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Research Opportunities at the School of Engineering

There are two different schemes across Chemistry, Engineering and Applied Maths:

1. 6 Dalian University of Technology/University of Leicester PhD scholarships funded by CSC (CSC provides stipend and UoL provides international fee waiver)
2. 7 DUT-UoL Collaborative PhD Studentships
   (DLI provides 20,000 RMB and University of Leicester provides international fee waiver. Only available to DLI students)

We are not considering applications for the two funding sources separately. Shortlisting for interview will be carried out purely on the basis of quality and aptitude for the PhD project for which you have applied. Only at the point of interview and appointment of successful candidates will we begin to consider funding source. If you get through to the interview, you will be asked about your funding preference (only to be considered for CSC, only to be considered for DUT, preference for CSC but also consider DUT, preference for DUT but also CSC, or no preference) and then we will allocate projects at that stage.

A formal application to the University of Leicester is essential (this can be carried out here https://le.ac.uk/study/research-degrees/funded-opportunities/cse-dut-partnership) and the **deadline for applications is: 5th January 2026**. Please choose two research projects and make it clear on your application form which is your first and which is your second choice research project. We will be holding **online interviews from Monday 2nd to Monday 9th February 2026**, so please check your email account regularly to find out if you have been selected for an interview. You should receive an email inviting you to interview by Monday 26th January 2026.

With your application, please provide:

- CV
- Degree certificates and transcripts of study already completed and if possible, transcripts to date of study currently being undertaken
- Personal statement
- In the references section, please enter the contact details of two academic referees in the boxes provided or upload reference letters if already obtained
- In the funding section, please state **DUT 2026 scholarship**
- In the research proposal section, please provide the names of the **project supervisors and the project titles** you want to be considered for. You can select up to 2 projects. List both in order of preference (a research proposal is not required).

Please take a look at the 23 different research projects which are available in the School of Engineering. The first two research projects are only available for the CSC funding (projects 1 and 2), the next 18 research projects are available for both Schemes (projects 3 to 20), whilst the last three research projects are only available for DLI funding (projects 21 to 23).

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Only available with CSC funding

1. Stability of supercritical fluids with buoyancy

Dr Benjamin Bugeat – bb283@le.ac.uk

Project Title	Stability of supercritical fluids with buoyancy	
Project Highlights:	1.	Develop a mathematical model for the linear stability of buoyant supercritical fluids
	2.	Provide new physical insights into the alteration of the supercritical fluid instability by buoyant forces
	3.	Establish a novel stability diagram identifying the instability regimes for different shear / buoyancy ratios

Project Overview (Maximum 350 words)

Above certain temperature and pressure conditions, fluids reach a supercritical state in which the distinction between liquid and gas no longer exists. Growing interest in supercritical fluids is currently observed in industrial applications such as energy production, rocket engines, or chemical processes. The nature of the flow regime (laminar or turbulent) is critical to the design of these systems, as turbulence promotes high heat transfer and mixing, thereby increasing efficiency.

Ren et al. (JFM 2019) discovered a new linear instability specific to supercritical fluids. This has opened exciting perspectives regarding the existence of new routes to turbulence, which could be leveraged by engineers to design more efficient systems. Bugeat et al. (JFM 2024) showed that this instability is caused by the large gradients of density and viscosity that occur in supercritical fluids. The authors proposed a physical mechanism based on the concurrent action of baroclinic and shear effects. However, buoyancy -- the force resulting from density differences under the action of gravity -- was neglected. This assumption is reasonable when inertial effects dominate buoyant forces. However, many engineering applications, such as heat exchangers, do not satisfy this condition. This calls for the development of new mathematical models that incorporate buoyancy.

The present project aims to provide new mathematical and physical insights regarding the effect of buoyancy on the stability of supercritical fluids. The usual Taylor-Goldstein equation cannot be employed because it is underpinned by the Boussinesq approximation, which neglects baroclinic forces. As a result, it is unsuitable for modelling the present instability. What, then, is an appropriate mathematical model for the buoyant supercritical fluid instability? After establishing this model, the effect of buoyancy on the primary instability mechanism will be analysed. Does buoyancy enhance or inhibit the instability? New quantitative data will be obtained, along with a physical interpretation in terms of vorticity production. Finally, the competition with Rayleigh-Bénard instability, which occurs in the limit of zero shear, will be investigated. The objective is to establish a novel stability diagram that identifies the key instability regimes.

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2. Development of feedback control strategies that exploit open-loop optimal control solutions for classical control problems

Dr Nadjim Horri – nmh22@leicester.ac.uk

<table>
<tr><td>Project Title</td><td colspan="2">Development of feedback control strategies that exploit open-loop optimal control solutions for classical control problems</td></tr>
<tr><td rowspan="3">Project Highlights:</td><td>1.</td><td>The convergence rates of Lyapunov functions are exploited to extend known open-loop optimal solutions to feedback control laws with improved robustness for classical linear control problems.</td></tr>
<tr><td>2.</td><td>Inverse optimal control will be used to generalise the proposed solutions to the nonlinear case (e.g., nonlinear pendulum models)</td></tr>
<tr><td>3.</td><td>Approximate solutions to the Hamilton-Jacobi-Bellman optimal control problem will be developed and approached using inverse optimal control laws that use the convergence rates of Lyapunov functions in the optimal control problems.</td></tr>
<tr><td colspan="3">Project Overview (Maximum 350 words)</td></tr>
<tr><td colspan="3">Practically significant optimal control problems such as the minimum-time, minimum-energy and minimum time-fuel problems under controller input (e.g., saturation) or finite time constraints have well-known solutions for linear systems, including the double integrator, representing idealised control problems, such as frictionless car or attitude control.

These solutions are however open-loop control laws, such as the bang-bang law for time optimality, bang-off-bang law for the optimal time-fuel problem or a saturated linear function of time for energy optimality. These open-loop solutions are not suitable for implementation in the presence of disturbances, noise and uncertainty [1].

To construct feedback controllers from open-loop optimal solutions, the combination of open-loop control for the reference change with feedback control near the origin where noise is present was investigated, but this provides insufficient robustness in large enough regions of the phase space domain.

The proposed approach is to ensure that the optimal phase space trajectories of the optimal open loop solutions are approached by closed loop controllers by careful controller tuning and Lyapunov design. Indeed, the controller maximising the minimum-time solution is only a special case of the one that maximises convergence rate of a Bilinear Lyapunov function under the same control input saturation constraints. Likewise, the bang-off-bang solution of the minimum time-fuel problem balancing time optimality with minimising the absolute value of control inputs is also a special case of a minimum-norm feedback controller subject to a maximum convergence rate of a bilinear Lyapunov function.

When the level sets of a Lyapunov function coincide with those of the value function of the Hamilton-Jacobi-Bellman (HJB) optimal control problem, Sontag's formula [1] provides a general solution of a quadratic energy-tracking trade-off for nonlinear systems. Methods were also recently developed to approximate the value function that solves the HJB problem [2], which was previously considered intractable.

This project will combine the theory of optimising Lyapunov function convergence rates (pointwise) using an inverse optimal control problem formulation and the numerical approaches used to solve the optimal control problem for linear and classical nonlinear systems (e.g.,</td></tr>
</table>

pendulum), analytically when possible, or using numerical approximations to the solution of the HJB problem.

References:

[1] Zhu, Z., Li, Y., & Lin, Z. (2024). *Global practical stabilization of the double integrator system with an imperfect sensor and subject to a bounded disturbance*. *Control Theory & Technology, 22*, 468–478.
[2] Sontag, E.d., (1995), Control-Lyapunov universal formulas for restricted inputs, in *Control-Lyapunov and barrier-function based design*, Y. Lin & E. D. Sontag, Eds., Rutgers University.
[3] Tsiotras, P., Park, C., & Chou, F. (2003) Successive Galerkin approximation of nonlinear optimal attitude. Proceedings of the American Control Conference, 1, 65–70.

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DUT/UoL CSC PhD studentships and DUT-UoL Collaborative PhD studentships

3. Topology optimisation of cooling channels layout and geometry in heat transfer

Dr. Essam Abo-Serie – e.aboserie@leicester.ac.uk

Project Title	Topology optimisation of cooling channels layout and geometry in heat transfer	
Project Highlights:	1.	Develop a new mathematical model for density-based topology optimisation that distributes solid material to generate an efficient cooling channel layout.
	2.	Generate an optimisation function that can balance the pressure drop in the fluid flow channels and heat transfer rate and uniformity
	3.	Develop a technique for avoiding local optimisation and ensure domain global optimisation is achieved.

