantly adds a new dimension to the broader national semiconductor skills agenda in our regional industrial manufacturing heartlands.

EPSRC Centre for Doctoral Training in Geometry and Topology (G&T@O&C: The Oxbridge Centre in Geometry and Topology)

Professor Jason Lotay University of Oxford

Lotay, Professor J,Lackenby, Professor M,Smith, Professor I,Rasmussen, Professor J

The Centre for Doctoral Training in Geometry and Topology is a partnership between the Mathematical Institute at Oxford and the Department of Pure Mathematics and Mathematical Statistics at Cambridge. Our aim is to train PhD students in the mathematical fields of geometry and topology, broadly interpreted. Although the word geometry may conjure up memories of measuring angles in secondary school, modern geometry is at the heart of much of mathematics. In many different scientific contexts, one is naturally confronted with higher-dimensional spaces and maps between them which are subject to various constraints. Modern geometry and topology study these objects using a huge range of mathematical ideas. The focus of the CDT will be pure mathematics; however, this pure mathematics underlies and informs a wide range of applied problems in areas such as the study of black holes and cosmology, control theory, cryptography, image reconstruction, and topological data analysis.

The UK has a clear need for PhD graduates in mathematics. The 2018 Bond Review, facilitated by EPSRC, states that "mathematics is arguably the single most pervasive and powerful of all drivers of innovation in the world today" and recommends that "Government and universities should create, at minimum, 100 additional PhD places per year dedicated to training mathematical scientists." Within UK mathematics, the fields of geometry and topology are a longstanding centre of excellence in which Oxford and Cambridge have played a major role. Our recent graduates in geometry and topology have gone on to permanent academic jobs at universities across the UK and around the world. Outside academia, our graduates have contributed in a wide variety of areas, including data science and analytics, finance, software development and chip design, management consulting, and clean energy. Our CDT aims to maintain and enhance the UK's world-class position in this important field, and to respond to the ever-greater integration of once-disparate parts of the subject: we will attract top-quality students and give them the joined-up training they need to become the next generation of leaders, both within and outside academia.

Geometry and topology are especially well-suited to the structure of a CDT: it is often essential for students specialising in one branch of the subject to be familiar with techniques from a different area. In a traditional PhD program, the sort of interaction needed to make progress in interdisciplinary areas is rarely possible, while in this CDT it will be actively facilitated. The expertise relevant for interdisciplinary training is available by combining that of both institutions, in ways made possible by leveraging AV systems installed during the pandemic. There will be many opportunities for the whole cohort to meet and work together. We will provide a set of bespoke short courses for 1st and 2nd year students, some targeted at specific crossover areas, before the start of each term, and two separate 1-week periods during the year where we will bring all students in the program together for planned activities such as research presentations. The CDT cohorts will be large enough, broad enough and interacting over a sufficient time period for collaboration with cognate PhD students to be an opportunity and not a constraint: such collaborations are invaluable long after the PhD. Finally, the CDT will offer students a wide variety of opportunities to interact with our industrial sponsors and gain experience relevant to careers in industry. These include the provision of relevant courses in areas such as computing and topological data analysis, a sandpit where students and representatives of sponsors discuss problems of interest, a set of mini-projects with an applied focus, and opportunities for summer internships. Companies and organisations which have expressed interest in supporting the CDT include Flare Bright, the Heilbronn Institute and G-Research.

EPSRC Centre for Doctoral Training in Biophysics and Engineering for Healthcare

Professor Jamie Hobbs University of Sheffield

Hobbs, Professor J,Wild, Professor J,Weinstein, Professor JA,Narracott, Dr A,Pyne, Dr ALB,Jayasinghe, Dr I,Offiah, Professor A,Reilly, Professor G,Clayton, Professor RH

Tomorrow's doctoral students will require wide-ranging interdisciplinary skills for the digital and technology-enabled healthcare solutions urgently needed to improve health outcomes across the UK and to keep pace with world-wide developments. Our students will develop these skills in partnerships spanning biophysicists, engineers and computer scientists with our local NHS hospital trusts and with companies in the healthcare technology and scientific instrument sectors. Expertise within the centre will span from the fundamental biophysics that determines the mode of action of the next generation of drugs and reveals new promising drug targets, to engineering needed for patient facing healthcare technology such as the development of novel imaging techniques for early diagnosis and the assessment of therapies. Students will choose their research projects from across the full range of the translational pathway from underpinning science to clinical application, giving them unique insight into how cutting-edge knowledge can lead to improved health outcomes for the public.

Government and learned society reviews point to the critical shortage of trained physical scientists and engineers at PhD level in this research and technology space. To address this shortfall in skills, our multiple industrial and NHS partners have engaged in co-developing our training programme which is shaped through the lens of their need. They have particularly emphasised the importance of interdisciplinary teamwork, high-level problem solving, data analysis and complex project management, underpinned by experience of working on novel and ground-breaking science and technology which we have embedded in the centre's training programme. Situated in an area with substantially lower than national average health outcomes, our students will contribute to the critical need to reduce health inequalities, and benefit from the deep understanding of this that comes from our clinical partners.

Our 50+ students will benefit from cohort-based learning throughout their programme. Taught components will be staged through the PhD to correlate with the natural development of research projects, moving from underpinning data analysis, coding, and statistics, through the skills required to translate their research, to writing and communication. All students will benefit from industrial and hospital placements via mini projects in year 2. Cohorts will grow connections both within and between year groups, through partnering and mentoring, and through cross-cutting multidisciplinary projects, for example trying a new technology in a more applied setting or utilising a data analysis approach in a different context. These short focused multidisciplinary challenges will enable our students to develop their leadership skills in teams of 3-5 fellow students. The projects will promote skill sharing, build interdisciplinary expertise and give a taste of the multi-tasking agility required in an industrial or more senior research position. Throughout, students will be at the centre of their training experience, choosing their projects, supporting their cohort, feeding into the training of subsequent years, and organising activities such as summer schools and annual student conferences.

At all stages of their PhD, from recruitment through research projects to graduation and beyond, the wellbeing and individual diverse pathways of our students will be central to the centre. Our leadership team, crossing disciplines from clinicians to computer scientists, has the extensive experience in cohort-based learning, technology transfer, and developing EDI programmes necessary to support the centre. Combining excellence in biophysics, engineering and computing, our students will form the new generation of scientists and engineers in medicine for the technology driven healthcare of the future.

EPSRC Centre for Doctoral Training in Digital Transformation of Metals Industry (DigitalMetal)

Professor Hongbiao Dong University of Leicester

Dong, Professor H,Green, Professor NR,Bateman, Dr N,Hussain, Professor T,De Maere, Dr G,ZHOU, Dr H,Ceglarek, Professor D,Bowen, Professor P,Kenny, Professor SD,Gu, Professor S

The EPSRC Centre for Doctoral training in Digital Transformation of Metals Industry will develop 80 future leaders with integrated expertise in the two disciplines of metals and alloy engineering and digital technology and AI, together with a broad foundation on manufacturing management, product development, personal and interpersonal skills, and leadership which are required to lead the digital transformation of metals industry.

The metals industry is a vital component of the UK's manufacturing economy and makes a significant contribution to key strategic sectors such as construction, aerospace, automotive, energy, defence and medical, contributing £20bn to UK GDP. For the UK metal industry to lead at a global level, we must raise its competitiveness and create robust and agile manufacturing processes and sustainable supply chains enabled by digital technology. This CDT is timely due to the readiness of smart digital technology and the availability of new scientific advances to help move the industry to Industry 4.0 and sustainability. It will enable this important industry sector to drive economic growth, job creation and global inward investment in the current challenging global economic landscape.

Research and training will be undertaken on metals and alloys, manufacturing and digital technology. The Centre will establish itself as a digital manufacturing hub across AI, digital, AI for manufacturing data and their application in metals industry and its supply chain, to synergise specialist resources across the Midlands universities and metals industry for students to access, including computing equipment, facilities and e-infrastructure so that their ambition and access to digital tools is not limited by the immediate specialisms of their supervisors and industry sponsors. our combined research & innovation capability and expertise provides a transformational opportunity to overcome the complex challenges in digitalising metal manufacturing. Our fast, robust and reliable data-driven materials and process models and digital technologies will enable first-time right and flexible operations for smartly connected metal factories, establishing agile and interconnected 'through-process' metal supply chains and enabling the UK manufacturing sector to make a step change in their productivity, sustainability and competitiveness, to deliver major UK manufacturing impact.

EPSRC Centre for Doctoral Training in Synthesis for a Healthy Planet

Professor Michael Willis University of Oxford

Willis, Professor M,Gouverneur, Professor V,Sneddon, Professor H,Anderson, Professor EA

Humanity faces critical global challenges in supplying clean energy, food, pharmaceuticals, and materials for a population forecast to reach 10 billion by 2050. Chemical synthesis has and will continue to play a central role in addressing these challenges, as organic molecules are the fundamental building blocks of drugs, agrochemicals, materials, and indeed life itself. However, the synthesis of chemicals today remains energy intensive, requires fossil fuel feedstocks and endangered metal catalysts, and produces huge levels of waste including non-recyclable organic solvents - far from what is needed for a net-zero future. The essential transition to a circular chemistry economy will materialise only with a total re-think of organic synthesis. To achieve this, we must train a generation of synthetic chemists to develop processes that use renewable feedstocks, environmentally benign reagents, catalysis using enzymes, abundant metals, photons, electrons, and intelligent reaction design, along with minimised/recycled waste. This is the overarching objective of our "Chemical Synthesis for a Healthy Planet" CDT: To meet a User Need by delivering cohorts of scientists equipped to use innovative and sustainable methods to synthesise functional organic molecules that can address the global challenges of human health, food security, and energy and materials.

To deliver this ambition, we have established a powerful alliance between the Department of Chemistry at Oxford, and the Green Chemistry Centre of Excellence (GCCE) at York. This synergistic union will exploit our joint expertise, offer geographical diversity, and provide a unique platform to develop a far-reaching, multi-skilled graduate network. An intrinsic component of the programme is our industrial partners - the Users who will ultimately benefit from this CDT - drawn from the pharmaceutical, agrochemical, fragrance, and fine chemical industries. These partners, who we expect to contribute £8M to the CDT, have been involved in conception of the programme, and will contribute to the design and delivery of the taught course. They will also co-develop and co-supervise every PhD project, which will focus on developing innovative chemical solutions to the above global challenges. The programme's reach extends internationally through affiliation with the 'Center for the Transformation of Chemistry', a Euro1.25 billion programme to revolutionise the supply chain of organic building blocks from biorenewable materials. We will also partner with SMEs through an 'Entrepreneurship Fellows' scheme; the fellows will deliver Entrepreneurship Surgeries to share their expertise on research commercialisation, as well as offering an alternative perspective and potential destination for our graduates.

