Final Year Internal Projects List 2023-2024

September 2023

*Projects with a * next to the project code have been identified as requiring student effort to be evenly distributed between both the autumn and spring/summer terms. Students should keep this in mind when selecting projects and choosing optional modules. Projects with (S) after the Project Title indicates space related projects.*

UG Final Year Internal Projects List

Aliabadi, Ferri Prof.

Project no: ***LRFA01***
Project title: Environmental effects on damage detection using Structural Health Monitoring techniques (S) - 3 projects available

Supervisor: Aliabadi, Ferri Prof.
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

Structural Health Monitoring (SHM) techniques are well established for impact and damage detection at laboratory conditions where the environmental factors are controlled. However, applying the SHM methodologies to real aircraft structure under real load conditions and environmental effects might not result in correct diagnosis of the structure. Therefore it is very important to study the effect of variable such as temperature and humidity on the wave propagation in composite structures. Most of the damage detection techniques based on guided waves are developed on the basis of comparing the response of the structure in its pristine state to the damaged state. This means that it is very important to study the influence of the environment on the sensor data when they are recorded under different conditions to avoid mis-detections or false alarms due to environmental factors. In addition pre-loading of the structures can also change the propagational properties of the baseline signals. Therefore the aim of the project is to identify the influence of the environmental effects together with the impact of the pre-loading on the wave propagation and possibly develop baseline free methods for damage detection in composite aircraft panels.
Students should have a very good knowledge of strucutres and composite in particular as well as programing with MATLAB. The project requires theoretical, compuational and experimental reserach.

Aliabadi, Ferri Prof.

Project no: ***LRFA02***
Project title: Deep Learning approach to Impact detection in sensorized panels (S) - 3 projects available

Supervisor: Aliabadi, Ferri Prof.
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

The purpose of the project is to detect an impact event in composite plates using Structural Health Monitoring techniques. The SHM technique is based on an array of Piezoelectric (PZT) transducers permanently mounted on the structure to capture any change occurring in the structure. SHM techniques can be divided into active and passive sensing. Passive sensing refers to the state where transducers are used as sensors only and the structure is activated by an external event such as

impact. When an impact event occurs, surface waves are generated in the structure and after propagation they are recorded by the mounted PZT sensors. The aim is to use these sensor data to develop SHM techniques for passive sensing to detect and characterize the impact event using deep learning approaches.
Students should have a very good knowledge of strucutres and composite in particular as well as programing with MATLAB. The project requires theoretical, compuational and experimental reserach.

Aliabadi, Ferri Prof.

Project no: *LRFA03 **
Project title: XFEM/Boundary Element Analysis of Crack Growth (S)

Supervisor: Aliabadi, Ferri Prof.
Co-supervisor(s):
Category: Computational;Theoretical
Software:
Confidential: No

Catastrophic fracture failure of engineering structures is caused by cracks that extend beyond a safe size. In this project crack growth processes are simulated with the boundary element method. Boundary element method is an alternative method to the more established finite element method. The attraction of the boundary element method is largely attributed to the reduction in the dimensionality of the problem; for two-dimensional problems, only the line-boundary of the domain needs to be discretized into elements, and for three-dimensional problems only the surface of the problem needs to be discretized. This means that, compared to the FEM, a boundary element analysis results in a substantial reduction in modelling effort. Boundary element has been particularly successful for crack growth analysis. The aim of the project is to extend the current in-house code to include thermal, centrifugal and other types of body forces.
A good level Abaqus Knowledge is essential.

Aliabadi, Ferri Prof.

Project no: *LRFA04*
Project title: Fracture Toughness of multilayer materials (S)

Supervisor: Aliabadi, Ferri Prof.
Co-supervisor(s):
Category: Experimental: Structures;Computational;Theoretical;Analysis
Software:
Confidential: No

The aim of the project is to investigate the influence of thickness on fracture toughness of compact tension specimen. The project requires manufacturing several specimen for testing. It also requires modelling multilayer and monolithic parts with FE commercial software and elevation for compliance and stress intensity factors. It is well known for intermediate and thin specimen the fracture tough varies and R-cure is normally utilised. Here the investigate would be aimed at multilayer structures.

This project is only suitable for students with good ability in manufacturing and testing and excellent knowledge of materials and Abaqus software.

Amato, Davide Dr

Project no: ***LRDA01 ****
Project title: Development of an advanced orbit propagation Julia package (S) - 2 projects available

Supervisor: Amato, Davide Dr
Co-supervisor(s):
Category: Computational;Numerical;Theoretical;Literature
Software: Julia
Orekit: https://www.orekit.org
Confidential: No

Orbit propagation means solving an Initial Value Problem (IVP) for given initial conditions, i.e., initial position and velocity, to compute the trajectory of a space object as a function of time. Efficient and accurate orbit propagation algorithms are essential in all areas of astrodynamics, such as orbit determination, trajectory design and optimization, and spacecraft guidance. Many orbit propagation packages exist; however, they are mostly closed-source (Ansys ODTK, FreeFlyer), or hard to integrate in existing research projects (NASA GMAT, Orekit).
The purpose of the project is to develop an in-house, flexible orbit propagator in Julia, a novel high-performance scientific computing language. Julia is being actively developed and possesses a rich ecosystem of numerical packages, such as linear algebra, a vast collection of ODE solvers, and machine learning. The project is available to two students.
The first student will focus on the development of high-fidelity physical models for orbit propagation. This will involve the development of accurate frame and time scale transformations (GCRF/ITRF according to IERS conventions), state-of-the-art time-varying geopotential and atmospheric drag models, modelling of solar radiation pressure, third-body accelerations, and relativistic corrections. An important component of the project is the verification of the package against trajectories produced with the open-source Orekit Java software, and its application to the trajectory propagation of Very Low Earth Orbit (VLEO) spacecraft.
The second student will focus on the development of a semi-analytical propagator. In a semi-analytical approach, one solves equations of motion that have been averaged over the fast variable (usually the mean anomaly). The resulting equations do not contain high-frequency components, which improves the numerical performance of the solution at the cost of a loss of accuracy. The student will perform a literature review of semi-analytical theories valid from LEO to GEO, with particular emphasis on Hamiltonian approaches. After the literature review, one theory will be selected and implemented in Julia.
Both students will assess the computational efficiency of applying automatic differentiation methods (such as those available in JuliaDiff) to the implemented propagators to derive state transition matrices. The development of the package will take place through the Git workflow; Git and GitHub will be used extensively throughout the project.

An outstanding background in orbital mechanics and a willingness to go beyond the module material, especially regarding learning Julia and Git, are essential to carry out this project successfully. Knowledge of Julia and Git is a plus.

Amato, Davide Dr

Project no: ***LRDA02 ****
Project title: Preliminary design of CICLOPS, a Space Situational Awareness optical station (S) - 2 projects available

Supervisor: Amato, Davide Dr
Co-supervisor(s):
Category: Survey;Design;Computational
Software: MATLAB

Confidential: No

Computational methods for Space Surveillance and Tracking (SST), which is the building block of Space Situational Awareness (SSA), must be verified and validated on high-accuracy space data (such as ephemerides). However, high-accuracy ephemerides are rarely available from public sources. The solution is to gather high-accuracy data through cost-effective optical sensors.
Two projects are available on a feasibility analysis and preliminary design of CICLOPS (Calibration Imperial College London Optical Sensor), a ground telescope based in Greater London. The students will first perform a literature review to understand the approaches followed and challenges encountered in the design of similar observatories, such as the Zimlat telescope at the Astronomical Institute of the University of Bern [1] and the AGO70 telescope at Comenius University [2], as well as a review of fundamentals of observational astronomy [3].
The first project will focus on the preliminary design of the telescope using commercial components, identifying design drivers (diffraction resolution, sensor resolution, field of view) and requirements for the observability of the LEO and GEO regions based on the modelling of the spacecraft apparent magnitude, observability conditions due to weather and light pollutions, and modelling of atmospheric refraction.
The second project will set up a pipeline for the orbit determination from angular measurements of objects detected by the telescope to satisfy accuracy requirements through Gauss' method of preliminary orbit determination. This will involve propagating objects in the US Space Catalogue and the computation of visibility conditions from the ground.
Both projects require a strong foundation in Spacecraft Systems and a strong willingness to explore topics outside the course material. The second project also requires excellent background in Orbital Mechanics.
References:
1. Herzog J. et al, "Space Surveillance Observations at the AIUB Zimmerwald Observatory", Proceedings of the 6th European Conference on Space Debris, 2013.
2. Šilha J. et al, "Development and operational status of AGO70 telescope", Proceedings of the 8th European Conference on Space Debris, 2021.
3. Scott Birney, D., Gonzalez, G., and Oesper, D., "Observational Astronomy", Cambridge University Press, 2006.

Amato, Davide Dr

Project no: ***LRDA03 ****
Project title: Simulation of light curves of resident space objects (S)

Supervisor: Amato, Davide Dr
Co-supervisor(s):
Category: Survey;Numerical;Theoretical
Software: Python; C++; Blender; POV-Ray

Confidential: No

In Space Situational Awareness (SSA), data is scarce, especially regarding the attitude of resident space objects (RSOs). Ideally, the attitude of a spacecraft could be inferred by acquiring images from ground- or space-based telescopes. However, due to the large distances involved, telescopes cannot generally resolve RSO features due to optical diffraction limits and sensor pixel resolutions. Therefore, there is great interest in inferring information on spacecraft attitude from measurements of its brightness, that is, its apparent magnitude. Many approaches have been published in the literature to recover the attitude of a RSO from a time series of measurements of its apparent magnitude, which is called a light curve.

The project consists of the development of a simulation framework for light curves of RSOs of known geometry and optical characteristics. The student will carry out a systematic literature review on the physical principles of light curve simulation and describe state-of-the-art approaches based on ray-tracing (POV-Ray, http://www.povray.org) and CAD rendering software (Blender, https://www.blender.org). Following the literature review, the student will develop analytical models for the light curve generated by object with simple geometries (panel, cube) depending on their optical characteristics and relative attitude with respect to the observer and the Sun. Finally, the student will develop a light curve simulator in C++/Python capable of simulating objects with complex CAD models (e.g., satellite buses and rocket bodies). The simulator will satisfy stringent computational requirements to generate light curves for many attitudes and objects, and shall accommodate varying optical properties depending on wavelength for the simulation of hyperspectral imaging. In this latter phase, the development of the package will take place through the Git workflow; Git and GitHub will be used extensively throughout the project.

A strong willingness to go beyond the module material is essential to carry out this project successfully. Knowledge of Python, C++, git, and interest in computer graphics are a plus.

References:

1. Kerr E. et al, “Light curves for GEO object characterisation”, Proceedings of the 8th European Conference on Space Debris, Darmstadt, Germany, 2021.
2. Nussbaum M. et al, “Spectral Light Curve Simulation for Parameter Estimation from Space Debris”, Aerospace 9(8), 2022. doi: 10.3390/aerospace9080403.

Bilotti, Emiliano Dr

Project no: ***LREB01 ****

Project title: Recyclable Fibre Reinforced Polymer (FRP) Composites for Wind Turbine Blades (S

Supervisor: Bilotti, Emiliano Dr
Co-supervisor(s): Pinho, Silvestre Prof.
Category: Experimental: Structures
Software:
Confidential: No

Achieving NetZero by 2050 will require a significant increase in wind energy capacity over the next decades. For instance, if we are to power the current aviation industry with green hydrogen produced by wind turbines, this alone would require that we increase by about 700% the wind energy currently produced. Each wind turbine blade contains more than one ton of polymeric matrix composite, where the matrix is a thermoset which cannot be easily recycled. Hence the only current end-of-life option for composites wind turbines blades is landfilling. This project will evaluate the suitability of thermoplastic (TP) polymer matrix composites for recyclable wind turbines. Thermoplastic polymers are more amenable of being recycled as they can be ‘melted’/liquified and solidified several times, without significantly changing their properties. TP are also generally tougher than thermoset matrices. Vice versa, the Young’s modulus and resistance to creep of TP are typically lower than thermoset. Moreover, TP/continuous fibres composites can be more difficult to manufacture due to higher viscosity and higher processing temperature.

In this project, you will:

i) Review the literature on the potentials and limitations of thermoplastics FRP for wind-turbine blades;
ii) Select the most suitable materials (e.g. thermoplastic polymer matrix and reinforcing fibres) and manufacturing method.
iii) Prepare and test TP composites and benchmark it against typical GFRP for wind turbines.
iv) Evaluate the feasibility of TP composites for welding/repairing.
v) If time allows, evaluate feasibility and efficacy of different recycling processes.

Bilotti, Emiliano Dr

Project no: ***LREB02 ****
Project title: Composites Engineering of Sustainable Food: Towards the next generation of Plan based Steaks

Supervisor: Bilotti, Emiliano Dr
Co-supervisor(s):
Category: Experimental: Structures;Experimental: Manufacturing intensive
Software:
Confidential: Yes

Most of the current plant-based ‘meat’ products on the market only partially satisfy meat lovers, with different levels of satisfactions depending on the type of product. While plant-based sausages and mince ‘meats’ are relatives easy to produce and can mimic rather well traditional animal-derived products, plant-based steaks are inadequate and unsatisfactory. This is due to the difficulty in reproducing the original texture of meat, fibrous and multicomponent in nature.

This project, in collaboration with THIS.co (a London-based leader in plant-based food), aims at overcoming the barrier to switch from animal steak to sustainable plant-based steak, by applying a novel Composites Materials Engineering approach.
This project requires innovative thinking to create, bottom-up and potentially at scale, a plant protein fibrous composite that closely mimic steak, namely with a hyper-realistic texture, appearance and, ultimately, taste. After an initial evaluation of typical 'composites' microstructures of steaks, including the use of optical and electron microscopy, the project will explore technologies to: i) create plant-based protein fibers (e.g. solution/gel spinning, electrospinning), ii) structure them in a bespoke 3D network and iii) include additional phases to the fibrous network (e.g. fats).
Additional Benefits:

- Save animals, in collaboration with THIS. The company's target for 2023 is saving 1 million animals.
- Help reducing carbon footprint (THIS claims its products produce 10x lower carbon emission compared with animal meat).
- Work with a group of passionate scientists at THIS and experience of a very dynamic environment in the London offices/development lab/kitchen.
- A goodie bag of THIS products

Bilotti, Emiliano Dr

Project no: ***LREB03 ****
Project title: Learning from Nature: from silk fibre to high performance materials

Supervisor: Bilotti, Emiliano Dr
Co-supervisor(s):
Category: Experimental: Structures
Software:
Confidential: No

Natural silk has been used in daily life for a long time. Thousands of years ago, the ancient Chinese raised silkworms and extracted silk fibres to make luxury clothes, exported across continents. Ancient Greeks reported the use of natural silk for wounds healing.
However, synthetic polymer materials have gradually replaced natural silks over the last 60 years because of their scalability and wider availability, lower costs and good chemical stability.
Recent progresses in the fields of synthetic biology and genetic engineering have reignite interest in silk, and, in particular, spider silk, which has become among the most promising natural materials. Drag-line spider silk, for instance, shows unique combinations of high thermal conductivity, high strength (0.9-1.4 GPa), high toughness (160-250 MJ/m3) and high energy absorption.
As part of this project, you will investigate manufacturing processes to convert silk fibres into high-performance composites materials. You will find inspiration in the hierarchical (nano)structures present in natural materials like spider silk – but also bone, nacre, enamel or tree – to develop the next generation of biomimetic high-performance sustainable materials.

Bilotti, Emiliano Dr

Project no: ***LREB04 ****
Project title: Edible Electronics (S)

Supervisor: Bilotti, Emiliano Dr
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

Electronic devices composed of 'green' materials that can be gradually degraded with time in the body, are called edible electronics. They can offer various range of applications from smart tags for food aging monitoring towards internal human body health tracking, which could precisely deliver the medications into the target tissues.
Although the technological desire for edible electronics is great, the field is at its infancy. As they are in contact with the human body, there are great challenges to be considered for real applications. One of these challenges is the very restricted spectrum of materials that can be safely used. Most of the materials in normal electronics are unsuitable for edible applications, due to cytotoxicity, non-biocompatibility, and instability in contact with human body fluids in Gastrointestinal (GI) tract, for instance.
This project will offer you to be a pioneer of this new exciting field. You will select suitable materials, manufacture simple edible electronic and, ideally, develop a proof-of-concept, which could range from smart edible packaging to non-invasive diagnostic and environmental remediation solutions.

Bilotti, Emiliano Dr

Project no: ***LREB05 ****
Project title: Reversible Actuation Mechanisms in Polymer Composites – Towards Morphing Structures and Devices (S)

Supervisor: Bilotti, Emiliano Dr
Co-supervisor(s): Pinho, Silvestre Prof.
Category: Experimental: Structures;Computational
Software:
Confidential: No

The ability to programme the shape of structures and functional devices, particularly when autonomously and in response to external stimuli, could be ideal for applications like space missions, micro-robotics, environmental remediation and minimally invasive surgery.
(Self-)Actuation has been demonstrated through several approaches, such as shape memory effect, swelling/deswelling, expansion/contraction. Different bending strategies have been used, including multilayers, material gradients and localised activation. Moreover, buckling strategies have also been proposed, such as material tessellation, in-plane material gradients, non-homogenous exposure and mechanically induced buckling.

However, achieving a fast and accurate deployment of complex 3D shapes contaclessly at low energy consumption, while embedding a number of physical properties and functionalities, not least load bearing capacity, remains very challenging.
This project will explore best strategies to obtain actuation mechanisms in polymer composites that are: i) reversible, ii) fast, iii) suitable for load bearing applications.

Bruce, Paul Dr

Project no: ***LRPB01***
Project title: Experimental study of the dynamic stability of re-entry vehicles (S)

Supervisor: Bruce, Paul Dr
Co-supervisor(s):
Category: Experimental: Manufacturing intensive
Software:
Confidential: No

The dynamic stability of re-entry vehicles at moderate to low supersonic and transonic Mach numbers can be critical to mission performance. This project will utilise a novel custom-built rig to explore the dynamic behaviour of (conventional and unconventional geometry) re-entry vehicles at transonic and supersonic conditions with 1, 2 and 3 degrees of freedom in Imperial's supersonic wind tunnel. The primary aim of the project is to provide high quality dynamic experimental data that will (1) improve our understanding of the physics that govern re-entry vehicle stability, (2) quantify the stability of unconventional re-entry vehicles including deployables, and (3) validate existing computational results from URANS and LES. This project is closely aligned to ongoing research at Imperial and a high degree of interaction and collaboration is expected.
Please note this project can only be undertaken as a full-time effort, starting in Jan 2024.

Buxton, Oliver Dr

Project no: ***LROB01 ****
Project title: Aerodynamic measurements for Martian flight (S)

Supervisor: Buxton, Oliver Dr
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

In April 2021 Ingenuity became the first man-made object to complete an extra-terrestrial powered flight; on Mars. Mars has an extremely "thin" atmosphere in comparison to Earth, with a much reduced surface pressure (as well as a different chemical composition; consisting primarily of carbon dioxide). As a result flight on Mars occurs at "peculiar" (with respect to Earth) conditions: a combination of high Mach number to extremely low Reynolds number. Current aerofoils have been designed (with over a century's experience) to operate efficiently in a typical terrestrial parameter space (in terms of Mach and Reynolds number combination). As a result our existing aerofoil designs are inefficient for Martian flight. At Imperial College London we are developing simulation-based approaches to optimising Martian aerofoils but this will require experimental data for validation. We will be commissioning our brand new supersonic wind tunnel later this year which has been designed to vary both Mach and Reynolds number independently, enabling us to approach typical Martian conditions. This project will develop our testing capabilities in this new supersonic wind tunnel with an eye towards producing high-quality data to help with our efforts to optimise Martian aerofoils. In particular we will aim to produce force and pressure measurements over specifically designed Martian aerofoil sections. This project will run in coordination with a sister project, supervised by Prof. Peter Vincent, that will develop our simulation capabilities for Martian rotorcraft aerofoils.

Buxton, Oliver Dr

Project no: ***LROB02 ****
Project title: Developing correction methodologies for CO2 flux measurements from an oceanographic measurement tower

Supervisor: Buxton, Oliver Dr
Co-supervisor(s): Callaghan, Adrian Dr (Civil Engineering)
Category: Experimental;Computational
Software: OpenFOAM and/or Star-CCM+

Confidential: No
Carbon dioxide exchange between the atmosphere and ocean is one of the largest uncertainties in global climate modelling. Given these uncertainties the acquisition of high-quality data on CO2 mass fluxes is essential to inform future climate modelling. This requires the deployment of specialist measurement stations at-sea and the acquisition of data over a sufficiently long time period to obtain high-quality statistics for the data in relation to differing conditions, e.g. seasonal/diurnal cycles, changes in wind direction etc. Structures that are robust enough to survive in harsh maritime conditions for such a lengthy period of time are, however, typically large enough to influence the atmospheric flows past them such that, as far as the flow is concerned, they are intrusive. It is thus imperative to understand the extent to which these measurement stations affect the flow around them so that correction methodologies can be developed in order to produce accurate data relating to CO2 mass flux. This project will attempt to produce correction strategies for the Acqua Alta Oceanographic Tower, which is situated off the Gulf of Venice in the Mediterranean, and will run in collaboration with Dr. Adrian Callaghan in the Department of Civil and Environmental Engineering and Dr. Alvise Benetazzo from the Italian Institute of Marine Sciences. There is flexibility in how to approach the project: the student can use CFD (OpenFOAM), produce a model for wind-tunnel testing, or a combination of both approaches. The tower will be exposed to wind approaching it from different directions and with different velocities in order to develop correction strategies for as many inflow conditions as possible.

Buxton, Oliver Dr

Project no: ***LROB03***
Project title: Feasibility study for domestic wind turbines

Supervisor: Buxton, Oliver Dr
Co-supervisor(s): Bilotti, Emiliano Dr
Category: Survey;Analysis
Software:
Confidential: No

The UK, and many other countries, are pursuing net-zero strategies that require the de-carbonisation of energy generation and hence an ever-greater reliance on renewables. In comparison to fossil fuels/nuclear renewable power-generation has a much lower energy-production density, requiring large spaces to be dedicated to power generation. It is thus vital to try and make the best use of available space. Further, generating electricity close to where it is required minimises transmission losses, driving up efficiency. In recent years there has been an increasingly widespread adoption of domestic solar power generation, with photo-voltaic cells being fitted to roofs of buildings within the urban environment. However, local generation of energy via domestic micro-scale wind turbines has not yet progressed. There are good reasons for this: the wind resource in an urban environment is not as rich as elsewhere (e.g. offshore) and the wind conditions are highly turbulent/unpredictable. Nevertheless, the fact that the electrical infrastructure required for domestic power production is proliferating, due to the adoption of domestic solar energy-production, and the fact that solar/wind resource have a tendency to be anti-correlated with one another thereby mitigating the problem of intermittency for renewable energy generation make domestic wind-energy production potentially very attractive. This will, however, require technological developments in order to make it feasible. The purpose of this project is to review the existing state-of-the-art for micro wind turbines and to assess their feasibility for domestic power production. The student will assess where this becomes feasible (e.g. in west-facing coastal regions, atop buildings such as skyscrapers that are appreciably taller than their surrounding neighbours etc.) and what technological advancements are required to improve the uptake of this technology (e.g. lighter weight materials/lower friction bearings that reduce the cut-in wind speed for the turbines). This project is thus a feasibility study for domestic wind energy production and will be jointly supervised by Dr. Emiliano Bilotti.

Cantwell, Chris Dr

Project no: ***LRCC01***
Project title: Predictive modelling of electrical wave propagation in the heart - 2 projects available

Supervisor: Cantwell, Chris Dr
Co-supervisor(s):
Category: Computational;Numerical
Software: Nektar++ (www.nektar.info), Python

Confidential: No

Cardiac electrophysiology describes the propagation of electrical signals in the heart which leads to its coordinated contraction and pumping of blood around the body. A cardiac arrhythmia is a disorganisation of these wavefronts, often due to the presence of diseased tissue and are treated clinically by isolating or destroying the problematic regions of tissue. However, for complex arrhythmias, identifying the appropriate treatment targets is challenging. Electrically activity can be mathematically modelled by a reaction-diffusion PDE. Computational modelling has the potential to revolutionise treatment of these conditions, while application of data science techniques and machine learning to measurements of the electrical signals can provide new insight into calibrating these models for personalised diagnostics and treatment. Projects are available in the development and application of these technologies which, while using techniques and software similar to that used for fluid dynamics, provides an interesting alternative to traditional aeronautics applications in the context of biological phenomena. Knowledge of C++ or Python is desirable.

Cantwell, Chris Dr

Project no: ***LRCC02***
Project title: Catching performance regressions in scientific codes

Supervisor: Cantwell, Chris Dr
Co-supervisor(s):
Category: Computational
Software: Nektar++ (www.nektar.info), Python

Confidential: No
Creating robust and efficient software for use in scientific research requires developers to adhere to a range of best practices to ensure continued correctness under the use-cases for which they are designed when the code is modified. For codes used in high-performance computing environments it is also critical to ensure new code developments do not adversely affect code performance. The aim of this project is to develop a system for the performance-testing of scientific codes, such as Nektar++, and integrate it with an existing continuous integration system. To verify parallel performance, the system should interface with the a local high-performance computer and potentially the College HPC system. The system should provide feedback in the form of various quantitative performance metrics across multiple tests. Test history should be able to be stored and plotted to show performance over time. This project has a strong software-engineering focus and provides real-world exposure to a wide variety of software development tools and practices, including version control (Git/GitLab), testing and continuous integration. Familiarity with the Linux command-line environment and Python is essential.