Project Overview (Maximum 350 words)

Efficient internal cooling is critical in applications from battery modules to turbine blades, but must satisfy space, material, manufacturing and other constraints. With the flexibility offered by modern additive manufacturing techniques, topology optimisation offers a systematic way to create novel, more efficient cooling networks that can meet complex manufacturing requirements.
Topology optimisation for cooling channel layout is typically aimed to maximise heat transfer efficiency or temperature uniformity while minimising pressure drop and material usage. This is achieved by solving the steady-state heat conduction equation coupled with fluid flow equations. The optimisation problem is then reduced to identifying the density of the material as a function of the domain space - the locations with low domain densities are representing the cooling channel.
The heat transfer is very sensitive to topology changes; thus, optimisation cycle will involve multiple iterations between the adjoint heat transfer problem and material distribution pattern. The mathematical analysis will involve regularisation techniques, such as filtering or penalization (e.g., SIMP method), and incorporating constraints related to minimum channel size, and thermal performance targets. For optimum heat transfer, the design will seek to maximise surface area contact between fluid and solid while maintaining uniform flow distribution to prevent hotspots. This often leads to branching channel structures resembling natural vascular networks, which can be captured through topology optimisation under multi-objective formulations.
One of the major challenges with such optimisation techniques is that it often leads to local optimisation, so that, for example, overall heat removal is improved without equalizing temperature distribution. To avoid this, additional constraints or penalty terms are used in the objective function, which complicates the formulation and may lead to convergence issues. Furthermore, local hotspots can persist due to flow maldistribution or geometric limitations.
This project will look at developing a novel, efficient optimisation framework which will balance computational cost with handling complex, industry-relevant geometries. The model will be validated by 3-D printing the geometry and channels and tested using a controlled temperature water supply system together with multi-channel thermocouples data acquisition system, magnetic flow meter and pressure transmitter. The facilities are available in the lab.

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4. Optimizing Ferrous Alloys for Durable Power-to-Ammonia Internal Combustion Engine Environments

Dr. Mohammed Azeem – mohammed.azeem@leicester.ac.uk

Project Title	Optimizing Ferrous Alloys for Durable Power-to-Ammonia Internal Combustion Engine Environments	
Project Highlights:	1.	**Addressing a Critical Material Gap for Future Green Fuel:** The project directly addresses the significant material challenges associated with ammonia as a promising carbon-free fuel. It focuses on overcoming issues like water vapour and hydrogen embrittlement in the alloys used for internal combustion engines. The research specifically targets the unexplored area of alloy performance in ammonia environments, enabling the transition to a viable alternative to fossil fuels.
	2.	**Novel Methodology Using Correlative 4D and *In Situ* Characterisation:** The project uses advanced 4D characterisation techniques (3D} + time\temperature\pressure, including *in situ* X-ray tomography at national synchrotron facilities (like Diamond Light Source). This is facilitated by a novel, confined, self-contained sample geometry, which allows for the unique observation and comprehensive quantification of crack nucleation and propagation. This *in situ* work will be complemented by correlative *ex situ* techniques like Diffraction Contrast Tomography (DCT) and high-resolution Electron Backscatter Diffraction (EBSD).
	3.	**High Industrial Impact on Net-Zero Goals and Alloy Redesign:** The research is certain to help companies manufacturing large engines in transitioning to ammonia. By establishing the mechanisms of failure, the project will have a direct impact on the alloy selection and redesign of future maritime engines, leading to greater fuel efficiency and reduced greenhouse gas emissions. The project outcomes will directly support and facilitate the UK's goal of net zero targets, with knowledge extending to earth-moving equipment and passenger vehicles.

Project Overview (Maximum 350 words)

Ammonia is rapidly emerging as a **promising carbon-free fuel alternative**, particularly for demanding applications like heavy-duty transportation and maritime use. It is a compelling candidate for replacing fossil fuels due to its high energy density, the existence of infrastructure for its production and distribution, and its potential for sustainable synthesis. Furthermore, ammonia offers a unique, safer pathway for storing energy from renewable resources compared to hydrogen and provides an opportunity to recycle existing internal combustion engine technology.

However, successfully implementing ammonia engines requires overcoming significant material challenges. These challenges stem from the fuel's unique combustion characteristics, which generate corrosive byproducts such as water vapor, and introduce the potential for hydrogen embrittlement. Cast irons are the standard material for major components in large-capacity internal combustion engines, prized for their superior fatigue resistance against the high operating temperatures and cyclic pressures. The critical performance of these existing alloys in ammonia environments, however, remains unexplored.

This research outlines a comprehensive program to address these challenges. The first objective is to comprehend the existing fatigue, creep, and wear performance of current cast iron alloys in ammonia environments. The core aim is to then develop modified cast iron alloys that are resistant to corrosive byproducts and minimise hydrogen embrittlement in engine components. Finally, the project will assess the performance of these modified alloys and establish the specific mechanisms of failure in ammonia environments for both current and modified materials.

The methodology will achieve these goals by leveraging advanced 4D characterisation techniques (3D + time)/temperature/pressure, including *in situ* X-ray tomography at national synchrotron facilities. This will facilitate the unique observation and comprehensive quantification of crack nucleation and propagation. *Ex situ* correlative characterisation will be used to quantitatively correlate cracks with grain orientations and sub-grain misorientations. The successful outcomes of this research, which include alloy design and mechanistic insights, are expected to have a far-reaching impact. By identifying the mechanisms of failure, the results will directly inform alloy redesign for future maritime engines. This knowledge base will support and facilitate national goals for net zero targets, with future applications extending to earth-moving equipment and potentially passenger vehicles.

5. Flexible Power Point Tracking and Grid Support Algorithms for High-Performance PV Integration

Dr Mostefa Kermadi - mostefa.kermadi@leicester.ac.uk

Project Title	Flexible Power Point Tracking and Grid Support Algorithms for High-Performance PV Integration	
Project Highlights:	1.	Develop a robust dc-link voltage controller that accurately tracks the reference set by the maximum power point tracking controller, thus enabling photovoltaic systems to operate as controlled sources and contribute to overall grid stability and resilience.
	2.	Implement an innovative algorithm that leverages the power reserve in the PV inverter to enhance grid frequency response and introduce a recovery mode based on grid frequency perturbation, achieving faster restoration of system frequency during disturbances.
	3.	Establish a reference power generator capable of providing optimal active and reactive power profiles during grid fault conditions, thus ensuring compliance with grid standards and delivering superior low-voltage ride-through performance for photovoltaic systems.

Project Overview (Maximum 350 words)

The increasing global adoption of solar photovoltaic (PV) systems has introduced significant challenges for power system stability, particularly during grid faults and frequency disturbances. As PV penetration grows, conventional inverter operations, focused solely on maximum power point tracking (MPPT) and unity power factor injection, are insufficient to maintain grid reliability. Issues such as voltage dips, flickers, and frequency perturbations can compromise power quality and even lead to outages. To address these challenges, this project investigates advanced control strategies that transform distributed PV generation units into intelligent, grid-supporting resources.

The proposed approach integrates multiple innovative components. First, a high-performance flexible power point tracking (FPPT) algorithm will be developed to accurately follow power profiles generated by a reference power generator. This ensures that PV systems can dynamically adjust their output to support grid stability without sacrificing energy efficiency. Second, a novel frequency support algorithm will utilize the power reserve of the inverter to enhance grid frequency response. The system will achieve faster restoration of nominal frequency during disturbances by implementing a proposed recovery mode triggered by frequency deviations. Third, the project introduces a reference power generator capable of determining optimal active and reactive power profiles during grid voltage faults. This feature ensures compliance with updated grid codes and standards, enabling superior low-voltage ride-through (LVRT) performance.

To realize these objectives, robust controllers including a dc-link voltage controller, and a grid current controller, will be designed to maintain precise tracking and high-quality current injection under normal and abnormal faulty conditions. The methodology involves comprehensive

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modeling and simulation using MATLAB/Simulink and validation using dSPACE-PLECS hardware-in-the-loop testbench to validate the proposed control schemes under various grid scenarios.

The research contributes to the development of smart PV inverters that deliver clean energy and actively enhance grid resilience. By enabling dynamic voltage and frequency support, the project aligns with global sustainability goals while addressing critical technical challenges in modern power systems.

6. Multi-Fidelity Modelling and Integration of Hydrogen Combustion for Sustainable Aircraft Propulsion

Dr Jinning Zhang – jz388@leicester.ac.uk

Project Title	Multi-Fidelity Modelling and Integration of Hydrogen Combustion for Sustainable Aircraft Propulsion	
Project Highlights:	1.	Develop detailed complex chemistry turbulent-chemistry interaction models for hydrogen micromix combustion
	2.	Implement surrogate model approach for propulsion system design space exploration
	3.	Evaluate aircraft mission-level life cycle emissions and economic viability

Project Overview (Maximum 350 words)

To reduce their environmental impact and achieve net-zero emissions in the aviation sector by 2050, there is a shift towards adopting hydrogen fuel in gas turbine engines, which would eliminate exhaust CO2 emissions. However, this transition presents technological challenges, the zero-emission hydrogen-fuelled propulsion systems should be developed to achieve ultra-low NOx emissions while also satisfying other performance and operability requirements, such as combustion efficiency, pressure loss, durability, stability.