Students will be recruited through an unbiased selection process that provides opportunity to candidates with the highest ability and potential, from a diversity of backgrounds. Cohorts (each 20 strong) will initially undertake a 16-week training course together at Oxford and York in fields such as contemporary chemical synthesis, catalysis, data science, and sustainable chemistry. Modular assessment of assignments, presentations and teamwork will provide constructive feedback to students, strengthening their learning and resilience. This environment will create a student skill network that permeates throughout the programme via intra- and inter-cohort interactions, with students applying their complementary expertise to elevate each other's research. Students will then carry out their research projects in Oxford or York, with industry placements providing access to cutting-edge facilities complementary to those at the Universities. The cohort will also undertake a 4-year programme in enhanced research skills to ensure they acquire transferable / employment-related expertise. Students will also be part of teams of 'Sustainability Ambassadors' who will engage widely across communities.

EPSRC Centre for Doctoral Training in Tissue Repair, Innovation and Collaboration (CenTRIC)

Professor Colin Campbell University of Edinburgh

Campbell, Professor CJ,Emmerson, Dr EP,Horrocks, Dr MH,Vendrell, Professor M,Kersaudy-Kerhoas, Professor M,Forbes, Professor SJ,Street, Dr AN,Faulds, Professor KJ,Stone, Professor V,Graham, Professor D,Sboros, Dr V

Our vision

The vision for our CDT is to provide a world-leading student experience that enhances employability through multidisciplinary training in innovation and translation. Our students will work on research projects that provide a link between innovative new ideas in engineering and physical sciences (EPS) and clinical challenges in tissue repair and regeneration (TRR). TRR is a critical aspect of the journey from disease to health and the promotion, support and monitoring of tissue repair plays a key role in the treatment of a multiplicity of diseases including long COVID, liver disease, cardiovascular disease, endometriosis, cancer, neurodegeneration, irritable bowel disease and chronic lung conditions such as COPD. The translation of approaches that support TRR to the patient requires innovation from engineering and physical sciences (EPS) spanning detection of damage, liquid or non-invasive biopsy, non-invasive assessment and monitoring of tissue repair, and therapeutic interventions that promote repair. Our objective in assembling such an interdisciplinary team of supervisors and students is to lower the barriers to translation of physical sciences research and to train students how to navigate the innovation pathway, building towards a career where they can make a positive impact across a diversity of diseases.

World leading partnership

Our CDT brings EPS researchers and social scientists from the University of Edinburgh, University of Strathclyde and Heriot Watt University together with TRR researchers from the University of Edinburgh College of Medicine and Veterinary Medicine. Our strengths in synthesis, analytical chemistry, computational molecular design, microfabrication, photonics, detectors and signal analysis have contributed to the establishment of the new Institute for Repair and Regeneration (IRR). IRR is an interdisciplinary initiative and from 2023 will be housed across two state-of-the-art buildings with capacity for over 1000 staff and students spanning medicine, biology, chemistry, physics, and engineering - the world's largest collection of researchers in TRR.

Transformative training

Excellence in scientific training draws on our approach to supervision which requires each project to have a minimum of one EPS supervisor and TRR supervisor. This structure gives students coming from a diversity of backgrounds the opportunity to cross-skill and use their existing expertise to address new challenges. In addition, we have developed a formally assessed, transformative training program designed to expose students to the healthcare challenges of a changing world and which prepares them to make a difference in careers as diverse as inventor, entrepreneur, clinical trials specialist, healthcare consultant and policy influencer. Such an ambitious program requires not just a structured collection of modules that addresses the program's objectives it also requires a cohort of students with a diverse set of skills who have opportunities to learn from each other and carry out the type of team-work that is required to solve real translational problems. The training program covers a variety of skills including idea generation and grant writing, intellectual property, public outreach, communication with diverse audiences, design with end-users in mind, finance, ethics, regulation and clinical translation.

EPSRC Centre for Doctoral Training in Modelling of Cleaning and Decontamination (ModCaD)

Professor William Zimmerman University of Sheffield

Zimmerman, Professor W,Wilson, Professor DI,Clarke, Professor SM,Dalziel, Professor SB,Whitehead, Professor KA,Landel, Dr JR,Kusumaatmaja, Professor H,Hall, Dr I,Patwardhan, Professor SV,Greenwell, Professor HC

This multidisciplinary Centre for Doctoral Training (CDT) will vastly improve the collaboration between engineering and sciences for innovation in cleaning and decontamination (C&D) operations. C&D activity is widespread in the UK (and worldwide), with a UK value of £4.5bn p.a. The operations range in sophistication from standard cleaning protocols to precision sensors and analysis techniques. Most, however, are far from optimal. Even in the most high-tech industries, i.e. biopharma, ~50% downtime is spent on C&D.

EPSRC recently (2021) supported a Roadmapping Exercise, building on a nascent community of multidisciplinary researchers, industry and government experts from a UK Fluids Network C&D Special Interest Group. Its workshop attracted 12 industry sectors, 7 government departments and 17 agencies & health/caring bodies and identified needs and challenges in sustainability, risk, diversity, networking, training, sensors and underpinning sciences. The published Roadmap outlined a framework to tackle these needs by step changes in communication, community, training and new research in particular aspects of the science base. A core feature is multidisciplinary training and PhD level research with input from non-academic experts (business, government and industry) who are problem owners. This engagement will enthuse and shape academic interest towards issues in C&D. Since the science is multiscale and multidisciplinary, combined experimentation and validation of multiphysics, multiscale modelling, chemical engineering, fouling and microbiological expertise are essential to translate best practise and innovate across sectors.

Models are essential for designing C&D innovations and optimising resource efficiency, as well as characterising risk levels associated with cleanliness. Properly informed models underpin innovations that promise sustainability in chemical usage, increase utilisation of manufacturing plant, and protect product integrity. They facilitate rapid response and deployment of resources for crises such as toxin releases (e.g. sarin or Novichok) or highly contagious disease (e.g. COVID-19 or MRSA) outbreaks. Currently, all of these are treated within discipline silos, in many cases with intractable challenges and needs that are met empirically with workarounds and traditional methods. For such issues, if the solution exists, it usually lies outside the discipline that owns the problem. ModCaD aims to bridge best practises through modelling, which starts with conceptual modelling, works through experimental investigation, and results typically in computational packages for design, control, strategic response, or system optimisation across discipline boundaries.

ModCaD will establish a world-leading centre for C&D, building on and integrating the dispersed high quality expertise in the UK. This proposal brings together 5 core institutes, defined by their ability to deliver the core training programme, starting with Sheffield and its unique ability to host fine chemical and biopharma training with purpose built pilot plants (~£6m total investment). Sheffield will deliver pilot scale practical training along with multiphysics/multiscale modelling, using science input and biochemical analysis from the other teams: (1) Manchester and MMU have workshops and training packages linked up on bio/chemical analysis with associated statistical and mathematical modelling. (2) Durham and Cambridge bring expertise on chemical engineering, chemistry and physics of soft matter, interfaces and surfaces, with associated mathematical and computational modelling as well as bespoke cleaning experimentation.

Additional industry facing cleaning training is offered by BRITEST, supporting translation from science to practice.

Novel project allocation and co-sponsor brokerage among 30+ partner organisations and across 15 institutes aims to achieve high relevance and new science for 60 projected studentships.

EPSRC Centre for Doctoral Training in Quantum Information Science, Sensing and Technologies

Dr Lucia Hackermueller University of Nottingham

Hackermueller, Dr L,Burrage, Professor C,Adesso, Professor G,Tuck, Professor CJ,Brookes, Professor MJ,Vedral, Professor V,Goodwin, Dr J F,Lvovsky, Professor A,Jensen, Dr K

Several recent market analysis (McKinsey, IOP, AUKUS) have provided clear evidence for a national need for increased doctoral training in the area of quantum physics and quantum technologies. Following an investment of ~£1bn in the UK Quantum Technology Programme, the UK is internationally leading in QT with multiple resulting benefits for the economy and national security.

Lack of sufficiently trained work-force is the main parameter that limits the growth of the QT sector. To exploit quantum advantages fully by transferring academic research breakthroughs to industry and transform them into economic/societal impact, a particularly important area is Engineering Quantum Devices for Applications. It has been recognised by EPSRC and by international reviews, that a multidisciplinary training approach is necessary to achieve this.

Our CDT links ground breaking, world-leading applications of quantum technologies (e.g. in brain research and brain imaging, rotation sensing, portable quantum sensors) to excellence in fundamental research (optimisation, error estimation, quantum information, machine learning). We exploit methods that have been developed for quantum metrology and quantum information to create, test and demonstrate the quantum sensors of tomorrow.

Our cohort-trained students will have the skills, ranging from mathematics through physics to engineering, required to boost the performance of existing quantum sensors, to create new sensors and transfer knowledge to industry, end-users and the associated companies. We have teamed with >26 national and international leading companies in the area of quantum sensing, quantum computing and quantum technologies and combine theoretical and experimental researchers from two world-leading institutions. We are particularly proud of the excitement, positive feedback and direct contributions to co-creation and delivery from our industrial partners.

Based on these interactions, we have co-designed a training plan focussing on a multi-disciplinary approach combining 3 areas: Quantum Information and Metrology, Fundamental Experiments and Sensing applications including advanced engineering and system testing/validation. Cohort-based training makes this multi-disciplinary approach possible - students will benefit from group work and prototyping, lab-exchanges, multidisciplinary seminars, links and placements with industry and international placements.

The three-interlinked training strands will comprise the following training:

Quantum Information and Metrology: building on foundations of quantum information and metrology we will teach top-level methodologies including uncertainty quantification (Fisher information and Bayesian risk), multiparameter quantum estimation theory, machine learning for optimal design, data handling and statistics.

Fundamental Experiments: Students learn how the above methods can be applied to fundamental quantum experiments in atomic physics, ion trapping, interferometry and super-resolution quantum microscopy. Students will receive hand-on training on high precision quantum experiments.

Sensing applications: Students will learn about engineering methods including low-noise electronics, optimisation and additive manufacturing and apply these to the development of high-end precision quantum sensor components and systems including brain imaging, magnetic sensing, rotation sensing, ion trapping, gravimetry and microscopy. Students will work with our industry partners who are active in these applications and so obtain entrepreneurship skills.

The resulting QISST doctoral cohorts, with a total of >60 students, will boost the QT economy and contribute to fascinating, groundbreaking research and technological development across sectors. Based in the Midlands the centre will strengthen transformative technological capability in the local region, lead to lasting industry-academia links and enhance the national levelling up scheme.