Cantwell, Chris Dr

Project no: ***LRCC03***
Project title: High-performance numerical algorithms for next-generation computer architectures - 2 projects available

Supervisor: Cantwell, Chris Dr
Co-supervisor(s):
Category: Computational;Numerical
Software: Nektar++ (www.nektar.info), RePLay (in-house HPC resilience code)

Confidential: No
High-performance computing is now used extensively for simulating a broad range of physical processes from fluid dynamics and material properties through to chemical reactions and the behaviour of complex biological systems. The challenging nature of these simulations and their huge computational requirements necessitate the use of codes which are highly optimised for performance. This requires understanding the capabilities of the computer architecture on which it will run and tailoring both the numerical algorithms and the code to align with and exploit the processor design. Projects are available to develop high-performance algorithmic implementations which target the next generation of supercomputers, from the low-level exploitation of the latest generation of CPU architectures through to resilient large-scale parallel computations of the up-coming exascale machines. Knowledge of C++ is essential. It is recommended that the student has a strong understanding of topics in the course on High-performance computing.

Cantwell, Chris Dr

Project no: ***LRCC04 ****
Project title: Improving the computational performance of a multi-scale graph neural network for predicting transient flow. - 2 projects available

Supervisor: Cantwell, Chris Dr
Co-supervisor(s):
Category: Computational;Numerical
Software: Python, PyTorch

Confidential: No
Humans gain an implicit understanding of physical laws through observing and interacting with the world. To predict the behaviour of dynamical systems, such as fluid dynamics, we traditionally have expressed these laws in the form partial differential equations and solved them using numerical methods. An alternative approach is to allow the computer to learn how to make predictions directly from observations. Using deep learning, it is now feasible to train computers to learn the complex mappings that allows it to extrapolate initial observations of a physical system to future states. Once trained, such mappings can be evaluated several orders of magnitude faster than numerical simulation allowing parameter- or design-spaces to be rapidly explored.
Projects are available in improving the computational performance of a multi-scale graph neural network, developed within the research group, for the prediction of fluid dynamics. Directions include examining the use of multiple GPUs to accelerate training, modification of the message-passing algorithm to reduce the computational cost of using these types of networks, or exploring their ability to extrapolate to unseen scenarios. Due to the time taken to generate training data and train the networks, this project is best undertaken across the entire academic year. Good proficiency in Python is essential.

Cantwell, Chris Dr

Project no: ***LRCC05***
Project title: High-performance software for modelling plasma kinetics in tokamaks - 2 projects available

Supervisor: Cantwell, Chris Dr
Co-supervisor(s):
Category: Computational;Numerical
Software: In-house PIC code, Nektar++
Confidential: No

Nuclear fusion technology has the potential to solve many of the worlds current energy needs in a safe and environmentally friendly way. However, designing a suitable reactor (a tokomak) which can harness energy is a major scientific and engineering challenge. Computational modelling is the key tool which will enable us to realise a working tokamak. One of the challenges is how to model the dynamics of plasma inside the reactor. Particle-in-cell (PIC) methods are often used to solve plasma kinetic models, particularly when tracking fast particle orbits, owing to their reduced computational cost compared to a fully Eulerian representation of the particle distribution function. Projects are available, aligned with on-going work with the UK Atomic Energy Authority, in extending an in-house PIC software tool. This includes integrating the code with Nektar++ to solve field variables, exploring the performance of semi-implicit methods, and optimising performance of the code on GPUs. These projects have a strong software engineering focus and knowledge of C++ is essential.

Chernyshenko, Sergei Prof.

Project no: ***LRSC01***
Project title: Sum-of-squares of polynomials optimisation in fluid dynamics and related problems. (S) - 6 projects available

Supervisor: Chernyshenko, Sergei Prof.
Co-supervisor(s):
Category: Computational;Theoretical
Software: Matlab
Confidential: No

This is a group of related projects, offered to several students in parallel.
All these projects are based on the same mathematical idea of an auxiliary function and in many cases rely on the same software (the Matlab toolbox YALMIP) implementing the sum of squares of polynomials/semialgebraic optimisation technique. The idea and the software can be applied to a large variety of problems. The students begin with studying this mathematical idea and the software and then choose a specific problem from the list of offered problems, or suggest their own problem, to which they will apply the idea and possibly the software. This then become the student's project.
Strong mathematical background will be needed. Some topics might also require programming skills. Before going any further, note that the heavily mathematical nature of these projects dictates deep

concentration on the work, which has to be done full time without distractions and has, therefore, to be mostly concentrated in one term only. Do not select this if you will not be able to devote yourself fully to this project in the spring term (this depends on your choice of optional modules).
If you can work full time on the project in the spring term, the next step is to watch a few short videos about this group of projects. The videos are highlighted in yellow at
https://www.imperial.ac.uk/aeronautics/fluiddynamics/ChernyshenkoResearch/misc.php
(If you like to watch videos, here is far a more serious video on this topic: at
https://www.youtube.com/watch?v=NrF7n3MyCy4&list=PLf_ipOSbWC86n18q4JMn_1J04S90FpdeE&index=8)
Next, read a short introduction to auxiliary functions at
https://www.imperial.ac.uk/aeronautics/fluiddynamics/Projects/IntroToAuxiliaryFunctions.pdf
This introduction, its content, and its style will give you an idea of what this group of projects is like.
In specific projects this can be complemented with programming, but there are also purely theoretical, pen-and-paper versions.
In addition to the topics covered in the videos, namely bounds for time averages, finding orbits in space, and accelerating averaging, more will be offered. For example, consider a pen-and-paper project on bounds for current in tokamaks and/or Hall thrusters, which would continue the work of previous students, see the ACM MSc 2022 project report
by J.Gong at https://imperiallondon.sharepoint.com/:b:/r/sites/foe/aero/student-reports/MSc%20Advanced%20Computational%20Methods/2022%20Project%20Reports/GONG%20Jiayi.pdf?csf=1&web=1).
There will be more. Another good sample is the FYP project report by M.Baber, 2014, at
https://imperiallondon.sharepoint.com/:b:/r/sites/foe/aero/student-reports/Undergraduate%20Reports/Final%20Year%20Projects/2014%20Final%20Year%20Projects/BABER,%20Monib.pdf?csf=1&web=1&e=bict6b
These projects are aligned with ongoing research in the department.

Doorly, Denis Prof.

Project no: ***LRDD01 ****
Project title: Quantum machine learning (S)

Supervisor: Doorly, Denis Prof.
Co-supervisor(s):
Category: Computational;Numerical
Software: Matlab, Qiskit library, Anaconda
Confidential: No
It is intended that this project will builds on experience gained in completing the short online course based on the Qiskit open simulator - see https://qiskit.org/learn/course/machine-learning-course/ to investigate the use of quantum computation to classify images. It will best suit a person with good mathematical/computational skills who is also a capable self-learner.

Doorly, Denis Prof.

Project no: ***LRDD02 ****

Project title: Modelling structural changes in heart muscle fibre arrangement and effects on diffusion in the beating heart - 2 projects available

Supervisor: Doorly, Denis Prof.
Co-supervisor(s): Pinho, Silvestre Prof.
Category: Computational;Theoretical;Numerical
Software: ABAQUS, Matlab, possibly Star CCM
Confidential: No

The arrangement of the muscle fibres in the heart changes as the muscle cells contract to compress the ventricles and eject blood to the major arteries. This re-arrangement changes the aspect ratio of the muscle cells or cardiomyocytes, altering the process of water diffusion, a process which can be probed by diffusion tensor imaging. In this project it is proposed to build simple structural models of the cardiomyocyte geometry using a solver such as ABAQUS and to investigate how dynamic changes in structure affect the diffusion process. Results will be compared with a random walk solver; a long term goal is to develop a new hybrid solver. This project should provide a good training in computational analysis, including the translation of complex geometries to finite element meshes.

Doorly, Denis Prof.

Project no: ***LRDD03 ****
Project title: Computational modelling of Left ventricular flow and perfusion - 3 projects available

Supervisor: Doorly, Denis Prof.
Co-supervisor(s):
Category: Computational;Numerical
Software: Matlab, Star ccm, Mesh lab
Confidential: No

The overall goal of this set of projects is to create a computational model of the left ventricular coronary arterial and venous trees together with the perfused myocardial tissue mass. The aim of the separate and independent projects include (i) modelling the coronary arterial tree; (ii) modelling the coronary venous network; modelling the process of myocardial perfusion. It is intended that all projects will use Star CCM. An interest in fundamental fluid mechanic along with good numerical/computational skills are desirable. There will be scope for some interaction with MR imaging physicists at the Royal Brompton Hospital. These projects should provide good training in CFD applied to more complex problems.

Doorly, Denis Prof.

Project no: ***LRDD04***
Project title: Modelling ventricular perfusion at the microscale

Supervisor: Doorly, Denis Prof.

Co-supervisor(s):
Category: Computational;Theoretical
Software: Some software: primarily Matlab, Star CCM
Possibly Materialise Mimics

Confidential: No

This project involves a continuing collaboration with the Cardiovascular Magnetic Resonance Centre at the renowned Brompton Hospital, with the objective of improving the imaging of cardiac muscle using theoretical and computational models of diffusion in complex geometries. MR imaging of cardiac muscle structure relies on diffusion tensor imaging, a technique that measures the anisotropy of the process of diffusion. From this it is possible to infer the spatial arrangement of the aggregation of cell membranes, which act as partial barriers. Convective processes, including perfusion and larger scale flows in the myocardial circulation are among the complicating factors. The project will build on recent theoretical solutions and compare with computational modelling. The specific aim of the project is to embed a realistic 3D model of capillary vessels into a semi-idealised model of the cardiac muscle fibres. An existing random walk computational solution method will then be applied to model the effect of capillary flow and the exchange of water molecules between the capillaries and the myocardial tissue; in turn this process affects the relation between the measured water diffusion signal and the underlying geometry of the tissues. It is proposed to use a CFD package such as Star CCM to produce an appropriate semi-idealised 3D geometry. This geometry will then be imported to a random walk-based solver written in C++. The project would ideally suit a student with good computational/numerical skills wishing to develop these further and explore new research areas.

Doorly, Denis Prof.

Project no: ***LRDD05 ****
Project title: Modelling exhaled aerosol spreading - 2 projects available

Supervisor: Doorly, Denis Prof.
Co-supervisor(s):
Category: Experimental;Computational
Software: Matlab, Star CCM+

Confidential: No

Up to 2 projects can be offered on aerosol transport in external flows, where the aerosols are generated by exhalation. One of these may be primarily computational and one could be experimentally focussed. The objective of these projects is to characterise the spread of aerosols of different sizes, produced under a variety of conditions: speech, coughing/sneezing, CPR, to investigate means to contain or limit aerosol spread using a hood with suction. Some of these scenarios have received little attention and the area of protective shielding is comparatively new. The problem of trapping of a jet by a shield and applied suction is actually a fundamental problem in continuum fluid mechanics. Whereas the free jet, the jet in cross-flow and to a lesser extent the impacting jet have all been subject to many investigations, the effect of combined suction and impaction has not been greatly studied.

It is expected that the computational project will rely mostly on Star-CCM, though the use of one of the department's in-house flow solvers may be considered for comparison if a student is particularly interested. Although primarily computational, study of previous works on aerosol dispersion in turbulent plumes is an important component of the project. The experimental project will rely on simple but clearly defined configurations to facilitate comparison with computations. Given the broad nature of the topic, the projects is well-suited for a pair students to work on in complementary areas, but either part could be handled independently.

Doorly, Denis Prof.

Project no: ***LRDD06***
Project title: Applications of statistical analysis

Supervisor: Doorly, Denis Prof.
Co-supervisor(s):
Category: Computational;Theoretical;Numerical
Software: Matlab, RStudio (can be installed as part of Anaconda distribution)

Confidential: No
The project will apply statistical analysis to test whether data supports various hypotheses. Most likely the data will comprise medical images, though may also consider other types, or even data gathering depending on availability. At some stage it may be useful for the student to become familiar with R, which is the de facto standard for statistical analysis, though Matlab should be sufficient for this work.

Fasel, Urban Dr

Project no: ***LRUF01***
Project title: Data-driven model discovery with active learning for control

Supervisor: Fasel, Urban Dr
Co-supervisor(s):
Category: Computational;Numerical;Theoretical
Software: Matlab; Python

Confidential: No
The sparse identification of nonlinear dynamics (SINDy) method enables the discovery of nonlinear dynamical system models purely from data [1]. The method has been combined with model predictive control (MPC), enabling the discovery of interpretable models for control of nonlinear systems [2]. In this project, we want to explore active learning methods for improved data efficiency of SINDy with control. Active learning methods are machine learning methods that can enable data-efficient exploration by the guided collection of relevant and descriptive data that optimally supports the model discovery process. In a recent work, we used E-SINDy [3] (an extension to the SINDy algorithm) for active learning, where we leverage the ensemble statistics of E-SINDy to identify and

sample high-uncertainty regions of the state space that maximally inform the sparse regression. In this project, we want to apply this method to systems with control, to enable data efficient model discovery for nonlinear model based control methods, such as MPC and model based reinforcement learning. We will first explore E-SINDy active learning and other active learning strategies, before applying the methods to a set of benchmark learning and control problems.
[1] https://doi.org/10.1073/pnas.1517384113
[2] https://doi.org/10.1098/rspa.2018.0335
[3] https://doi.org/10.1098/rspa.2021.0904

Fasel, Urban Dr

Project no: ***LRUF02***
Project title: Optimization and control of reprogrammable structures

Supervisor: Fasel, Urban Dr
Co-supervisor(s): Sakovsky, Maria Prof (Stanford University)
Category: Computational;Numerical;Theoretical
Software: Abaqus; Matlab; Python

Confidential: No
Reprogramming the mechanical properties (e.g. stiffness and Poisson's ratio) of a structure on-demand in response to changes in the operating environment can improve the performance of aerospace structures, such as deployable space structures, reconfigurable communications antennas, or morphing wings. Approaches to reprogram the mechanical properties of these structures vary from exploiting elastic instabilities to using smart materials. The Reconfigurable & Active Structures Lab at Stanford University recently developed a new variable stiffness element that achieves stiffness modulation by reversible lamination of stiff material layers using dry adhesives [1]. The element achieves stiffness modulations in bending of up to a factor of 50x (large stiffness variability), works with stiff aerospace materials including metals and carbon fiber reinforced polymers (high load carrying capability), and only requires energy to switch between stiffness states so that it is not permanently powered (low power requirements).
In this project, we are interested in integrating these new variable stiffness elements into lattice-based metamaterial structures (e.g. anti-tetrachiral metamaterial structures). We will investigate how and to what degree we can reprogram the stiffness and Poisson's ratio of lattice structures with integrated variable stiffness elements for active and passive shape control. The aim is to develop design and control methods that enable optimization and control of reprogrammable structures with applications in deployable space structures and morphing wings.
[1] https://doi.org/10.2514/6.2022-0652

Fasel, Urban Dr

Project no: ***LRUF03***

Project title: Design and control optimization of eVTOL aircraft

Supervisor: Fasel, Urban Dr
Co-supervisor(s): Armanini, Sophie Prof (TU Munich)
Category: Computational;Numerical;Theoretical
Software: Matlab; Simulink; Python

Confidential: No

Recent technological advances have boosted the development of electric propulsion, which may help to address environmental challenges and enable new forms of mobility. In particular, electric vertical take-off-and-landing (eVTOL) aircraft are gaining traction in both industry and academia. Thanks to zero in-air emissions, these are promising solutions to replace highly climate-impacting regional and commuter aircraft, improve connectivity, and reduce ground traffic and emissions. However, such vehicles are still in the early stages of development and several challenges must be met before they can take to the skies. eVTOLs have complex dynamics and a wide variety of different design concepts have been proposed. Additionally, eVTOLs will need to operate in confined spaces, close to critical infrastructure and densely populated areas – which implies stringent safety requirements, and a need for accurate, reliable control. Lastly, current batteries only allow for limited endurance, hence maximising the efficiency of flight operations is crucial.
The aim of this project is to investigate energy efficient operation strategies for eVTOLs, developing a mission optimisation approach that considers different flight modes. One of the key limitations of eVTOLs is their limited endurance due to the high weight of current batteries. However, eVTOLs are highly versatile: they exist in widely differing configurations and can exploit different flight modes. Energy-efficient mission-level design and control approaches could significantly increase the endurance of such vehicles, extending their practical applicability. In this project, we will explore optimisation methods to determine efficient flight control and navigation strategies that directly consider the vehicle design and its planned mission.

Fasel, Urban Dr

Project no: ***LRUF04***
Project title: SINDy reinforcement learning - 2 projects available

Supervisor: Fasel, Urban Dr
Co-supervisor(s):
Category: Computational;Numerical;Theoretical
Software: Python

Confidential: No

The sparse identification of nonlinear dynamics (SINDy) method enables the discovery of nonlinear dynamical system models purely from data [1]. Recently, SINDy has been combined with reinforcement learning (RL) to discover computationally efficient, interpretable dynamics models that can act as surrogate environments to speed up RL training. The effectiveness of this dyna-style RL method was demonstrated on several tasks, including benchmark continuous controls tasks from the

MuJoCo Suite [2], and challenging fluid-dynamics control problems in HydroGym [3]. In this project, we want to explore different methodological extensions to the SINDy algorithm for improving SINDy-RL in terms of optimality (cumulative reward) and time complexity (real-world sample complexity, model sample complexity, and computational complexity). We will evaluate the different SINDy-RL variants on a range of benchmark control problems in MuJoCo [2], HydroGym [3], and FishGym [4].
[1] https://doi.org/10.1073/pnas.1517384113
[2] https://mujoco.org/
[3] https://github.com/dynamicslab/hydrogym
[4] https://arxiv.org/abs/2206.01683?context=cs

Fumarola, Isabella Dr

Project no: ***LRIF01 ****
Project title: Analysis of the effects of surface waves on turbulent boundary layers for drag reduction.

Supervisor: Fumarola, Isabella Dr
Co-supervisor(s): Morrison, Jonathan Prof.
Category: Experimental;Analysis
Software:
Confidential: No

We have been developing kagome lattices for drag reduction and the analysis of the effect of surface waves using surface measurements of digital image correlation DIC and the near-velocity field using PIV. The basic ideas and the initial experiment is described in the paper, https://doi.org/10.1007/s10494-018-9926-2.
Here we are developing a novel system in which green PIV light is used to measure fluid measurement simultaneously and distinct from measurement of the surface motion using DIC. The latter uses the speckle pattern from the surface, in which blue light fluoresces to produce a wavelength shift and a reflection of orange light. With the appropriate narrow-band filters, to minimise interference between the two signals, we can make examine the effect of the forcing on the boundary layer in detail

Fumarola, Isabella Dr

Project no: ***LRIF02 ****
Project title: Turbulence interaction with attachment-line boundary layer

Supervisor: Fumarola, Isabella Dr
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

What happens to the freestream turbulence when it encounters the leading edge of a swept wing? The student will design a cylindrical model that can be mounted at a variable sweep angle. Particle Image Velocimetry (PIV) measurements will be carried out in front of the leading edge to compare the swept with the unswept case. Eventually, a turbulent grid will be installed to repeat the experiment at higher freestream turbulence. The experiment will be compared to two-dimensional theories and previous experimental results.

Fumarola, Isabella Dr

Project no: ***LRIF03 ****
Project title: Skin friction measurements using oil film interferometry

Supervisor: Fumarola, Isabella Dr
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

We have been developing oil film interferometry to direct measure skin friction in wind tunnels. Using an existent flat plate model, with different active and/or passive flow control devices, direct measurements of skin friction by means of oil film interferometry will be compared to indirect measurements using hot-wire anemometry. The goal of the analysis will be validation and improvements of the algorithm to calculate skin friction from the oil film interferometry images.

Gouder, Kevin Dr

Project no: ***LRKG01 ****
Project title: Transverse Correlation of Forces on a Circular Cylinder in an Atmospheric Boundary Layer (ABL)

Supervisor: Gouder, Kevin Dr
Co-supervisor(s): Graham, Michael Prof.
Category: Experimental
Software:
Confidential: No

This experimental aerodynamics project makes use of the 10x5 wind tunnel set up with an Atmospheric Boundary Layer (ABL). Transverse correlations of measured forces on a cylinder, and transverse correlations of measured turbulent velocity are made. Measurements better our understanding of loads from incident turbulent flows; quasi-steady theory assumes that the corresponding force and velocity correlations are the same.

Gouder, Kevin Dr

Project no: ***LRKG02 ****

Project title: Section model studies on a standard monobox bridge deck: the effect of wind shield arrangements on bridge flutter and comfort

Supervisor: Gouder, Kevin Dr
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

This is an experimental aerodynamics project carried out in the 10x5 wind tunnel, specifically on the bridge section model rig. A section model of a bridge deck is mounted across the wind tunnel on a system of springs, giving the deck the scaled structural dynamic properties. We aim to conduct a systematic study on the effect of wind-shields, sometimes proposed as an after-thought to completed bridge deck, on the flutter speed and vehicle 'comfort'. Data better our understanding of the effects of wind-shields, and aim to inform the next revision of the design code (the current version has nothing on bridges with wind-shields).

Gouder, Kevin Dr

Project no: ***LRKG03 ****
Project title: Common Research Model in High-Lift configuration (CRM-HL) - 2 projects

Supervisor: Gouder, Kevin Dr
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

The CRM-HL is a global initiative being led by Boeing and NASA. A generic commercial transport aircraft with conventional high-lift system has been designed and the geometry has been made open source. The grand vision is that labs around the world would build and test the same common geometry provided, and make the data open access, for tunnel-tunnel and tunnel-CFD comparisons and validations. Data would improve our understanding of high-lift flow physics, and help establish and validate more advanced computational methods.

In collaboration with Boeing UK, we have started building a semi-span, 4% scale model for testing in the 10'x5' wind tunnel. The first round of projects have been tackling the conversion of the full-scale geometry into a wind tunnel model, installation of the model on a 6-axes balance and model motion system, and provision of symmetry plane boundary layer suction. The two projects now being offered will acquire and analyse direct load measurement and on-body / off-body flow data, and explore the effects that treatments of the symmetry plane (e.g. no treatment : where upstream tunnel floor boundary layer spillage onto the fuselage and wing leading edge is known to be detrimental; with peniche; without peniche; with boundary layer suction...) have on data reliability.

Gouder, Kevin Dr

Project no: ***LRKG04 ****
Project title: Setup and Characterisation of an Atmospheric Boundary Layer in the 10'x5' Large Test Section

Supervisor: Gouder, Kevin Dr
Co-supervisor(s): Graham, Michael Prof.
Category: Experimental
Software:
Confidential: No

Ongoing research on wind turbine rotor inflow turbulence distortion and wind turbine wake trajectory control, involves scaled model turbine rotors installed in the 10'x5' wind tunnel smaller test section set up to generate a scaled Atmospheric Boundary Layer type of flow. We are now embarking on new research that involves an array of six scale model turbine rotors, a mini wind farm formation, in the 10'x5' *larger* test section. The research aims at power generation optimisation and turbine load alleviation, transitioning from current greedy turbine control to integrated wind farm control. Again, this requires a realistic flow field, an appropriately scaled Atmospheric Boundary Layer, this time in the 10'x5' larger test section. The design and installation of selected hardware, e.g. spires, trip fences and roughness fetches, to generate the right (onshore or offshore) Atmospheric Boundary Layer, and its characterisation, are the aims of this FYP. Data acquired during the measurement campaign enables the characterisation of the set Atmospheric Boundary Layer, such as its Earth-normal distribution of the mean velocity, turbulence intensity, von Karman lengthscale, spectra and two-point correlations.

Greenhalgh, Emile Prof.

Project no: ***LREG01 ****
Project title: Multifunctional design & analysis for structural power in e-micro-mobility (S)

Supervisor: Greenhalgh, Emile Prof.
Co-supervisor(s): Nguyen, Sang Dr
Category: Theoretical;Design;Analysis
Software: Matlab and Abaqus
Confidential: No

Background: To date, structural power studies have focussed on aerospace and automotive applications, but we want to explore other areas where we could potentially apply structural power. We feel that one such field is micro-mobility. We now have a good methodology for multifunctional design of structural power in a range of aerospace and automotive applications and want to apply these methodologies to micro-mobility.
Research question: What are the potential benefits, hurdles, performance targets and a route map for adoption of structural power in micro-mobility such as e-scooters and e-bikes?
Knowledge of and ability to undertake finite element modelling of composites is a requirement for this project.

Greenhalgh, Emile Prof.

Project no: ***LREG02 ****
Project title: Development of the next generation Structural Power Composites (S)

Supervisor: Greenhalgh, Emile Prof.
Co-supervisor(s): Nguyen, Sang Dr
Category: Experimental
Software:
Confidential: No

Background: One of the key challenges with structural power is the development of the structural electrolyte. The alternative approach we have taken to this has been to print epoxy droplets on the surface of the electrode, assemble the device, cure the epoxy and flood the device with liquid electrolyte. This method provides a pragmatic solution to addressing the balance between mechanical and electrochemical performance. However, we need to take a rigorous approach to understanding how the areal coverage of the epoxy droplets influences the balance between electrochemical and mechanical performance.
Research question: What is the relationship between areal coverage by the monofunctional matrix and the multifunctional performance?

Greenhalgh, Emile Prof.