This project aims to investigate the design, performance evaluation, and integration approaches and assess the emissions characteristics of a novel carbon-free ultra-low NOx emissions hydrogen-fuelled propulsion system, by developing multi-fidelity tools for the computational modelling and numerical simulation of chemical processes, ranging from reduced order models to high-fidelity numerical simulation models.

The objectives of this project are as follows:

WP1. Develop detailed complex chemistry turbulent-chemistry interaction models for hydrogen micromix combustion with high-fidelity large eddy simulations, to investigate the flame characteristics, including flame thickness, length, position temperature and emissions.

WP2. Implement surrogate model approach for propulsion system design space exploration and optimisation. A Reduced Order Model (ROM), such as the Flamelet Generated Manifold, will be developed to utilize pre-tabulated combustion chemistry, offering lower computational cost than detailed chemical mechanisms. Results from detailed complex chemistry model will calibrate the ROMs, thereby enhancing their accuracy. Following that, the impact of micromix injector design parameters on hydrogen/air mixing, flame characteristics, and NOx formation will be investigated through design space exploration.

WP3. Hydrogen-fuelled propulsion system integration with advanced airframe configurations, such as blended wing body, boundary Layer Ingestion, etc., and further achieve aircraft mission-level assessments including trajectory and engine cycle optimisation, as well as evaluations of life cycle emissions and economic viability.

This work is well positioned within **the subject theme of 'Power Engineering and Engineering Thermophysics'**, representing interdisciplinary research of chemical engineering, environmental engineering, and mathematics. The research outcomes are expected to guide the design, operation, and control of future hydrogen gas turbine engines. This has the potential to significantly impact decarbonisation of the UK civil aviation sector and facilitate a cost-effective transition to a sustainable and resilient future in aviation by 2050.

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7. Advanced Modelling and Characterisation of Polymeric Materials for Hydrogen Energy Systems

Dr Elsiddig Elmukashfi – emae2@le.ac.uk

<table>
<tr><td>Project Title</td><td colspan="2">Advanced Modelling and Characterisation of Polymeric Materials for Hydrogen Energy Systems</td></tr>
<tr><td rowspan="3">Project Highlights:</td><td>1.</td><td>Developing advanced predictive models and experimental methods to quantify hydrogen transport properties in polymers, including permeability, solubility, and diffusion.</td></tr>
<tr><td>2.</td><td>Investigating hydrogen-induced damage mechanisms in polymers, such as rapid gas decompression (RGD) and swelling-induced failure.</td></tr>
<tr><td>3.</td><td>Enabling the development of next-generation, reliable, and safe materials for hydrogen energy systems through experimental validation and computational techniques.</td></tr>
<tr><td colspan="3">Project Overview (Maximum 350 words)</td></tr>
<tr><td colspan="3">Addressing climate change and preserving natural resources for future generations requires adopting sustainable energy solutions. Greenhouse gas (GHG) emissions drive global warming, pollution, and other environmental challenges. Hydrogen, as a low-carbon energy carrier, offers a versatile and sustainable alternative to conventional fuels, enabling decarbonisation across power, heat, and transport sectors.
Polymeric materials play a crucial role in the hydrogen economy, particularly in high-pressure systems for production, storage, and transportation. Compared to metals, they excel due to their resistance to hydrogen embrittlement, cost-effectiveness, and lightweight nature. These materials are subjected to extreme operational conditions, including temperatures ranging from −40 to 200°C, pressures up to 100 MPa, and loading rates between 0.1 and 90 MPa/min. Despite their advantages, challenges such as hydrogen permeation, rapid gas decompression (RGD), swelling-induced damage, and long-term degradation under high-pressure hydrogen remain critical issues that must be resolved to ensure their reliability and safety.
This project focuses on advancing the next generation of polymeric materials through predictive modelling and experimental validation, contributing to the development of cost-effective, safe, and reliable hydrogen energy infrastructure. The study aims to develop experimental testing methods and devise predictive models that characterise hydrogen transport properties—including permeability, solubility, and diffusion—under mechanical loading, while investigating the interactions between hydrogen and polymer microstructures. These models will also address critical damage mechanisms caused by hydrogen, such as rapid gas decompression (RGD) and swelling-induced damage, ensuring material safety and reliability. The research aims to develop precise constitutive models to predict material behaviours under diverse conditions by integrating theoretical frameworks and computational simulations with experimental data.
By addressing these challenges, this research will provide essential insights into material behaviour in hydrogen energy applications, ultimately contributing to the development of cost-effective, reliable, and safe systems to enable the hydrogen economy.</td></tr>
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8. Mutifunctional Thermal Energy Storage

Dr Audrius Bagdanavicius - ab746@leicester.ac.uk

Project Title	Multifunctional Thermal Energy Storage	
Project Highlights:	1.	Design of novel thermal energy storage systems that functions simultaneously as integrated components of larger energy storage systems and as flexible thermal hubs for other energy services.
	2.	Modelling and transient analysis of new multifunctional thermal energy storage systems integrated with energy networks.
	3.	Innovations in thermal energy storage through improved system design, advanced storage materials, and AI-based control and operation strategies.

Project Overview (Maximum 350 words)

Thermomechanical Energy Storage systems (TMES), such as Compressed Air Energy Storage, Pumped Thermal Energy Storage, Liquid Air Energy Storage or Heat-to-Power energy storage systems are designed to store energy for the electricity networks. A unique feature of all these systems is that a large amount of heat is generated during operation. To avoid energy losses and improve the overall system performance, the generated heat must be captured and stored in a **Thermal Energy Storage (TES)** that is an integral part of the TMES structure. The use of TES significantly increases the overall efficiency of thermomechanical energy storage by reusing the stored heat during charging and discharging phases.

In addition to being an important component of TMES systems, TES can also function as a thermal energy source for external applications, such as heating and cooling in buildings, District Energy Networks, or industrial processes. It is therefore possible to conceive **multifunctional TES** systems that simultaneously store heat from TMES and deliver thermal energy to other applications.

The development of such innovative **multifunctional TES** systems requires adventurous research by unconventional research methods. Heat transfer during charging and discharging must be fast and efficient; therefore, these processes should be well understood. TES systems integrated with TMES often operate at high temperatures and require a suitable, durable storage medium, which this research will investigate. Promising materials for TES applications encompass fluid and solid-based media for sensible heat storage, phase change materials (PCMs) for latent heat storage, and reactive or sorbent materials suitable for thermochemical energy storage. Furthermore, the performance of TES systems, especially **multifunctional TES**, depends on varying thermal loads, so a detailed understanding of their dynamic behaviour is essential.

In this project, novel **multifunctional Thermomechanical Energy Storage (TES)** systems will be developed and modelled. These TES systems will operate both as integrated TMES components and as flexible thermal hubs meeting a range of energy needs. The aim of this research is to address key challenges in developing efficient **multifunctional TES** systems, focusing on improving design, selecting suitable storage materials, and implementing AI-based control for goal-oriented operation.

9. Development of Bifunctional Catalysts for One-Step Hydrodeoxygenation and Isomerisation in Sustainable Bio-Jet Fuel Production

Dr Bo Tian – Bt156@leicester.ac.uk

Project Title	Development of Bifunctional Catalysts for One-Step Hydrodeoxygenation and Isomerisation in Sustainable Bio-Jet Fuel Production	
Project Highlights:	1.	**The student will get training in One-Step Catalytic Conversion** The PhD student will be trained to design and synthesise a novel bifunctional catalyst that performs hydrodeoxygenation and isomerisation simultaneously. This hands-on work will build skills in catalyst development, characterisation, and reactor testing, while advancing an energy-efficient, single-step process for converting biomass into sustainable jet fuel.
	2.	**Waste-to-Fuel Sustainability Approach** Using waste cooking oils, esters, and lipids as feedstocks, the research promotes circular-economy principles by converting low-value waste into high-value renewable jet fuels. This supports global aviation decarbonisation targets set by the International Civil Aviation Organisation (ICAO).
	3.	**Comprehensive Catalyst Design and Validation** The study combines advanced materials synthesis (wet-chemistry fabrication) with rigorous characterisation techniques (TEM, BET, XRD) and reactor-scale performance testing. Product composition and fuel quality will be evaluated via GC-MS and benchmarked against aviation fuel standards, generating valuable data for industrial and computational model validation.