Innovation and Entrepreneurship for the Digital Transformation of the Water Sector: Digital Water

Professor Raziyeh Farmani University of Exeter

Farmani, Professor R,Chen, Professor AS,Butler, Professor D,Memon, Professor FA,Djordjevic, Professor S,Keedwell, Professor E,Tornikoski, Professor E,Melville-Shreeve, Dr P P,Fu, Professor G,Smith, Dr J

The water sector faces a series of long-term challenges including climate change, demographic change, aging assets, water demand increase, aging workforce and inadequate investment. As never before, the sector is under intense political, media and public scrutiny on issues ranging from local intermittent pollution incidents to the national water resource strategy. The need for innovation and the potential role of digitalisation in areas such as decarbonisation, improved environmental performance, strategic water resource management and meeting customer expectations is understood but has yet to make sufficient headway at the scale and pace required.

The water industry is slowly moving from reactive, operator-led solutions to newer IoT platforms for predictive and proactive monitoring and control. However, digitalisation of the water sector is characterised by technological, economic, social, regulatory (legal and ethical), and environmental change and involves a wide range of actors. This requires new technologies, new services, and new business models. Consequently, there is an urgent need for more highly trained water informatics specialists or researchers, across planning, operations and management of water systems to ensure a future-proof workforce for the water sector, and to be ready to address the above challenges.

This CDT in Innovation and Entrepreneurship for the Digital Transformation of the Water Sector will address this skills gap and train digital water innovators, entrepreneurs and intrapreneurs capable of reinventing current approaches and delivering sustainable, resilient and competitive smart water management. We will create a value-creation framework adopting entrepreneurial methods to generate impact pathways and a culture of rapid translation of research innovation. All of our students will undertake a customer and end-user discovery activity prior to commencing their research to ensure the projects cover customer-centric propositions. Students will be trained in the field with a broad set of technical and social problem-solving skills in tackling multidisciplinary water management challenges and collaborating with a range of stakeholders.

It is a joint venture between Exeter's internationally leading researchers in Water Engineering and Hydroinformatics in the Centre for Water Systems, the Business School, and the Computer Science and Psychology Departments working together to improve access to the skills needed to deliver innovation and entrepreneurship in the water sector. Our CDT students will benefit particularly from the cutting edge, state-of-the-art technology and facilities at the newly opened (2023) £30M Centre for Resilience in Environment, Water and Waste, funded by Research England and the Pennon Group plc. This will provide not only a first-class research environment but also excellent industrial collaboration opportunities. Other key facilities include the Institute for Data Science and Artificial Intelligence, the Joint UoExeter/Met Office Centre for Excellence in Environmental Intelligence and our Environment and Sustainability Institute. In addition, leading experts from across the University at the Centre for Entrepreneurship, the Exeter Centre for Circular Economy, Exeter's Entrepreneurship Programmes and the Politics Department will deliver a lecture series to equip students with a broad range of knowledge and skills required to manage innovation and engender an entrepreneurial mindset.

CDT in Resilient Digitalised Critical National Infrastructure

Professor Steve Schneider University of Surrey

Schneider, Professor SA,Irvine, Dr J,Asghar, Dr M,Strens, Professor F,Stansfield, Professor NP,Rogoyski, Dr A,Boureanu, Professor IC,Neri, Professor F,Patelli, Professor E

This proposal is concerned with the challenges of building resilience in the UK's increasingly digitalised Critical National Infrastructure (CNI).

The UK Government Resilience Framework defines resilience as "the UK's ability to anticipate, assess, prevent, mitigate, respond to, and recover from natural hazards, deliberate attacks, geopolitical instability, disease outbreaks, and other disruptive events, civil emergencies or threats to our way of life." As we have seen over the last few years in the context of the global pandemic, the cost of living crisis, climate change and the war in Ukraine, the world is becoming increasingly volatile, uncertain, complex and ambiguous. In parallel, some remarkable advances in technology have led to changes, improvements and sometimes new vulnerabilities in the CNI. This combination of events, shocks and rapid change leads to unforeseen disruptions that are increasingly difficult to predict, in part because they cascade through the interconnected fabric of our society. The need for resilience poses particular challenges to the CNI including power, communications and transport systems. New approaches, demanding new solutions and new skills are needed to limit the increasing fragility of modern systems, requiring new ways to minimise impact, respond and recover, adapt and evolve, when disruptions occur. Such advances need to accommodate CNI's continued pursuit of efficiencies, cost reductions and aims to meet NetZero targets.

We aim to develop a new community of PhD-level "resilience thinkers", with the research and technical experience, as well as the leadership and soft skills needed to tackle the emerging challenges of embedding resilience within the future versions of CNI, especially as it becomes increasingly digitalised. To this end, we will combine new approaches to training, mixing the teaching of advanced concepts in relevant aspects of computer and engineering sciences (e.g., cyber-security, control systems, safe AI), with management and leadership training. Delivery of our training programme will benefit from strong engagement of partners.

Our research agenda is innovative, taking a "total resilience" systems-of-systems approach, focusing on Resilience Management, Resilience Engineering, Digitalisation, and Cyber Security, all anchored in the context of CNI and in strong partnership with industry. We are working closely with external stakeholders from industry, government and public sector to identify and tackle real-world research challenges across the CNI sectors.

The ultimate purpose of the CDT is to produce a new cadre of specialist resilience experts who can handle the complexities, pace and scale of the challenges ahead, becoming agents for change, to protect the critical services on which we all rely.

EPSRC Centre of Doctoral Training in Next Generation Synthesis (NGS)

Professor Matthew Gaunt University of Cambridge

Gaunt, Professor M,Colwell, Dr LJ,Lapkin, Professor A

Synthesis, the ability to manufacture & manipulate molecules, positively impacts society in many ways, such as medicines, food security, materials & chemical products. It is clear that improved synthesis is of direct benefit to UK GDP, but cost-effective & sustainable preparation of new molecules against the context of contemporary environmental concerns & unexpected global emergencies is increasingly challenging. Incremental synthesis advances are no longer fit for purpose & step changes are needed to deliver the chemical commodities of the future rapidly, efficiently & sustainably.

Data science will underpin the next-generation of chemical research. Fields such as ML & AI are central to the future of chemistry & will enhance our ability to design & synthesize the molecules that will impact tomorrow's society. These molecules, small or large, include the medicines we use to treat disease, the agrochemicals we need for food security, the basic components of advanced materials that drive technology & the commodity chemicals that support the everyday life that we take for granted. However, new challenges are on the horizon that we need to address, such as synthesis of biopharmaceuticals, organic materials, chemical valorization (breaking down) of biomass & waste or the creation of synthetically resilient supply chains. We need new technologies & approaches to develop solutions to these problems. Although traditional approaches have proven capable of supplying society with our essential molecules, the current discovery & development process is under severe pressure. In particular, the continuing increase in target complexity, environmental constraints on how we make molecules & increasingly aggressive business-driven timelines for delivery means we often miss out on essential products that we need.

Future molecule-makers will need to be polymaths, with skill sets beyond synthesis that provide a fluency in ML, computation & whole-system analysis. They will converse with & inform engineers, enabling these partners to use the data-science momentum to develop self-learning automated platforms & manage synthetic resilience in supply chain, thereby facilitating a transformation in molecular manufacture. Data scientists must recognize how computational exploration of chemical space can enable the digitisation of molecular reactivity, leading to reliable predictive tools, which will design optimised transformations & discover new processes.

How do we bring about a step change in our approach to making (& breaking) molecules. Paradigm change in molecular manufacture will not happen overnight because a critical mass of researchers in academia & industry will be needed to bring about the data-driven synthesis revolution. We began the process of change 5 years ago with our SynTech CDT, which brought traditionally disparate areas of science together by training researchers in 'digital molecular technologies', which would lead in a change of approach to how we make molecules. This process has already brought demonstrable progress, but it will take several generations to bring about the change needed to establish the data-driven synthesis revolution. Therefore, the Next Generation Synthesis CDT aims to accelerate the revolution in molecule making. By drawing together students from scientifically disparate backgrounds but focused by exposure to innovative cross-disciplinary training & expanded research programs, the CDT aims to create a synergy through a cohort model that will deliver polyglot scientists with the skills to deliver solutions across the spectrum of future molecule-making challenges. The NGS CDT, through its activities will help create a new inter-disciplinary research community for data-driven synthesis, where scientists are working together at all levels of higher education & in end user industries. This community will be uniquely positioned to solve the molecule synthesis problems that affect our present & future society

EPSRC Centre for Doctoral Training in Ecosystems Engineering for the Living Planet

Dr Samraat Pawar Imperial College London

Pawar, Dr S,Chachuat, Professor B,Pearse, Dr WD,Nanayakkara, Professor T,Harrison, Prof. S,Bharath, Professor AA,Holderbaum, Professor W,Michalickova, Dr K,Arcucci, Dr R,Gonzalez Suarez, Dr M,Graven, Dr HD

In the face of the global environmental crisis, there is a clear political will to drive the UK's transition to a more sustainable "green" (bio-)economy. Indeed, the UK was the first country to commit to achieving net zero greenhouse gas emissions (by 2050). However, a major bottleneck in the path of this economic transition is a critical skills gap in the UK academic and non-academic workforce: the modelling and data skills needed for ecosystem- ("nature"-) based solutions to real-world problems. Addressing this skills gap requires rigorous postgraduate-level training in developing technology to quantify, monitor and engineer complex ecosystems.

We propose a new Centre for Doctoral Training in Ecosystems Engineering for the Living Planet (EcoEng CDT) to address this skills gap and tackle four challenges that underpin any green economy: (I) Increasing Industrial Bio-Processing and Bio-production; (II) Accelerating and Monetising Ecosystem Recovery; (III) Optimising Land Use for Food, Energy and Nature; (IV) Adapting to and Mitigating Climate Change Impacts. Although ostensibly disparate, innovation for each of these four requires a shared core of technical skills from STEM disciplines, albeit in different combinations and to different degrees.

The EcoEng CDT will achieve its objectives by pioneering an innovative training program that combines world-leading expertise in technical EcoEng components (Complex Systems, Ecosystem Processes, Process Engineering, Monitoring Technologies, Data Science & Artificial Intelligence). The technical training will be enhanced and applied to real world problems thorugh partnerships with key Data Expert Hubs, Industrial partnerships, and six world-class training & innovation hubs covering the four listed challenges (Georgina Mace Centre, Walker and Grantham Institutes, Centre for Climate Finance & Investment, Centre for Agri-Environmental Research, and the Sargent Centre for Process Systems Engineering). By balancing industrial partnerships and cofunding across the startup, small and medium-sized enterprise (SME) to large company spectrum, EcoEng CDT will effectively create a unique inter-disciplinary cross-sector catapult with potential to significantly acclerate growth and development of the UK green economy.