Project no: ***LREG03***
Project title: Multifunctional design for structural power in commercial electric vehicles (S)

Supervisor: Greenhalgh, Emile Prof.
Co-supervisor(s): Nguyen, Sang Dr
Category: Computational;Theoretical;Design;Numerical
Software: Matlab and Abaqus

Confidential: No

Background: To date, structural power studies have focussed on aerospace and automotive applications, but we want to explore other areas where we could potentially apply structural power such as commercial electric vehicles (EVs). We now have a good methodology for multifunctional design of structural power in a range of aerospace and automotive applications and want to apply these methodologies to commercial EVs.
Research question: What are the potential benefits, hurdles, performance targets and a route map for adoption of structural power in commercial EVs, such as vans, trucks and lorries?
Knowledge of and ability to undertake finite element modelling of composites is a requirement for this project.

Greenhalgh, Emile Prof.

Project no: ***LREG04***
Project title: Multifunctional design for structural power in personal electronic devices (S)

Supervisor: Greenhalgh, Emile Prof.
Co-supervisor(s): Nguyen, Sang Dr
Category: Theoretical;Design;Computational;Numerical
Software: Matlab and Abaqus

Confidential: No
Background: To date, structural power studies have focussed on aerospace and automotive applications, but we want to explore other areas where we could potentially apply structural power such as personal electronic devices. We now have a good methodology for multifunctional design of structural power in a range of aerospace and automotive applications and want to apply these methodologies to personal electronic devices. Research question: What are the potential benefits, hurdles, performance targets and a route map for adoption of structural power in electronic devices, such as phones, tablets and laptops?
Knowledge of and ability to undertake finite element modelling of composites is a requirement for this project.

Greenhalgh, Emile Prof.

Project no: ***LREG05 ****
Project title: Fractography of composites tested under cryogenic conditions (S)

Supervisor: Greenhalgh, Emile Prof.
Co-supervisor(s): Katafiasz, Tomas Dr
Category: Experimental
Software:
Confidential: No
Storage of hydrogen in tanks is generally performed either in gas or liquid form. The tank is required to withstand a typical pressure of 350-700 bars and if hydrogen is stored in liquid form, temperatures of −253°C must be maintained. To prevent the leakage of hydrogen gas that could arise by the deterioration of composite materials, it is essential to understand the different failure modes caused by ageing and cycling at low temperatures and/or in a cryogenic environment. Specifically, the fibre/matrix interfacial properties have been identified as critical to ensure low leakage rates and adequate mechanical properties. The aim of this project is to identify different failure mechanisms that can be found in specific composite materials tested at low temperature / cryogenic conditions. The effect of fibre architecture and matrix (thermoplastic and thermoset) will be investigated in specimens tested under controlled laboratory conditions. The work entails the sectioning and microscopic analysis of the samples to glean the failure modes.

Hewson, Robert Prof

Project no: ***LRRH01***
Project title: AI for metamaterial design (S)

Supervisor: Hewson, Robert Prof
Co-supervisor(s):
Category: Design;Theoretical;Numerical
Software: python, fenics or firedrake and PyTorch.

Confidential: No
The design optimisation of metamaterials typically requires a means of parameterising and analysing a small scale geometry also known as a representative volume element (RVE). Its characteristics then have to be represented and used to model a large-scale problem, leading to optimisation. The challenge is how to do this when the small-scale problem is complex, perhaps including heat transfer or progressive failure of members. One solution may be to use AI to learn how a small-scale behaves. However, this then needs to be propagated to the finite element simulation of the large-scale problem, and ideally be differentiatable so gradient based optimisation can be applied. This is what the project will focus on, using python and a number of open source finite element and AI codes. My group has considerable expertise in the finite element code, and are starting to get to grips with AI!

Hewson, Robert Prof

Project no: ***LRRH02***
Project title: Morphing Meta-Shells (S)

Supervisor: Hewson, Robert Prof
Co-supervisor(s):
Category: Computational;Design;Analysis;Numerical
Software: fenics or firedrake - python packages

Confidential: No
Meta-materials are materials which have an architectured or hierarchical structure with a small-scale geometry giving apparently different material properties from the bulk material. A meta-shell is this in 2D, and has the potential to give counter-intuitive, morphing characteristics. For example (i) a surface which morphs into an optimal aerodynamic surface when a pressure is applied, perhaps along with a change in surface roughness or (ii) a shell with a super-hydrophobic surface which varies its properties to be able to steer droplets on the surface in response to changes in geometry (see also https://youtu.be/4nbrgUubOKo).
This project will use an open source python based finite element code (either FEniCS or its development Firedrake).

Hewson, Robert Prof

Project no: ***LRRH03***
Project title: Designing complex metamaterials (S)

Supervisor: Hewson, Robert Prof
Co-supervisor(s):
Category: Experimental
Software: Python and the open source packages FEniCS or Firedrake.

Confidential: No

Multiscale (or metamaterial) structures are very often modelled by calculating the average/homogenised/equivalent material properties of a unit geometry. The problem with this is that it assumes the material properties and geometry are at most slowly changing in space. This project will consider what happens when there are abrupt changes in geometry. One of the proposed ways to consider this is to build a model of a unit geometry - essentially like a very high order element and to link the nodal displacements with the boundary forces. This is what we will do during this project, eventually adding complex behaviour and non-linear characteristics of the unit geometry.
The project will use an open source finite element python package (either FEniCS or Firedrake) for the small-scale analysis, with additional python libraries used such as numpy and scipy as needed.

Hewson, Robert Prof

Project no: ***LRRH04***
Project title: Designing Complexity with Topology Optimisation (S)

Supervisor: Hewson, Robert Prof
Co-supervisor(s): Schwerdtfeger, Jan Dr (Lincotek) and Li, Qianqian Dr
Category: Experimental;Computational;Theoretical;Design;Analysis;Numerical
Software: Python packages FEniCS or Firedrake, numpy and scipy. Local support provided.

Confidential: Yes

This project will develop new topology optimisation methodologies for complex real world parts. Conventional topology optimisation usually just considers the part's stiffness, however this is often not what the designer is concerned with. This project will focus on manufacturability (reducing overhangs etc), stress constraints, temperature gradients and a range of other challenges in topology optimisation. The parts will then be printed by colleagues at Lincotek (https://www.lincotek.com/additive/), inspected and tested - it is going to be a fun balance between some complex optimisation and interesting manufacturing.
The computational work will be undertaken with an open source python based finite element package (FEniCS or successor Firedrake), which Dr Hewson's group has extensive expertise in using. Understanding manufacturing capability and constraints, and then integrating these into the optimisation will be undertaken in consultation with Dr Schwerdtfeger from Lincotek, who you will be welcome to visit when your part(s) are being manufactured.

Hewson, Robert Prof

Project no: ***LRRH05***
Project title: Optimising 3D printed bone screws

Supervisor: Hewson, Robert Prof
Co-supervisor(s):
Category: Experimental;Computational;Theoretical;Design;Numerical
Software: Open source Python package FEniCS or Firedrake along with standard python numerical computing packages (numpy, scipy etc),

Confidential: No

A range of surgical procedures require the attachment of an implant or device to human bone. A couple of examples include i) in corrective surgery for scoliosis, where vertebrae are fused together and screws are used to provide the initial stabilisation and support, or ii) for some non-standard knee or hip replacement surgery when the components of the joint replacements require fixation to the bone. Current screws are fairly conventional and even the most advanced screw geometries can still result in what is known as "screw pull-out" where the thread becomes lose in the bone. This can lead to significant complications and pain for the patient.
The source of the problem includes the significant differences in the screw (typically a titanium alloy) stiffness and bone stiffness. This leads to the load being carried on the first part of the screw thread only, leading to significant local bone loading. There are also issues concerning bone remodelling, where bone grows when loaded, and decreases in density when lightly loaded.
How will we address this? This is a challenging problem, and one which aeronautical engineers are well placed to address. The project will use topology optimisation approached to determine the best screw design to reduce attachment failure. We will account for local stresses to consider how the screw should be designed for a range of different requirements.
A stretch goal will be to do some testing on bone models and 3D printed screws. We also have colleagues who would be happy to support more advanced testing if we get that far. We also have some excellent support from spinal surgeons who we can speak to as required.
This should be a really interesting impactful project which uses and develops a lot of key aerospace technologies in an field where heavy numerical optimisation methodologies are under-utilised.

Hewson, Robert Prof

Project no: ***LRRH06***
Project title: A hip and humerus project

Supervisor: Hewson, Robert Prof
Co-supervisor(s):
Category: Experimental;Computational;Design;Theoretical;Analysis;Numerical
Software: Python and packages - FEniCS or Firedrake, and general numerical computing packages numpy and scipy.

Confidential: No

This project concerns the design optimisation of bone surrogates - that is artificial, manufactured bones. There are a couple of reasons why we might want to make realistic bone surrogates, the first is for surgical and medical training purposes, the second is to be able to realistically test devices and situations (such as accidents) where we want to avoid the significant challenges of using biological tissue.
Current bone models are often foam wrapped in some sort of denser polymer, which is a good start, but with 3D printing we can do a lot better and this project will focus on both the mechanical properties of the surrogate bone (things like stiffness etc) and the local characteristics which influence things like screw pull-out and other failure mechanisms.
Being able to do this for a range of different 3D printer types and materials would also be fascinating, where the ultimate goal would be to provide a database of surrogate bone geometries ready to be printed by the user themselves and tailored to the type of printer and materials they have as well as the bone they want to replicate.
But why is this project being proposed to aeronautical engineering students? Because we do computational mechanics better than most! And behind the biomedical application is some serious multiscale design optimisation. I think we are therefore best placed to tackle such a challenge.
The aim of this project is to print some surrogate bones, and do some testing towards the end of the work, but the majority of the work will be computational.

Hewson, Robert Prof

Project no: ***LRRH07***
Project title: Soft and viscous biological tissue

Supervisor: Hewson, Robert Prof
Co-supervisor(s):
Category: Computational;Theoretical;Design;Numerical
Software: Python packages fenics or firedrake, along with general numerical computing packages numpy and scipy.

Confidential: No

This project is concerned with simulating the visco-elastic properties of human tissue using a tailored and graded multiscale small-scale geometry comprising of at least one fluid phase and an elastic material. Tailoring the mechanical properties of the tissue surrogate has a number of potential applications including being able to make realistic tissue for (i) laboratory testing of medical devices and simulating injury, (ii) robotic devices and (iii) for implantable and realistic tissue to replace the properties of human tissue lost as a result of a medical procedure.
The approach to be taken will initially be computational with some small scale experiments undertaken if sufficient progress is made. The multiphase fluid-structure interaction problem will be simulated using the finite element method within a multiscale modelling framework. This will allow the local geometry to be coupled to the large scale properties of the simulated tissue.
It would also be good to undertaken some limited small scale experimental tests if we have time.

Hwang, Yongyun Dr

Project no: ***LRYH01 ****
Project title: Data-driven model reduction of turbulent flow - 3 projects available

Supervisor: Hwang, Yongyun Dr
Co-supervisor(s):
Category: Computational;Theoretical
Software: Matlab
Confidential: No

The project is aimed to examine a novel technique that construct a nonlinear dynamical system using the data obtained by direct numerical simulation. Direct numerical simulation will first be performed to obtain the data associated with the dynamics of coherent structures (i.e. highly organised motions) in a wall-bounded turbulent shear flow. Using this data, a set of optimisation will be formulated to generate a model in the form of systems of ODE. Finally, the constructed model will be studied in detailed comparison with the original direct numerical simulation data. The project is both theoretically and computationally demanding, and it enables the student to learn the theories of chaos and turbulence.

Hwang, Yongyun Dr

Project no: ***LRYH02 ****
Project title: Dynamical systems modelling for compressible turbulent boundary layer - 2 projects available

Supervisor: Hwang, Yongyun Dr
Co-supervisor(s):
Category: Computational;Theoretical
Software:
Confidential: No

The goal of this project is to develop a linear dynamical systems model for compressible turbulent boundary layer. There is growing interest in the dynamics of high speed turbulent boundary layer, and, in particular, the turbulence is known to be suppressed on increasing Mach number. The student participating this project will learn modelling of turbulent boundary layer using linear dynamical systems approach and understand the underlying physical processes on how Mach number would influence the emergene of turbulence statistics.

Hwang, Yongyun Dr

Project no: ***LRYH03 ****
Project title: Noisy dynamics of turbulence

Supervisor: Hwang, Yongyun Dr
Co-supervisor(s):

Category: Computational;Theoretical
Software:
Confidential: No
Noisy and disturbances are commonly present in the flow environment of many aeronautical engineering devices (e.g. wings). Their influence is often studied for transition, but rarely for turbulent flows. In this project, we shall consider noise generated by Wiener process and its influence on turbulent flows. Direct numerical simulations will be performed using an in-house code, and a detailed spectral analyis on the effect of noise will be quantified.

Hwang, Yongyun Dr

Project no: ***LRYH04 ****
Project title: Optimisation in fluid mechanics using ensemble variation - 2 projects available

Supervisor: Hwang, Yongyun Dr
Co-supervisor(s):
Category: Computational;Theoretical
Software: Fortran, Matlab

Confidential: No
Conventional optimisation technique requires the solution to the adjoint Navier-Stokes equations. However, such a technique is practically infeasible for application to turbulent flows at high Reynolds numbers due to the highly chaotic nature. In this project, we will introduce the Ensemble Variation (EnVar), a data-assimilartion technique orgintating from the meteorology. The student will suitably formulate an optimisation problem of interest (e.g. optimal shape design, optimal flow control or estimation, statistical characterisation of extreme events) and solve it using the EnVar. Any experience on high-fidelity numerical simulations would be useful, but is not necessary.

Kerrigan, Eric Prof.

Project no: ***LREK01 ****
Project title: Distributed numerical optimization for trajectory planning of unmanned air vehicles

Supervisor: Kerrigan, Eric Prof.
Co-supervisor(s): Nita, Lucian
Category: Computational;Theoretical;Design;Analysis;Numerical
Software: Julia

Confidential: No
This project will focus on derivative-free methods for real-time predictive control. Predictive control is the most widely implemented advanced control technique in industry. Predictive control is a technique that relies on solving an optimization problem repeatedly in order to compute the desired control action. However, as the size of the problem grows, it becomes increasingly more difficult to

solve it in real-time. Imagine a large network of agents that need to coordinate with each other. To perform a desired task, each agent is running estimation and control algorithms on the on-board computer. The questions that naturally arise are: Can existing algorithms be adapted to cooperatively find a single solution to the desired problem? In any application, constraints on computational time play a critical role - how should a new optimization approach should look like to be able to achieve the best performance in the given time? If the time limit is very short, agents can execute the best control action that can be obtained for a fixed amount of computation and improve it the next time the algorithms are executed. This forms the basis of machine learning and numerous models are constructed every day based on data. The aim of this research is to generate acceptable solutions quickly and improve them as new data comes in.

The main objective of this project is to explore the applicability of recent, state of the art derivative-free methods for designing distributed optimization algorithms and develop a new package for distributed optimization that considers the computational time constraints. This project will build on the past work of the group that used gradient-based methods for a trajectory-planning problem involving a network of UAVs, as well as the internally developed DirectSearch.jl package (https://github.com/ImperialCollegeLondon/DirectSearch.jl).

COMPULSORY PRE/CO-REQUISITE: You should have completed or be completing the Optimisation module. It is essential that you be proficient with more than one programming language (two or more of Matlab, C/C++, Python, etc.) and have experience with object-oriented programming. DO NOT CHOOSE THIS PROJECT IF YOU ONLY KNOW MATLAB.

Kerrigan, Eric Prof.

Project no: ***LREK02 ****

Project title: On-line learning and optimization of controller performance for planetary rovers (S)

Supervisor: Kerrigan, Eric Prof.

Co-supervisor(s): Airbus Defence and Space

Category: Computational;Theoretical;Design;Analysis;Numerical

Software: MATLAB and Simulink/Simscape

Confidential: No

Outer space and planetary environments are extremely harsh – substantial temperature gradients of different frequencies, dusty environments, unintuitive impacts of low gravity and/or vacuum and effects of solar wind are just few examples. Degradation of mechanisms is common and unavoidable. Moreover, the application field requires solutions that are zero-maintenance and can work multiple (Earth) years. Within this project we are looking for ways to counteract such degradations that impact driving mechanisms of planetary rovers. Planetary rovers (like ExoMars https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars or SFR https://www.esa.int/ESA_Multimedia/Videos/2020/02/Sample_Fetch_Rover_for_Mars_Sample_Return_campaign) utilise multiple driving and steering actuators that are exposed to those harsh conditions and its performance will vary in time. Control of those actuators to execute body-level commanding is done by low-level controllers (typically a set of PID controllers to control lateral and longitudinal errors), which are sub-systems of the rover's trajectory control system. The objective of this project is to develop a solution to monitor the performance of

those controllers and adjust their parameters to achieve best results, while respecting actuator limitations and minimising the impact of wear on them.
The project will build on the material taught in the Control Systems, Signals and Systems and Flight Mechanics modules. The student will be expected to be confident with Matlab and experience with Simulink/Simscape is desirable.
You should have completed or be completing the Optimisation module.

This project is in collaboration with Airbus Defence and Space, but will be carried out in the Department of Aeronautics. However, the student will be expected to interact with and deliver regular progress updates to Airbus engineers.

Kerrigan, Eric Prof.

Project no: ***LREK03 ****
Project title: Dynamic optimization in the Julia programming language (S)

Supervisor: Kerrigan, Eric Prof.
Co-supervisor(s):
Category: Computational;Theoretical;Numerical
Software: Julia

Confidential: No
Nearly all optimal control and estimation problems, as well as many system design problems, can be formulated as dynamic optimization problems. These are also often called trajectory optimization problems in the aerospace or robotics communities, where one typically wants to get a dynamical system from one point in space to another, while minimising time, energy or cost.
In dynamic optimization one seeks to optimize an objective functional to determine the state and input functions of time, subject to differential equations (arising due to modelling the dynamics) and inequality constraints (arising due to safety, performance or physical considerations), while providing guarantees despite modelling uncertainties, disturbances and noise. These problems can be solved efficiently using tailored, structure-exploiting finite-dimensional numerical methods. For an introduction to numerical methods for dynamic optimization, see https://doi.org/10.1137/16M1062569 and https://doi.org/10.1137/1.9780898718577.
Julia is a modern high-level language, which employs sophisticated ideas from computer science to allow for rapid algorithm development (similar or easier than Matlab or Python) with an emphasis on high performance (comparable or faster than C). Julia might just one day overtake C/C++ as the language of choice for high-performance scientific computing. See julialang.org and the paper https://doi.org/10.1137/141000671 for more details. If you have not yet heard of Julia, you will certainly hear a lot about it in the future!
This project will involve contributing towards the development of a user-friendly and efficient package for dynamic optimization in the Julia Language called Interesso. The proposed extensions will build up on past work of the group implementing integrated residual methods as it can be found at https://github.com/JuDO-dev/Interesso.jl.
The main task of the project will be to implement well-documented and unit-tested direct collocation methods as an alternative to the currently implemented least squares method. Depending on time

and programming proficiency, other methods such as Runge Kutta and Galerkin can be implemented. The existing implementation will be benchmarked against new methods.
The student assigned to this project should also choose one or more engineering case studies to which they have to apply and test their code. This list is constantly evolving, but a list of possible case studies include: Formation flight of UAVs; Rocket launch and landing; Spacecraft rendezvous and docking; Aerial communication networks. Other suggestions and ideas from the student are encouraged.
COMPULSORY PRE/CO-REQUISITE: You should have completed or be completing the Optimisation module. It is essential that you be proficient with more than one programming language (two or more of Matlab, C/C++, Python, etc.) and have experience with object-oriented programming. DO NOT CHOOSE THIS PROJECT IF YOU ONLY KNOW MATLAB.

Kerrigan, Eric Prof.

Project no: ***LREK04 ****
Project title: Model predictive control of a minidrone over a wireless network

Supervisor: Kerrigan, Eric Prof.
Co-supervisor(s): Wehbeh, Jad
Category: Numerical;Design;Analysis;Computational;Experimental: Ready-made experiment
Software: MATLAB and Simulink/Simscape

Confidential: No
This project aims to develop a trajectory generation controller to navigate an Unmanned Aerial Vehicle (UAV) around obstacles in its environment to its target. This will be based on the Mathworks Minidrone Competition (https://uk.mathworks.com/academia/student-competitions/minidrones.html) using the Parrot Mini Drone simulation model, with testing the design on hardware. The student will be exploring the capabilities of the MATLAB Model Predictive Control and Optimization toolboxes, including the integration with the FORCES-Pro solver (https://www.embotech.com/products/forcespro/overview/).
Model Predictive Control (MPC) is the most widely implemented advanced control technique in industry and allows one to implement nonlinearities and constraints in a straightforward manner during the controller design and implementation. MPC therefore allows one to solve much more challenging control problems than linear control design methods, such as LQR.

Kerrigan, Eric Prof.

Project no: ***LREK05 ****
Project title: Computer Vision, Sensor Fusion and State Estimation for a Parrot Minidrone

Supervisor: Kerrigan, Eric Prof.
Co-supervisor(s): Wehbeh, Jad

Category: Experimental: Ready-made experiment;Computational;Theoretical;Design;Numerical
Software: MATLAB and Simulink/Simscape

Confidential: No
This project focuses on the development of a state estimation framework for a Parrot quadrotor vehicle. The vehicle is designed for indoor operation, which complicates the problem of position estimation due to the inability to use GPS as a means of correcting for estimator drift. Instead, the quadrotor must process images generated by its onboard camera alongside the data produced by its ultrasonic sensor, inertial measurement unit (IMU), and pressure sensor into a single state estimate that is reliable enough to enable indoor navigation.
The project entails building upon the rudimentary optical flow implementation currently used on the drone and designing a filter framework to combine all of the sensor measurements. Areas of focus include implementing more recent computer vision techniques to improve the quality of the image-based velocity estimation, incorporating loop-closure for position estimation as part of the vision pipeline, and deriving a Kalman filter from the vehicle and sensor dynamics. Work will begin inside a realistic Simulink simulation environment then proceed to deployment and testing on real hardware. As such, any approach developed is expected to work within the constraints of the limited computational power available onboard the quadrotor.
Anyone interested in taking this project should be familiar with MATLAB and Simulink, as well as with the basics of modern computer vision and state estimation.

Knoll, Aaron Dr

Project no: ***LRAK01***
Project title: Numerical modelling of a novel plasma lens using negative ions (S)

Supervisor: Knoll, Aaron Dr
Co-supervisor(s):
Category: Computational;Theoretical
Software: PlasmaSim (in-house code written in Julia)
Confidential: No
A plasma lens is a device that focuses a beam of charged particles using a plasma column. Such devices have applications in particle accelerators and for medical applications. The working principle to create a region of trapped negatively charged particles, which exert a radial force on a beam of positively charged particles passing through them. The effect is to focus the beam of positively charged particles, analogous to an optical lens. Traditionally, the plasma lens is formed of electrons confined in a configuration of electric and magnetic fields. The aim of this project is to investigate a new approach based on negatively charged ions that are trapped using inertial electrostatic confinement.
This project will make use of an existing code, PlasmaSim, that is written in Julia language. No prior plasma physics experience is necessary, but I'm looking for students with an openness to learn new things. Through this project you will learn many practical skills that are specific to modelling plasmas numerically, so it's an ideal opportunity for those interested in becoming involved in the field of applied plasma physics.

Knoll, Aaron Dr

Project no: ***LRAK02***
Project title: Development of a testbed for plasma stabilization using superconductors (S)

Supervisor: Knoll, Aaron Dr
Co-supervisor(s):
Category: Theoretical;Design;Analysis
Software: Autodesk Fusion 360FEMM

Confidential: No

The pursuit of fusion energy through magnetic plasma confinement is an enduring challenge for humankind. One of the biggest challenges in achieving stable fusion power generation using magnetically confined plasmas is plasma turbulence and instabilities that lead to excessive energy and plasma loss from the system. The purpose of this project is to design a testbed for demonstrating a new concept for plasma stabilisation based on magnetic flux pinning using superconductors. This project will involve the conceptual design, sizing, and detailed mechanical design and modelling of the experimental setup. It is anticipated that follow-on Final Year Project students will proceed to build and eventually conduct the first experimental testing of the hardware.
No prior plasma physics experience is necessary, but I'm looking for students with an openness to learn new things. Through this project you will learn many practical skills that are specific to magnetically confined high energy plasmas, so it's an ideal opportunity for those interested in becoming involved in the field of plasma fusion.

Knoll, Aaron Dr

Project no: ***LRAK03***
Project title: Development of a compact plasma toroid generator (S)

Supervisor: Knoll, Aaron Dr
Co-supervisor(s):
Category: Experimental: Ready-made experiment;Theoretical;Design;Analysis
Software: Autodesk Fusion 360

Confidential: No

The pursuit of fusion energy through magnetic plasma confinement is an enduring challenge for humankind. While generating the required temperatures and pressures needed to produce fusion energy is theoretically possible, natural instabilities and turbulence occurring within the plasma allow the high energy particles to escape the magnetic field and rapidly drain energy from the system.
The goal of this project is to create an experimental test-bed to study the turbulence within a magnetically confined plasma, and investigate possible strategies to control (tame) this turbulence.
This project will involve the development of a generator for a compact plasma toroid – a self-stable

magnetically confined plasma structure, with a donut-like shape. This project builds on three previous MSc/MEng projects (2020/21, 2021/22, 2022/23). The focus of this current project will be on the development and testing of the pulse forming network used to power the compact plasma toroid within the lab.