Project Overview (Maximum 350 words)

The aviation sector currently accounts for approximately 2 % of total global CO_2 emissions. While this proportion appears relatively small, aviation is the most emission-intensive mode of transport on a per-capita basis, producing around 12 % of CO_2 from all transport sources. With the continued growth in air travel demand, reducing aviation's environmental impact has become a global priority. The ICAO has identified renewable jet fuel as the primary route towards decarbonising the sector and achieving long-term sustainability targets.

Bio-jet fuels derived from biomass are typically produced through multiple catalytic processes, including hydrogenation, deoxygenation, isomerisation, and hydrocracking. Each stage requires specific catalysts and reaction conditions, resulting in complex, energy-intensive, and costly production pathways. Noble-metal catalysts such as Pt, Pd, and Ni, supported on activated carbon, alumina, or zeolite, are widely employed for isomerisation and cracking reactions. Bimetallic systems and sulphide catalysts (e.g., $NiMoS_2$, $CoMoS_2$, $NiWS_2$) have shown improved hydrodeoxygenation activity owing to increased surface acidity and enhanced catalytic performance. Nevertheless, dependence on precious metals and the necessity for multiple sequential reactions remain major barriers to efficient and economical bio-jet fuel synthesis.

This project aims to address these challenges by developing a bifunctional catalyst capable of performing hydrodeoxygenation and isomerisation simultaneously within a single processing step. By integrating these two key reactions, the study seeks to simplify the overall conversion pathway, minimise energy consumption, and improve product selectivity and yield, thereby enhancing the economic feasibility of renewable jet fuel production.

The project will employ waste cooking oils, esters, and waste lipids as representative feedstocks. Bifunctional catalysts will be synthesised via a wet-chemistry approach and comprehensively characterised using transmission electron microscopy (TEM), Brunauer–Emmett–Teller (BET) surface analysis, and X-ray diffraction (XRD). Product composition and physicochemical properties will be determined by gas chromatography–mass spectrometry (GC-MS) and compared against standard jet-fuel specifications.

By combining catalyst design, characterisation, and performance evaluation, this project will deliver both scientific and practical advances in sustainable fuel technology. It will develop efficient multifunctional catalysts and reveal key reaction mechanisms governing hydrodeoxygenation and isomerisation in bio-jet fuel synthesis. The findings will provide benchmark data for modelling and process optimisation, supporting the industrial conversion of waste lipids into renewable aviation fuels. The PhD student will gain advanced training in catalyst engineering, analytical techniques, and sustainable process development—skills directly applicable to the low-carbon energy sector.

10. Nano-polymer enabled novel minichannel heat exchanger for Artificial Intelligence data centres

Dr Aldo Rona – Ar45@leicester.ac.uk

Project Title	Nano-polymer enabled novel minichannel heat exchanger for Artificial Intelligence data centres	
Project Highlights:	1.	Low friction high heat capacity nano-polymer in water suspensions are used novelly in minichannel heat exchangers to improve the thermo-hydraulic effectiveness of liquid-cooled minichannel heat sinks.
	2.	Archimedes' screw principle is applied for the first time in the minichannel to concurrently enhance the heat transfer rate while also providing a pumping effect.
	3.	Application to electronics in Artificial Intelligence data centres will reduce cooling power per unit compute, with the new active mini-channel heat sink providing greater locality of heat extraction compared to current air door technology.

Project Overview (Maximum 350 words)

The world annual use of electrical energy for running Artificial Intelligence data is approximately equal to the annual energy consumption of Austria, about 1 million TJ (2023). With a European carbon intensity of 46.3 tCO2e/TJ, the environmental impact of just running the clusters is 46.3 million tonnes CO2 equivalent per annum. Computer core cooling requires about 0.3 J of cooling pump effort for every 1 J of electricity supplied to the core, hence urgent action is required to significantly reduce the heat removal cost from clusters, currently standing at approximately 0.3 million TJ, 14 million tCO2e, £41.6bln (£0.5/kWh).

This challenge will be tackled by this PhD pursuing a disruptive technology for liquid cooled mini-channel heat sinks. This emerged from an investigation on enhancing the heat transfer effectiveness by a rotary twisted tape (10.1016/j.enconman.2018.04.086).

The stirring action of the tape, which would typically produce unwanted hydraulic pumping performance loss by secondary flows in a pump, is beneficial to the heat transfer effectiveness when this occurs in a heat sink. This PhD will develop this concept towards a self-pumping liquid-cooled heat sink, using numerical modelling and digital design. A novel nanoparticle polymer will be used to lower the mechanical friction and raise the heat transport compared to established nanofluids like TiO2.

The PhD is likely to generate publishable foundational knowledge on the best Reynolds number a rotary flow may have to maximise heat transfer, by having a turbulent-like convection heat transfer coefficient, while maintaining low hydraulic loss, by having a laminar-like friction factor; such concept is known and used in axial flow through pipes but it is not established in rotary flows. This is material for a 4* fluid mechanics top journal like the Journal of Fluid Mechanics.

The PhD student will explore in year 1 alternative nano-polymers, impeller shapes e.g. screw impeller, test in year 2 their effectiveness in a representative heat sink geometry, and produce optimized geometries in year 3 as well as the fundamental advance in heat transport in unsteady rotary flows.

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11. Intelligent Edge-AI SiC Motor Drives for Autonomous Downhole Drilling

Dr Bing Ji – bing.ji@leicester.ac.uk

Project Title	Intelligent Edge-AI SiC Motor Drives for Autonomous Downhole Drilling	
Project Highlights:	1.	SiC-Native, Harsh-Environment VSDs: High-temperature packaging and resilient gate drivers tailored for downhole shocks, vibration, and H_2S—delivering higher torque density and uptime.
	2.	Edge AI for health aware control and protection: TinyML + physics-informed analytics for sub-millisecond fault detection, aging-aware derating, and adaptive control—cutting drive-related non-productive time.
	3.	Digitalised Drives with Twins & Machine Learning: Physics-informed digital twins and secure drive-level model updates (no raw data export) to predict RUL, optimise set-points, and generate certifiable health logs that improve efficiency and reduce failure-induced emissions.

Project Overview (Maximum 350 words)

Context: This PhD project aims to address the challenges in oil extraction, where reliable, efficient, and intelligent variable-speed drives (VSDs) are essential in extreme downhole oil and gas exploration conditions. These VSDs must operate in harsh thermal and mechanical environments, requiring high precision and robustness. Silicon Carbide (SiC) and Gallium Oxide (Ga_2O_3) power semiconductors, known for their superior switching speed, high-temperature tolerance, and power density, have emerged as potential candidates to replace silicon-based components, improving the efficiency and reliability of downhole drilling VSDs.

Objective: The project seeks to unlock the full potential of SiC-based VSDs in downhole oil extraction. It aims to implement in-situ status-awareness and optimal control strategies for SiC devices to extend operational lifespan, improve fault detection, and enhance VSD reliability under extreme conditions.

Approach:

1. Standardized Power Switching Framework:
   - Develop a standardized framework for testing and monitoring SiC-based power switching units, tailored for downhole conditions.
   - Key features include enhanced status-awareness through smart sensing, active gate control algorithms for high-pressure environments, and robust protection mechanisms.
2. Innovative SiC Embedded Power (ISEP) Technology:
   - Design a 10 kW SiC-based high power-density inverter for AC motors used in downhole drilling, incorporating ISEP technology.
   - Key features include real-time adaptive control, optimized energy use, and cognitive capabilities for self-adjustment based on real-time drilling data.
3. Advanced Status-Awareness and Health Monitoring:
   - Implement multi-dimensional feature extraction for in-situ health monitoring of SiC-based VSDs.
   - Use multivariate machine learning for early fault detection, hybrid diagnostic algorithms, and aging-sensitive electrical parameters to ensure accurate fault detection with reduced hardware costs.

Expected Outcomes:

- A robust, reliable SiC-based VSD system optimized for downhole operations.
- Improved real-time fault detection and status-awareness to reduce downtime.
- Contribution to the digitalization of power electronics in oil extraction, providing tools to enhance system performance and reliability.

12. A System-Theoretic Framework for Stability Analysis of Networked PDE Systems

Dr Khaled Laib – Kl314@leicester.ac.uk

Project Title	A System-Theoretic Framework for Stability Analysis of Networked PDE Systems	
Project Highlights:	1.	Unified PDE Framework: Systematic modelling of coupled hyperbolic–parabolic networks.
	2.	Reduced-Order Models: Galerkin projections with finite elements preserving key network properties.
	3.	Stability and Energy Assessment: Lyapunov methods and LMIs for assessing network-wide stability and energy propagation.