Beyond its intellectual and pedagogical agenda, the EcoEng CDT will aim to expand the innovation potential within the UK green economy by recruiting and training students from diverse STEM and socio-cultural backgrounds. This is key to generating a robust, self-sustaining "assembly line" of cohorts of skilled professionals that keeps pace with (and continuously catalyse) the long-term growth of the UK's green economy.

EcoEng CDT training will be delivered through a 1+3 model: an interdisciplinary 1-year MSc program followed by a 3-year PhD dissertation. Recruitment will target Undergraduates from diverse backgrounds, with particular focus on the chronic under-representation of female and ethnic minority Undergraduates entering postgraduate quantitative biology and engineering degree studies. The MSc program will consist of 20 weeks of taught modules and a 5-month research project, both tailored to find the appropriate balance of training across the five technical EcoEng components, given individual students' STEM backgrounds (e.g., balance of biology- versus non-biology topics in their Undergraduate degree). The PhD dissertation component will either address one or more of the four green-economy challenges, guided by an interdisciplinary team of academic and non-academic supervisors facilitated through external placements. This will also maximise employment success and optimise balance of academic versus non-academic career destinations of the CDT's graduates. Additional technical training will be delivered during the PhD phase thorugh the six T&I hubs as needed, along with "soft skills" training including responsible research and innovation (RRI) principles.

EPSRC Centre for Doctoral Training in Biomass and Direct Carbon Capture Negative Emission Technologies (Bio-NET)

Professor Elizabeth Thornley   Aston University

Thornley, Professor EP,LIU, Professor H,Rooney, Professor D,Gu, Professor S,Granollers-Mesa, Dr M,Onwudili, Dr J A,Robertson, Professor P A,Binner, Dr E R,Rebrov, Professor E,Wu, Dr C

Increasing carbon dioxide (CO2) levels in the atmosphere from excessive use of fossil fuels has led to global warming throughout the world and unless it is countered will lead to excessive temperature rises in many areas of the world. Counter measures include major reductions in use of coal oil and gas to reduce CO2 outputs, replacement of energy sources by biomass and related materials such as waste, and capture of CO2 in the atmosphere with deposition in safe storage. This CDT focusses on use of biomass to replace fossil fuels and removal (capture) of CO2 from the atmosphere with the potential for reaction to create novel sources of fuels and chemicals. Integration of these two areas will lead to significant cost savings and efficiency advantages.

Biomass and wastes are expected to be a major player in the energy transition toward low-and neutral carbon economies in response to the pressing challenges of climate change and security of energy supplies. For example, the UK Government's 'Building a High Value Bioenergy' (2015) report highlights the importance of the bioenergy sector if the UK is to become a global leader in producing materials, chemicals and energy, with significant anticipated technology and business exports. Direct capture of CO2 offers many opportunities to use the CO2 as a raw material in the manufacture of a wide range of energy, chemical and fuel products. In more global scenarios which provide opportunities for the UK, bioenergy may contribute up to half the total use of primary energy worldwide by 2050 (IPCC). Complementary to bioenergy is direct carbon capture, which will offer a set of unique opportunities to first capture CO_2, convert it to valuable products with the potential to integrate this technology with bioenergy. This will require a substantial increase in the production of all bioenergy vectors including heat, power, fuels and commodities, and poses major challenges for all areas of bioenergy, biofuel and bio-chemical value chains, which are a key focus of this CDT. In a recent survey, 71 research centres were recently identified in the UK with a significant bioenergy research activity, all of whom will require suitable expertise in the coming decades.

The uniqueness of this CDT lies in the potential for multidisciplinary projects and integrated approaches to resolve challenges in bioenergy, biorefineries and biofuel value chains. Successful outcomes will include reduced costs, higher conversion efficiencies, reduced wastes, new products and further CO_2 reduction. The benefits will result in innovative solutions for this entire sector, as well as giving all students in the programme a sound appreciation of the interactions and opportunities for these value chains. Successful commercialisation of the resulting bio-related processes will result in a high demand for suitably qualified engineers, scientists and managers graduating from this CDT.

EPSRC Centre for Doctoral Training in Machine Learning Systems

Professor Amos Storkey University of Edinburgh

Storkey, Professor AJ,Mai, Dr L,Rajan, Dr A,O'Boyle, Professor M

Machine Learning is the modelling of data to predict future outcomes and is the core technology of all AI applications; from advert personalisation to drug design. Machine Learning (ML) already has a dramatic impact on our daily lives, yet the recent explosion in ML, is built largely on the back of improved computer systems. Computer Systems range from the everyday mobile phones connected to cloud services to super-computers and data warehouses and underpin all aspects of the modern economy. Leading US research and advisory firm Gartner Inc. reports that worldwide IT spending is projected to total $4.5 trillion in 2023, and the market for ML based systems will grow to 31.1% in 2025, considerably outpacing other sectors. ML systems will have a significant impact on the UK economy. While we are increasingly aware of the economic impact of ML on our lives, the ability to train and generate ever more powerful models is based on innovation in computer systems. Systems research and ML research are, in fact, symbiotic. Modern systems research innovation is driven by the ubiquitous need for efficient ML. ML research, conversely, is heavily influenced by how methods are deployed and the wider environmental and social impact of them.

Major gains are made when the development of ML and systems are co-developed and co-optimized. This is relevant across a broad spectrum of industries: in-car systems, medical devices, mobile phones, sensor networks, condition monitoring systems, high-performance compute centres and high-frequency trading-houses. Yet PhD training that brings together Systems and ML is rare; such research training is often siloed in the individual sub-disciplines. Instead, we need researchers trained in both fields and experienced in working across them. Hence the ML Systems CDT will train a new type of student - the ML-systems researcher, critically capable in both fields, and with collaborative research experience across the systems-ML stack.

There is a strong industrial need for graduates who have both real technical depth and wider communication and entrepreneurial skills. Throughout the programme, students will take courses addressing: responsible AI research; environmental impact; equality diversity and inclusion; entrepreneurship and career development. A key part of the CDT is that all students are expected to undertake at least one significant industrial internship during their studies. Our world-class researchers and over 80 potential supervisors makes Edinburgh an ideal place for such a CDT. With the Bayes Centre, Edinburgh City Deal and the Alan Turing Institute, it make it a unique one.

The CDT will develop tomorrow's future leaders, helping them achieve intellectual independence, engage with industry and develop a long term career trajectory. We will use our CDT to address the diversity deficit in the ICT workforce, with a target of at least 30% female representation in the student cohort. More broadly we have an outreach programme aimed at engaging with undergraduates and schools to increase wider appreciation and participation with ML systems. Our CDT will develop the future leaders of ML systems.

EPSRC Centre for Doctoral Training in Autonomous Intelligent Machines and Systems

Dr Michael Osborne   University of Oxford

Osborne, Dr M A,Rogers, Professor AC

The UK's 2022 National AI Strategy recognizes the potential of AI for both prosperity and human flourishing, but its impact is hindered by two obstacles. Firstly, AI's impact must be realized through under-prioritised end-to-end autonomous systems, and secondly, we must address present skills shortages. The Autonomous Intelligent Machines and Systems (AIMS) Centre for Doctoral Training (CDT) aims to tackle both challenges by training cohorts in theoretical and systems skills in autonomous systems, with industrial partnerships shaping AIMS training and ensuring the delivery of Oxford's research to various UK sectors, including transport (partnering with Toyota, Oxbotica, Hyundai), space (Satellite Catapult, Deimos Space) and healthcare (CRUK, Oxehealth).

AIMS is building on success in training future leaders in autonomous systems. AIMS has delivered high-quality research and impact, with students publishing 157 papers in high-impact venues such as Science, Nature Communications, and NeurIPS. AIMS students have won best paper awards from CVPR, outstanding reviewer awards from ICLR and NeurIPS, awards from Qualcomm, and fellowships from IBM. Two AIMS students published a sequence of papers on the effectiveness of interventions against Covid-19 that led to broad media and policy impact, along with an Impact Award from the MPLS division of the University of Oxford. AIMS graduates have secured posts in top universities, companies, and have founded their start-ups. Indicative of AIMS's success is that in its most recent five years, AIMS averaged 223 applications per year for only 12 places. In the first year, our cohort-focussed programme trains students in 15 bespoke week-long graduate courses, centred in Machine Learning, with spokes in Robotics and Vision, Control and Verification, and Cyber-Physical Systems. Training also includes components devoted to transferable skills (e.g. entrepreneurship), responsible research and innovation and AI safety and governance. Subsequently, students complete two 9-week mini-projects, followed by a three year research project, most designed in partnership with industry.

AIMS is building on success in engagement with industry, with current partners contributing £3 million of cash support to AIMS, in addition to in-kind support. Schlumberger, BP, YouGov, Nvidia, Samsung, and Mathworks have successfully organized workshops that foster co-creation of research problems in the context of real-world applications and in training on specific technical tools (e.g. Nvidia's CUDE architecture).

Additional investment will enable AIMS to continue to innovate. AIMS firstly plans to enrich a growing cluster of applications in biotechnology. Students and supervisors are currently working on robotic bioreactors, algorithms for automation of biological design, and autonomous platforms operating from micro-scale to macro-scale. Secondly, AIMS plans to develop a cluster of applications in AI for Ecology and the Environment, including robotics for ecosystem monitoring (Digiforest Horizon 2020 project), AI for battery analytics, and autonomous systems for social care, manufacturing, logistics, service, inspection or agriculture (Embodied Intelligence Programme Grant EP/V000748/1). AIMS will also continue to innovate in its training programme, with the pandemic already having led to many lectures being pre-recorded, with lecture times devoted to cohort discussion.

AIMS's chosen primary focus area is delivering an EPSRC research priority, and AIMS is aligned with EPSRC's mission-inspired research priority of artificial intelligence, digitalisation and data: driving value and security.

EPSRC Centre for Doctoral Training in Quantum Technology from Materials to Systems (QTM2S)

Professor Jason Smith University of Oxford

Smith, Professor JM,Tew, Professor DP,Taylor, Professor RA,O'Brien, Professor D

Practical quantum technology is only possible with advanced materials. Whether used to make physical qubits, as the active element of quantum sensors, as light sources and detectors, or to ensure low noise environments, materials are essential to systems performance and the requirements placed on them are extreme. Growth of the quantum technology industry will require significant improvements in existing materials, the introduction of new materials with superior properties, and in some cases materials which offer radical new approaches. The research required is necessarily interdisciplinary, involving quantum technologists (until now mostly physicists and engineers), materials scientists and chemists.

The Centre for Doctoral Training in Quantum Technology from Materials to Systems (QTM2S) will create a new skilled workforce at the interface of materials and quantum technology to define the research agenda and lead new innovations.The centre will emphasise materials research performed in the context of system performance requirements and applications. It will train researchers to tackle pressing issues such as reducing decoherence in superconducting circuits, understanding anomalous heating due to electrode surfaces in ion trap systems, engineering semiconductors and insulators with high performance spin qubits, and use of quantum simulation and computation methods to accelerate materials modelling and the understanding of quantum many-body phenomena in solids. It will include projects on the advancement of materials processing, characterisation and modelling that enhance our capabilities towards these goals. The impact of quantum technology on Materials research will also be in scope, with projects on quantum simulation and quantum sensing of materials.