Knoll, Aaron Dr

Project no: ***LRAK04***
Project title: Construction of a 3-axis Langmuir probe instrument for plasma thruster plume characterization (S)

Supervisor: Knoll, Aaron Dr
Co-supervisor(s):
Category: Experimental: Manufacturing intensive;Design;Analysis
Software: Autodesk Fusion 360
LabView

Confidential: No
A Langmuir probe instrument is used to directly measure physical properties of a plasma including density, temperature and potential (voltage). To understand/verify the underlying physics of operation of plasma thrusters, it is useful to profile the plasma parameters of the thruster plume over a 3-dimensional volume. The purpose of this project is to construct a 3-axis translating Langmuir probe instrument capable of surveying the plasma properties with minimal disruption to the plasma thruster discharge. The translation mechanism will operate within a vacuum chamber environment, and interface with an external PC via LabView. This project builds on the design that was developed during an MSc project in 2019/20. It is anticipated that this instrument will play an essential role in future experimental activities conducted within Imperial's new Plasma Propulsion Lab.

Knoll, Aaron Dr

Project no: ***LRAK05***
Project title: Experimental testing of an E×B probe for plasma thruster plume characterization (S)

Supervisor: Knoll, Aaron Dr
Co-supervisor(s):
Category: Experimental: Ready-made experiment;Analysis
Software: Matlab
LabView

Confidential: No
An E×B probe is an instrument used to measure the velocity and charge state of ions. While there are various methods for determining the average velocity of an ion beam, the advantage of the E×B probe is that it also distinguishes the velocity of each ion type (singly ionized, doubly ionized, triply ionized,

etc.). The aim of this project is to experimentally qualify a new E×B probe that can be used to measure the plume of spacecraft plasma thruster (Electric Thruster) within Imperial's new large vacuum test facility: the Boltzmann Vacuum Chamber. This will involve the initial testing of the probe, as well as the development of a LabView software interface to collect and analyse the data. It is anticipated that this instrument will play an essential role in future experimental activities conducted within Imperial's Plasma Propulsion Lab. This project builds on three prior MSc projects (2019-20, 2020-21, 2022-23) that involved the theory, sizing, CAD modelling and construction of the probe. No prior plasma physics experience is necessary, but I'm looking for students with an openness to learn new things. Through this project you will learn concepts and theory related to applied plasma physics, so it's an ideal opportunity for those interested in becoming involved in the field of spacecraft electric propulsion.

Laizet, Sylvain Prof.

Project no: ***LRSL01***
Project title: Fluid simulations with the Domain Specific Library OPS

Supervisor: Laizet, Sylvain Prof.
Co-supervisor(s):
Category: Computational;Numerical
Software: OPS

Confidential: No
This project consists in writing from scratch an incompressible flow solver using the Domain Specific Library OPS. OPS (Oxford Parallel library for Structured mesh solvers) is a high-level embedded domain specific language for writing multi-block structured mesh algorithms, and the corresponding software library and code translation tools to enable automatic parallelisation of the high-level code on multi-core and many-core architectures. The aim of the project is to leverage OPS to automatically write an incompressible flow solver suitable for modern hardware (CPUs/GPUs). The solver will be based on high-order implicit finite-difference schemes on a Cartesian mesh. The reference test case will be the Taylor Green Flow, a well-known benchmark in the Computational Fluid Dynamics community which will be used for performance analysis. Comparisons will be made with a modern Fortran flow solver on multiple CPUs and GPUs. Previous experience with High Performance Computing and modern C & Fortran would be extremely useful but is not mandatory.

Laizet, Sylvain Prof.

Project no: ***LRSL02***
Project title: High-fidelity simulations of a turbulent Couette-Poiseuille flow

Supervisor: Laizet, Sylvain Prof.
Co-supervisor(s):
Category: Computational;Numerical
Software: Xcompact3d

Confidential: No

Near-wall turbulent flows arise under several dynamical effects. Recent high-fidelity simulations results of homogeneously sheared turbulence suggest that a key factor in the generation of near-wall coherent structures (streaky and vortical structures), is the high mean shear rate caused by the no-slip condition on a wall surface. Hence, it is obvious that it should be desirable to study possible dynamical effects individually such as (1) viscosity (low Reynolds number effects), (2)blocking of wall-normal motions, and (3) mean shear rate, in order to understand the basic mechanisms of near-wall turbulence phenomena. In this project, high-fidelity simulations of a turbulent Couette-Poiseuille flow will be performed to study the effects of the mean shear rate on turbulence statistics and structures. Previous experience with High Performance Computing and modern Fortran would be extremely useful but is not mandatory.

Laizet, Sylvain Prof.

Project no: ***LRSL03***
Project title: High-fidelity simulations of two-dimensional turbulence

Supervisor: Laizet, Sylvain Prof.
Co-supervisor(s):
Category: Computational;Numerical
Software: Xcompact3d
Confidential: No

Turbulence is ubiquitous in nature: We observe its manifestation at all scales, from a cup of coffee being stirred to galaxy formation. Among its numerous manifestations, two-dimensional (2D) turbulence is special in many respects. Strictly speaking, it is never realized in nature or in the laboratory, both of which have some degree of three-dimensionality. Nevertheless, many aspects of idealized 2D turbulence appear to be relevant for physical systems. For example, large-scale motions in the atmosphere and oceans are described, to first approximation, as 2D turbulent fluids owing to the large aspect ratio (the ratio of lateral to vertical length scales) of these systems. In this project, high-fidelity incompressible simulations of a 2D turbulent channel flow and 2D homogenous isotropic turbulence will be performed to better understand the main properties of 2D turbulent flows. The Navier-Stokes equations and transport equation will be solved using the high-order flow solver Incompact3d (www.incompact3d.com). It is a Fortran 90 solver based on a Cartesian mesh, sixth-order finite-difference schemes and a fully spectral solver for the Poisson equation. Previous experience using modern Fortran would be very useful but is not mandatory.

Laizet, Sylvain Prof.

Project no: ***LRSL04***
Project title: Fortran or C for Computational Fluid Dynamics: which one is the fastest on CPUs?

Supervisor: Laizet, Sylvain Prof.
Co-supervisor(s):

Category: Computational;Numerical
Software:
Confidential: No
This project consists in writing from scratch two flow solvers, one in Fortran and one in C. The solvers will deal with the compressible Navier-Stokes equations. The solvers will be based on finite-difference methods on a Cartesian mesh. Once the solvers are up and running, comparison will be made with various compilers and various CPUs to evaluate which one is the fastest. The flow configuration of interest is the wake generated by a circular cylinder for low Reynolds numbers. Previous experience in Fortran and/or C would be extremely useful but is not mandatory.

Laizet, Sylvain Prof.

Project no: ***LRSL05***
Project title: Simulation of a pulsating flow past a stenosed 2D artery with atherosclerosis

Supervisor: Laizet, Sylvain Prof.
Co-supervisor(s):
Category: Computational;Analysis;Numerical
Software: Incompact3d

Confidential: No
Atherosclerotic plaque can cause severe stenosis in the artery lumen. Blood flow through a substantially narrowed artery may have different flow characteristics and produce different forces acting on the plaque surface and artery wall. The disturbed flow and force fields in the lumen may have serious implications on vascular endothelial cells, smooth muscle cells, and circulating blood cells. In this work a simplified model is used to simulate a pulsating blood flow past a stenosed artery caused by atherosclerotic plaques of different severity. The focus is on a systematic parameter study of the effects of plaque size/geometry, flow Reynolds number, shear-rate dependent viscosity and flow pulsatility on the fluid wall shear stress and its gradient, fluid wall normal stress, and flow shear rate. The computational results obtained from this idealized model may shed light on the flow and force characteristics of more realistic blood flow through an atherosclerotic vessel. The Navier-Stokes equations and transport equation will be solved using the high-order flow solver Incompact3d (www.incompact3d.com). It is a Fortran 90 solver based on a Cartesian mesh, sixth-order finite-difference schemes and a fully spectral solver for the Poisson equation. The modelling of the artery is achieved thanks to an Immersed Boundary Method (IBM) based on a direct forcing approach to ensure the no-slip boundary condition at the wall of the artery. Previous experience using Fortran would be very useful but is not mandatory.

Lee, Koon-Yang Prof.

Project no: ***LRKL01 ****
Project title: Designing "artificial wood" from low cost ionic liquids - 2 projects available

Supervisor: Lee, Koon-Yang Prof.

Co-supervisor(s): Sun, Amy (Jiayi)
Category: Experimental
Software:
Confidential: No

Nature has been very efficient at manipulating and exploiting cellulose microfibrils in wood (a natural composite) to produce high performance materials. This project will take inspiration from wood and manufacture “artificial wood”, i.e. cellulose microfibril-reinforced lignin composites with the native cellulose-I structure preserved (mimicking wood cell wall), using selected ionic liquids. It is envisaged that the resulting “artificial wood” will target engineering applications that cannot be achieved by conventional bio-based polymers or renewable natural fibre-reinforced polymers alone and could serve as alternative to traditional glass fibre-reinforced polymers. Up to two positions are available for this project.
Students wishing to select this project are highly encouraged to speak to Professor Lee first to understand the needed background knowledge for this FYP. This FYP is particularly suited for students who have previously taken A-levels chemistry (or equivalent) as the synthesis of ionic liquids will require some basic physical/organic chemistry knowledge (it's a strong acid-base reaction). Having taken or will be taking AERO70002/AERO96020 Advanced Manufacturing is also highly recommended.

Lee, Koon-Yang Prof.

Project no: ***LRKL02 ****
Project title: Making wooden foams from wood particles using deep eutectic solvent

Supervisor: Lee, Koon-Yang Prof.
Co-supervisor(s): Zhang, Jiawei
Category: Experimental
Software:
Confidential: No

Currently, there is a property-performance gap between traditional porous engineering materials and bio-based porous materials, and this FYP will address this challenge. We will dissolve lignin in wood without dissolving the highly crystalline cellulose structure using selected deep eutectic solvents. This will allow wood particles to fuse together upon lignin regeneration. The introduction of air bubbles (e.g. mechanical frothing) during the regeneration process will allow us to manufacture "wooden foams" from wood particles. Only one position is available for this project.
Students wishing to select this project are highly encouraged to speak to Professor Lee first to understand the needed background knowledge for this FYP. This FYP is particularly suited for students who have previously taken A-levels chemistry (or equivalent) as the synthesis of deep eutectic solvents will require some basic physical/organic chemistry knowledge. Having taken or will be taking AERO70002/AERO96020 Advanced Manufacturing is also highly recommended.

Lee, Koon-Yang Prof.

Project no: ***LRKL03 ****

Project title: Lignin-coated wood plastic composites

Supervisor: Lee, Koon-Yang Prof.
Co-supervisor(s): Zhang, Jiawei or Sun, Amy (Jiayi)
Category: Experimental
Software:
Confidential: No

Wood-plastic composites are a class of composite materials made by combining wood particles (in the form of fibre or flour) with a thermoplastic. However, one major challenge still remains; the incompatibility between the hydrophilic wood particles and the hydrophobic thermoplastic matrix. In this FYP, we will explore the dissolution of lignin in wood particles using either ionic liquids or deep eutectic solvents, followed by precipitation back onto the surface to render hydrophilic wood particles hydrophobic. Such lignin-coated hydrophobic wood particles will be used to fill a thermoplastic matrix and investigate its mechanical performance improvement. Only one position is available for this FYP.
Students wishing to select this project are highly encouraged to speak to Professor Lee first to understand the needed background knowledge for this FYP. A background in A-levels chemistry is not strictly required but having taken or will be taking AERO70002/AERO96020 Advanced Manufacturing is highly encouraged.

Lee, Koon-Yang Prof.

Project no: ***LRKL04 ****
Project title: Solving the flexible plastics packaging pollution problem I: Paper-based flexibles

Supervisor: Lee, Koon-Yang Prof.
Co-supervisor(s): Wloch, Daniela
Category: Experimental
Software:
Confidential: Yes

Probably the biggest contributor to FMCG's plastic waste footprint are products contained within single use, single dose flexible packaging. Today, there is no formal or informal collection infrastructure for these environmentally persistent formats, leading to very high levels of littering, with the rest ending up in landfill. The only solution is to develop flexibles with dual end-of-life options. This FYP will develop paper-based flexibles suitable for the packaging of moisture sensitive solids. Only one position is available for this FYP.
Students wishing to select this project are highly encouraged to speak to Professor Lee first to understand the needed background knowledge for this FYP. A background in A-levels chemistry is not strictly required but having taken or will be taking AERO70002/AERO96020 Advanced Manufacturing is highly encouraged.

Lee, Koon-Yang Prof.

Project no: ***LRKL05 ****

Project title: Solving the flexible plastics packaging pollution problem II: Filled biodegradable polymer films

Supervisor: Lee, Koon-Yang Prof.
Co-supervisor(s): Wloch, Daniela
Category: Experimental
Software:
Confidential: Yes

As previously mentioned, the biggest contributor to FMCG's plastic waste footprint are products contained within single use, single dose flexible packaging and the only solution is to develop flexibles with dual end-of-life options. In this FYP, we will take a composite approach - filling selected non-environmentally persistent biodegradable polymers with fillers to create packaging suitable for storing moisture sensitive solids. Only one position is available for this FYP.
Students wishing to select this project are highly encouraged to speak to Professor Lee first to understand the needed background knowledge for this FYP. Having taken or will be taking AERO70002/AERO96020 Advanced Manufacturing is highly encouraged.

Lee, Koon-Yang Prof.

Project no: ***LRKL06 ****
Project title: Artefacts storage in museums: Do we really have a "plastic" problem?

Supervisor: Lee, Koon-Yang Prof.
Co-supervisor(s): Li, Joanne
Category: Experimental
Software:
Confidential: No

Each generation creates and curates cultural heritage objects, which require conservation treatments to preserve them long term. Plastics are a particular concern for museums as relatively little is known about their degradation and preservation. In this FYP, we will investigate the structure-property of museum grade plastic storage containers for long term (>30 years) artefact storage. Only one position is available for this FYP.
Students wishing to select this project are highly encouraged to speak to Professor Lee first to understand the needed background knowledge for this FYP. This FYP is particularly suited for students who have previously taken A-levels chemistry (or equivalent) as the degradation of plastics would need to be understood at a molecular level. Having taken or will be taking AERO70002/AERO96020 Advanced Manufacturing is also highly recommended.

Levis, Errikos Dr

Project no: ***LREL01***
Project title: Prediction of seaplane hull hydrodynamics

Supervisor: Levis, Errikos Dr

Co-supervisor(s):
Category: Computational;Theoretical
Software: Matlab, Python

Confidential: No
Predicting the hydrodynamic performance of planning hulls is a key step in determining the thrust requirement for seaplanes. While some semi-empirical methods have been developed in the past they fail to capture the hull's behaviour throughout the different regimes encountered during takeoff and landing. This project will thus aim to make use of machine learning tools to develop better design methods for seaplane hulls.

Levis, Errikos Dr

Project no: ***LREL02***
Project title: Hybrid-Electric/distributed propulsion for aircraft - 2 projects available

Supervisor: Levis, Errikos Dr
Co-supervisor(s):
Category: Computational;Design
Software:
Confidential: No
In June 2016, NASA anncounced that the X-57 research plane would be used to study the aerodynamic and propulsive efficiency improvements made possible by the use of hydbrid electric distributed propulsion systems. Projects on this area will build on the work of past students and concentrate on:
1) Investigating the applicability of such technologies to aircraft of different types and sizes.
2) The design and optimization of a wing-distributed propulsion system.
3) The effects that using such systems may have on the stability and controlability of aircraft.
4) The design & optimization of hybrid electric aircarft for minimum cost vs CO2 and the impact of extraneous factors
A good understanding of the principles of aircraft design and good coding skills are required.

Levis, Errikos Dr

Project no: ***LREL03***
Project title: Handling Qualities of Wing in Ground Effect Vehicles

Supervisor: Levis, Errikos Dr
Co-supervisor(s):
Category: Computational
Software: Matlab, Fortran compilers
Confidential: No

Wing In Ground effect vehicles The Wing-In-Ground Effect (WIG) concept has been around for some time and was investigated in depth by Soviet designers, resulting in number of vehicles known as Ekranoplans. Due to the potential reduction in drag achieved by flying in close proximity to the ground the concept has recently been revived by Boeing and other research institutes. Flying near the surface however does also complicate the aerodynamics and stability of the craft.
A review of available literature has shown that there are few design rules relating to the handling qualities of such vehicles. This project will aim to determine what the appropriate levels of pitch and height stability for such crafts should be by simulation the behavior of WIG craft with and without a pilot in the loop. Students will have to derive the equations of motion for a WIG and model the effects of pitch and altitude on the aerodynamic forces. Matlab/Simulink will be used extensively for this project.

Levis, Errikos Dr

Project no: ***LREL04***
Project title: Cost prediction of Aircraft Structures

Supervisor: Levis, Errikos Dr
Co-supervisor(s):
Category: Computational;Analysis;Literature
Software: Matlab
Confidential: No

During the conceptual and preliminary design phases, designers often try to identify an optimum design for the aerodynamic and structural layout of major aircraft components. With the introduction of novel materials, manufacturing cost has become an increasingly important parameter, greatly affecting the aircraft’s final acquisition cost and therefore marketability. This project will further develop a manufacturing cost prediction tool for aircraft structures, to be used in conjunction with a structural weight prediction code developed by a past student. Work will concentrate on expanding the applicability of the code to all major structural assemblies (wingbox and fuselage are mostly done) and couple with a conceptual sizing code to optimize a light aircraft for mass production. Alternatively students may choose to fous on improving the supply chain and production line modeling, improving the quality of assumptions currently being employed

Levis, Errikos Dr

Project no: ***LREL05***
Project title: Improving Aircraft System Sizing Methodologies

Supervisor: Levis, Errikos Dr
Co-supervisor(s):
Category: Theoretical;Design;Analysis;Literature
Software: Matlab or Python

Confidential: No

With increased interest in the more/all-electric aircraft, there is a need to improve the level of detail in which the aircraft's major subsystems (electrical, hydraulic, fuel, control, pneumatic and pressurization) must be designed. For example electrifying the pressurization or pneumatic systems can lead to a reduced need for bleed air extraction from the engines (reducing installation thrust losses) but increase the need for electrical power extracted (increasing electrical system weight and level of power extraction from the engine).
To investigate the advantages/dissadvantages of such changes, this project aims to develop parametric models for each of the major subsystem's layouts, develop empirical relations for the sizing of each of their major components and rely entirely on physics for the sizing of the overall system. Ultimately metrics of power required, weight and reliability shoudl be obtained for each subsystem, allowing for architectures to be compared and optima to be identified.

Levis, Errikos Dr

Project no: ***LREL06***
Project title: Design & Optimization of Hydrogen Powered Aircraft

Supervisor: Levis, Errikos Dr
Co-supervisor(s):
Category: Computational;Design;Numerical;Literature
Software:
Confidential: No

The need to reduce the aviation sector's CO2 emissions requires the adoption of carbon neutral energy sources. One of the energy sources increasingly looked at as a viable option for long range flight is hydrogen. This project will build on existing work on the design and optimization of a hydrogen fueled hybrid powerplant, concentrating on it's incorporation into a medium-long range civilian aircraft and investigating the aircraft-level implications of adopting hydrogen as an energy source.

Li, Qianqian Dr

Project no: ***LRQL01***
Project title: Nanoparticle reinforced lightweight metal composites via melt stirring (S) - 2 projects available

Supervisor: Li, Qianqian Dr
Co-supervisor(s):
Category: Experimental: Manufacturing intensive;Experimental: Ready-made experiment
Software:
Confidential: No

Nanoparticles such as nanocarbon and SiC have attracted great attention as reinforcements in composites due to their excellent physical and mechanical properties. They are considered as ideal reinforcements to produce composites. Much research has been done on polymer composites; while metal composites have not been fully exploited due to the more difficult production process and more complicated reinforcing mechanisms, despite hugh potential of such composites. In this project, the student will produce nanoparticle reinforced magesium composites via melting route and investigate the composites mechanical properties and microstructure. The production parameters will be investigated and optimised.

Li, Qianqian Dr

Project no: ***LRQL02***
Project title: Nanocarbon based thermalplastic composites: manufacturing and characterisation (S)

Supervisor: Li, Qianqian Dr
Co-supervisor(s): Tagarielli, Vito Dr
Category: Experimental: Manufacturing intensive;Experimental: Ready-made experiment
Software:
Confidential: No

Nanocarbon such as carbon nanotubes and graphene based polymer composites have become a hot topic in composites in recent years. This is due to nanocarbon extraordinary physical and mechanical properties (very high Young's modulus, high electrical conductivity etc.), which makes it a highly interesting candidate for multifunctional composites. In this project, the student will optimise the production process and check the influence of the different parameters on the procedure (e.g. different concentration of graphene, different dispersion methods…) and manufacture such composites using casting and hot pressing. Characterisation of the mechanical properties, electrical and thermal conductivity of the composites will be a second focus point.

Li, Qianqian Dr

Project no: ***LRQL03***
Project title: Advanced materials development for hypersonic vehicles (S)

Supervisor: Li, Qianqian Dr
Co-supervisor(s): Rigas, Georgios Dr, Bruce, Paul Dr
Category: Experimental;Theoretical;Analysis;Literature
Software: Matlab

Confidential: No

While the aerodynamic challenges related to hypersonic aerospace vehicles have been frequently explored in the past, the advanced materials which could be suitable for providing the desired properties in these applications have not been well-explored yet. Targeting certain properties such as heat flux and heat conductivity of aerospace components for given surface boundary conditions, potential materials and composites, together with their appropriate manufacturing methods and structural design, will be investigated in this project. The project student will first model and calculate the required properties for components of a representative aerospace vehicle at hypersonic conditions, and then match possible materials/composites and manufacturing ideas to the selection.

Particularly nano-materials and nanocomposites will be focused on as they provide the possibility of high specific strength, multifunctionality and tuneability of properties. This multidisciplinary project spans the fields of high speed aerodynamics and advanced materials and offers a unique opportunity to explore the research challenges in these areas.

Li, Qianqian Dr

Project no: ***LRQL04***
Project title: CFD simulation of nanoparticle dispersion in metal melt (S)

Supervisor: Li, Qianqian Dr
Co-supervisor(s): Peiro, Joaquim Prof.
Category: Computational;Analysis;Numerical
Software: The flow simulations will be performed using STARCCM+ and validated against experimental data. Initially we will consider SiC nano-whiskers (650 nm in diameter and 5 µm in length, rigid stick like) dispersing in magnesium melt at about 650 C. Then we wi
Confidential: No

The use of carbon nanotubes (CNTs) in nano-composites is increasingly attracting interest due to their ability to increase the ductility and tensile properties of the composite. The focus of this project is on the use of CNTs in magnesium-based metal matrix composites (MMCs) which have extensive application in the automotive, aerospace and biomedical industries, especially for components working at temperatures above 150°C.

Our interest is on MMCs produced using methods involving molten metal. The major drawback of this type of methods is that CNTs tend to agglomerate resulting in poor interfacial bonding between the CNTs and the metal matrix after solidification, which deteriorates the mechanical properties of the nano-composite.

This project aims at investigating, through flow simulations, suitable configurations of the stirrer and crucible in the furnace to promote shear stresses that can be used to reduce or ideally prevent agglomeration. The flow simulations will be performed using STARCCM+ and validated against experimental data. Initially we will consider SiC nano-whiskers (650 nm in diameter and 5 µm in length, rigid stick like) dispersing in magnesium melt at about 650 C. Then we will proceed to simulate melts with nano-particles of smaller diameters such as multiwall carbon nanotubes (15 nm diameter and 1 µm length, softer tube shape). As part of the investigation, we will assess a few furnace configurations with different nanoparticle concentration, energy input, stirring speed etc.

Lubbock, Roderick Dr

Project no: ***LRRL01 ****
Project title: A cycling-sports helmet with air filtration - experimental

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Experimental: Manufacturing intensive;Design

Software:
Confidential: No
FFP2 respirator face masks have several problems:
• They are uncomfortable to breath through under conditions of high exertion, for instance when cycling or running.
• They typically leak around the nose area making them incompatible with sunglasses, which suffer from condensation under heavy breathing.
• They trap moisture against the skin and can be irritating to wear for longer periods.
• They are inconvenient to put on around the ears whilst wearing a helmet, e.g. for cycling or sport.

Several prototypes have already been developed based on earlier computational studies. These prototypes demonstrated the feasibility of a filtration device attached to a sports helmet that is able to filter out harmful air particles without causing breathing discomfort or affecting the wearers vision. The aim of this project is to develop and test a fully functional prototype including functional head-impact protection. The functionality will need to be demonstrated via some form of impact tests with accelerometer measurements.
This is a challenging experimental project. Students interested in this project must have a solid understanding of undergraduate fluid mechanics and thermodynamics and must be confident designing and building prototypes and carrying out laboratory experiments.

Lubbock, Roderick Dr

Project no: ***LRRL02 ****
Project title: Development of an assistive knee brace - experimental

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Experimental: Structures;Experimental: Manufacturing intensive;Design;Analysis
Software:
Confidential: No
Knee problems such as osteoarthritis and sports injuries to cartilage and ligaments affect millions of people around the world, and can have severe impacts on patients' physical and mental health. Assistive knee braces allow these patients to live a more normal active lifestyle. Numerous knee brace designs have been proposed [1] however the design problem is far from solved. The aim of this project is to design, build and test an assistive knee brace.
Students interested in this project must have a solid understanding of structural mechanics and mechanical design and must be confident in designing, building and testing prototypes and carrying out laboratory experiments.
[1] L. Zhang, G. Liu, B. Han, Z. Wang, H. Li and Y. Jiao, "Assistive devices of human knee joint: A review", Robotics and Autonomous Systems, vol. 125, p. 103394, 2020. Available: 10.1016/j.robot.2019.103394.