Project Overview (Maximum 350 words)

Modern critical infrastructures, such as district heating and power transmission systems, are inherently networked and multi-physical. Their dynamics are governed by interconnected subsystems—some exhibiting wave-like (hyperbolic, $\partial_{tt}u - c^2\,\partial_{xx}u = 0$) behaviour and others diffusive (parabolic, $\partial_t\theta - \alpha\,\partial_{xx}\theta = 0$) behaviour coupled through nonlinear interface terms ($\gamma_i(u,\theta)$) and complex vertex boundary conditions. The core challenge is to manage these complex, coupled dynamics, defined on spatial graphs, to ensure stability and resilience against faults and disturbances. This research addresses the lack of a unified theoretical framework for modelling and analysing such heterogeneous networked systems.

Objective and Approach

The project aims to develop a robust framework for networked PDE systems with the following objectives:

- Develop a rigorous representation of coupled hyperbolic–parabolic network dynamics.
- Characterise energy propagation, dissipation, and interconnection structure using operator-theoretic tools.
- Certify stability and robustness under nonlinearities, uncertainties, and coupling constraints.

A network-level state-space representation will be derived

$$\dot{Z}(t) = AZ(t) + Bu(t), y(t) = CZ(t)$$

where $Z(t)$ aggregates distributed states across the network and operator A encodes spatial derivatives and interconnections.

Using dissipative operator theory, the project will first analyse how the system stores, transfers, and dissipates energy, providing the foundation for Lyapunov-based stability conditions and energy balance characterisation at the PDE level.

Next, structure-preserving finite element and Galerkin methods will be developed to construct reduced-order models

$$\dot{Z}_N(t) = A_N Z_N(t) + B_N u(t)$$

that retain the dissipative and network-coupled structure of the full PDE system. These reduced models form the computational basis for tractable control and analysis.

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Finally, Integral Quadratic Constraints and Linear Matrix Inequalities will be applied to the reduced models to assess and certify robust stability under nonlinearities and parametric uncertainties. The resulting explicit Lyapunov matrices will provide quantitative certificates of energy dissipation, robustness, and closed-loop implementability.

Validation and Applications

The framework will be validated on energy-infrastructure case studies—district heating networks and power transmission systems modelled via the telegrapher's equations—using FEniCS for spatial discretisation and MATLAB/YALMIP for LMI-based control. Tests under realistic faults and disturbances will demonstrate improved resilience and closed-loop stability.

Work Packages and Timeline

- **WP1 –** Theoretical Modelling and Energy Analysis (Months 1–10).
- **WP2 –** Structure-Preserving Model Reduction (Months 10–20).
- **WP3** – IQC-Based Stability and Numerical Validation (Months 20–36).

13. Mathematical Modelling and Simulation of Adaptive Support Systems for Inclusive Action Sports

Dr Manuela Trejo – Mpptr1@leicester.ac.uk

Project Title	Mathematical Modelling and Simulation of Adaptive Support Systems for Inclusive Action Sports	
Project Highlights:	1.	Social Impact: Designing adaptive systems that enable children with disabilities to safely participate in action sports such as skateboarding, BMX, etc.
	2.	Scientific Innovation: Developing biomechanical models of falls and impacts, and optimizing control algorithms for smart support systems (e.g., dynamic braking, balance assistance).
	3.	Disciplinary Contribution: Advancing applied mathematics in biomechanics and mechanical control through simulation, optimization, and system design.

Project Overview (Maximum 350 words)

This PhD project aims to develop mathematical models and simulation frameworks for adaptive support systems that enhance safety and performance in action sports, with a focus on inclusivity for children with disabilities. Action sports present unique challenges due to their dynamic, high-impact nature, which can be particularly risky for individuals with motor impairments or balance issues. Despite growing interest in inclusive sport technologies, there remains a critical gap in adaptive devices that are lightweight, responsive, and capable of absorbing shocks while maintaining stability.

The proposed research will address this gap by modelling the biomechanics of falls, impacts, and compensatory movements using multi-body dynamics and finite element methods. These models will inform the design of adaptive systems, such as wearable supports or smart braking mechanisms, that respond in real time to changes in motion or force. Optimization algorithms, including machine learning-based control strategies, will be developed to fine-tune system responses for individual users and specific sport scenarios.

The project sits at the intersection of applied mathematics, biomechanics, and mechanical control systems. It will contribute to the field by advancing simulation techniques for human movement and impact dynamics, and by proposing novel control frameworks for adaptive devices. Collaborations with rehabilitation engineers, sports scientists, and inclusive design experts will ensure the research remains grounded in real-world needs.

Ultimately, the outcomes of this project could inform the development of new materials and systems applicable not only to action sports, but also to rehabilitation, assistive technologies, and inclusive design more broadly, empowering more children to engage in physical activity safely and confidently.

14. Multimodal Non-Destructive Testing (NDT) for Polymers and Composite Material Systems

Dr Muhammad Zubair – muhammad.zubair@leicester.ac.uk

<table>
<tr><td>Project Title</td><td colspan="2">Multimodal Non-Destructive Testing (NDT) for Polymers and Composite Material Systems</td></tr>
<tr><td rowspan="3">Project Highlights:</td><td>1.</td><td>Integrate electromagnetic, ultrasonic, and optical sensing for non-destructive multiscale defect detection in polymeric materials and polymer-matrix composites.</td></tr>
<tr><td>2.</td><td>Develop multiphysics-guided data-fusion models linking dielectric, elastic, and thermal responses to material degradation.</td></tr>
<tr><td>3.</td><td>Deliver validated multimodal NDT methodologies and predictive reliability models for advanced polymer and composite systems.</td></tr>
<tr><td colspan="3">Project Overview (Maximum 350 words)</td></tr>
<tr><td colspan="3">Polymeric and fibre-reinforced composites enable lightweight, high-strength structures for aerospace, transportation, and renewable-energy systems. Their hierarchical makeup, polymer matrices, fibre reinforcements, and multi-phase interfaces, produces complex failure modes such as fibre–matrix debonding, matrix crazing, porosity, and delamination. Numerous non-destructive testing (NDT) methods probe different contrasts in polymers and composites; ultrasonic (bulk and guided waves), electromagnetic (microwave, terahertz, eddy current), optical and infrared (lock-in thermography, shearography, DIC), and X-ray or micro-CT imaging. Yet issues of cost, portability, penetration depth, and resolution mean that no single technique offers a complete quantitative picture of evolving damage. This PhD will develop a multiphysics-based, multimodal NDT framework integrating electromagnetic, ultrasonic, and optical/IR modalities to resolve coupled dielectric, elastic, and thermal interactions that govern defect initiation and growth in polymers and composites. Finite-element and full-wave simulations will model how dielectric relaxation, viscoelastic damping, guided-wave dispersion, and anisotropic heat diffusion influence measurable signals. Guided by these models, controlled experiments on range of widely used polymers and composites under mechanical, thermal, and environmental ageing will generate benchmark datasets, with selected coupons validated by gold standard tests. Multimodal data will be fused through inverse-problem formulations and physics-guided machine learning to reconstruct spatial maps of voids, cracks, and interfacial degradation, distinguishing manufacturing flaws from in-service fatigue. The unified framework will bridge materials physics and sensor engineering, linking property variations, including permittivity, stiffness, and thermal diffusivity, to microstructural evolution. Expected outcomes include: (i) validated simulation–experiment datasets, (ii) an integrated multimodal NDT methodology, and (iii) predictive reliability models for polymeric materials and polymer-matrix composites. Aligning with UK priorities in advanced manufacturing and net-zero innovation, this project will enhance national capability in sustainable materials evaluation and digital-twin-ready inspection for safer, more efficient composite components in aerospace, transportation, and energy sectors.</td></tr>
</table>

15. Optimizing Mini-Table Die Filling: Mechanistic Models and Process Windows for Quality-by-Design Manufacturing

Dr Reza Baserinia – rb662@leicester.ac.uk

Project Title	Optimizing Mini-Tablet Die Filling: Mechanistic Models and Process Windows for Quality-by-Design Manufacturing	
Project Highlights:	1.	Design & Development of a Rotary Feeding Simulator for Mini-Tablets
	2.	Establishing Critical Process Windows for Mini-Tablet Manufacturing
	3.	Developing Predictive Mechanistic Models for Powder–Process Interactions

Project Overview (Maximum 350 words)

Mini-tablets, typically 1-3 mm in diameter, are increasingly recognised as an advanced dosage form for paediatric, geriatric, and personalised medicine, offering precise dosing and improved patient compliance. However, their industrial adoption is constrained by a critical challenge: weight variation during die filling. At this micro-scale, even minor inconsistencies in powder flow or feeder dynamics can lead to unacceptable variability, compromising product quality and regulatory compliance. Current approaches rely heavily on empirical adjustments, and there is limited mechanistic understanding of how gravity-driven filling compares with suction-assisted filling or how powder properties interact with process parameters to influence filling variability.