Over the course of the CDT we will train 50 doctoral students across the broad range of research relevant to Materials and Quantum Technology and provide them with wide ranging opportunities to engage with the quantum technology industry. To facilitate interdisciplinarity, QTM2S students will be drawn from undergraduate courses in Materials, Physics, Chemistry and Engineering and the course structured to foster communication, collaboration and 'hopping' across disciplines. In the first six months all students will be provided with a baseline of understanding of quantum technology and relevant aspects of materials science. Each participating department will provide cross-disciplinary lectures and introductory laboratory training so that an Engineering student, for example, can learn relevant Chemistry, Physics and Materials and gain a feel for the different research environments before selecting their doctoral project. Introductory postgraduate training will be provided in materials modelling, characterisation and processing. During this time students will also have courses on topics such as EDI, research integrity and intellectual property. After this initial training period of 6 months, and familiarisation with projects available and discussions with potential supervisors, students will apply for doctoral research topics. Once their project is determined, each student will develop a Personal Training Plan (PTP) in communication with their supervisor and the Associate Director for Training which will map out additional training during their Doctorate.

QTM2S will be based at the University of Oxford making use of world leading facilities and expertise in both quantum technology and materials science. It will provide a dynamic and supportive environment with students working closely with others in their cohort and across cohorts as their projects progress.

EPSRC Centre for Doctoral Training in Informatics for Multi-hazard Risk Reduction and Infrastructure Resilience (i-Risk)

Professor Qiuhua Liang Loughborough University

Liang, Professor Q,Rossetto, Professor T,Fowler, Professor H,D'Ayala, Professor DF,Sebastian, Professor WM,Chen, Dr L,LU, Dr Q,Chmutina, Dr K,Lewis, Dr E,Forshaw, Dr MJ

The world is rapidly changing. Climate change, rapid urbanisation and large-scale population movement have significantly increased the risk of disasters from natural and man-made drivers, creating enormous pressure on local and national governments to enhance the security and sustainability of our societies. Today's socio-economic systems are intrinsically interconnected through a range of infrastructure and communication networks. Whilst efficient operation of such systems can generate economic gain, they are fragile, and vulnerable to environmental shocks/disasters, which may create cascading and cumulative impacts at multiple spatial scales (local to global) across different timescales (from immediate to decadal and beyond); disaster risk really is systemic. Much current DRR research/practice is 'siloed', with insufficient consideration of the systemic, interconnected and interdependent nature of complex risks and multiple interacting hazards threatening society. This is a key challenge widely recognised by the UN Office for Disaster Risk Reduction (UNDRR), national governments and global academics. We need a new generation of research scientists with an interdisciplinary research vision and capability to push current research frontiers to tackle the critical challenges. We need a new knowledge base and solutions to step change current disaster risk reduction (DRR) research and practice.

Responding to the research need and skills gap, the EPSRC Centre for Doctoral Training in Informatics for Multi-hazard Risk Reduction & Infrastructure Resilience (i-Risk) will develop five cohorts of doctoral researchers, through structured training and industry co-created interdisciplinary projects, to deliver innovative tools and solutions for multi-hazard systemic resilience and sustainability practice. The i-Risk CDT builds on long-standing strengths of three leading UK universities at the forefront of integrated informatics and multi-hazard risk research. In addition, Loughborough and UCL will leverage the powerful global networks associated with two DRR-related UNESCO Chairs to provide unique and prestigious opportunities for the CDT cohorts, whilst Newcastle will provide direct links to UK government and its national agencies, institutions and UKCRIC scientific facilities.

i-Risk's students will register at one of the three universities and initially take a one-year Masters in Research degree programme. A "Learning by Doing" approach will prepare candidates from diverse backgrounds to pursue high-quality research in the subsequent PhD programme. Carefully designed cohort development and training activities will build cohort networks and develop skills to broaden student's capabilities across the years. Each student will have placement opportunities, spending 4+ months with different collaboration partners to participate in real projects and develop different career pathways. i-Risk graduates will deliver high-calibre research, enhancing the UK's leading international position in infrastructure resilience and societal security solutions under climate change, enabling UK engineering companies to grow their share of the expanding global construction and services market. They will form a critical mass to influence future DRR and climate resilience research and practice.

EPSRC Centre for Doctoral Training in Entrepreneurship for Physical Sciences into Complex Biology & Healthcare (EPiC)

Professor Angela Russell University of Oxford

Russell, Professor AJ,Bayley, Professor H,Schofield, Professor C,Davis, Professor B,Robinson, Professor CV,Wood, Professor MJA,Baldwin, Professor A,Kukura, Professor P,Platt, Professor F

Our aim is to create a unique doctoral training centre in Entrepreneurship for Physical Sciences into Complex Biology and Healthcare (EPiC) to train the next generation of scientist innovators and entrepreneurs to work on complex multi-disciplinary, cross-sector research and innovation challenges. Through this CDT we aim to build an environment to foster a cohort approach to learning encompassing ongoing training, research, translation and innovation in emerging experimental measurement and imaging technologies in physical sciences and to apply these in complex physiological models with real world application in basic biology and healthcare. To deliver this vision we will work alongside investor groups, start-ups, biotech companies and industry 'end users' and embed in our students an entrepreneurial mindset from day 1, equipping them with the skills to translate their ideas into the successful businesses of the future. Through the diversity in our training programme, our students will also be uniquely skilled to move into a range of careers post PhD, including working in leadership roles across this sector, which will be as highly valued an outcome as translation.

EPiC's primary fit is to the EPSRC's focus area 'meeting a user-need or supporting civic priorities'. EPiC arises from long-term discussions with colleagues in industry, biotechnology, entrepreneurship and investment sectors; we have identified two major gaps in science and entrepreneurship training. Across the commercial and academic sectors there is a recognised need to move beyond chemical technologies to integrate with biophysical sciences and measurement technologies to develop direct, sensitive, label-free, quantitative methods to monitor molecular interactions and their perturbations in complex systems. While such breakthrough methods have been emerging from the physical sciences over the past 5-10 years, these are not yet being translated efficiently into real world biomedical applications, but have the potential to underpin new platform technologies, diagnostics and therapeutics development in the biotechnology and healthcare sectors in the future. Moreover, a major bottleneck to successful translation are the numbers of scientists with both innovative ideas and real commercial knowhow and understanding. To address these gaps we are co-developing EPiC alongside our industry partners, with US and UK investment groups, local start-up companies and other groups in the entrepreneurial sector.

EPiC centres around a Team Science approach which will foster training, support and cohesion within and between successive cohorts together with the wider CDT network team including partners across sectors. This approach will be at the forefront of everything that we do: support in training, development of innovative projects, nurturing a positive research culture for the entire CDT, students, supervisors, collaborators and management team.

Overall our expected outcomes are as follows: (i) to train a new generation of scientific leaders at the interface of physical sciences and biomedicine equipped to enter a range of sectors in their future careers; (ii) to overturn conventional thinking for outcomes for doctoral research: students will be encouraged and supported throughout the CDT to plan long-term goals and opportunities for major scientific and commercial advances (rather than short term outputs, e.g. publications); (iii) to provide new insights into biomedicine through collaborative research outputs (papers, patents) using innovative approaches; (iv) to stimulate new student-led innovations and commercial ventures in platform technologies, devices, diagnostics or new therapeutics; (v) the adoption of our technologies by the broad biomedical research community to study biology & medicine and (vi) to establish the entrepreneurial equivalent of an MD/PhD in Oxford and beyond in the UK.

EPSRC Centre for Doctoral Training in Renewable Energy Northeast Universities Plus (ReNU+)

Professor Neil Beattie Northumbria University

Beattie, Professor NS,Gibson, Professor EA,Xing, Dr L,Ireland, Dr MT,Johnston, Dr KE,Phan, Professor A,Groves, Professor C,Zoppi, Professor G,Mendis, Dr B,Barrioz, Dr V

The ESPRC Centre for Doctoral Training in Renewable Energy Northeast Universities Plus (ReNU+) is a transformative programme that will train a new generation of Doctoral Carbon Champions (DCCs) who are characterised by scientific and engineering excellence and capable of interdisciplinary systemic thinking to accelerate Net Zero. The outcome from ReNU+ will be that DCCs will meet critical needs in high-skill employment across industry, policy, education and government and convert key challenges in resilience and equity into economic opportunities for the United Kingdom. This will be achieved through a professionally accredited training programme in a thriving environment of research excellence led by Northumbria, Newcastle and Durham universities.

The 2023-2035 energy landscape sets a compelling context for ReNU+ and in particular, the need for future leaders in this space in the United Kingdom. Locally generated renewable energy will provide the UK with increased energy security and critically important additions in electricity capacity to meet domestic and industrial demands. This is only one piece of the landscape however, which also includes sustainability (e.g. critical materials supply), resilience (e.g. climate change mitigation) and an equitable transition to Net Zero, which offers both economic and health benefits. The absorptive capacity for ReNU+ DCCs is partly evidenced by the forecast of 694,000 new UK jobs in the low carbon and renewable energy economy by 2030 (source: UK Local Government Association).

The ReNU+ training programme has a core focus on developing key skills that facilitate understanding of and engagement with the wider Net Zero system including investment, regulation and end-user engagement. It will become a reference for high-skill training in Net Zero that redefines the role of scientists and engineers as critical catalysts for decarbonisation who deliver impact well beyond technology. ReNU+ identifies a critical link between equality, diversity and inclusivity and decarbonisation and includes key innovations to leverage this link. Consequently, DCCs will also develop societal and citizenship values as they become living examples of the future workforces to enable an equitable and sustainable transition to Net Zero. This approach has been validated by our partners who have co-designed and will co-deliver the ReNU+ training programme. This support includes national and local Government, multinational companies, small-to-medium enterprises and charity organisations.

EPSRC Centre for Doctoral Training in Human-Centric Cyber and Decision-Making

Professor Rupak Kharel University of Central Lancashire

Kharel, Professor R,Wallace, Professor CA,Sim, Dr G R,Mauger, Dr A,Read, Professor J,Liversedge, Professor SP,Ball, Professor L,Donnelly, Professor N,Khan, Dr S S,Richards, Dr P,Smy, Dr V

The proposed doctoral training centre aims to provide a step change in Human-Centric Cyber and Decision Making research through a co-development focused on the complex intersection between cognitive (human) and physical (machine) spaces in the context of cyber, to address the bio-psycho-social aspect of cyber at individual, team and interface levels. Our vision and ambition is to create a CDT learning ecosystem shaped by world-leading academic and industry experts, with the drive of solving real-world cyber problems.