Lubbock, Roderick Dr

Project no: ***LRRL03 ****
Project title: Design optimisation of knee braces

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Analysis
Software: FEA/optimisation software e.g. Ansys or 3DExperience (Abaqus), Matlab, CAD.

Confidential: No

There are numerous knee braces on the market featuring a variety of different designs. There appears to have been little work done on design optimisation of supportive knee braces. Many of the braces on offer are also very expensive.
The aim of the proposed project is therefore to use design optimisation to develop an optimum low-cost knee brace design. Extensions of the project could look at the use of additive manufacturing to generate further optimised designs. Such a design could incorporate 3D scanning to develop cost-effective braces custom made to fit individual users. Currently such braces are available but are prohibitively expensive.
Students interested in this project must have a solid understanding of structural mechanics, design optimisation (e.g. topology optimisation) and be confident using industry standard FEA software such as 3DExperience SIMULIA (Abaqus FEA).

Lubbock, Roderick Dr

Project no: ***LRRL04 ****
Project title: Design optimisation of sports helmets

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Analysis
Software: FEA/optimisation software e.g. Ansys or 3DExperience (Abaqus), Matlab, CAD.

Confidential: No

There are numerous designs of sports helmets specific to a number of sports, however these all have more or less the same purpose: to prevent harmful brain decelerations.
The aim of the proposed project is therefore to use design optimisation to develop an optimum sports helmet design to meet numerous helmet testing standards that could therefore find application in multiple sports.
This will likely involve designing an impact absorbing structure from one or more materials, and evaluating designs using computational models.
Extensions of the project could look at the use of additive manufacturing to generate further optimised designs. Such a design could incorporate 3D scanning to develop cost-effective helmets custom made to fit individual users, that could bring offer further benefits in reducing harmful decelerations.

This is a challenging design project. Students interested in this project must have a solid understanding of structural mechanics, design optimisation (e.g. topology optimisation, generative design) and be confident using industry standard FEA software such as 3DExperience SIMULIA (Abaqus FEA).

Lubbock, Roderick Dr

Project no: ***LRRL05 ****
Project title: Integrated helmet - breathing apparatus for avalanche survival - experimental

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Design;Experimental: Manufacturing intensive;Experimental
Software:

Confidential: No

85% of avalanche deaths are caused by asphyxiation due to the inability of the victim to evacuate exhaled CO2 from around their airways due to burial in snow. Almost two decades ago [1] a winter sports manufacturer developed a solution to this called the "Avalung", which was essentially a breathing tube for drawing in fresh air (through the snow) from a point behind the victim away from their airways, meaning that the victim is able to avoid rebreathing their own CO2. The manufacturer claimed their device would increase the avalanche burial survival window from 15 minutes to 58 minutes (although this does not appear to have been supported by independent test data).

The Avalung had a major design flaw however (e.g. [2], [3]), which was the requirement of the victim to either insert the breathing tube in their mouth once they were already in the avalanche - a very difficult thing to do while being violently thrown down a mountain - or to ski with it in their mouth leading to obvious discomfort. The product appears to have been discontinued and is no longer for sale on the manufacturers website at the time of writing.

Aside from these impracticalities the basic principle of the Avalung - evacuating CO2 away from the user's airways - appears to be sound. Helmets are a sensible platform for a breathing apparatus since their use is becoming more and more common amongst snow sport enthusiasts, with many ski resorts and snow sports competitions now making them compulsory.

This project will build on computational modelling in a previous project in order to develop a prototype breathing apparatus that integrates into a ski helmet. The student will need to devise some way to test this device in avalanche-representative conditions.

[1] Dawson, L., BLACK DIAMOND AVALUNG – REVIEW, 30th September 2004, https://www.wildsnow.com/13925/black-diamond-avalung-review/, [accessed 1st May 2022].
[2] NEWSCHOOLERS Forums, Avalung discontinued?, https://www.newschoolers.com/forum/thread/888877/Avalung-discontinued, [accessed 1st May 2022].
[3] Brown, J., Should You Use An Avalung?, 7th February 2018, https://www.powder.com/gear-locker/should-you-use-an-avalung/, [accessed 1st May 2022].

Lubbock, Roderick Dr

Project no: ***LRRL06 ****
Project title: Development of a combined liquid spring/shock absorber for bike applications - computational and experimental

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Experimental;Computational
Software: CFD software e.g. Ansys Fluent or StarCCM

Confidential: No

This project seeks to develop a combined spring and shock absorber system for bike applications using liquid springs. Liquid springs are sealed devices which exploit the slight compressibility of fluids such as silicone oil in order to store and return energy. Combined with fluid elements, e.g. small orifices, it should be possible to design a device that offers shock absorption as well as energy storage. This has the potential to offer high energy storage density and tuned dissipation in a highly-compact and potentially low-weight device, that could be used for saddle suspension and handlebar suspension systems on road and gravel bikes, as well as full suspension for mountain bikes and potentially used to develop full-suspension for road and gravel bikes.
See e.g.
https://asmedigitalcollection.asme.org/biomechanical/article/142/1/014502/975512/Design-Evaluation-of-a-Novel-Multicompartment for a recent liquid-spring design for a knee brace application.

Lubbock, Roderick Dr

Project no: ***LRRL07 ****
Project title: Development of a portable vertical tower axial wind turbine - computational and experimental

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Experimental
Software: CFD software e.g. Ansys FLUENT or StarCCM

Confidential: No

This project aims to develop an open-source vertical tower axial wind turbine for small-scale power generation. The scale is to be determined as part of the project based on the relationship between size and generated power and the target market; two possibilities are portable power generation and residential power generation (e.g. roof-mounted devices).
See e.g. https://www.sciencedirect.com/science/article/pii/S0360544214002837 for a recent commercial device as well as https://www.youtube.com/@RobertMurraySmith for some interesting home-builds.

The design process will start with first principles design calculations followed by CFD modelling before proceeding onto development of an experimental prototype, should time allow.

Lubbock, Roderick Dr

Project no: ***LRRL08 ****
Project title: Development of an open source vertical axis wind turbine - experimental

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

This project aims to develop an open-source vertical axis wind turbine (VAWT) for charging personal devices such as laptops and mobile phones when e.g. camping/hiking in remote areas and during crisis situations (see e.g. mobile phone charging clubs in war-torn Ukraine).
A closed-source HAWT device has recently been developed (https://shineturbine.com) however this is expensive and has relatively low power for its size. Amateur developers have also developed interesting open-source HAWT devices (https://hackaday.io/project/185070-3d-printed-portable-wind-turbine) however these are low power offering a lot of scope for development by an experienced engineer. Similar VAWT devices have also been developed: https://makezine.com/article/science/energy/this-30-wind-turbine-is-made-from-bike-parts-and-discarded-aluminum/ .
The project will primarily focus on developing a functional HAWT device for continued development and improvement by the open-source community. The prototype should easily accommodate various blade designs.

Lubbock, Roderick Dr

Project no: ***LRRL09 ****
Project title: Development of an open-source portable wind turbine - experimental

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

This project aims to develop an open-source horizontal axis wind turbine (HAWT) for charging personal devices such as laptops and mobile phones when e.g. camping/hiking in remote areas and during crisis situations (see e.g. mobile phone charging clubs in war-torn Ukraine).
A closed-source device has recently been developed (https://shineturbine.com) however this is expensive and has relatively low power for its size. Amateur developers have also developed interesting open-source devices (https://hackaday.io/project/185070-3d-printed-portable-wind-

turbine) however these are low power offering a lot of scope for development by an experienced engineer.
The project will primarily focus on the non-aerodynamic aspects of a HAWT device in order to develop a protoype that can easily accommodate various blade designs, and ideally can also be used as a test stand for continuous development of improved blades by the open-source community (this may however require a separate test vehicle).

Magri, Luca Prof

Project no: ***LRLM01***
Project title: Physics-constrained turbulence learning with quantum computing (S)

Supervisor: Magri, Luca Prof
Co-supervisor(s):
Category: Computational;Theoretical;Numerical;Machine learning
Software: Tensorflow, Python, Pytorch (maybe)

Confidential: No
The student will further develop the Auto-Encoded Reservoir-Computing (AE-RC) approach to learn the dynamics of a 2D turbulent flow by constraining the machine with physical knwoeldge (conservation laws):
https://arxiv.org/abs/2012.10968
The AE-RC consists of an Autoencoder, which discovers an efficient manifold representation of the flow state, and an Echo State Network, which learns the time evolution of the flow in the manifold. The AE-RC is able to both learn the time-accurate dynamics of the flow and predict its first-order statistical moments.
The AE-RC approach opens up new possibilities for the spatio-temporal prediction of turbulence with machine learning.
Emphasis will be put on quantum algorithms.

Magri, Luca Prof

Project no: ***LRLM02***
Project title: Physics-constrained turbulence learning (S)

Supervisor: Magri, Luca Prof
Co-supervisor(s):
Category: Computational;Theoretical;Literature
Software: Python or Matlab

Confidential: No
Background:
The Auto-Encoded Reservoir-Computing (AE-RC) approach can learn the dynamics of a 2D turbulent flow. The AE-RC consists of an Autoencoder, which discovers an efficient manifold representation of

the flow state, and an Echo State Network, which learns the time evolution of the flow in the manifold. The AE-RC is able to both learn the time-accurate dynamics of the flow and predict its first-order statistical moments.
The AE-RC approach opens up new possibilities for the spatio-temporal prediction of turbulence with machine learning.
The student will examine existing methods to constrain the physics in machine learning algorithms for turbulence learning.
The student is expected to propose new methods based on the literature, which will be implemented in the AE-RC (ultimately).
https://arxiv.org/abs/2012.10968

Mainini, Laura Prof

Project no: ***LRLAM01 ****
Project title: Data-efficient early diagnostics and prognostics for sustainable aviation (2 projects)
Supervisor: Mainini, Laura Prof
Co-supervisor(s):
Category: Computational; Theoretical; Literature
Software: MATLAB and Simulink; modelling and simulation SW; possible access to HPC
Confidential: No

Next generation aircraft require the development and integration of a deal of innovative technologies to meet the ambitious sustainability goals set for aviation. This transformational effort is associated with a tremendous increase of the complexity of the onboard systems and their multiphysics coupled behaviours. Additional tangles arise from the stringent requirements on safety, reliability and operational performances of aerospace systems which further complicate the introduction onboard of novel technologies. In this scenario, the rapid identification of incipient multimodal faults constitutes a significant opportunity to accelerate the actualization of sustainability ambitions. The project focuses on (i) study of power systems/architectures for low emissions and their fault modes; (ii) investigation of computational methods and active learning strategies for data-efficient diagnostics and reliability assessment of multi-physics onboard systems; (iii) study and assessment of the impact of advanced (early-stage, data-efficient) diagnostics and prognostics on the time-to-adoption/integration of new technologies. The thrusts build upon concepts of modelling and simulation, dynamic data driven methods, uncertainty quantification, data assimilation, predictive digital twins and scientific machine learning.

Mainini, Laura Prof

Project no: ***LRLAM02 ****
Project title: Multisource learning for multidisciplinary design of aerospace vehicles (2 projects)
Supervisor: Mainini, Laura Prof
Co-supervisor(s):

Category: Computational; Theoretical; Literature
Software: MATLAB (or Python); modelling and simulation SW; possible access to HPC
Confidential: No

The adoption of detailed models for the multidisciplinary design of aerospace vehicles permits to enhance the identification of superior design solutions, but would prohibitively rise the demand for computational resources and time. Multisource methods acknowledge the availability of multiple representations (models) of physical systems and phenomena that can be interrogated to inform the design process. Those representations can differ for their underlying governing assumptions, their resolution or level of captured details, the cost required to be evaluated or obtain responses, etc.. Based on the Box's principle of model usefulness, these models can be used in concertation to achieve major savings of computational time and resources. This project focuses on the study and development of computational methods to dynamically elicit different models to efficiently inform and guide the multidisciplinary design of aerospace vehicles. Specific applications are defined across (i) novel power architecture solutions and non-conventional configurations for sustainable aviation; or (ii) scalable benchmark problems for aeronautics and/or space applications. The project requires interest in enriching the familiarity with the specific application and the associated technologies. The studies build up on modelling and simulations, and leverage concepts of multidisciplinary design optimization, multifidelity methods for design optimization, physics based machine learning, active learning from multiple oracles.

Mainini, Laura Prof

Project no: ***LRLAM03 ****
Project title: InfoSymbiotics for next generation aerospace vehicles' readiness and operations (3 projects)
Supervisor: Mainini, Laura Prof
Co-supervisor(s):
Category: Computational; Theoretical; Literature
Software: MATLAB (or Python); modelling and simulation SW; possible access to HPC
Confidential: No

Reliability and readiness of aerospace vehicles in future operational scenarios can be augmented through a dynamic reshaping of their mission profiles in response to the evolution of their health state and contingencies. The hazards might be hard to characterize a priori, but the impact onto the mission could result in catastrophic failure. The structural integrity or the nominal functioning of the systems could be dramatically jeopardized, eventually leading to the loss of the vehicle. The possibility to reconfigure the mission would allow the aerospace vehicle to complete the mission successfully and continue operating safely under degraded conditions, without over-replacing parts, oversizing components, and multiplying systems redundancies. This project focuses on computational methods to enable dynamic mission replanning: forms of artificial reasoning that (i) learn from sensor measurements and predict in real-time the evolving/residual capabilities, (ii) use those predictions to enable fast and trustworthy autonomous operational decisions, (iii) use sensor measurements, capability predictions and the updated decision space to dynamically refine data acquisition strategies. The thrusts build upon concepts of modelling and simulation, infosymbiotics and dynamic data-driven methods, predictive digital twins, model order reduction, scientific machine learning, data fusion and virtual sensing.

Morrison, Jonathan Prof.

Project no: ***LRJM01 ****
Project title: Downforce control - 3 projects available

Supervisor: Morrison, Jonathan Prof.
Co-supervisor(s):
Category: Experimental
Software:
Confidential: Yes
A new collaboration with McLaren is being set up focusing on their new tunnel at Woking. Due to FIA rules, usage of the tunnel has to be optimised to gain maximum benefit, involving comparison to CFD. New chassis designs to improve downforce are being investigated.

Nortmann, Benita

Project no: ***LRTM03 ****
Project title: Control of robotic systems for space applications (S)

Supervisor: Nortmann, Benita
Co-supervisor(s):
Category: Computational;Theoretical;Analysis;Numerical;Literature
Software: Matlab

Confidential: No
Robotic systems are ubiquitous, and space is no exception. In this project the student will consider robotic systems that are of interest to space applications (e.g. robotic arms). For certain types of missions, accurate models describing the behaviour of such robotic systems may be lacking (e.g. due to the robotic system operating in an unknown environment) and, simultaneously, efficient operation may be crucial (e.g. due to energy limitations).
Namely, robotic systems in space may be required to operate efficiently and reliably in unknown environments. Motivated by this, the student will consider data-driven and/or optimal control of robotic systems for space applications. The student will explore existing models describing the dynamics of such systems in “typical” environments and exploit these to build a “simulation environment” in Matlab. The student will then consider data-driven control (treating the dynamics as fully/partially unknown) and/or optimal control of the considered robotic system. Both objectives may necessitate the consideration of nonlinear control techniques. The performance of developed controllers will be studied via simulations.
The project will involve the consideration of nonlinear dynamical systems and advanced control techniques, as well as convex optimisation. For this reason, an excellent background and a keen interest in mathematics and control theory is absolutely essential. The project will involve a significant amount of programming in Matlab (and will require gaining familiarity with various toolboxes available for solving semidefinite programming problems).

Nortmann, Benita

Project no: ***LRTM05 ****
Project title: Data-driven control for autonomous robotic systems

Supervisor: Nortmann, Benita
Co-supervisor(s):
Category: Experimental: Ready-made experiment;Computational;Design;Theoretical
Software: Matlab (and potentially some small amount of coding in Pythin/C++/similar languages, just to interface hardware with Matlab).

Confidential: No
Robotic systems are ubiquitous and oftentimes their dynamics are partially unknown (due to parameters that are difficult/costly to estimate precisely). A recently developed data-driven control strategy that uses (a relatively small amount of) data to bypass the need for accurate models has been demonstrated (via simulations) to be particularly appealing for control of robotic systems. These recent results are very exciting.
This project will focus on the aforementioned data-driven control strategy in the context of autonomous ground and/or air vehicles. In the first phase the student will gain familiarity with the underlying theory and perform simulation studies. In the second (main) phase the student will work towards developing a set-up to experimentally validate the results on a parrot drone and/or ground robots (Khepera robots developed by K-team). Note that the second phase can start only once an adequate theoretical understanding is in place. Thus, progressing to the second phase relies on first completing the first phase to an excellent standard.
The project will involve advanced control engineering concepts and considerations of nonlinear dynamical systems. Thus, an excellent background in control engineering and mathematics is essential. In addition the project will involve several practical aspects. Thus, the student should be comfortable and interested in experimental robotics and working with hardware independently. Most of the programming will be done in Matlab, but some use of other languages may be required for interfacing the hardware with Matlab.

Palacios, Rafael Prof.

Project no: ***LRRP01***
Project title: Model reduction and interpolation in dynamic aeroelastic systems

Supervisor: Palacios, Rafael Prof.
Co-supervisor(s):
Category: Computational;Theoretical;Numerical
Software: Matlab
Python

Confidential: No
Aeroelastic analysis of complex configuration requires hundreds of thousands of simulations to identify potential operational risks across a vehicle's flight envelope. This currently limits the fidelity

of the computational methods that can be effectively used in aeroelastic certification. This can be addressed in a two-stage process where, first, reduced-order descriptions of a higher-fidelity are built based on efficient projection algorithms, and, second, interpolation is performed on the resulting systems. By optimally sampling using methods for design of experiments, and property-preserving matrix interpolation algorithm, this results in computational reductions of several orders of magnitude. This general method will be applied in this project to the aeroelastic analysis of flexible wings. The project will make extensive used of Imperial's computational aeroservoelastic software, which has been used in the design of several flying prototypes (https://github.com/ImperialCollegeLondon/sharpy). It requires excellent analytical thinking and a strong interest in programming. It will be done in Python, although previous knowledge is not required. Further reading: http://dx.doi.org/10.2514/1.J058153

Palacios, Rafael Prof.

Project no: ***LRRP02***
Project title: Control system design for wind tunnel demonstration of flutter suppresion

Supervisor: Palacios, Rafael Prof.
Co-supervisor(s):
Category: Experimental;Computational;Design
Software: Matlab
Python
LabView

Confidential: No
This project is an investigation on aeroservoelastic vehicle design, in particular, the integration of control systems on wings to increase their flutter speed (an stability augmentation control problem). This can tilt the trade-off between aerodynamic and structural constraints towards much lighter wing designs, but at the expense of a much complex design evaluation. In this project, flutter supresion strategies will be first numerically investigated on an existing actuated composite wing. A flap driven by an Arduino card has been shown to produce efficient actuation for a wind-tunnel implementation with minimum delays, but the optimal layout of sensors (accelerometers and strain gauges) and the identification of the closed-loop system dynamics needs to be identified. The project will address those issues to identify and demonstrate effective aeroelastic stability augmentation strategies, both through simulation and experiments.

Palacios, Rafael Prof.

Project no: ***LRRP03***
Project title: Aerodynamic shape optimization of wings with compliant winglets (S)

Supervisor: Palacios, Rafael Prof.
Co-supervisor(s):
Category: Computational

Software: C++, access to the HPC
Confidential: No
Aerodynamic shape optimization using high-fidelity tools is now routinely performed to identify optimum aerofoil shapes and wing planforms. A key pending challenge is the integration of aeroelastic effects on the optimization, since wing deformations fundamentally alter its performance. A potential strategy for this, which is being investigated by researchers at Imperial, is to use algorithmic differentiation strategies to approximate gradients automatically through the manipulation of a computer code without having to derive (and code) any analytical expressions. This has been implemented at Imperial in the open-source SU2 code (https://su2code.github.io). The project will investigate the increase in performance across multiple operating points of a wing with a compliant winglet against traditional (rigid) designs. For that purpose, the project will be make extensive used of the C++. No previous knowledge of the language is required, but excellent programming skills are a must. Further reading: https://dx.doi.org/10.1007/s00158-020-02600-9

Palacios, Rafael Prof.

Project no: ***LRRP04***
Project title: Hinged winglets for aircraft load alleviation

Supervisor: Palacios, Rafael Prof.
Co-supervisor(s):
Category: Computational
Software: python
Confidential: No
Hinged winglets have been recently proposed to reduce adverse aerodynamic loading due to atmospheric gusts (https://www.airbus.com/newsroom/stories/the-albatross-is-inspiring-tomorrows-next-generation-of-aircraft-wings.html). As this is a passive mechanism, the challenge is to obtain a single design that shows good performance in different flight segments. In this project, this will be investigated using an in-house aeroelastic solver for flexible aircraft dynamics that includes a multibody implementation to model the hinge dynamics (www.imperial.ac.uk/aeroelastics/sharpy). The aeroelastic response of wings of increased flexibility and aspect ratio, under different hinge partitions will be explored aiming to identify any sweet spots in the design space for this setup. This project extensively uses python.
Further reading: https://doi.org/10.2514/1.C035602

Palacios, Rafael Prof.

Project no: ***LRRP05***
Project title: Conceptual design of a hydrogen-powered regional aircraft

Supervisor: Palacios, Rafael Prof.
Co-supervisor(s):
Category: Computational

Software: matlab, python

Confidential: No
Hydrogen may be the solution to achieve net-zero aviation, although there are many technological questions that need addressing. We also need suitable design tools to size vehicles with this new power-system. This project will explore this last point, using SUAVE, a state-of-the-art open source conceptual design environment (https://suave.stanford.edu/) and OpenVSP, a vehicle parametrization engine (http://openvsp.org/). A new propulsion system will need to be developed, to incorporate hydrogen fuel cells, for exploration of the design space of next-generation zero-emissions regional aircraft.

Palacios, Rafael Prof.

Project no: ***LRRP06***
Project title: Conceptual design of a hydrogen-powered long-range aircraft

Supervisor: Palacios, Rafael Prof.
Co-supervisor(s):
Category: Computational
Software: python, matlab

Confidential: No
Hydrogen may be the solution to achieve net-zero aviation, although there are many technological questions that need addressing. We also need suitable design tools to size vehicles with this new power-system. For long-range flight, direct hydrogen combustion may be avalable, and a major challenge is regarding hydrogen storage, both in terms of safety and volume constraints. This project will explore this problem, using SUAVE, a state-of-the-art open source conceptual design environment (https://suave.stanford.edu/) and OpenVSP, a vehicle parametrization engine (http://openvsp.org/).

Panesar, Ajit Dr

Project no: ***LRAP01***
Project title: Anisotropic aperiodic structures via mathematical programming

Supervisor: Panesar, Ajit Dr
Co-supervisor(s):
Category: Computational;Numerical;Theoretical
Software:

Confidential: No
Engineering design is traditionally limited to using materials provided by nature. To broaden the range of bulk properties covered by materials, material scientists and engineers have begun focusing on the design of metamaterials -- architected materials with vastly improved performance based on their underlying microscale and mesoscale geometric features. Many metamaterials in practical use are

based on the periodic array of a recognizable repeating unit of ordered trusses and are adequate for basic applications of light-weighting. However, typical design problems require complex trade-offs in mechanical properties to achieve certain target performance objectives. Bone implants, for example, face multi-axial loads and complex stress states for which periodic metamaterials may be suboptimal. Novel superior materials based on the mathematics of aperiodic order present a fascinating alternative since their geometric features promise a robust control of anisotropic mechanical properties. This project will derive anisotropic aperiodic metamaterials suitable for applications in biomedical and aerospace industries for patient-specific bone implants, energy absorption and for problems featuring complex uncertainties in stress loading. Aperiodic lattice structures can be extended to three-dimensions though the project is targeted at two-dimensional structures at onset. The student will be equipped with the numerical skills for homogenisation of mechanical properties for metamaterials as well as optimisation problem formulation.
Programming Language/Software: Python and Abaqus

Panesar, Ajit Dr

Project no: ***LRAP02***
Project title: Metamaterial toolbox - 2 projects available

Supervisor: Panesar, Ajit Dr
Co-supervisor(s):
Category: Computational;Design;Numerical
Software:
Confidential: Yes

The first use of the underpinning software can be found in the 2018 paper (https://doi.org/10.1016/j.addma.2017.11.008) which has maintained its spot amongst the top 10 most cited & downloaded papers in the Additive Manufacturing journal. The existing capability of the tool can be found here (https://www.youtube.com/watch?v=7A2i791V340) which broadly covers the following types of grading: a) material (i.e. volumetric), b) unit cell size (i.e. hierarchal) and c) unit cell type (i.e. morphing).
The next phase of this project involves enhancing the software functionalities to include: a) High-quality surface rendering for quick visualisation during design phase and for print-ready file for AM techniques, b) Quicker lattice generation speed by approaches like utilising GPUs for computing, c) Generate the infill within desired structure and d) Extension to more novel designs, for example, polar coordinate and bio-inspired possibilities.
Programming Language: Python

Panesar, Ajit Dr

Project no: ***LRAP03***
Project title: Multifunctional metamaterials for electric vehicles

Supervisor: Panesar, Ajit Dr
Co-supervisor(s):

Category: Analysis;Numerical;Computational
Software:
Confidential: No
Metamaterials provide a foundation for enhancing performance of multifunctional multiscale structures by enabling unique properties to be attained. The design of multiscale structures from metamaterials can be formulated as - firstly, determine the properties of the metamaterial elements with equivalent, effective properties and secondly, use effective properties for subsequent system design. This research project aims to apply this philosophy to the design of real-world engineering components, e.g. battery casing in an electric vehicle (can be for both road or air transport) and will require fulfilling competing requirements of: high resistance to impact, vibration damping capability and thermal dissipation.
Programming Language/Software: Python and Abaqus

Panesar, Ajit Dr

Project no: ***LRAP04***
Project title: Recycled Composites

Supervisor: Panesar, Ajit Dr
Co-supervisor(s): Lee, Koon-Yang Prof.
Category: Analysis;Literature;Computational
Software:
Confidential: No
There is a growing interest and even regulatory requirements for sustainable manufacturing. While fibre reinforced polymer composites are a wonder-material, it’s the continuous fibre variant that gets most of the attention owing to their excellent specific performance. This project aims to assess the feasibility of recycling both continuous and short FRPs into composites with chopped fibres and evaluate their mechanical properties and economic potential. Several approaches to realising the recycled composites will be explored and a detailed assessment on the quality (effected by defects), scale-up issues, etc. will need to be considered.