This research aims to systematically examine the physics governing mini-tablet die filling under both gravity and suction-assisted regimes. Controlled experiments will quantify the effects of powder properties and feeder kinematics on die weight variability by utilising a custom-designed bench-scale rotary feeding simulator developed and fabricated to accurately replicate industrial mini-tablet die-filling conditions. Pharmaceutical powders with different particle size distributions, cohesiveness, and permeability will be characterised using advanced powder rheology and flowability measures to establish links between material properties and filling performance. Small weight variation, expressed as the coefficient of variation (CoV), will be the primary metric of success ensuring compliance with stringent regulatory requirements for uniformity of dosage units. Measurement will combine high-speed imaging for rapid estimation of fill volume with microbalance validation for selected samples to ensure accuracy.

Existing literature provides limited understanding of weight variations at this product scale, with most research focused on production of conventional tablet sizes. By isolating key variables and quantifying their effects, the project aims to:

- Identify critical process windows for achieving CoV ≤ 2%.
- Develop semi-empirical models linking powder properties and feeder settings to variability.
- Produce dimensionless operating maps to guide scale-up.

These outcomes will deliver practical design rules for mini-tablet feeding systems and generate a validated dataset that supports industrial quality-by-design strategies. Beyond pharmaceuticals, the mechanistic insights and predictive models developed here are directly applicable to industries where precision powder dosing is essential, including additive manufacturing, food, chemicals, and advanced ceramics.

16. Sustainable Stretchable Biopolymer Nanofiber Electrodes for Real-Time Wearable ECG Monitoring

Dr Saravana Kumar Jaganathan – skj24@leicester.ac.uk

Project Title	Sustainable Stretchable Biopolymer Nanofiber Electrodes for Real-Time Wearable ECG Monitoring	
Project Highlights:	1.	Development of biodegradable, stretchable nanofiber electrodes using sustainable biopolymers for real-time ECG monitoring.
	2.	Integration of AI and signal-processing algorithms to enhance biosignal quality and reduce motion artefacts in wearable devices.
	3.	Strengthens the DLI–UoL partnership in Smart and Sustainable Biomedical Engineering through Leicester's innovation in biomaterials, electrospinning, and intelligent sensing.

Project Overview (Maximum 350 words)

This interdisciplinary project aims to create sustainable, stretchable, and flexible dry nanofiber electrodes for real-time electrocardiogram (ECG) monitoring, addressing the urgent need for eco-friendly and skin-compatible alternatives to disposable Ag/AgCl hydrogel electrodes. Conventional electrodes rely on non-biodegradable components and electrolytic gels that cause skin irritation, lose adhesion over time, and generate biomedical waste, limiting their suitability for long-term or environmentally conscious applications.

Leveraging Dr. Jaganathan's expertise in electrospun biomaterials [1], this project will fabricate biodegradable nanofiber films using polycaprolactone (PCL) and naturally derived polymers such as gelatin and chitosan, blended with conductive carbon nanomaterials including graphene and carbon black. Electrospinning provides a green, solvent-efficient approach to producing lightweight, porous, and flexible films with high surface area and tuneable conductivity. These nanofiber composites will serve as sustainable electrode platforms that conform comfortably to the skin while maintaining low impedance and high signal stability.

Under the guidance of Dr. Pearce and Dr Li, whose expertise in sensing, intelligent systems and biomedical signal processing [2-3] complements this research, the project will integrate signal acquisition electronics and machine learning algorithms to enhance ECG signal quality by minimizing noise and motion artefacts. This AI-enabled feedback loop will enable adaptive filtering and predictive modelling for robust, real-time monitoring in wearable applications.

The research will culminate in the development of a biodegradable, flexible ECG electrode prototype suitable for integration into smart clothing and wearable devices, alongside a patentable, sustainable electrode design that combines green materials with advanced signal processing. The project is expected to generate high-impact publications across the fields of biomaterials, wearable electronics, and sustainable engineering.

Overall, this work strengthens the DLI–UoL collaboration under the Smart Chemical and Biochemical Engineering theme and contributes to UN SDG 3 (Good Health and Well-being), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production). The PhD candidate will gain interdisciplinary expertise in biopolymer fabrication, electrospinning, sustainable materials engineering, and intelligent biosignal analysis, equipping them to lead future innovation at the intersection of biomedical technology and environmental sustainability.

References:

1. https://doi.org/10.1016/j.polymer.2025.129188
2. https://doi.org/10.1007/s00542-013-2020-8
3. https://doi.org/10.1093/ehjdh/ztae004

17. Oblique entry with unsteady outcome: stability and control in devices with rectangular channels

Dr Svetlana Aleksandrova – sa1020@leicester.ac.uk

Project Title	Oblique entry with unsteady outcome: stability and control in devices with rectangular channels	
Project Highlights:	1.	Using a robust methodology combining high fidelity LES, modal and signal analysis, and targeted validation experiments.
	2.	Development of fundamental understanding of nature of complex 3D instability of the shear layer in separating channel flows
	3.	Direct application impact through development of stability maps, reduced order predictor models, and clear guidance to reduction of pressure loss, shear stress, noise, and flow maldistribution.

Project Overview (Maximum 350 words)

Gas or fluid flow through narrow channels is encountered in many applications - for example, compact heat exchangers that cool batteries and electronics, turbine blade internal cooling, or breathing tubes used in hospitals. Such flows are generally well understood, and reliable correlations exist to predict flow and energy losses when the flow enters the channels straight on. In reality, the flow often enters the channels at an angle. Then an asymmetric separation bubble can appear, with a shear layer that can become unstable even at low speeds normally associated with laminar flow. Our recent work has shown that this instability is a complex, three-dimensional effect where large vortex roll-up structures are observed, and interact with the secondary flow vortices formed at the channel corners (Figure 1).

In engineering context, however, this exciting phenomenon can bring undesirable effects - noise, high pressure losses, non-uniform species transport and heat transfer, or oscillatory wall shear leading to tissue damage in biological systems. A general, physics-based understanding of the causes and nature of such instabilities is urgently needed to predict when and how unsteadiness starts, how it couples to downstream components, and how to control it with minimal penalty.

This PhD project will develop that understanding using high-fidelity Large-Eddy Simulation, combined with signal processing and modal analysis, and complemented by targeted experiments for validation. The Laser Doppler Anemometry (LDA) measurements of the temporal variation airflow velocity components will provi**de high spatial and temporal resolution data for characterising this complex turbulent flow field (Figure 2).**

The relationship between the entry angle, flow and channel geometry parameters and the resulting dominant instability patterns will be established. Their impact on device-level metrics (e.g. flow uniformity, pressure drop, shear) relevant to applications will be studied to establish how these can be tailored to meet application requirements.

Thus, the project outcomes will include stability and transition maps over the relevant parameter space and reduced-order models that predict dominant frequencies, mode amplitudes, and wall-shear parameters, as well as recommendations for improved design for relevant applications.

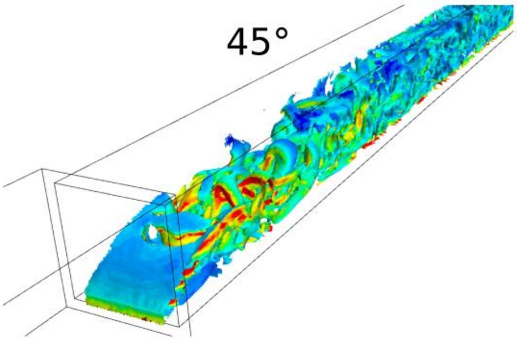

Figure 1. Shear layer instability for Re = 2000, entry angle 45 deg - Samuels et al. (2025), under review

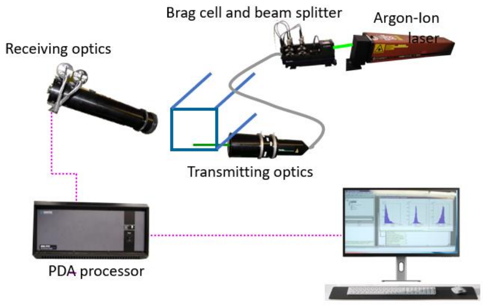

Figure 2: 2-D LDV system for airflow velocity measurements

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18. Safety-critical control-based decision-making framework for smart engineering: Integrating optimization and machine learning

Dr Xuefang Wang – xw259@leicester.ac.uk

Project Title		Safety-critical control-based decision-making framework for smart engineering: Integrating optimization and machine learning
Project Highlights:	1.	Development of safety-critical control algorithms in smart engineering to allow systems to adapt to external changes and internal fluctuations, enhancing robustness and stability.
	2.	Integration of intelligent technologies to monitor and assess potential risks in real-time, supporting safety-related decisions.
	3.	Establishing a networked human-machine collaboration control system that interconnects various components to facilitate a more flexible, scalable, manageable, and safe operation environment.