10 research strands have been co-designed to develop a research campaign with a bespoke focus. A 4-year integrated training and PhD research model will be applied based on UCLan DTC experience. Students will receive extensive research specific and professional/transferable skills training throughout the programme. Training will be cohort-based and bespoke to the individual and will facilitate both the early start of research programmes to meet user requirements and timely completion within 4 years.

EPSRC Centre for Doctoral Training in Cyber-physical Systems for Medicine Development and Manufacturing (CEDAR)

Professor Alastair Florence University of Strathclyde

Florence, Professor AJ,Adjiman, Professor CS,Perrie, Professor Y,Schroeder, Professor SLM,Cardona, Dr J,Markl, Dr D,Smith, Dr R,Hoskins, Dr C

Pharma R&D investment totalled over £4.7Bn in 2019 representing 18% of commercial R&D investment in the UK and is projected to generate £45Bn to the broader economy in the next 30 years. Workforce projection shows a need for 43,000 high skilled jobs in the UK pharma sector by 2030. Over 60% of the future workforce in the science-driven pharma industry will require higher education with an increasing demand for doctoral-level qualifications

This CDT program will train 90 future leaders to transform the development and manufacture of essential and novel medicines through the creation and implementation of integrated novel cyber-physical systems (CPS). The emerging application of CPS in medicines development and manufacture is essential if the sector is to realise the benefits from seamless connection between physical and digital domains. This innovative program will enable researchers to design and optimise process and product performance and physical production system operation to create an Industry 5.0 medicine manufacturing sector that is sustainable, resilient, and human-centric. The program is crucial to addressing societal and industry challenges, including pandemic preparedness, supply resilience, aging populations, rising healthcare costs, and the climate crisis. The CDT will be delivered by an internationally leading, multidisciplinary team from four universities and industry partners (e.g. AstraZeneca, Pfizer, Eli Lilly, Roche, Takeda, UCB, Chiesi, Sanofi), supported by state-of-the-art facilities and experienced operational support.

The CDT will deliver doctoral graduates who have attained advanced technical, digital, and transferable skills with deep understanding of the interdisciplinarity of medicines development and manufacturing, enabling them to excel in high-performing, intercultural, inclusive and diverse environments in industry or academia. The cohort-based formal, student-centric, 60-credit training is co-delivered across four streams:

1) Core and advanced multi-disciplinary technical skills;

2) Digital technologies, CPS and data literacy;

3) Industrial and regulatory practice;

4) Personal development through transferable & professional skills.

The program will deliver doctoral graduates who have attained advanced technical, digital, and transferable skills with deep understanding of medicines development and manufacturing. The CDT will co-create innovative, industry-inspired research projects that collectively realise a system-level, digital, and advanced processing toolbox from particle formation to biorelevant performance. Every research project will tackle a particular challenge within one of the three predictive frameworks:

1) CPS for Molecule to Particle Design & Manufacture: the design and formation of structured nano- and micro-particles of pharmaceutical materials;

2) CPS for Particle to Product Design & Manufacture: design and production of formulated medicinal products;

3) CPS for Product to Patient Design: biorelevant particle and product performance for clinically relevant predictive design.

The CDT will deliver cross-cutting Industry 5.0 components underpinning the predictive frameworks, with long-lasting impact on future manufacturing research, training of MSc and doctoral students beyond the CDT, and CPDs for upskilling and career converters.

EPSRC Centre for Doctoral Training in Healthcare Data Science

Professor Thomas Nichols University of Oxford

Nichols, Professor T,Kamnitsas, Dr K,Lythgoe, Dr K,Rittscher, Professor J,Davies, Professor J

The UK is a global leader in health research and healthcare technology. It is one of the most important sectors in our economy, and the largest in terms of commercial expenditure on research and development. It is also critical to the future of our health service: we need new ways of diagnosing and treating illness, new ways of delivering care, and new ways of planning for and dealing with challenges such as the recent pandemic.

To maintain this leading position, the UK needs more healthcare data scientists. It needs data scientists who can advance the state of the art in computer science, statistics, and engineering in support of health and healthcare transformation. These scientists need to have an excellent understanding of the application domain: that is, they need to know how healthcare works, and what is required.

They need also to know how to behave responsibly and ethically. For example, the methods and tools that they produce, and the research that they conduct, should take proper account of the variation and diversity in our population. Above all, they need to know how to work effectively with people from different backgrounds: health professionals, health researchers from academia and industry, patients, and the public.

The Oxford EPSRC CDT in Healthcare Data Science will provide the research training that turns talented science graduates into this kind of data scientist. Supporting the EPSRC strategic delivery plan in the research priority area of transforming health and healthcare, it will work in partnership with the NHS, with the UK Health Security Agency, and with a range of research groups and organisations in academia and industry, ensuring that students obtain the essential combination of scientific rigour and real-world experience.

The training programme is cohort-based, meaning that students learn how to work together and support one another. This is important: the challenges that we face can only be addressed through trust and collaboration. The programme is designed to be accessible to graduates in different subjects, and we will make efforts to ensure that the cohorts are properly diverse.

Our experience to date shows that this approach works very well indeed. Our students have developed new approaches using real data to solve important problems, and to deliver real benefit in terms of health and healthcare transformation.

EPSRC Centre for Doctoral Training in Surfactant Innovation: Revolutionary Science and Technology

Dr Robert Lindsay   The University of Manchester

Lindsay, Dr R,Saiani, Professor A,THOMAS, Dr AG,Routoula, Dr E,khodaparast, Dr s,Spallina, Dr V,Campbell, Dr K,Barker, Dr R,Leach, Dr A G,Winterburn, Dr J,Siperstein, Professor FR

Surfactants are chemicals that typically consist of a water-loving head group and water-hating tail. These opposing properties make them ideal ingredients in a huge variety of valuable applications, ranging from everyday goods, such as shampoos and engine lubricants, to life-changing/saving products, e.g., COVID-vaccines. Consequently, there is a thriving commercial sector that focuses on manufacturing and exploiting these chemicals. Such activity is distributed across the globe, with the UK having a vibrant mix of successful multinationals, SMEs, and start-ups. In line with other areas of UK industry, however, the surfactant sector urgently needs to pursue greener surfactant production/use to survive in a landscape increasingly dominated by Circular Economics and Net-Zero considerations, e.g., British multinational Unilever (6000+ employees in the UK) have committed to eliminating fossil fuels from their surfactant-based cleaning range by 2030. No longer can current products be tweaked to maintain a competitive edge. Instead, discovery-led research is required to pioneer radical green innovation for both current and future surfactant-based technologies.

Exceptional STEM talent will be essential for delivering the transformative science required by the surfactant sector, including doctoral graduates that can take on leadership roles. The Centre for Doctoral Training in Surfactant Innovation: Revolutionary Science and Technology (SurfIn) will be an incubator for these future leaders (SurfIn-PhDs). It will offer a bespoke training experience, encompassing both Research and Formal elements, that will provide each SurfIn-PhD with a technical/professional skillset tailored for a rewarding career in the surfactant sector. A central tenet of SurfIn is to promote success for all through forging an inclusive cohort culture that will ensure peer-to-peer learning and mutual support are the accepted norm. This approach will hugely improve the SurfIn-PhD experience, as well as enhance the prospect of game-changing scientific breakthroughs.

To ensure that research excellence is dovetailed with real-world awareness, SurfIn will be co-created/delivered by a Core Team of three leading northern universities, Manchester (UoM), Leeds (UoL) and Sheffield (UoS), two surfactant sector multinationals, Unilever and BASF, start-up Holiferm, and the Society of Chemical Industry (SCI). They will provide Formal Training through a series of assessed units, targeting a wide range of competencies, including fundamentals of surfactant chemistry and physics, machine learning algorithms, effective communication, and commercialisation and entrepreneurship.

In tandem with Formal Training, each SurfIn-PhD will receive Research Training through carrying out their project under the supervision of academics from one or more of the three universities, as well as being supported by a non-academic supervisor/mentor. More than 60 research active academics, who have extensive accumulated expertise in surfactant-based science, have expressed their desire to develop/supervise SurfIn-PhD projects. Their technical proficiency is broad and includes surfactant synthesis and formulation, performance/application testing, and characterisation with cutting-edge tools, e.g., X-ray/neutron scattering and vibrational spectroscopies. Multi-scale computational modelling, from atomic scale simulation of interfaces, through artificial intelligence approaches, to continuum descriptions of flow and related phenomena, is also well represented in the cohort. This mixture of academic supervisory skills/expertise, in concert with the cohort of industrial partners, is extremely well equipped to support a diverse range of exciting projects for SurfIn.

EPSRC Centre for Doctoral Training in UK as World Leader in Timing and Future Applications

Professor Antonios Tsourdos   Cranfield University

Tsourdos, Professor A,Everitt, Dr M,Shean, Dr T,Schioppo, Dr M,Petrunin, Dr I,Guo, Professor W,Riis, Professor E,Tafazolli, Professor R,Margolis, Dr H,Burguete, Dr R

Precise timekeeping is the great hidden organiser and enabler of our modern society. It enables synchronized cooperation and accurate location services. Whether it is safely orchestrating thousands of autonomous vehicles in a city, synchronizing global trade transactions, performing lifesaving remote surgery, or crowd participation in a metaverse; clocks and the dissemination of timing data is vital to all of them. Most modern timing signals are disseminated via global navigation satellite systems (GNSS) and it is estimated to be a key part of 11% of UK GDP, monetising £6.7bn per annum and supporting over 4000 jobs directly.

The National Timing Centre (NTC), run by NPL and funded by BEIS/DSIT, is there to ensure that a future hybrid network can avoid common vulnerabilities, threats, and failure modes. It will also help safety-critical users maximize triple modular redundancy via GNSS, terrestrial distribution, and local clocks. Future UK optical clocks aim to improve the accuracy of time measurement by a factor of 10-100, while reductions in size will improve local holdover capabilities. This requires new cross-disciplinary knowledge, and creation of a technology dialogue with emerging end users, to enable UK end-users to better benefit from the technology.

A skills survey and training blueprint from the NTC programme highlight a UK-wide skills shortage in time and frequency and the need to nationally develop skills in timing at multiple profession levels (particularly at a doctoral level). Early drafts of the UK PNT Strategy concluded that at least a 4-fold increase in researchers, engineers and applications specialists will be required with a specific recommendation given to have a timing focussed CDT programme. The UK must maintain its leadership position in timing via excellent research, cohort based multi-disciplinary doctoral training, and driving this process with engagement and investment. In response to the end-user skill gaps, the consortium has designed cross-disciplinary training across the 4 nations of the UK to ensure comprehensive challenge and skill coverage.