Panesar, Ajit Dr

Project no: ***LRAP05 ****
Project title: Metamaterial topology discovery

Supervisor: Panesar, Ajit Dr
Co-supervisor(s):
Category: Computational;Analysis;Literature;Theoretical;Design;Numerical
Software:
Confidential: Yes
Metamaterials are a new class of functional materials, which exhibit properties typically not found in naturally occurring materials. For example, auxetic material, that has negative Poison’s ratio, is one of the mostly studied mechanical metamaterials. However, there’s no guideline for the discovery/design

of metamaterials. The aim of this project is to create a library of metamaterial topologies for different end-use applications through literature and numerical methods. Based on the existing metamaterial templates, the project will explore the microstructure of metamaterial through design-optimisation method, and establish a formal methodology to analyse the behaviour of metamaterials (e.g. RVE using homogenisation method). In addition, the adoption of Machine Learning may be considered for micro-structural discovery, which can potentially speed up their engineering developments.
Programming Language/Software: Python and Abaqus

Panesar, Ajit Dr

Project no: ***LRAP06 ****
Project title: Shape memory polymer for intelligence design using AM (S)

Supervisor: Panesar, Ajit Dr
Co-supervisor(s): Bilotti, Emiliano Dr
Category: Experimental: Structures;Design;Literature
Software:
Confidential: Yes

Shape memory polymers (SMPs) are materials with the unique ability to return to their original shape when subjected to specific stimuli (e.g. heat). With the advent of additive manufacturing (AM), the design possibilities for SMPs have expanded. To demonstrate and broaden the design potential of these materials to revolutionise aerospace applications. The initial part of the project involved investigating the SMPs AM part's behaviour and their heating conditions. The project aims to explore the bio-inspired design opportunities, such as origami folding, intelligent hinge, for industrial applications.

Papadakis, George Prof.

Project no: ***LRGP01 ****
Project title: Identification and estimation of flow around an airfoil (S)

Supervisor: Papadakis, George Prof.
Co-supervisor(s):
Category: Computational;Theoretical
Software: OPEN-FOAM or STAR-CCM+

Confidential: No

The project aims to reconstruct the 2D flow around an airfoil using shear stress and pressure measurements on the airfoil surface. In order to achieve this objective, numerical simulations will be first performed to develop a low order model of the flow. The time evolution of the flow field will be used to derive the dominant flow structures, using for example the POD method. Using a novel identification technique that was developed very recently by the group of the supervisor, the shear stress and pressure mesurements (obtained from a separate simulation) will be employed to determine the amplitude of each mode, making possible the reconstruction of the whole flow field. In particular, the ability of this method to capture the CL and CD coeffcients will be assesed. A critical aspect is the optimal location of a small number of sensors. Where these should be located and how these positions are related to the flow physics?

Papadakis, George Prof.

Project no: ***LRGP02 ****
Project title: Application of machine learning to control. (S)

Supervisor: Papadakis, George Prof.
Co-supervisor(s):
Category: Computational;Theoretical;Numerical
Software: MATLAB

Confidential: No
The aim of this project is to apply machine learning to control of non-linear systems that can exhibit chaotic behaviour. Simplified non-linear models that describe the self-sustaining process in near-wall turbulence will be used as test beds to examine the performance of this control method. The method will be also applied to the Stuart-Landau equation that can describe the flow around a circular cylinder. This equation can also exhibit chaotic behaviour if perturbations are added to the system.

Papadakis, George Prof.

Project no: ***LRGP03 ****
Project title: Use machine learning to extract equations from data (S)

Supervisor: Papadakis, George Prof.
Co-supervisor(s):
Category: Computational;Theoretical
Software: MATLAB

Confidential: No
The central aim of this project is to derive governing equations from simulation data. A technique has been proposed recently in the literature for this purpose. We will apply the technique to the flow around an airfoil, where the velocity recorded at various points in the wake will be used as input data. The output will be a non linear system that characterises the wake. We will compare the results of this system to fully resolved simulations in order to quantify its accuracy. This is a very new and rapidly growing area of research with many application in aerodynamics.

Papadakis, George Prof.

Project no: ***LRGP04 ****

Project title: Characterisation of mixing behaviour in the wake of a group of square cylinders. (S)

Supervisor: Papadakis, George Prof.
Co-supervisor(s):
Category: Computational
Software: Pantarhei, an inhouse code for incompressible Navier Stokes equations.

Confidential: No
Lyapunov exponents are widely used to characterise the chaotic behaviour of a dynamical system. The central aim of this project is to characterise the mixing behaviour in the wake of a group of cylinders using Lyapunov exponents (and the associated covariant vectors). We will implement a computational technique to an inhouse CFD code to find all the positive Lyapunov exponents. We will study the effect of numerical parameters (spatial disretisation and time step) on the results to make sure that the exponents really characterise the system and are not numerical artifacts. We will then investigate the dynamics of the covariant vectors and their relation to the shedding activity. This approach will be used to explain the improved mixing behavour of a recently proposed modification in the geometry of the cylinder array.

Papadakis, George Prof.

Project no: ***LRGP05 ****
Project title: Sensitivity of chaotic flow to boundary conditions

Supervisor: Papadakis, George Prof.
Co-supervisor(s):
Category: Computational;Theoretical
Software: MATLAB

Confidential: No
The computation of sensitivity of time-average velocity to boundary condition changes in a chaotic flow is a very difficult (but important) problem. There are many applications where such sensitivity can be very useful, for example control applications. Recently a method was developed by the supervisor that makes this problem tractable. We will apply the method to compute the sensitivity of the time average velocity and turbulent kinetic energy to 1D Burgers equation and, time permitting, to 2D channel flow. The perturbation will take the form of boundary condition change. We will compare the prediction against finite difference calculations.

Papadakis, George Prof.

Project no: ***LRGP06 ****
Project title: Data Assimilation in complex flows. (S)

Supervisor: Papadakis, George Prof.
Co-supervisor(s):
Category: Computational;Theoretical
Software: Free-fem (free to download from Inetrnet).

Confidential: No
Data Assimilation techniques allow the incorporation of experimental data into a computational model in order to improve its accuracy. For example, the model may contain unknown coefficents, whose optimal values are determined from the experimental data. In this project, we will apply a new technique that allows the extraction of values of the unknown parameters directly from the measurements. We will apply this technique to complex flows and assess its performance and accuracy.

Papadakis, George Prof.

Project no: ***LRGP07 ****
Project title: Flow reconstruction from scalar measurements and application to environmental flows. (S)

Supervisor: Papadakis, George Prof.
Co-supervisor(s):
Category: Computational;Theoretical
Software: Star-ccm or OPEN FOAM

Confidential: No
In many environmental problems, pollutant dispersion is due to turbulence. However, the turbulent flow fields are not known, only some concentration measurements are available at several sensor points. The central aim of the project is to recover the unknown turbulent velocity field from pollutant concentration measurements. A technique that was recently developed by the group of the supervisor will be extended to handle scalar concentrations. We will apply this technique to a simplified environmental problem, the flow around a building. Success in extracting the flow from scalar measurements has many other diverse applications, for example in biomedical engineering or the prediction of the spread of a disease.

Paranjape, Aditya Dr

Project no: ***LRADP01 ****
Project title: Control of flutter on moderate-to-high AR wings

Supervisor: Paranjape, Aditya Dr
Co-supervisor(s): Palacios, Rafael Prof
Category: Theoretical
Software: Python; SHARPy
Confidential: No

Light, moderate-to-high aspect ratio wings are of considerable interest for application to efficient, long-endurance aircraft. These include electric-powered commercial aircraft and long-range, high-altitude remote sensing aircraft. These aircraft are prone to flutter instabilities driven by a coupling between the "rigid body" flight dynamics and the structural dynamics of the wing. The NASA Helios is a case in point.

Our objective is to design a control law for mitigating flutter on moderate-to-high AR wings (AR around 10). We are specifically interested in design techniques that exploit the underlying dynamics described by partial differential equations. Towards that end, we will design output feedback control laws and determine their stability margins using bifurcation analysis and related techniques. We will use a high fidelity model implemented using software called SHARPy developed at Imperial College London.

Note: Dr Paranjape holds an honorary position at Imperial College London. He is a senior scientist at TCS Research, a part of Tata Consultancy Services Ltd, in Pune, India. He will participate remotely. The student would be expected to report on a regular basis to Prof Palacios.

Paranjape, Aditya Dr

Project no:	***LRADP02 ****
Project title:	Optimal control of a network of traffic signals using real-time data
Supervisor:	Paranjape, Aditya Dr
Co-supervisor(s):	Panesar, Ajit Prof
Category:	Computational
Software:	Python; SUMO (open-source software for simulating traffic flows).
Confidential:	No

Intelligent traffic management plays a significant role in reducing not only the commute times in cities, but also the environmental impact of urban commute. One approach to intelligent traffic management relies on controlling the signals at traffic junctions using real-time data from a network of distributed sensors. This data is used to build an estimated model of the traffic flow, and the resulting model is fed to a logic that actually controls the traffic signals. The objective of this project is to design a logic that can be used for controlling the traffic signals in the presence of high demand and uncertainty.

It is important to appreciate that individual signals cannot be controlled in isolation for sound traffic management. At the same time, it is computationally cumbersome, if not outright intractable, to devise a logic that attempts to solve for the optimal state of every single junction simultaneously. Thus, a practically viable logic needs to work with a combination of intelligently chosen groups of signals and a model that captures the right mix of information about local and global traffic flows.

In this project, we will model an urban area with an archetypal network of roads and regulated traffic junctions. We will simulate this model using Eclipse SUMO, an agent-based traffic simulation package. We will design optimal laws for managing traffic junctions and traffic flow models using synthetic real-time data about traffic at specific points in the network. This project will involve a mix of theoretical modeling, modeling using machine learning, and optimal control using a mix of heuristics and reinforcement learning. The project will also involve extensive coding in Python.

Students will learn about cutting edge topics in the fields of optimization, machine learning, optimal control and decision-making.

Note: Dr Paranjape holds an honorary position at Imperial College London. He is a senior scientist at TCS Research, a part of Tata Consultancy Services Ltd, in Pune, India. He will participate remotely. The student would be expected to report on a regular basis to Dr Panesar.

Peiro, Joaquim Prof.

Project no: ***LRJP01***
Project title: Modelling of fluid sloshing using smooth particle hydrodynamics (S) - 2 projects available

Supervisor: Peiro, Joaquim Prof.
Co-supervisor(s):
Category: Computational
Software: Matlab or C++ and CUDA (for GPUs).
Confidential: No

The purpose of this work is to assess the suitability of a code, based on the smoothed particle hydrodynamics (SPH) methodology, for modelling fluid sloshing with large amplitud motions; to verify it against other CFD formulations (e.g. volume-of-fluid); and to validate it against available experimental data. Today very few grid dependent or independent CFD techniques are available to accurately simulate this type of flows. SPH is a mesh-free, particle-based formulation for the numerical simulation of physical problems. It is one of the few techniques able to handle complex phenomena such as liquid break-up, fracturing, shattering, and possible phase change etc. It permits an easy implementation of complicated physics such as multiple phases, realistic equations of state, electromagnetic, compressibility, solidification, vaporization, porous media flow and history dependence of material properties. Further, it is able to deal with complex geometries in two and three dimensions.

Peiro, Joaquim Prof.

Project no: ***LRJP02***
Project title: Simulation of air flow and heat transfer in networks of tunnels - 5 projects available

Supervisor: Peiro, Joaquim Prof.
Co-supervisor(s):
Category: Computational;Theoretical;Design

Software: Matlab, C++, Fortran or python for projects 1, 3, and 4; StarCCM+ license for projects 2 and 5.

Confidential: No

Passenger comfort and safety are the main concerns in the design of tunnels. A train travelling at high speed through a tunnel generates a pressure wave that might cause discomfort to the passengers. Similarly, the transit of trains in a network of tunnels generates heat that affects the temperature environment. These are a few of the projects proposed under this theme:

1. Aerodynamic interaction of a train entering a tunnel: A 1D code for the modelling of pressure waves in tunnels will be used to select the optimal tunnel section so that the increase in pressure does not go beyond the threshold of discomfort.
2. Analysis and design of a tunnel ventilation system in the event of a fire. Fires increase the resistance to air flow due temperature increases which also lead to significant bouyancy efects for large fires. The CFD code STARCCM+ will be used to model this "throttling" effect of the fire and flow stratification due to heat-induced buoyancy.
3. Long term evolution of the temperature in an underground network: To ensure that the fluctuations of temperature within the network are within acceptable limits for passenger comfort. The major challenge is the slow release of heat through the tunnel walls that often requires to model temperature fluctuations over several years.
4. Modeling of tunnel boom cause by micro-pressures waves generated by the entry in the tunnel of trains traveling at high speeds (above 300 km/h). The sound produced at the exit of the tunnel is a function of the pressure history. This will be calculated by the 1D code and the results processed using a suitable model of sound generation from pressure fluctuations.
5. CFD modelling of the pressure wave generated by the entry of a train in a tunnel using StarCCM+. For short tunnels three-dimensional effects are important and the one-dimensional approximation is no longer accurate. This project will compare CFD simulations with those of the 1D and experimental. These comparisons will be used to validate the CFD simulation and investigate the range of validity of of the one-dimensional approach.

Peiro, Joaquim Prof.

Project no: ***LRJP03***

Project title: Simulation of flow in physiological networks - 3 projects available

Supervisor: Peiro, Joaquim Prof.

Co-supervisor(s):

Category: Computational;Numerical;Literature

Software: Matlab, Python, and C++ or Fortran compilers

Confidential: No

Arterial, venous, lymphatic and respiratory networks are made up of millions of vessels so 3-D flow simulations are just not feasible. Reduced 1-D models of such physiological systems based on the area-averaged governing equations provide a computationally affordable and reasonably accurate simulation capability to study the flow in networks of vessels. These are a few of the projects proposed under this theme:

1. A 1-D model of the venous system: To adapt an existing 1-D solver for the arterial system to the venous system. This will require investigating suitable constitutive laws to represent the elastic

behaviour of veins and the effect of their valves and implement these by means of an appropriate pressure-area relation in the existing solver.
2. A 1-D model of the respiratory network: To adapt an existing 1-D solver for the arterial system to the respiratory system. This will require devising suitable constitutive pressure-area relations to represent the distensibility of the airways and implement these in the existing solver.
3. Modelling auto-regulation in the arterial system: To investigate the mechanisms of regulation of blow flow in the arterial system when it is subject to external actions such as, for instance, changes in temperature, pressure or posture. To devise suitable models and to implement them in an existing 1-D solver for the arterial system.
4. A 1-D model of the lymphatic system: To devise a set governing equations to model of the lymphatic system that connects tissues to the bloodstream. The model of the collecting lymphatic vessels will consist of lymphangions, deformable vessels which contract and propel lymph, enclosed between valves which promote unidirectional flow. To develop a numerical method of solution of the set of differential equations.

Peiro, Joaquim Prof.

Project no: ***LRJP04***
Project title: Uncertainty quantification in simulation (S) - 3 projects available

Supervisor: Peiro, Joaquim Prof.
Co-supervisor(s):
Category: Computational;Numerical
Software: Python, Matlab, or computer language of choice.

Confidential: No
There many sources of uncertainty in modelling any type of physical phenomena: operational, geometric,
and model inadequacy. We will look at a number of methods to investigate the effect of operational and geometrical uncertainty:
1. Markov Chain and Multi-level Monte Carlo;
2. Intrusive polynomial chaos;
3. Non-intrusive polynomial chaos;
4. Surrogate models.
These can be used in a to compute probabilistic expectations in a number of application areas such as one-dimensional hyperbolic problems, aerofoil performance, vehicle trajectories, epidemic modelling, and predictive microbiology, to name but a few.

Peiro, Joaquim Prof.

Project no: ***LRJP05***
Project title: Reconstruction of high-order surface data from triangulations

Supervisor: Peiro, Joaquim Prof.

Co-supervisor(s):
Category: Computational;Numerical;Literature
Software: Python, C++, Matlab, or computer language of choice.

Confidential: No
The definition of a computational domain for fluid simulation requires an analytical definition of its boundary which is usually generated using a CAD system. However, if the geometry of the domain is obtained via a laser scan or medical imaging, the geometry of the boundary is often given by a triangulation of its surfaces. CFD simulations require the generation of meshes of varying resolution for a given problem for instance to adapt the mesh to a solution or simply to perform mesh convergence studies. In such cases we require a highly accurate, continuous geometric representation of the surface to generate these meshes. This project will review the state-of-the-art of methods for high-order surface reconstruction and implement, in the programming language of your choice, suitable candidate methods that satisfy these requirements: a) the reconstructed surface has a high degree of continuity, i.e. above first order; b) the method is numerically stable and c) it preserves sharp features of the surface and represents the geometry accurately.

Pinho, Silvestre Prof.

Project no: ***LRSP01***
Project title: Overall structural design of a hydrogen-powered aircraft dry-wing

Supervisor: Pinho, Silvestre Prof.
Co-supervisor(s):
Category: Computational;Design;Analysis
Software: Catia, Abaqus
Confidential: No
Hydrogen is the most promising technology to allow aviation to meet NetZero by 2050. Airbus carried out an extensive programme (ZEROe) where they proposed three aircraft concepts that could meet NetZero requirement for different market segments. Two of these solutions include dry-wing solutions. In the UK, the Aerospace Technology Institute recently concluded another project (FlyZero) with similar aims where they proposed three new concepts, all of which including dry-wings. In dry-wing solutions, the fuel is not carried inside the wings, and these can therefore be thinner. This poses significant challenges to their internal structure as they need to resist large bending moments with a smaller second moment of area.
In this project, you will start by reviewing the outcome of the FlyZero project and of a previous FYP project, and then proceed to create a CAD and subsequently a FEM model of a dry wing for one of the FlyZero concepts, including its internal structure of stiffeners and ribs and you will design it to resist the applied forces while keeping deformations within an acceptable range.

Pinho, Silvestre Prof.

Project no: ***LRSP02***

Project title: Structural design of a liquid hydrogen tank for an aircraft

Supervisor: Pinho, Silvestre Prof.
Co-supervisor(s):
Category: Computational;Design;Analysis;Numerical
Software: Abaqus

Confidential: No
Hydrogen is the most promising technology to allow aviation to meet NetZero by 2050. Airbus (ZEROe) and The ATI (FlyZero) carried out extensive programmes (ZEROe and FlyZero respectively) where they proposed in total siz aircraft concepts that could meet NetZero requirement for different market segments: all of them are hydrogen-powered, in some cases with liquid hydrogen.
Safe storage of liquid hydrogen in tanks is challenging due to the pressures required, to the low temperatures, and the ease with which hydrogen can leak from any cracks. In this project, you will review various solutions for liquid hydrogen tanks, design your own, create a CAD model and an FE model for it, and finally iterate your solution until you have a solution with suitable structural integrity.

Pinho, Silvestre Prof.

Project no: ***LRSP03***
Project title: Physics-informed AI and Bayesian optimisation

Supervisor: Pinho, Silvestre Prof.
Co-supervisor(s):
Category: Computational;Numerical
Software: Abaqus, TensorFlow

Confidential: No
Currently, material models for advanced composite materials used in aircraft structures are based on sophisticated analytical idealisations of the material at very small scales. This physical basis gives engineers some confidence that their structural designs will be sound. However, then manufactured at large scales, materials are often different to those manufactured at small scales. There is therefore a need for developing material models from information arising at larger scales.
Digital Image Correlation allows us to obtain the stain field for a large component being tested, including during failure, all while measuring the external work done by the applied forced.
In this project, you will design, train and test a physics-informed AI model to extract the constitutive response (including during damage growth) from the strain field and external work in one or more simple components. Rather than use experimental strain data (which would be the ultimate aim but is more time consuming), you will create FE models of these simple components to generate the training strain data. You will then train your model and iterate the model architecture until your model is able to predict the constitutive response.
Once your ML model is built and validated, you will use Bayesian Optimisation to find out the configuration of the FE model (shape, layup, features such as holes, etc) that maximise the predictive capability of the ML model.

The outcome of this project will be a proposed architecture for the ML model, as well as the definition of the corresponding experimental test specimens that should be manufactured and tested to apply your model in a real scenario.

Pinho, Silvestre Prof.

Project no: ***LRSP04***
Project title: Bio-inspired structures manufactured by Automated Fibre Placement

Supervisor: Pinho, Silvestre Prof.
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

We recently acquired an AFP machine suitable for manufacturing continuous fibre reinforced composites which provides us with unique manufacturing capabilities extremely relevant for industry. AFP can be used to design and automatically manufacture complex CFRP parts that would otherwise be overly labour intensive or even impossible.
In this project, you will design, simulate, manufacture (using AFP) and test a bio-inspired structure, such as a skin-stiffener structure.

Pinho, Silvestre Prof.

Project no: ***LRSP05***
Project title: Doubling the service life of a wind turbine blade

Supervisor: Pinho, Silvestre Prof.
Co-supervisor(s):
Category: Survey;Design
Software: Abaqus

Confidential: No

Achieving NetZero by 2050 will require expanding very significantly our capability to produce green energy. In this context, we will likely experience exponential growth of wind-turbine farms over the next decades. However, this comes with a problem: despite extensive research, the prospects for recycling or even re-purposing wind-turbine blades are grim. Used wind turbine blades are therefore a large and rapidly growing problem. The expert opinion is that the most effective way to reduce the environmental impact of a turbine blade is to increase its service life: it is estimated that its service life can be doubled with an increase in mass of about 10%.
In this project, you will analyse the most modern designs for wind turbine blades and how they fail, and propose how to modify the design so that their service life can be increased by a factor of 2.

Pinho, Silvestre Prof.

Project no: ***LRSP06***
Project title: A holistic approach to achieve NetZero in aviation by 2050

Supervisor: Pinho, Silvestre Prof.
Co-supervisor(s):
Category: Survey;Analysis
Software:
Confidential: No

Airbus and ZeroAvia expect to have a large demonstrator aircraft fuelled by hydrogen flying by 2035. Even if they are successful, relying solely on these hydrogen-fuelled aircraft to achieve NetZero by 2050 would give us only 15 years to replace all kerosene-fuelled aircraft in the world. This seems unlikely. Achieving NetZero in aviation by 2050 will instead require many factors, including: hydrogen propulsion; SAF; e-fuels; carbon capture; demand management; airport infrastructure; green energy generation, distribution, and storage; coordinated policies around the world, etc.
Some of these challenges are purely engineering challenges, but others are psychological, economic and geo-political challenges. Some of them are indirect or not immediately obvious: e.g. reducing demand via green fees could make air travel a privilege of only the rich; any demand management will likely reduce the economic value of the aerospace sector (which could additionally disincentivise research investments for greener aircraft technologies); reducing our dependence on kerosene can destabilise oil-exporting countries; SAF can replace other crops and contribute to famine; Silicon, needed for photovoltaic cells, is mostly produced in one single country; 50% of the world's copper, of which each wind turbine needs several tons, comes from only two countries.
In this project, you will review relevant factors that can play a role in achieving NetZero in aviation, analyse their direct and indirect effects, and discuss corresponding considerations. Based on this review and analysis, you will propose several policy scenarios that could lead to NetZero in aviation by 2050, and discuss the relative implications of each scenario in terms of environment, engineering, economics and geo-politics.

Pinho, Silvestre Prof.

Project no: ***LRSP07***
Project title: Development of an automated validation infrastructure for advanced failure models

Supervisor: Pinho, Silvestre Prof.
Co-supervisor(s):
Category: Computational;Numerical
Software: Abaqus

Confidential: No

Failure models for composites have evolved tremendously in the past decades and continue to evolve. A typical characteristic of current validation procedures is that they tend to be restricted to a

few test cases and with models built from scratch every single time. This differs from cade validation methodologies in other areas, where an automated and comprehensive code validation and verification is carried out ahead of new versions of a code being committed.
In this project, you will: compile and rationalise a series of test cases; use, modify or build a corresponding FE model (as appropriate); and build a Python code that will take a more recent version of a failure model, run the various test cases (including generating failure envelopes), and create suitable infographics of the most significant results, with an indication of how they differ from reference data.