Project Overview (Maximum 350 words)

Context: The integration of optimization and machine learning within a safety-critical control-based decision-making framework is indispensable for the advancement of smart engineering. This fusion empowers the system to dynamically optimize processes while leveraging machine learning for real-time risk assessment and decision-making. The significance lies in its potential to enhance operational safety, streamline efficiency, and adapt to evolving conditions. However, challenges arise in balancing the trade-off between computational complexity and the need for rapid decision-making, ensuring the reliability of machine learning models in dynamic environments (e.g., dynamic chemical processes), and addressing cybersecurity concerns associated with interconnected threats. Overcoming these challenges is fundamental to unleashing the full potential of smart chemical engineering, ushering in a new era of safer, more efficient, and intelligent chemical processes.

Object: This project aims to explore the development of advanced safety-critical control strategies and its implementation in smart engineering such as chemical processes, robotics, and autonomous vehicles. Advance intelligent tools towards design, integration, and evaluation of optimization-based and learning-based architectures for smart engineering. The research activities for this position include:

1) Developing intelligent algorithms make the system recognize patterns and trends that may lead to unsafe conditions, enabling proactive risk mitigation strategies. Especially, in smart chemical engineering, the developed intelligent technologies can be used to predict analytics, use historical and real-time data to forecast potential safety risks throughout the chemical processes.
2) Establishing a networked human-machine collaboration decision system by providing real-time insights into safety-related risks. Human-machine collaboration ensures that operators have access to comprehensive information, allowing them to make informed decisions swiftly and effectively in response to potential safety concerns.
3) Techno-economic-environmental assessment of novel optimization and learning technologies, improving operation efficiency, reduce costs, and ensure safe and stable operation environment for smart engineering system.

The applicants should have interests in advanced safety-critical control strategies design for smart engineering based on optimization and machine learning methods, and sufficient knowledge of programming such as Matlab, Python, C/C++, etc.

19. AI-assisted 3D printing design of heat sink in lightweight electrified aviation propulsion machines

Dr. Yang Liu – yl832@leicester.ac.uk

Project Title	AI-assisted 3D printing design of heat sink in lightweight electrified aviation propulsion machines	
Project Highlights:	1.	Next-generation thermal management for sustainable high power density electrified aviation: Develop a novel integrated air-cooled channel and frame design and manufacturing solution for high power density and light weight motor drives in electrical aircraft exhibiting cutting edge thermal and mechanical performance.
	2.	Thermal management design from multi-scale modelling strategy: Multi-scale heat transfer modelling including bulk structure topology optimisation and micromechanical analysis of high-fidelity microstructure aiming for studying manufacture strategy, material selection and microstructure sensitivity.
	3.	Optimising the design parameters for electric motor: Machine learning driven real in-service design to optimise the bulk and microstructural parameters for selected heat sink material and manufacturing process to maximise heat dissipation without losing structural integrity.

Project Overview (Maximum 350 words)

High power density, high efficiency, and lightweight electrical machines are core components of propulsion systems in electrified aviation. However, the intensive power demands of modern aircraft—particularly during take-off and in-flight acceleration—lead to excessive localized heat generation in conductive and permeable electromagnetic materials. This thermal buildup significantly impacts motor performance, structural integrity, and lifespan. Conventional heat sink and cooling designs are no longer adequate to meet the NASA 2030 goals for power density, weight, and thermal management efficiency.

To address these challenges, this project proposes a novel 3D-printed air-cooled thermal management system that combines cooling channels with the structural frame of the electric motor. This integrated approach leverages machine learning-driven design and additive manufacturing to enable uninterrupted heat transfer from the heat source (e.g., silicon steel core and conductive windings) to the ambient environment. The 3D-printed heat sink eliminates the inefficient air gap found in current designs and enhances the surface area for convective heat exchange, accelerating dissipation and improving temperature uniformity.

The project adopts a multi-scale modelling strategy to inform both macro- and micro-level thermal management. Bulk-scale topology optimization is used to configure the structural layout for maximum heat removal with minimal material use, while micromechanical simulations investigate microstructure sensitivity, manufacturability, and material behaviour under thermal-mechanical stress. Material selection is guided by performance metrics at different scales, including conductivity, strength, and printability.

A unique feature of this research is the incorporation of machine learning algorithms to optimize design parameters in real-time based on in-service thermal loads. These models help to tailor the heat sink structure and material microstructure to varying operational conditions, ensuring thermal reliability and mechanical integrity under all flight phases.

By integrating cutting-edge additive manufacturing, AI-driven design optimization, and advanced heat transfer modelling, this project offers a transformative solution for next-generation aero electric motors. The outcome will contribute to sustainable aviation by enabling compact, lightweight, and thermally efficient motor drives that can operate safely under extreme power conditions—thereby pushing the frontiers of electrified aviation propulsion.

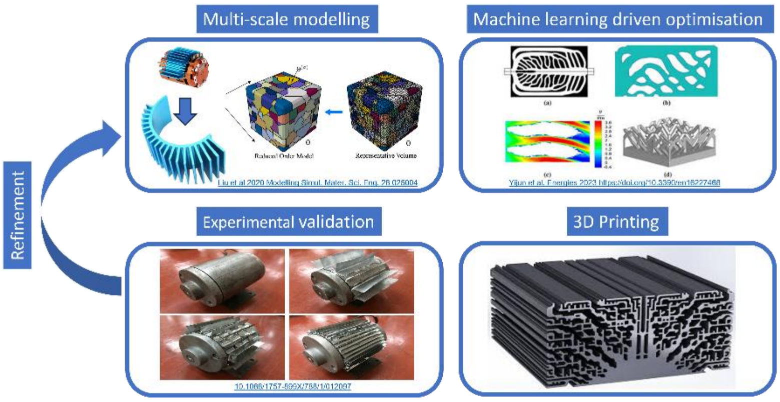

Fig. 1 Machine learning based thermal management strategy

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20. Power converter control for power systems with high-penetration renewables

Dr Yuan Gao – yuan.gao@leicester.ac.uk

Project Title	Power converter control for power systems with high-penetration renewables	
Project Highlights:	1.	**Intelligent Converter Control**: Develop adaptive grid-forming and grid-following converter control strategies that can autonomously regulate frequency, voltage, and power flow in systems with high renewable penetration.
	2.	**Machine Learning–Enhanced Stability:** Integrate reinforcement learning and neural network–based optimization to enable converters to learn from grid data, predict instability, and self-tune control parameters under dynamic and uncertain operating conditions.
	3.	**Real-Time Validation and Impact:** Demonstrate the proposed control framework through Hardware-in-the-Loop (HIL) and Real-Time Digital Simulation (RTDS) experiments, providing practical solutions for stable and resilient renewable-dominated power grids.

Project Overview (Maximum 350 words)

The global transition toward low-carbon energy has driven a rapid increase in renewable generation, especially wind and solar power. As inverter-based resources replace conventional synchronous machines, power systems are becoming converter-dominated and increasingly complex. This high penetration of renewables introduces new technical challenges, including reduced inertia, degraded frequency stability, and altered fault dynamics. Traditional control and protection methods are no longer sufficient to ensure grid reliability under such dynamic and uncertain conditions.

This PhD project aims to develop intelligent control strategies for power converters to enhance the stability and resilience of power systems with high-penetration renewables. The research combines advanced converter control theory with machine learning techniques to achieve adaptive, data-driven decision-making. The project will focus on the design of grid-forming and grid-following converter controls that can autonomously provide system support such as frequency regulation, voltage stability, and synthetic inertia, even under rapidly changing renewable outputs.

The scientific approach integrates dynamic modeling, control design, and intelligent optimization. First, the candidate will build detailed dynamic models of converter-interfaced renewable generation under weak grid conditions. Then, machine learning methods—including reinforcement learning, adaptive neural networks, and Gaussian process regression—will be applied to optimize control parameters in real time and predict grid stability margins. These algorithms will enable converters to learn from operational data, anticipate disturbances, and adapt to uncertain or nonlinear system conditions.

The developed strategies will be validated through Hardware-in-the-Loop (HIL) and Real-Time Digital Simulation (RTDS) experiments to ensure robustness, safety, and scalability for real-world deployment.

Expected outcomes include new AI-enhanced converter control architectures that combine physical modeling with data-driven adaptability. The results will provide fundamental insights into the interaction between machine learning and power electronics, forming the technical basis for intelligent, resilient, and carbon-neutral grids. This research directly supports global renewable integration targets and contributes to the development of next-generation smart grid control technologies.

The applicants are expected to have interests in advanced converter control strategies for smart grid and machine learning techniques, and sufficient knowledge of programming such as Matlab, Python, etc.