EPSRC CDT in Future Technologies in Ultra Wide Bandgap Semiconductors (UltraWiBS CDT)

Dr Vishal Ajit Shah   University of Warwick

Shah, Dr V,Gunasekar, Dr NK,Williams, Professor OA,Martin, Professor RW,Dawson, Professor M,Kuball, Professor M,Oliver, Professor RA,Green, Dr BL,Jahdi, Dr S

Semiconductors are at the heart of most technology as we know it. The success of wide bandgap (WBG) semiconductors, such as Silicon Carbide and Gallium Nitride is well known for applications in optoelectronics, communications, and power electronics. Meanwhile, there is an increasing drive for the next revolutionary solid-state technology which will displace WBG in 10-15 years' time: namely, the development and application of ultra-WBG (UWBG) semiconductors with bandgaps above 4eV, such as Gallium Oxide, Diamond, Aluminium Nitride and Boron Nitride.

UWBG materials are necessary enablers of the next generation of traditional semiconductor applications such as high voltage transmission lines, and fast charging of electric vehicles. Additionally, UWBG materials have also shown promise in disruptive technologies such as quantum information processing (QIP), as well as UV optoelectronic and photonic applications (sanitisation, switching, purification and biosensing), micro and nano-electromechanical systems (sensors, microfluidics) and harsh-environment operations (aerospace, offshore operation and exploration). Power electronics alone is a major technology sector for the UK: £50 billion to UK GDP, and QIP is set to become a multi-billion-pound market. The UK will require UWBG semiconductor experts with associated skills due to this demand.

UltraWIBS' students will become the next generation of semiconductor scientists which have training in UWBG materials and applications with the knowledge, ability and network to fast-track new materials' technology cycles which typically take decades to develop. By engaging UWBG materials and application leaders at Warwick, Bristol, Cambridge, Strathclyde, and Cardiff, UltraWIBS will give students world-class training in semiconductors and provide a foundation for the UK to capitalise on these materials and related technologies.

UltraWIBS' mission:

1. Take the national initiative on developing skills & leaders for a semiconductor workforce to drive the current industry. The recent semiconductor review by BEIS highlighted the critical importance for the UK to maintain its strength in compound semiconductors - including WBG.

2. Develop the critical mass in research for emerging UWBG semiconductors for the UK. This CDT will secure the UK's position as a world leader in the next-generational wave of UWBG semiconductor technologies.

3. Cultivate the skills in doctoral students needed to facilitate translation from UK semiconductor research into impact. This is a historic weakness of the UK which requires improvement (as highlighted in the BEIS report). By engaging with user applications, we will tutor cohorts on critical skills required to translate base research to impact.

The interdisciplinary nature of the delivery teams' strengths and material/application challenges means that a cohesive, cohort-based approach will maximise the cross-pollination of ideas, solutions, and challenges far beyond students trained in individual groups. It will also foster student-driven interactions between different groups, promoting the mixing of ideas, materials systems, technologies, facilities, and application areas from all partners.

The training priorities will ensure a wide knowledge base with an emphasis on different semiconductor materials systems and industrialisation routes. New training modules will be created by academics and industrial partners to cover: synthesis of UWBG materials, the physics underpinning their properties, the fabrication and integration of devices from UWBG materials (including scale-up manufacturing), innovation (including new product development, IP, and entry to market) and applications (power, communications, quantum, sensing).This skill base is needed to ensure that the UK has a pipeline of people with standard and emerging semiconductor knowledge that can take advantage of the critical mass of blue skies materials research already happening.

EPSRC Centre for Doctoral Training in Engineering and Physical Interventions for Cancer (CDT EPIC)

Professor Richard Hall University of Leeds

Hall, Professor RM,Bryant, Professor M,Sebag-Montefiore, Professor D,Oeflke, Professor U,Walker-Samuel, Professor S,Salto-Tellez, Professor M,Shipley, Professor RJ,Thomas, Dr BG,Cheema, Professor U,Harris, Dr EJ

Cancer is the one of the UK's biggest killers, and the second most common cause of death worldwide. In 2020, it resulted in 10 million deaths, and the incidence is predicted to rise to 28 million by 2040. Approximately 3 million people are living with cancer in the UK and this number is set to rise considerably over the next two decades to 5.3 million. In the UK, 1 in 2 people in the UK will be diagnosed with cancer in their lifetime, and someone in the UK dies from cancer every 4 minutes. Despite significant progress over the last 20 years, survival 10 years after diagnosis is still only 50%.

A significant proportion of cancer diagnosis and treatment utilise underpinning engineering and physical science (EPS) technology including novel diagnostics, advanced radiation therapy, robotic surgery, minimally invasive robotics and surgery. However, rapidly changing technologies are bringing to the fore newer developments in these existing therapies and importantly a range of newer engineering-based treatments that promise a radical shift in outcomes for patients. As novel interventions continue to develop at a rapid pace, a new generation of engineers and scientists are urgently needed to develop, utilise and maintain these tools and technologies for cancer diagnosis and treatment. Indeed, national policy and strategies in the NHS and the wider life sciences industry recognises the critical need for the next generation of highly skilled scientists and engineers, without which these new treatments will not be made available to patients.

We propose an EPSRC Centre for Doctoral Training in Engineering and Physical Interventions for Cancer (CDT EPIC) to address this skills shortage, where no EPSRC CDT currently exists at the EPS/cancer interface. It is dedicated to training talented PhD researchers from diverse backgrounds with the interdisciplinary, technical and innovation skills to develop advances in the diagnosis and treatment of cancer. It is a highly collaborative programme of research training delivered by three world-leading leading institutions; University of Leeds, University College London and the Institute of Cancer Research and co-created with industry, healthcare providers and civil bodies and patients. Internationally, the Universities are recognised leaders in their fields; EPS and cancer research, and bring to the training a wealth of experience, research excellence and training leadership. The new programme's focus is on training researchers in the development and use of novel tools and technologies in the laboratory for use in clinic, enhanced by a deep understanding of the wider regulatory, societal and health challenges.

Cohorts of researchers will gain the necessary interdisciplinary skills demanded by industry and the NHS to deliver timely and cost-effective solutions to some of the most intractable UK healthcare problems in cancer utilising engineering technology. From the training, these researchers will become future leaders in the cancer research sector supporting the NHS, industry, patients and government. The training goals, which have been developed in collaboration with patients and partners, will be achieved by bespoke training activities, providing skills and capabilities that cross traditional discipline boundaries. Importantly, cohort-based training will be delivered not only in the taught elements but in the research projects themselves, where students will work together in small teams to seek solutions to cancer grand challenges. Secondments and interactions with industry and the NHS is a key aspect, with students spending time in NHS Trusts, industry and international partners to garner experience. The students will learn how to distribute the knowledge to the public, doctors and industry advocating the need for these technologies. Importantly, equality diversity and inclusion, and patient and public involvement engagement are at the heart of the CDT.

SATURN - Skills And Training Underpinning a Renaissance in Nuclear

Professor Scott Heath The University of Manchester

Heath, Professor SL,Lunn, Professor RJ,Walkley, Dr B,Patel, Dr M K,Hanson, Professor BC,Patterson, Professor EA,Boxall, Professor C

Since the 2004 Energy Act, nuclear fission has rapidly grown, and continues to grow, in significance in the UK's Energy and Net Zero Strategies. Government's Nuclear Industrial Strategy states clearly that the nuclear sector is integral to increasing productivity, driving growth across the country and meeting our Net Zero target. Nuclear is, and will continue to be, a vital part of our energy mix, providing low carbon power now and into the future, and the safe and efficient decommissioning of our nuclear legacy is an area of world-leading expertise. In order for this to be possible we need to underpin the skill base. The primary aim of SATURN is to provide high quality research training in the science and engineering underpinning nuclear fission technology, focussed on three broad themes: Current Nuclear Programmes. Decommissioning and cleanup; spent fuel and nuclear materials management; geological disposal; current operating reactors (AGRs, Sizewell B, propulsion); new build reactors (Hinkley C, Sizewell C, possibly Wylfa Newydd;

Future Nuclear Energy: Advanced nuclear reactors (light water reactors, including PWR3, gas cooled reactors, liquid metal cooled reactors, other concepts); advanced fuel cycles; fusion (remote handling, tritium);

Nuclear Energy in a Wider Context: Economics and finance; societal issues; management; regulation; technology transfer (e.g. robotics, sensors); manufacturing; interaction of infrastructure and environment; systems engineering.

It has become clear that skills are very likely to limit the UK's nuclear capacity, with over half of the civil nuclear workforce and 70% of Subject Matter Experts due to retire by 2025. High level R&D skills are therefore on the critical path for all the UK's nuclear ambitions and, because of the 10-15 year lead time needed to address this shortage, urgent action is needed now.

SATURN is a collaborative CDT involving the Universities of Manchester, Lancaster, Leeds, Liverpool, Sheffield and Strathclyde, which aims to develop the next generation of nuclear research leaders and deliver underpinning (Technology Readiness Level (TRL) 1-3), long term science and engineering to meet the national priorities identified in Government's Nuclear Industrial Vision. SATURN also provides a pathway for mid technology level research (TRL 4-6) to be carried out by allowing project to be based partly or entirely in an industrial setting. The consortium partners have been instrumental in a series of highly successful CDTs, Nuclear FiRST (2009-2013), NGN (Next Generation Nuclear, 2013-2018) and GREEN (Growing skills for Reliable, Economic Energy from Nuclear, 2018-2023). In collaboration with an expanded group of key nuclear industry partners SATURN will create a step-change in PhD training to deliver a high-quality PhD programme tailored to student needs; high profile, high impact outreach; and adventurous doctoral research which underpins real industry challenges

EPSRC Centre for Doctoral Training in Statistics and Operational Research in Partnership with Industry (STOR-i)

Professor Idris Eckley Lancaster University

Eckley, Professor IA,Tawn, Professor J,Sachs, Dr A,McCrea, Professor R

Lancaster University, together with a formidable array of industrial and third-sector partners, proposes a Centre for Doctoral Training (CDT) to develop international research leaders in Statistics and Operational Research (STOR) through a programme in which cutting-edge real-world challenge is the catalyst for methodological advance.

The reality faced by our partners is that the demand for highly-trained STOR data specialists far outstrips supply. This situation is becoming more acute due to the ever-increasing importance of data within the economy and society. Our proposal therefore addresses the priority area `meeting a user-need' in response to this challenge.

The new Centre builds on the strengths and learning derived from an existing, internationally recognised, EPSRC CDT. Together with the input of an expanded partner community (blue chip companies, SMEs, and third sector organisations) we propose a new Centre that will recruit and train 70 students, across 5 cohorts, within a programme that seeks to draw on industrial and charitable challenges as inspiration for the highest quality research.