Pinho, Silvestre Prof.

Project no: ***LRSP08 ****
Project title: Bio-inspired composites with thermoplastic interleaves

Supervisor: Pinho, Silvestre Prof.
Co-supervisor(s): Bilotti, Emiliano Dr
Category: Experimental
Software:
Confidential: No

Engineers have developed intricate composite materials over the last decades (and in the whole history of humankind), but nature has often outdone us, as you can see in this TEDx talk:
https://www.youtube.com/watch?v=Bqpa4-RErCc&list=TLGGRmvyvUXvZesxOTA0MjAyMw&t=5s
In this project, you will add an additional level of hierarchy to a bioinspired structure previously developed in the department, hence triggering further mechanisms for dissipating energy. In particular, we will be looking at inserting a suitably-patterned high-performance (nanocomposite) thermoplastic linking various layers in a thin-ply carbon-fibre reinforced composite, hence improving its delamination resistance. In this project, you will:
- Review the literature in bio-inspired inter-ply toughening solutions
- Building on previous work in the department, design and create a prototype for their own solution
- Test it (as well as a baseline) to determine the performance improvement.

Quino Quispe, Gustavo Dr

Project no: ***LRGQ01 ****
Project title: Design and implementation of a novel compression experiment for pultruded rods - 2 projects (S)
Supervisor: Quino Quispe, Gustavo Dr
Co-supervisor(s): Robinson, Paul Prof.
Category: Design;Analysis;Experimental: Structures;Experimental
Software: Abaqus, DIC, MATLAB

Confidential: No

Carbon fibre pultruded rods are highly used in numerous industrial applications due to their lightweight properties, corrosion/fatigue resistance, and exceptional performance in the axial direction. Despite the abundance of literature on the mechanical characterisation of pultruded rods under bending and tension, their response to compression has not received adequate attention. This is due to the challenges associated with uniaxial direct compression testing, such as the high sensitivity to alignment, stress concentration in the gripping zone, and complexities involved in manufacturing specimens, especially for small diameter rods (~1mm).
This project involves the modification and optimisation of a direct compression and/or a bending experiment to comprehensively characterise the compression response (stress vs. strain) of composite pultruded rods. The researcher will leverage analytical and/or computational tools to refine the experiment's design. Additionally, the project will include the practical experimentation of composite specimens using specialized instrumentation. Data analysis techniques that may be used: digital image correlation, analytical models, and/or coding. There is potential for the project to result in a journal article.

Quino Quispe, Gustavo Dr

Project no: ***LRGQ02 ****
Project title: Testing 2.0 of high-performance materials

Supervisor: Quino Quispe, Gustavo Dr
Co-supervisor(s): Robinson, Paul Prof.
Category: Analysis;Computational
Software: Abaqus, MATLAB
DIC software

Confidential: No
Conventional mechanical testing methods require direct measurement of force and deformation to obtain the material's constitutive response (e.g. stress versus strain). While these methods are reliable, they can be costly and time-consuming. "Testing 2.0" represents a new approach to material characterisation, combining computational simulations and non-conventional data-rich tests to achieve a more complete understanding of complex behaviour and properties.
This project aims to utilise finite element modelling updating/virtual field method to characterise the mechanical response of high-performance materials. A first case of study will be the property identification of pultruded rods previously tested under compression in a complex bending configuration. The researcher will utilise both experimental full-field strain data and numerical modelling simulations to develop an optimization framework for characterizing constitutive material parameters. The project will involve coding, analysis of experimental data, Digital Image Correlation, and FE software such as Abaqus. The results of this project have the potential to be published in a journal paper.

Quino Quispe, Gustavo Dr

Project no: ***LRGQ03 ****

Project title: Digital twinning of environmentally damaged composites (S)

Supervisor: Quino Quispe, Gustavo Dr
Co-supervisor(s):
Category: Computational;Analysis
Software: Abaqus, MATLAB
Confidential: No

Despite the many advantages fibre composite materials offer, in-service conditions such as humidity or temperature cycling that can arise in marine or aerospace applications, affect the integrity of composite structures. This poses an important challenge that must be considered to design safe and long-lasting structures.
In this project, the student will build computational micromechanical models to reproduce and predict effects of humid environments upon the non-linear behaviour of fibre composites. The researcher will work with existing experimental data, FEA software (e.g. Abaqus) and MATLAB. This project has the potential to produce a journal paper.

Quino Quispe, Gustavo Dr

Project no: ***LRGQ04 ****
Project title: Multi-scale shear mechanical behaviour of polymeric systems
- 2 projects available

Supervisor: Quino Quispe, Gustavo Dr
Co-supervisor(s):
Category: Experimental: Structures;Design
Software:
Confidential: No

Accurate design and safe usage of polymer and composite components in engineering require reliable experimental characterisation techniques. While compression and tension testing are commonly used, shear behaviour is often overlooked. Furthermore, shear is typically only analysed on a macro-scale, which may not be representative of the behaviour of small volumes of polymer found in complex materials like composites.
This project aims to investigate and evaluate various specimen geometries to better understand shear behaviour in a multi-scale environment. Experiments will be conducted using a specialised rig and advanced techniques such as microscopy, image analysis, and digital image correlation. The findings from this project will contribute to the development and design of new polymer and polymer-based materials by providing more accurate and comprehensive characterization techniques.

Ribera Vicent, Maria Dr

Project no: ***LRMR01***

Project title: Analysis of helicopter performance in ground effect with a time accurate free wake model

Supervisor: Ribera Vicent, Maria Dr
Co-supervisor(s):
Category: Computational;Analysis
Software: FORTRAN, MATLAB

Confidential: No
A comprehensive rotorcraft flight mechanics code is available to model helicopter performance for a range of flight conditions. This model includes different methods for the calculation of the induced velocities, including a time accurate free vortex wake model. The wake model has been tested in stand-alone mode in ground effect by mirroring the main rotor. The proposed project will analyse the performance of a UH-60 helicopter in ground effect, as compared with the out of ground effect equivalent. Moreover, the results will be compared to other induced velocity methods and to the experimental evidence found in the literature.

Ribera Vicent, Maria Dr

Project no: ***LRMR02***
Project title: Upgrade and validation of a helicopter flight dynamic simulation solver for stiff scenarios

Supervisor: Ribera Vicent, Maria Dr
Co-supervisor(s):
Category: Computational;Numerical
Software: MATLAB, FORTRAN

Confidential: No
A comprehensive helicopter flight dynamics code, capable of modelling both steady-state and transient manoeuvres for a range of flight conditions, is available as a baseline for this project. This code has been expanded on by different contributors to add more features or extend its range of usability. The proposed projects will extend this code by adding new functionality.
Previous projects have expanded the model with additional features, but found limitations with the numerical solvers included when facing stiff equations. The proposed project will incorporate new (publicly available) numerical solvers to remove this limitation. The solver will be validated against previous solvers and flight test data for existing trim and manoeuvre cases and then try to resolve the cases with stiff conditions.

Ribera Vicent, Maria Dr

Project no: ***LRMR03***

Project title: Analysis of tilt-rotor wakes in transition using a time-accurate free-vortex wake model

Supervisor: Ribera Vicent, Maria Dr
Co-supervisor(s):
Category: Computational
Software: FORTRAN, MATLAB

Confidential: No
Free-vortex wake models can accurately describe the behaviour of the tip-released vorticity of a rotor at a fraction of the cost of Eulerian CFD calculations. A time-marching free wake model is available that can capture the dynamics of manoeuvring rotors. The proposed projects will model a tilt-rotor during transition by prescribing a time history of the 3-dimensional velocities and angular rates, and analyse the dynamics of the rotor wake using such a model.

Ribera Vicent, Maria Dr

Project no: ***LRMR04***
Project title: Helicopter flight dynamics modelling with state-of-the-art Dynamic Inflow for ground effect

Supervisor: Ribera Vicent, Maria Dr
Co-supervisor(s):
Category: Computational;Analysis
Software: FORTRAN, MATLAB

Confidential: No
Modelling the induced flow on a rotor is an important aspect of helicopter aeromechanics modelling. Free vortex models can provide a very accurate representation of the wake structure and the induced velocities by the vortex field, however they are computationally expensive and subject to numerical instabilities. Dynamic wake models, which are mathematical representations of the induced velocities at the rotor in the form of ordinary differential equations, are a simpler and computationally efficient approach.
A comprehensive helicopter flight mechanics code is available, with several options for the computation of the induced velocities: from dynamic inflow (Pitt-Peters, Peters-He models) to free wake models (Bagai-Leishman, Bhagwat-Leishman). Since the last inflow model added (Peters-He) was developed in the early nineties, the family of dynamic inflow models has expanded to capture additional behaviour of the wake and to expand the range of applications it can be used for, including operating in ground effect.
The purpose of this project is to introduce the state of the art version of the dynamic inflow family in a comprehensive helicopter flight mechanics code and to validate it for the UH-60 helicopter. The model should explore some of the advantages provided by the new inflow model with respect to the original methods.

Ribera Vicent, Maria Dr

Project no: ***LRMR05***
Project title: Modelling of a rotor wake distortion due to the presence of the fuselage

Supervisor: Ribera Vicent, Maria Dr
Co-supervisor(s):
Category: Computational;Analysis
Software: FORTRAN, MATLAB

Confidential: No

The aerodynamic environment of a helicopter is very complex, with the main rotor wake interacting with the fuselage, empennage and tail rotor wake. A comprehensive helicopter flight dynamics model is available which has been validated against the UH-60 flight test program. This code includes a time-marching rotor vortex wake model which is capable of capturing the wake dynamics during manoeuvres and allows the wake vortices to distort under their mutual influence. The free wake model, however, does not currently distort due to the presence of the fuselage. The proposed project will investigate approaches to modelling the distortion of the wake filaments and implement the most suitable one into the free wake code. The model will be compared to the current approach (without distortion) and to flight test data for the UH-60 Blackhawk helicopter.

Rigas, Georgios Dr

Project no: ***LRGR01***
Project title: Data-driven hydrodynamic stability analysis

Supervisor: Rigas, Georgios Dr
Co-supervisor(s):
Category: Computational;Analysis;Numerical
Software: Tensorflow

Confidential: No

During the last decade, we have extensively used Proper Orthogonal Decomposition (POD) and variants of this decomposition method (known also as Principal Component Analysis-PCA) for feature extraction. This method has enabled the discovery of coherent structures that dictate the dynamics of flow behind road vehicles, jet engines and wall bounded flows. However, typically a large number of POD/PCA modes is required to capture the dynamics of the inherently nonlinear flow. Nowadays, machine-learning algorithms offer a new paradigm for investigating complex systems. The POD, or linear PCA, can be formulated as a two-layer Neural Network (an autoencoder) with a linear activation function for its linearly weighted input, which can be trained by stochastic gradient descent. This formulation is an algorithmic alternative to linear eigenvalue/eigenvector problems in terms of NNs, and it offers a direct route to the nonlinear regime and deep learning by adding more layers and a nonlinear activation function on the network. In this project we will explore this novel framework in order to generate an optimal basis of modes to describe the flow dynamics.

Rigas, Georgios Dr

Project no: ***LRGR02***
Project title: Drag and flow instabilities in the wake of realistic car geometries

Supervisor: Rigas, Georgios Dr
Co-supervisor(s):
Category: Computational;Theoretical;Analysis
Software: FreeFem++

Confidential: No
Hydrodynamic instabilities in the wake of bluff-bodies (such as vortex shedding) are responsible for aerodynamic drag, structural fatigue and noise. We have demonstrated these instabilities computationally in simplified geometries with one or more homogeneous directions. In this study, we will apply recently developed numerical tools to fully three-dimensional geometries of industrial relevance to examine their hydrodynamic stability. Specifically, we will investigate the 3D bifurcations and instabilities occurring in the wake of the Ahmed body, a widely accepted benchmark geometry used in the automotive industry.

Rigas, Georgios Dr

Project no: ***LRGR03 ****
Project title: Reinforcement learning and behavioural flow control of road-vehicle aerodynamic
2 projects available

Supervisor: Rigas, Georgios Dr
Co-supervisor(s): Kerrigan, Eric Prof.
Category: Computational;Theoretical;Analysis
Software: Tensorflow

Confidential: No
Many high-performance street and F1 cars have recently added moving surfaces (moving spoilers and wings) for adjusting the downforce at various speed regimes. The position of the surface is determined for static conditions based on a look-up table. In this study, we will exploit modern data driven control techniques (reinforcement learning & behavioural control) for discovering optimal control laws and dynamically adapting the position of the control surfaces during attitude changes in the car (yaw, speed). The demonstration will be performed using simplified 2D Direct Numerical Simulations, and will guide the current wind tunnel experiments.
RL: https://arxiv.org/abs/1808.07664
Behavioral control: https://imarkovs.github.io/tutorial.pdf
Experiment: https://doi.org/10.1017/jfm.2016.495

Rigas, Georgios Dr

Project no: ***LRGR04 ****
Project title: Experimental reinforcement learning: application to road-vehicle flow control

Supervisor: Rigas, Georgios Dr
Co-supervisor(s): Kerrigan, Eric Prof.
Category: Experimental;Computational
Software:
Confidential: No

Many high-performance street and F1 cars have recently added moving surfaces (moving spoilers and wings) for adjusting the downforce at various speed regimes. The position of the surface is determined for static conditions based on a look-up table. In this study, we will exploit modern reinforcement learning algorithms for discovering optimal control laws and dynamically adapting the position of the control surfaces during attitude changes in the car (yaw, speed). For the first time, the demonstration will be performed using wind tunnel experiments.
RL: https://arxiv.org/abs/1808.07664
Behavioral control: https://imarkovs.github.io/tutorial.pdf
Experiment: https://doi.org/10.1017/jfm.2016.495

Robinson, Paul Prof.

Project no: ***LRPR01***
Project title: Investigating the behaviour of shape memory composites for deployable structure applications (S)

Supervisor: Robinson, Paul Prof.
Co-supervisor(s):
Category: Experimental: Structures
Software:
Confidential: No

An interleaved composites has been developed in the College which can exhibit controllable flexural stiffness and shape memory capability. This material may find uses in deployable, collapsible and morphing / adaptive shape structures. This project will devise, manufacture and investigate simple deployable configurations and will investigate whether it is possible to 'retrain' a configuration to adopt a different memorised shape.

Robinson, Paul Prof.

Project no: ***LRPR02***
Project title: Experimental investigation of new concepts for ductile composites

Supervisor: Robinson, Paul Prof.
Co-supervisor(s):
Category: Experimental: Structures
Software:
Confidential: No

High performance lightweight composites, such as carbon fibre reinforced polymers, usually exhibit very little ductility before failure. A recent large research project at Imperial and Bristol University has been developing new composite systems which exhibit significant ductility. The concepts include discontinuous fibres and laminae, new fibre architectures including hybrid fibre systems and new fibre types. In this project the student will manufacture and experimentally characterise the mechanical performance of one of the new composite systems that has been developed and investigate the effect of the ductility in the presence of a stress concentration.

Robinson, Paul Prof.

Project no: ***LRPR03***
Project title: Test method development and evaluation for polymer shear stress-strain characterisation

Supervisor: Robinson, Paul Prof.
Co-supervisor(s):
Category: Experimental: Structures
Software:
Confidential: No

The shear stress-strain behaviour of polymers plays a key role in the behaviour of fibre reinforced polymer composites. A characterisation technique has already been devised in which a circular section tube made of the polymer is subjected to torsion loading. This test gives the shear stress-strain response of the bulk polymer. However, the thickness of the polymer between the fibres of a composite can be very thin and so this FYP will design a test to measure the stress-strain responses of thin polymer layers and compare these to the bulk response.

Robinson, Paul Prof.

Project no: ***LRPR04 ****
Project title: Investigation of an interleaved strategy for easy repair of impact damage in composites

Supervisor: Robinson, Paul Prof.
Co-supervisor(s):
Category: Experimental: Structures
Software:
Confidential: No

Impact damage in a laminated composite often consists of interlaminar fracture between the laminae and repair of this damage usually involves removal of the damaged material by machining and adhesive bonding of a repair patch. Recent work at Imperial has explored an easy repair concept in which a thermoplastic interleaf is added to the composite to provide a repairable 'weak link'. The properties of the interleaf are chosen such that on impact the damage occurs preferentially within the interleaf. The composite can then be heated and the damage repaired. This project will perform further experimental investigations to help develop and assess this easy repair concept.

Robinson, Paul Prof.

Project no: ***LRPR05***
Project title: Finite element investigation of strategies for improving the resistance of laminated composites to delamination

Supervisor: Robinson, Paul Prof.
Co-supervisor(s):
Category: Computational
Software: Abaqus

Confidential: No

Laminated polymer matrix composites are susceptible to delamination (i.e. crack growth between the laminae). In this project strategies to improve the resistance to delamination will be investigated using finite element modelling. For example, some composites possess a high resistance to delamination because they develop a considerable amount of fibres which bridge between the delaminated surfaces in the wake of the crack tip. FE modeling will be used to investigate methods for modifying the composite to ensure that extensive fibre bridging will occur in the event of a delamination.

Robinson, Paul Prof.

Project no: ***LRPR06***
Project title: Experimental investigation of strategies for improving the resistance of laminated composites to delamination

Supervisor: Robinson, Paul Prof.
Co-supervisor(s):
Category: Experimental: Structures
Software:
Confidential: No

Laminated polymer matrix composites are susceptible to delamination (i.e. crack growth between the laminae). In this project strategies to improve the resistance to delamination will be investigated experimentally. For example, some composites possess a high resistance to delamination because they develop a considerable amount of fibres which bridge between the delaminated surfaces in the wake of the crack tip. This experimental study will investigate methods for modifying the composite to ensure that extensive fibre bridging will occur in the event of a delamination.

Santer, Matthew Prof

Project no: ***LRMS01 ****
Project title: Aero-thermo-structural optimization of integrated TPS for hypersonic vehicles (S) · projects available

Supervisor: Santer, Matthew Prof
Co-supervisor(s):
Category: Computational
Software: Python

Confidential: No
Integrated thermal protection systems (ITPS) have both insulating and structural characteristics. This project will analyse and optimize the thermo-structural behaviour of next-generation hypersonic vehicles in relevant trajectories to determine optimal ITPS configurations and determine novel architectures. The analysis will be based on an in-house design and optimization framework built on the open-source finite element solver Fenicx. A familiarity with coding in python and the Linux operating system will be very helpful for this project.

Santer, Matthew Prof

Project no: ***LRMS02 ****
Project title: Modelling tape spring behaviour using advanced finite elements (S)

Supervisor: Santer, Matthew Prof
Co-supervisor(s):
Category: Computational
Software: Abaqus; python

Confidential: No
Tape springs are thin curved shells which are used as self-deploying hinges in space applications. They are mechanically complex and when they are subject to bending exhibit a highly nonlinear response which is challenging to model numerically. Conventionally they are modelled using shell elements, but this is numerically inefficient and additionally fails to capture import details of the buckling behaviour. This project will explore the use of unified beam elements based on the Carreira formulation to model the response in the Abaqus commercial FE solver. These will be implemented as user defined elements coded within the Abaqus framework.

Santer, Matthew Prof

Project no: ***LRMS03 ****

Project title: Development of a tabletop gravity offload rig (S)

Supervisor: Santer, Matthew Prof
Co-supervisor(s):
Category: Experimental;Design
Software:
Confidential: No

Testing deployable structures on Earth can be challenging as they are typically designed to operate in a zero-g environment. To address this gravity forces are (approximately) cancelled out via a gravity offload device. For deployable structures designed for very small spacecraft such as CubeSats the challenges of gravity offload are even greater as low inertial forces during deployment can be insufficient to overcome the friction inherent in typical gravity offload devices. The experimental project will consist of the design, manufacture and validation of a gravity offload deployment rig for a small deployable solar array. Validation will be carried out with the Abaqus commercial finite element package.

Santer, Matthew Prof

Project no: ***LRMS04 ****
Project title: Analysis of multistable tetrahedra (S)

Supervisor: Santer, Matthew Prof
Co-supervisor(s):
Category: Computational
Software: Abaqus

Confidential: No

In the field of digital robotics, continuous motion is approximated by a large number of discrete steps. A bistable structure is one which has two distinct energy minima corresponding to different geometric configurations. If n bistable structures are connected correctly then a structure with 2n discrete stable configurations can be generated. In this project a bistable structure consisting of coupled linear and nonlinear springs — called a bistable tetrahedron — will be analysed using the Abaqus commercial finite element package. A parametric investigation will be carried out to determine optimal design configurations and, when the single bistable unit is well understood, how to connect multiple tetrahedra to result in highly reconfigurable adaptive structures.

Santer, Matthew Prof

Project no: ***LRMS05 ****
Project title: Membrane-substrate buckling for flow control

Supervisor: Santer, Matthew Prof
Co-supervisor(s):
Category: Computational

Software: python

Confidential: No

When a relatively stiff thin membrane is attached to a relatively compliant thick substrate and subjected to compression un unexpected phenomenon occurs. Depending on the specific geometry, stiffness and loading a range of different and complex patterns spontaneously form in the membrane surface. This has application as a means of precisely controlling aerodynamic roughness which can be switched repeated on and off. In this project the open source python-based finite element solver fenics will be used to analyse this behaviour. In addition optimization will be carried out to determine the configurations necessary to achieve a precise desired surface deformation. A familiarity with coding in python and the Linux operating system will be very helpful for this project.

Seifikar, Masoud Dr

Project no: ***LRMSE01 ****

Project title: Investigation of Piezoelectric Materials for Health Monitoring, Sensors, and Energy Harvesting in Aerospace Applications - 2 projects available

Supervisor: Seifikar, Masoud Dr

Co-supervisor(s):

Category: Computational;Theoretical

Software: ABAQUS, MATLAB

Confidential: No

Piezoelectric materials generate an electrical charge when subjected to mechanical stress, making them useful in various applications, including in the field of aeronautics. In recent years, piezoelectric materials have played a vital role in the aerospace industry, particularly in health monitoring, sensors, and energy harvesting. The objective of this project is to investigate the potential use of piezoelectric materials in these applications and explore effective methodologies for simulating and analysing their electrical and structural properties.

The project will employ the finite element method to make precise numerical models of piezoelectric materials when dielectric, piezoelectric, and mechanical properties are known. We will investigate the static and dynamic responses of piezoelectric material using commercially available finite element software ABAQUS. The project will also design and test various types of sensors, specifically tailored to meet the requirements of the aerospace industry. We will evaluate the performance of these sensors and optimize their design for maximum efficiency. Furthermore, we will explore energy harvesting techniques and investigate how piezoelectric materials can be used to harvest energy from ambient sources. We will compare and evaluate various harvesting techniques to determine the most efficient and cost-effective methods.

Shamsuddin, Siti Rosminah Dr

Project no: ***LRSRS01 ****

Project title: Shear properties of thermoplastic PES interleaved carbon fibre reinforced thermosetting composites - 2 projects available

Supervisor: Shamsuddin, Siti Rosminah Dr
Co-supervisor(s):
Category: Experimental: Manufacturing intensive;Analysis
Software:
Confidential: No

Polyethylsulfone (PES) is an amorphous engineering thermoplastic with high Tg and relatively good service temperature. It possesses high resistant to heat, impact, creep, fire and hot water and has been used widely in automotive industries as well as in electrical/electronic applications. PES is also compatible with epoxies which makes it an excellent choice of material to be used as toughening agent in composites. Interleaving thermosetting composites with thermoplastics have been studied previously but using PES as interleaving material is still in its infancy. This is an experimental project where the aim is to manufacture interleaved composites having various thickness of PES and investigate the composite's shear properties.

Shamsuddin, Siti Rosminah Dr

Project no: ***LRSRS02 ****
Project title: Toughened Epoxy composites with carbon-based inclusions - 2 projects available

Supervisor: Shamsuddin, Siti Rosminah Dr
Co-supervisor(s):
Category: Experimental: Manufacturing intensive;Theoretical;Design;Analysis
Software:
Confidential: No

Carbon inclusions such as carbon nanotube, graphene or graphite flakes can improve material's electrical and mechanical properties. Epoxy matrices on the other hand are intrinsically brittle and causes catastrophic failure. To improve the brittleness of the epoxy matrix, thermoplastic PES having a relatively high Tg can be added at a controlled loading fraction which is very compatible with epoxy. The project is divided into two sections, the first is to investigate the best method of adding PES into epoxy that provides the best toughening properties and then different loading fractions of carbon inclusions will be added to reinforce the toughened epoxy. Theoretical calculations based on discontinued reinforcement in composites will be carried out and compared to the experimental results.

Shamsuddin, Siti Rosminah Dr

Project no: ***LRSRS03 ****
Project title: Mechanical properties of polyethersulfone (PES) Interleaved CFRP

Supervisor: Shamsuddin, Siti Rosminah Dr
Co-supervisor(s):

Category: Experimental: Manufacturing intensive;Design;Analysis
Software:
Confidential: No

Carbon fibre composite is an attractive material owing to its excellent mechanical properties especially with its specific strength and stiffness, but they can exhibit poor performance due to impact damage. This project involves manufacturing of PES interleaved composites with different fibre orientations and investigating their mechanical properties to compare them to non-interleaved composites.