Only available with DLI funding

21. Insights from the bushcricket ear: Nature-based engineering towards advanced sound detection technologies

Dr Emine Celiker – ec403@leicester.ac.uk

<table>
<tr><td>Project Title</td><td colspan="2">Insights from the bushcricket ear: Nature-based engineering towards advanced sound detection technologies</td></tr>
<tr><td rowspan="3">Project Highlights:</td><td>1.</td><td>Scientific Impact: Pioneering numerical models of bushcricket auditory mechanics
Robust and validated finite element models integrating 3D reconstructed, high resolution micro-Computed Tomography images of the bushcricket ear and novel mesh-based physics-informed neural networks (M-PINN). The finite element analysis (FEA) will decode the thermoviscous acoustic-structure interaction biomechanism behind the high-acuity bushcricket sound processing abilities.</td></tr>
<tr><td>2.</td><td>Engineering Innovation: Low-power acoustic sensor design
Comprehensive mechanical networks analogous to the bushcricket auditory system to realize novel, efficient, low-power design of acoustic technologies.</td></tr>
<tr><td>3.</td><td>Societal Impact: Novel insect-inspired sound processing for hearing aids
Insights derived from the complex auditory mechanics of bushcrickets to significantly enhance the performance of next-generation hearing aids and cochlear implants, through variable stiffness materials or multi-point stimulation to improve frequency selectivity and signal clarity.</td></tr>
<tr><td colspan="3">Project Overview (Maximum 350 words)</td></tr>
<tr><td colspan="3"><u>Background:</u>
Similar to mammals, insects also need sharp hearing abilities to function and survive in their environment. As a consequence, insects have evolved sophisticated hearing organs in various parts of their bodies, whose high-acuity are engineering marvels of nature. For instance, located within the tibia of their forelegs, bushcrickets (Insecta: Orthoptera: Ensifera: Tettigoniidae) have micro-scale, tympanal hearing organs processing sound with a striking convergence to mammalian hearing (Montealegre-Z et al., 2012; Celiker et al, 2024). However, the mechanical parallels and distinctions between the two systems are not yet fully understood. A more complete understanding is required for a definitive assessment of how the remarkable bushcricket ear could serve as a model for bio-inspiration for auditory healthcare technologies (Göpfert & Hennig, 2016).
<u>Aim and Objectives:</u>
This project aims to investigate the analogies between the bushcricket and mammalian auditory mechanisms, contributing to cutting-edge research in nature-based engineering. This will be</td></tr>
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achieved through the integration of advanced computational engineering techniques (FEA, M-PINN) with state-of-the-art micro-CT imaging. Numerical results will be validated through comparison with experimental (Laser Doppler Vibrometer, LDV) recordings. The results will be used to form a comprehensive mechanical network of the bushcricket auditory system, highlighting analogies with the complex auditory mechanisms of mammals.

Methodology

Laser Doppler Vibrometer Experiments

The tympana (ear-drum) response to sound pressure will be recorded in the frequency and time domains with a single-point LDV.

Micro-CT

Micro-computed tomography (μ −CT) scans of the bushcricket ear anatomy will be obtained and 3D reconstructed to be used in the finite element simulations.

Finite Element Analysis

Robust finite element models will be developed to simulate the biophysical mechanisms governing the bushcricket ear. Models will be validated against LDV recordings, and then used to go beyond experimental limitations.

M-PINN

M-PINN models will be developed as inverse problems to quantify the material properties (Young's modulus) of the bushcricket ear not available in the literature. The obtained values will be fed into the finite element models for reliable numerical results.

Project Outputs:

Comprehensive and novel mechanisms with applications in the design of efficient, low-power sound sensors and the next-generation of hearing aids.

References:

Celiker, E., et al. (2024). *PLOS Computational Biology*, *20*(12), e1012641.

Göpfert, M. C., & Hennig, R. M. (2016). *Annual Review of Entomology*, *61*(1), 257-276.

Montealegre-Z, F., Jonsson, T., Robson-Brown, K. A., Postles, M., & Robert, D. (2012). *Science*, *338*(6109), 968-971.

22. Novel Compact Motor Drive System with Integrated Solid-state Supercapacitor

Dr Yang Xiao – Yx224@leicester.ac.uk

Project Title	Novel Compact Motor Drive System with Integrated Solid-state Supercapacitor	
Project Highlights:	1.	This project pioneers a fully integrated motor-drive architecture that embeds solid-state supercapacitors for unprecedented compactness, power density, and transient performance.
	2.	By internalising short-term energy buffering within the drive system, the solution dramatically reduces peak battery stress, significantly enhancing propulsion reliability and lifespan.
	3.	This project will be co-supervised by Dr Yang Lu (Research Fellow, Harvard University), with possibilities of international exchange and up to £30k additional stipend subject to research excellence.

Project Overview (Maximum 350 words)

Electrified propulsion systems based on electrical energy storage and motor drive technologies have become the prevailing architecture for fully electric propulsion across a broad range of applications. However, current battery technologies remain constrained by limited power density, which hinders the development of compact and lightweight propulsion systems. Furthermore, the reliability and lifespan of batteries are significantly challenged under operating conditions that demand frequent high-power charge/discharge cycles, posing potential safety risks.

To mitigate these limitations, hybrid energy storage systems (HESS)—combining batteries with high-power storage devices such as supercapacitors or flywheels—have been proposed as a promising solution to enhance system efficiency, reliability, and control flexibility. Nevertheless, the separated multiple components typically leads to increased system volume and weight, which is undesirable for applications requiring high power density, compactness, and lightweight structures.

This project aims to bridge this gap by developing a next-generation motor drive architecture that holistically integrates the motor, power electronics, and solid-state supercapacitor into a single compact system. The proposed integrated drive system will be capable of handling short-term high power/torque transients and rapid operational fluctuations internally, thanks to the high-power density, high temp compatibility and superior cycle stability for solid-state supercapacitors, thereby greatly reducing the peak power and current demands on the primary long-term energy storage unit (e.g., battery). This, in turn, is expected to significantly enhance propulsion system reliability, improve lifecycle performance, and enable substantial reductions in system size and weight. The outcomes of this project have the potential to redefine the paradigm of electrical propulsion by embedding HESS-like functionality within the motor drive itself, achieving a breakthrough combination of high-power density, flexible control, high efficiency, and compact system design.

Key Research Topics

1. Conceptual architecture and design methodology for integrated motor drive systems embedding motor, power converter, and solid-state supercapacitor modules.
2. Multiphysics modelling and optimisation of the integrated system to achieve compact/light-weight design, high reliability, and thermal-electromagnetic-mechanical robustness.
3. Data-driven co-design and control framework combining electrical engineering and materials science to optimise energy buffering, drive control, and storage utilisation.

23. Multiscale CFD-PK/PD Modelling of Inhaled Antimicrobial Aerosol Delivery in the Human Lung

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Project Title	Multiscale CFD–PK/PD Modelling of Inhaled Antimicrobial Aerosol Delivery in the Human Lung	
Project Highlights:	1.	Develop a hybrid multiscale framework that links computational fluid dynamics (CFD)–based aerosol deposition with spatial pharmacokinetic/pharmacodynamic (PK/PD) modelling in the human respiratory system.
	2.	Quantify how airway geometry, inhalation pattern, and particle size influence regional drug exposure and predicted antibacterial efficacy.
	3.	Establish a computational workflow that supports rational design of inhaled therapies and optimised dosing strategies for future translational and clinical applications.

Project Overview (Maximum 350 words)

Inhaled antimicrobials provide targeted delivery to the lungs, offering high local drug concentrations and reduced systemic exposure compared to oral or intravenous routes. However, achieving efficient and reproducible delivery depends on complex interactions between airway anatomy, airflow dynamics, particle properties, and patient breathing patterns. This PhD project aims to develop a computational framework that integrates detailed airflow and particle transport modelling with pharmacokinetic/pharmacodynamic (PK/PD) analysis to predict local drug distribution and antibacterial effects in the human lung.

The study will employ computational fluid dynamics (CFD) methods to simulate airflow and particle deposition for respirable aerosols (0.5–5 µm) within anatomically realistic airway geometries derived from clinical imaging data. Deposition patterns obtained from CFD simulations will be coupled to a spatial PK/PD model to describe subsequent drug dissolution, absorption, and local bacterial response. Simplified mucociliary clearance and peripheral 1D/MPPD sub-models will be incorporated to account for particle transport and deposition in smaller airways beyond the CFD domain.

This hybrid CFD–PK/PD framework will enable quantitative predictions of local drug exposure across different lung regions and provide insight into how factors such as inhalation flow profile, aerosol size distribution, and airway geometry affect antimicrobial performance. Sensitivity and optimisation analyses will identify the key determinants of efficient pulmonary delivery and support evidence-based design of inhalation strategies and device parameters.

The project is computational and data-driven, offering an excellent training opportunity in multiscale modelling, numerical methods, and respiratory drug delivery science. The outcomes will advance predictive tools for aerosol therapy design and support translation of inhaled drug formulations into clinical use.