The new programme will innovate by

* Developing a new MRes programme co-designed and delivered with our partners;

* Including a comprehensive training programme on advanced, reproducible programming for STOR, co-ordinated by the Centre's dedicated, industry-funded, Research Software Engineer;

* Embedding industrial and third-sector collaboration throughout the student experience;

* Hosting thematic research summits: vibrant, cross-cohort, cross-sector retreats to explore and develop early-stage challenges emerging from the shared interests of STOR-i and its partners;

* Developing an ambitious doctoral exchange programme with highly regarded international university partners, comprising student exchanges, co-supervision and shared training activities.

Our partners are integral to the new Centre's plans: 80% of doctoral projects will be CASE-like, co-funded and co-supervised by industrial partners. All other students will undertake industrial research internships. Partners will also lead problem solving days, data dives and contribute to CPD activities, e.g., leadership talks, fireside chats and advanced programming training.

STOR-i will deliver a wide range of benefits and scientific outcomes to the end-user community focused on three key pillars:

* People - Our CDT will provide a critical injection of 70 highly talented PhD graduates who possess the technical, interpersonal, and leadership skills needed for successful careers in STOR across a wide range of sectors. Graduates will serve as catalysts for innovation and

progress, driving forward cutting-edge research and contributing to the growth and competitiveness of the UK economy.

* Knowledge - Our CDT will generate a wealth of leading-edge research that will be published in top STOR journals, disseminated at major international conferences, and used as a stimulus for outreach and engagement. This research will tackle substantive real-world problems, leading to new insights and breakthroughs in STOR.

* Impact - Our CDT will have a tangible impact on society and the economy through the development of (i) case studies and (ii) a body of documented and reproducible software that will be publicly available, allowing for the widespread adoption of our research.

EPSRC Centre for Doctoral Training in Sensing, Processing, and AI for Defence and Security (SPADS)

Dr James Hopgood University of Edinburgh

Hopgood, Dr JR,Davies, Professor M,Cheung, Professor R,Petillot, Professor Y,Repetti, Dr A,Albrecht, Dr SV,Serb, Dr A,ALTMANN, Dr Y,Hospedales, Professor TM,Ramamoorthy, Professor S

Security and defence are fundamental functions of the UK government, enabling a safer society while maintaining a strong national industry. In a globally connected context, where information acquisition and analysis is paramount, it is imperative to maintain a long-term training programme supplying the UK's defence ecosystem with technical experts and highly qualified personnel, equipped to evolve in a rapidly evolving environment.

The task of the user-led EPSRC Centre for Doctoral Training in Sensing, Processing, and AI for Defence and Security (SPADS) is to admit recent university graduates, boost their core engineering skills, equip them with a portfolio of defence-related complementary skills, and allow them to carry out academic research in collaboration with the UK defence community. SPADS will be led by an experienced team of internationally recognised, defence-oriented academics, from the Universities of Edinburgh and Heriot-Watt, and who have long-lasting research collaborations with government institutions and many industrial partners. The CDT will run over 8 years and develop five cohorts of PhD graduates specifically trained to integrate themselves into the UK's defence ecosystem as top-tier talent. The expectation is that upon graduation, SPADS students will fulfil roles such as top-level scientific experts, large-team leaders and high-level executives across defence contractors, government agencies and defence-oriented start-ups, although this list is not exhaustive.

To achieve this, SPADS has identified four core areas of critically important defence-related engineering expertise: hardware design, sensing and data processing, AI and autonomy, and multi-agent systems. Notably these areas span from low-level hardware design, where key challenges relate to system consumption, size and performance, all the way to the top-level where networks of systems/sensors can coordinate their behaviour. These areas are highly interconnected, share common engineering foundations, and require technical personnel with at least one core expertise and sufficiently generally trained to communicate and work within multi-disciplinary environments; precisely the people the SPADS seeks to train. Not only will SPADS train the next-generation workforce that the UK defence organisations critically need, it will also equip them with the tools to pioneer and lead in generation-after-next systems and adapt to new and emerging technologies.

The expected outcomes have key implications for both UK national security and economic prosperity. (1) SPADS will fund an array of scientific/engineering projects, led by industrial applications, contributing very directly to UK technological capability. (2) It will create a pool of top-tier talents for UK defence-related institutions, which will significantly facilitate their currently intense and risky talent-hunt. (3) It will create and a strong network of skilled engineers and researchers and knit together the next generation UK's defence ecosystem.' (5) SPADS' original 8-year span will lay the foundations long-term training of defence-related PhD-level specialists, encouraging private investment in UK defence. (6) The fundamental and underpinning nature of the SPADS projects will ultimately be exploited in the defence sector, but also in the civilian sector such as healthcare, automotive or the gaming industry, much like NASA projects jump-started entire civilian industries and products.

In summary, SPADS will make the UK defence industry and defence-related government institutions capable of hiring expert personnel more easily, develop novel AI technology faster, invest in the UK with increased confidence and work together more tightly than ever before, maintaining the world-leading position of the UK in a rapidly evolving global landscape. The underpinning research and projects will also find applications in other industries, making the UK a safer and more productive nation.

EPSRC Centre for Doctoral Training in Security-science and Technology for Advanced Resilient Systems (STARS)

Professor Washington Ochieng Imperial College London

Ochieng, Professor WY,Ryan, Professor M,Burnap, Professor P,Chana, Dr D,Eakins, Dr D,Giuliani, Professor F

The ability of nations to provide security for citizens relies on a complex interplay between cyber and physical systems. As these systems become more advanced, and their supply chains and interconnectivity become global, the challenges of delivery and protection becomes even more challenging. Security scientists and engineers need a holistic understanding of systems, as well as deep technical knowledge. A new type of training is needed for the next generation - creating future-fit security scientists who are able to understand this complex landscape from multiple perspectives: technical, political, economic and social. Our programme brings together three universities with complementary skills and networks in the sectors. In combination the students will gain deep understanding of the key aspects of security science.

We will focus our programme around three key strategic themes: i) Advanced Materials and Infrastructure for National Resilience, ii) Cyber-Threats in an Evolving World and iii) Cyber-Physical Interfaces in Global Security. Cross cutting themes of supply-chains, resource scarcity, remote sensing and data analytics will be explored within projects and via cross project collaborations (e.g. industry-led hackathons, policy exchange workshops, outreach activities). Students will be assessed via written examinations, oral examinations, problem sheets, practical work and team-work - all used to ensure a range of competencies are assessed and that students get rapid feedback on their learning. The Management Board will ensure that module assessments reflect the needs of the training course. Resits will be permitted but repeat failure will result in exit from the programme. We will hold an annual meeting with invited international speakers as well as presentations by all of the cohort. A summer school and a series of student-led workshops & public engagement activities will be held in years 2 - 4, each aimed at a different target audience from our focused topics. We will align (appropriate) international PhD students from our institutions with the STARS CDT cohort where experience can be shared and global networking achieved. We will develop leadership skills in the cohort by having them lead and organise these events. We will ensure peer-to-peer learning across cohorts by having year 1 cohorts organise all annual events with an adviser from later year cohorts. The STARS CDT will ensure timely, relevant research, foster student professional development and breadth of vision, and ensure strong on-going linkage and interchange of information between all collaborating partners.

The number of PhD level graduates in the broad field of security is small and those that do graduate tend to be overly focused on one topic area and lack breadth, a network of contacts and a global perspective. The EPSRC Centre for Doctoral Training in Security-science and Technology for Advanced Resilient Systems will address this gap. The STARS CDT focused on 'Mission-inspired research'; and need and meets a recognised shortage of UK technical skills in this area as emphasised in the National Security Strategy and Strategic Defence and Security Review (2015) which highlights the need for "investment in skills and increased recruitment and training needs in the security and intelligence fields especially to deter increasing international terrorist, cyber and other global threats" Furthermore, there is a lack of collaboration between the technology/security teams and the analysis teams in Government and the civil service - such a doctoral training programme would produce potential employees who can help to break these silo.

EPSRC Centre for Doctoral Training in Quantum Informatics

Dr Christiaan Johan Marie Heunen   University of Edinburgh

Heunen, Dr C,Kashefi, Professor E,Green, Professor AG,Del Debbio, Professor L,Kendon, Professor VM,Leimkuhler, Professor B,Parsons, Professor M,Andersson, Professor E,Safari, Dr M

Quantum computing brings unmatched effectiveness at solving certain computational problems, unprecedented possibilities in computer networking, and unparalleled opportunities in secure communication. It will make a positive impact in many important societal challenges such as net zero and digital futures, with applications in pharmaceuticals, chemicals, materials, automotive, and finance. Experimental physics and engineering have brought quantum hardware to the point where it has taken commercial flight.

The Centre for Doctoral Training in Quantum Informatics will be the first in the UK fully dedicated to systematic training in quantum software and application development, complementing previous efforts focused on core technology development. By drawing together expertise from partners all over the country into a coherent programme, it will close the divide between machine and application in two ways: first, the CDT will address the fundamental knowledge gaps in quantum software architecture and integration with classical high-performance computing; second, the CDT will address translating end user problems into useful quantum solutions in an application-driven way.

Augmenting the National Quantum Technologies Programme, and involving the National Quantum Computing Centre, the CDT will train a new generation of students with knowledge across computer sciences, mathematics, physics, and engineering; scientists and engineers who understand the structure, behaviour, and interactions between quantum hardware, software, and applications.

This ambition will be realised by a structured training programme. Students from diverse backgrounds in computer science, mathematics, physics, and engineering, will be brought on the same knowledge level in a Master by Research first year, which includes a tailored curriculum of taught courses on the foundations and practice of quantum informatics complementary to their background knowledge. The foundation year also includes multiple opportunities to directly experience interdisciplinary research and industry applications in mini-projects.

In the subsequent 3 years students will work towards a PhD degree with in-depth research, supervised by the centre's exceptional pool of over 50 academics which approaches national coverage of the expertise in quantum informatics. Additionally, students will benefit from quantum computing practice through internships and placements at over 30 industry partners, and a residence programme at the National Quantum Computing Centre, other national laboratories, and international centres such as the Lawrence Berkeley National Laboratory. The training is rounded out by building transferable skills in entrepreneurship, venture building, responsible research and innovation, and personal development.

The demand for qualified personnel in quantum computing outstrips supply by far: small and medium UK quantum enterprises hired more people in 2022 alone than the National Quantum Technologies programme trained in 5 years. The CDT aligns with the national priorities outlined in the National Quantum Technologies Programme and the National Quantum Computing Centre's strategic intent. Within the quantum technology priority area, quantum computing, and specifically quantum software applications, is the largest estimated market. Graduates of the CDT's new talent pipeline will be in a great position to advance the UK quantum ecosystem with a multidisciplinary perspective, novel research training, and experience of quantum informatics practice.