Shamsuddin, Siti Rosminah Dr

Project no: ***LRSRS04 ****
Project title: Creep/recovery and stress relaxation of carbon fibre reinforced epoxy with thermoplastic Interleaving

Supervisor: Shamsuddin, Siti Rosminah Dr
Co-supervisor(s):
Category: Experimental: Manufacturing intensive;Theoretical;Analysis
Software:
Confidential: No

Composites offer advanced design possibilities, improved safety and extended service life with respect to its resistance to corrosion as well as reduced through-life cost. Thermoset-based polymer composites have dominated the market since 1960, but the intrinsic brittleness of the matrix makes the composite susceptible to catastrophic failure. This study is aimed at manufacturing carbon fibre reinforced epoxy with various thermoplastic interleaving and the viscoelastic properties of the resultant composite will be analysed and compared to theoretical values.

Sherwin, Spencer Prof.

Project no: ***LRSS01***
Project title: Computational fluid dynamics using spectral/hp element methods (S) - 3 projects available

Supervisor: Sherwin, Spencer Prof.
Co-supervisor(s):
Category: Computational;Analysis;Numerical
Software: Nektar++
VisIt or Paraview

Confidential: No

Projects are available in the development and application of high order finite element methods known as spectral/hp element discretisations. These project will be based around the library, Nektar++, details of which can be found under (www.nektar.info). The primary focus of the projects will be the development and/or application of these techniques to incompressible and compressible flow problems similar to those shown under www.nektar.info. Although there are no specific prerequisites for the projects priority will be given to students with computing and coding skills.

Sherwin, Spencer Prof.

Project no: ***LRSS02***
Project title: Software Engineering in open source CFD package Nektar++

Supervisor: Sherwin, Spencer Prof.
Co-supervisor(s):
Category: Computational;Numerical
Software: Nektar++
Paraview/VisIt
Confidential: No

Software engineering is an integral part of any computational package. For example, to improve the robustness and flexibility of the Nektar++ (www.nektar.info) flow solver and to help provide an easier way to understand the fundamentals of the spectral/hp element methods we have been developing a python interface. We also maintain a Continual Integration environments within gitlab (gitlab.nektar.info) which helps us ensure that previous developments are robust with respect to new developments. However we do not currently have a performance monitoring framework. This project is therefore focussed on the software engineering aspects of the code development and can be tailored depending on mutual discussion on your interests and the needs of the project.

Sherwin, Spencer Prof.

Project no: ***LRSS04***
Project title: Machine Learning for Inflow Turbulence in Boundary Layer

Supervisor: Sherwin, Spencer Prof.
Co-supervisor(s): Yuri Frei (Rolls Royce), Montomoli, Francesco Prof.
Category: Numerical, Computational
Software: Nektar++, Python

Confidential: No

Machine learning is playing a major role speeding up computational fluid dynamics simulation. The current project will investigate how to use ML to have correlated inflow fluctuations for BL simulations. The CFD solver Nektar++ will be used for simulations, while Tensorflow will be used for the ML framework. The project is offered jointly with Rolls Royce.

Steiros, Kostas Dr

Project no: ***LRKS01 ****

Project title: Wind Farm simulation using FLORIS and stability analysis of the farm wake

Supervisor: Steiros, Kostas Dr
Co-supervisor(s):
Category: Computational;Theoretical
Software: FLORIS (open source)Matlab

Confidential: No
Wind farms are becoming larger, clustered, and prone to ``steal the wind" from each other. Farm-to-farm interactions are thus expected to become a major challenge in the expanding wind industry. For example, the region northeast of the strait of Dover will become particularly clustered by 2050, with multiple farm-arrays belonging to UK, France and Belgium in close proximity. Unfortunately, there is very little knowledge on the dynamics of wind farms - their flow physics remain a big unknown.
This project will aim to simulate the average flow field inside and around a wind farm using the open source software FLORIS. Particular focus will be placed on the wake of the farm, and the instabilities that can be developed there. The latter will be investigated using local linear instability analysis of the mean flow.

Steiros, Kostas Dr

Project no: ***LRKS02 ****
Project title: A new model for high loaded wind turbines

Supervisor: Steiros, Kostas Dr
Co-supervisor(s): Gouder, Kevin Dr
Category: Experimental;Design
Software:
Confidential: No
The rapid growth of the wind and tidal energy sectors require a better modelling of the wind/tidal turbine aerodynamics. These are conventionally modeled using the Blade Element Momentum theory, which is valid only for low turbine loading, i.e. turbines that have a very small number of blades and spin relatively slowly. For higher loadings, the empirical "Glauert's correction" is used. The latter, however, is based on experimental data from over a century ago which are notoriously inaccurate.
In this project, the student will 3D print several highly-loaded wind turbine hubs, and will install them on a dedicated (already existing) experimental rig. Their thrust and torque will then be monitored using a force transducer. The results will be used to derive a novel high-loaded turbine correction, that has the potential to alter the BEM modelling procedures currently employed in the wind and tidal energy industry.

Steiros, Kostas Dr

Project no: ***LRKS03 ****

Project title: Drone Aerodynamics

Supervisor: Steiros, Kostas Dr
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

The agility of multi-rotor drones renders them ideal candidates for applications which require difficult manoeuvres, allowing swift alterations between cruise and vertical flight. Such abrupt manoeuvres however generate intense transient aerodynamic phenomena that may compromise the integrity, stability and endurance of drones. These phenomena are poorly understood and have only now started to become the focus of academic research.
In this project, the student will place a drone in the T1 wind tunnel, and will control it appropriately so that it performs repeatable manoeuvres. Its flow field will be documented using Particle Image Velocimetry. Advanced post processing methods will be used in order to capture the coherent structures emanating from the drone during its unsteady motion. These will be linked to power fluctuations.

Steiros, Kostas Dr

Project no: ***LRKS04 ****
Project title: Periodic gusts on buildings

Supervisor: Steiros, Kostas Dr
Co-supervisor(s): Gouder, Kevin Dr
Category: Experimental; Design
Software:
Confidential: No

A major challenge of wind engineering is predicting the flow response after a gust has occurred. Periodic gusts cause the vortex shedding downstream buildings to become "phase locked". If this locking occurs at a resonance frequency, this can lead to detrimental fatigue. Unfortunately, periodic gusts are very hard to simulate experimentally, as conventional wind tunnels only produce steady and uniform inflows.
To resolve this issue, the 20'' wind tunnel of the Department has been recently renovated to house a unique gust generator. In this project the student will do some further design work to improve the gust quality, i.e. by installing an optical encoder and controlling the rotational frequency of the generator. Subsequently, the student will test a building replica. In particular, the phase-locking effect of the vortex shedding will be tested using hot wire anemometry, and the unsteady loads using a force transducer.

Steiros, Kostas Dr

Project no: ***LRKS05 ****

Project title: Fluid structure interaction of oscillating plate, with application to turbofan vibrations

Supervisor: Steiros, Kostas Dr
Co-supervisor(s):
Category: Experimental;Design
Software:
Confidential: No

Turbofan propellers suffer from intense vibrations which can lead to flutter and failure. Conventionally, these vibrations are modeled using Theodorsen's unsteady theory, i.e. the blade performs small oscillations and the resulting flow field is then monitored to ascertain whether the system is unstable. However, the above approach treats the oscillation as forced, rather than driven, i.e. energy is inserted into the fluid rather than removed from it. As a result, important phenomena that would otherwise arise due to the flow-structure interaction, are neglected. This method therefore presents severe flaws and needs to be revised.

In this project, the student will design and build an oscillating plate experiment in the Aeronautics flume. The plate will vibrate due to the flow, and its amplitude will be controlled via a torsion spring. The flow field will be monitored via high speed particle image velocimetry. The aim will be to discover which of the flow physics are neglected in the Theodorsen theory approach, currently employed by big aircraft engine manufacturers.

This project will be overlooked and receive input from experts in Safran.

Tagarielli, Vito Dr

Project no: ***LRVT01****
Project title: Hydrocarbon deflagration inside a spherical deformable shell: a theoretical, numerical and experimental study - 2 projects available
Supervisor: Tagarielli, Vito Dr
Co-supervisor(s):
Category: Experimental; Theoretical; Numerical
Software:
Confidential: No

Please be advised that the project requires enthusiasm, preparatory work since the beginning of the academic year (and full-time during the project period), constant physical presence in the department, and a strong motivation to learn and apply the scientific method. The ideal student is one whose passion for science outweighs the worries about project marks, confident to be able to learn advanced topics quickly and eager make contributions to science at PhD-level. Please discuss informally with the supervisor before selecting this project.

Consider a mixture of air and a hydrocarbon, for example hydrogen, contained at a certain pressure in an elastic balloon of given diameter, surrounded by atmospheric air. At t=0, a spark at the centre of the balloon ignites the gas. We want to determine the compete pressure, velocity and temperature fields inside and outside the balloon, as well as the position of the rubber membrane, as a function of time. The problem is 1-dimensional as everything depends only on the radial position and time. Depending on how many students are allocated this project, activities will be predominantly experimental or

theoretical/numerical, but you should expect a mixture of both. Existing research papers by my group will serve as training.
We shall write an analytical model for this problem and implement it numerically. We will conduct experiments reproducing this problem in a lab environment and measuring the flame speed and balloon diameter via high speed photography, and the pressure history at selected points.
The project will particularly suit a student who is confident to be able to tackle the theoretical predictions quickly, comfortable with maths and CFD, able to safely play with equipment and fire in a lab environment.

Tagarielli, Vito Dr

Project no: ***LRVT02****
Project title: Fracture mechanics of UD fibre composites - 2 projects available
Supervisor: Tagarielli, Vito Dr
Co-supervisor(s):
Category: Experimental; Theoretical; Numerical
Software: Abaqus
Confidential: Yes

Please be advised that the project requires enthusiasm, preparatory work since the beginning of the academic year (and full-time during the project period), constant physical presence in the department, and a strong motivation to learn and apply the scientific method. The ideal student is one whose passion for science outweighs the worries about project marks, confident to be able to learn advanced topics quickly and eager make contributions to science at PhD-level. Please discuss informally with the supervisor before selecting this project.
My group has recently achieved conducting Mode I fracture tests on UD composites loaded in the fibre directions, using a bespoke apparatus well documented by previous publications. We shall conduct extensive mechanical testing on composite specimens and accompanying analyses of the fracture problem. Depending on how many students are allocated this project, activities will be predominantly experimental or theoretical/numerical, but you should expect a mixture of both. Existing research papers by my group will serve as training; a PhD student will also offer lab support.
We measure the fracture toughness of UD composites in Mode I and mixed modes, explore the effects of factors such as strain rate, size and temperatures, and analyse the problem via Abaqus FE simulations and accompanying theoretical analyses.
The project will particularly suit a student who is confident to be able to understand advanced fracture mechanics, comfortable with maths and software, able to safely play with delicate equipment in a lab environment.

Tagarielli, Vito Dr

Project no: ***LRVT03****
Project title: Applications of machine learning to the mechanics of solids (and possibly fluids) - 3 projects available
Supervisor: Tagarielli, Vito Dr
Co-supervisor(s):
Category: Theoretical; Numerical

Software: Python (all 3 projects), Abaqus (for 1 project only)
Confidential: Yes

Please be advised that the project requires enthusiasm, preparatory work since the beginning of the academic year (and full-time during the project period), and a strong motivation to learn and apply the scientific method. The ideal student is one whose passion for science outweighs the worries about project marks, confident to be able to learn advanced topics quickly and eager make contributions to science at PhD-level. Please discuss informally with the supervisor before selecting this project.

My group has now been active for years at the forefront of advanced applications of machine learning to constitutive modelling of solids and to the mechanics of fluids in explosion/combustion events. We have produced several publications (some yet to appear) which will serve as a basis for your training. If a student from the MSc in composites picks this project, we will apply techniques similar to those we have previously published to data generated via FE simulations in Abaqus; about half the student's time will be devoted to conducting these simulations, the rest will be spent on applications of machine learning. For this composites MSc student, a good understanding of mechanics of solids, composites, homogenisation, and the FE method will be welcome. For students from other cohorts, the focus will be on machine learning only. Large datasets will be provided, obtained from previously conducted numerical analyses or directly from special measurements of the response of selected materials of interest. The students will focus on applications of advanced machine learning techniques to preform classifications, regressions, dimensionality reduction and autoencoding, then used to construct constitutive models of high accuracy and negligible computational cost. Some previous hands-on experience in machine learning will obviously be an advantage, but it is not strictly required and lack of experience can be compensated by a strong record of success in maths and coding, and a strong motivation to pick up machine learning and data analytics skills. PhD students will offer additional support to the enthusiastic guidance of the project's supervisor. The objective is to quickly publish strong papers in leading journals (which typically translates in project marks above 85%).

Tagarielli, Vito Dr

Project no: ***LRVT04****
Project title: Development of advanced stiffness-sensing mechanical tests
Supervisor: Tagarielli, Vito Dr
Co-supervisor(s):
Category: Experimental; Theoretical; Numerical
Software:
Confidential: No

Please be advised that the project requires enthusiasm, preparatory work since the beginning of the academic year (and full-time during the project period), constant physical presence in the department, and a strong motivation to learn and apply the scientific method. The ideal student is one whose passion for science outweighs the worries about project marks, confident to be able to learn advanced topics quickly and eager make contributions to science at PhD-level. Please discuss informally with the supervisor before selecting this project.

We will perform a new class of instrumented mechanical tests, namely multiaxial, non-monotonic, non-proportional tension/compression-torsion experiments on specimens made from a selected material, while simultaneously measuring the material's conductivity during the test. The objective if to create datasets describing the material's response, to then be fed to artificial intelligence to develop constitutive descriptions of the material without the need of any theoretical assumptions on

their behaviour. My group has substantial experience in the field and several publications exist to aid your training. A PhD student will be involved and provide hands-on help in the lab. The planned experiments are difficult and have never been conducted before, therefore the focus of the projects will be on those. Time permitting, some machine learning techniques could be applied to the data produced.
The project will particularly suit a student who is methodical, calm and competent, with a good understanding of mechanics, stress analysis, plasticity and fracture.

Venetsanos, Demetrios Dr

Project no: ***LRDV01 ****
Project title: A.I.-driven Topology Optimisation of variable thickness sheets - 2 projects available

Supervisor: Venetsanos, Demetrios Dr
Co-supervisor(s):
Category: Computational;Theoretical;Numerical
Software: Matlab

Confidential: No
Topology Optimization (TO) concerns the optimum distribution of matter within a design space, so that a predefined objective obtains an extreme value, and all the imposed constraints are fulfilled. Due to its nature, (TO) is of primary importance in the design of lightweight structural components, as those found in the aerospace and automotive industry.
One of the most popular (TO) problem statements is that of minimizing the compliance of a structure under a volume constraint. For the solution of this well-posed problem, numerous approaches have been proposed in the literature. Among others, the most popular approaches are the SIMP (Solid Isotropic Material with Penalization) method, the SERA (Sequential Element Rejection and Admission) procedure and the BESO (Bidirectional Evolutionary Structural Optimization) approach.
The present projects concern the (TO) problem where an upper bounded variable elemental thickness distribution is sought, so that the compliance is minimized under a single volume constraint.
Nowadays, Additive Manufacturing processes allow for the manufacturing of Variable Thickness Topologies, hence the rationale of revisiting the well-known concept of variable thickness.
In total, five typical planar benchmark problems, retrieved from the literature, will be analysed, namely: (i) MBB beam (half model due to symmetry); (ii) short cantilever; (iii) long cantilever; (iv) cantilever beam with a fixed hole; and (v) the Zhou-Rozvany tie-beam.
For the FE analyses required, a Matlab code will be provided.
For the optimisation, functions from Matlab toolboxes will be utilised. For comparison, codes available in the literature, for the methods SIMP, SERA and BESO, will be used.
References
Xia, L., Xia, Q., Huang, X. et al. (2018) Bi-directional Evolutionary Structural Optimization on Advanced Structures and Materials: A Comprehensive Review. Arch Computat Methods Eng 25, 437–478. DOI: 10.1007/s11831-016-9203-2

Ansola Loyola, R., Querin, O.M., Garaigordobil Jiménez, A. et al. (2018) A sequential element rejection and admission (SERA) topology optimization code written in Matlab. Struct Multidisc Optim 58, 1297–1310. DOI: 10.1007/s00158-018-1939-x.
Sigmund, O. (2001) A 99 line topology optimization code written in Matlab. Struct Multidisc Optim 21, 120–127. DOI: 10.1007/s001580050176.

Venetsanos, Demetrios Dr

Project no: ***LRDV02 ****
Project title: Machine Learning-powered optimum design of functionally graded lattice structures under quasi-static loading - 3 projects available

Supervisor: Venetsanos, Demetrios Dr
Co-supervisor(s):
Category: Computational;Numerical;Theoretical
Software: Abaqus or Ansys Workbench or any other available industry-based CAE softwareMatlab

Confidential: No
Additive Manufacturing, and 3D-printing in particular, has significantly simplified the manufacturing of complex geometries. Of particular interest are the so-called “lattice structures”, which can be developed by repeating one (or more) unit cell, along any axis and with no gaps between cells. The requirement is that the unit cell is formed only of slender members. When optimised, lattice structures can combine reduced structural weight and increased structural performance. Such characteristics are essential in the design of components for the needs of the aerospace and the automotive industry.
In more advanced designs, a lattice may be formed of cells with varying geometric characteristics (e.g. diameter of slender members, height of unit cell, etc), or even material properties (e.g. modulus of elasticity), along a direction and at a specific rate of change. Such configurations are called “Functionally Graded Structures”.
The aim of this set of projects is to reveal the effect of functionally graded characteristics on the response of a lattice structure under a given loading, which is imposed in a quasi-static manner. Understanding this effect can allow for the optimum design of functionally graded lattices.
To quantify the response of a lattice structure, typical metrics will be used such as the Total Absorbed Energy (TEA), the Specific Absorbed Energy (TEA), the Peak and Average Crushing Force, and the Crushing Force Efficiency.
For the computational part of the project, an industry-standard CAE software (e.g. Abaqus, Ansys Workbench, or alike) will be used. For the optimisation, functions available within the Matlab optimisation toolboxes will be utilised.
It is clarified that the designs to be studied will concern typical examples of 3-point and 4-point bending, retrieved from the literature (e.g. MBB beam).
References
Nian, Y. et al. (2021) Energy absorption characteristics of functionally graded polymer-based lattice structures filled aluminum tubes under transverse impact loading. Materials & Design, vol. 209, 110011, ISSN 0264-1275. DOI: 10.1016/j.matdes.2021.110011.

Bai, L., et al. (2020) Mechanical properties and energy absorption capabilities of functionally graded lattice structures: Experiments and simulations. International Journal of Mechanical Sciences, vol.182, 105735, ISSN 0020-7403. DOI: 10.1016/j.ijmecsci.2020.105735.
Maskery I, Hussey A, Panesar A, et al. (2017) An investigation into reinforced and functionally graded lattice structures. Journal of Cellular Plastics. Vol. 53(2):151-165. DOI:10.1177/0021955X16639035

Venetsanos, Demetrios Dr

Project no: ***LRDV03 ****

Project title: Effect of size and geometric tolerances in the mechanical performance of additive manufactured strut-based lattice structures - 2 projects available

Supervisor: Venetsanos, Demetrios Dr

Co-supervisor(s):

Category: Computational; Experimental

Software: Abaqus or Ansys Workbench or any available industry-standard CAE software

Confidential: No

A lattice structure is a space-filling unit cell that can be tessellated along any axis with no gaps between cells. These structures are of primary importance in aerospace engineering, as they can combine, in an optimum manner, weight, energy and advanced manufacturing time reduction.
The aim of this set of projects is to investigate the effect of size and geometric tolerances on the mechanical performance of additively manufactured strut-based lattice structures. To this end, lattice unit cells, such as (but not limited to) body-centred cubic (BCC), face-centred cubic (FCC), simple cubic, and Kelvin unit, will be considered, and their mechanical response will be simulated (using industry-standard CAE software) under typical load cases and various tolerances. In this manner, the difference in the mechanical response between the “as designed” and the “as printed” unit cells will be quantified.
Having accomplished this task, a small number of literature examples (e.g. MBB beam) will be studied using an industry-standard CAE software (such as Abaqus, Ansys Workbench or alike), where deviations from the “as designed” structure, and within given tolerances, will randomly be distributed over the design space. Typical (theoretical) distributions from Statistics will be used. For the validation of the so-formed Finite Element models, data from the literature will be used, while some experimental measurements may be taken, provided that the required laboratory resources will be available.
Due to the multi-variable nature of the lattice structures, it is possible to form a set of projects, which have sufficient commonality for students to form a mini working group but, at the same time, sufficient differentiation to justify the individuality of each project.
This set of projects is within an on-going collaboration with the National Technical University of Athens (Greece) - Section of Manufacturing Technology.
References
Li, D., Qin, R., Chen, B., Zhou, J. (2021) Analysis of mechanical properties of lattice structures with stochastic geometric defects in additive manufacturing. Materials Science and Engineering: A, vol. 822, 141666, ISSN 0921-5093. DOI: 10.1016/j.msea.2021.141666.

Cao., X., et al. (2020) Compression experiment and numerical evaluation on mechanical responses of the lattice structures with stochastic geometric defects originated from additive-manufacturing. Composites Part B: Engineering, vol. 194, 108030, ISSN 1359-8368; DOI:10.1016/j.compositesb.2020.108030.
Lozanovski, B., et al. (2019) Computational modelling of strut defects in SLM manufactured lattice structures. Materials & Design, vol.171, 107671, ISSN 0264-1275. DOI: 10.1016/j.matdes.2019.107671

Venetsanos, Demetrios Dr

Project no: ***LRDV04 ****
Project title: Crashworthiness of thin-walled tubular structures with non-uniform stiffeners - 4 projects available

Supervisor: Venetsanos, Demetrios Dr
Co-supervisor(s):
Category: Computational;Theoretical
Software: Abaqus or Ansys Workbench or LS-Dyna oranother equivalent industry-standard CAE softwareMatlab

Confidential: No

For the emerging electric Vertical Take-Off and Landing (eVTOL) vehicle industry, there is a need for crash mitigation systems, which will be able to attenuate impact energy during a crash, and, thus, protect passengers. One solution is to introduce impact attenuators, in the form of tubular structures attached underneath the passenger seats. For given specifications (as described e.g. by the Federal Aviation Administration), the buckling (i.e. telescopic collapse) of such components can provide an acceptable occupant injury risk.
Impact attenuators in the form of thin-walled tubular configurations can be unitubular, bitubular or multitibular, with constant or variable wall thickness, with longitudinal and/or circumferential stiffeners, of constant or variable profile. Also, the imposed impact load can be axial or oblique.
The aim of this set of projects is twofold: firstly, to explore the effect of design parameters on the crashworthiness of various tubular configurations under different impact loads, and, secondly, to suggest such configurations with improved (optimised) performance.
It is assumed that the tubular configurations are manufactured using an Additive Manufacturing process (e.g. 3D-printing), thus the stiffeners will, seamlessly and simultaneously, be manufactured along with the main body of the configurations (i.e. the stiffeners will not be added at a later stage as external components).
The novelty of this study is the introduction of “non-uniform stiffeners” and implies that the cross-section of each stiffener may vary in the longitudinal (circumferential) direction. In this manner, it is possible to introduce trigger points and, when an impact load is applied, achieve a controllable telescopic collapse.
To measure the said crashworthiness, typical metrics will be used, e.g. Total Absorbed Energy (TEA), Specific Absorbed Energy (TEA), Peak and Average Crushing Force, Peak and Average Acceleration, Crushing Force Efficiency, etc.
For the FE analyses required, an industry-standard CAE software (e.g. Abaqus, Ansys Workbench, LS-Dyna) will be used.

For the optimisation, it is possible to use a scheme found in one of the Matlab Optimisation toolboxes, to include Artificial Intelligence-powered approaches. Alternatively, a Taguchi approach may be utilised.
For the description of the non-uniform stiffeners, it is possible to use splines or similar geometric entities.
Due to the multi-variable nature of the design, it is possible to form a set of projects, which have sufficient commonality for students to form a mini working group but, at the same time, sufficient differentiation to justify the individuality of each project.
Upon availability of the necessary testing equipment, it would be possible to run some experimental testing.
References
Littell, J. D. (2019) Challenges in Vehicle Safety and Occupant Protection for Autonomous electric Vertical Take-off and Landing (eVTOL) Vehicles. AIAA/IEEE Electric Aircraft Technologies Symposium (EATS), pp. 1-16. DOI: 10.2514/6.2019-4504.
Mohamed, M.N., Kumar, A.P. (2017) New Insight to Improve Energy Absorption Characteristics of Long Circular Tubes with Stiffeners as Controllable Energy-dissipating Devices. Procedia Engineering, Vol. 173, pp. 1399-1406, ISSN 1877-7058. DOI: 10.1016/j.proeng.2016.12.199.
Federal Register. “Special Conditions: Airbus A350-900 Airplane; Crashworthiness, Emergency Landing Conditions.” Vol 79. No. 43. Friday July 25, 2014.
Song, J., Xu, S., Zhou, J., Huang. H., Zou, M. (2021) Experiment and numerical simulation study on the bionic tubes with gradient thickness under oblique loading. Thin-Walled Structures, vol.163, 107624, ISSN 0263-8231; doi: 10.1016/j.tws.2021.107624.
Nikkhah, H., Baroutaji, A., Kazancı, Z., Arjunan, A. (2020) Evaluation of crushing and energy absorption characteristics of bio-inspired nested structures. Thin-Walled Structures, vol. 148, 106615, ISSN 0263-8231; doi: 10.1016/j.tws.2020.106615.
Tran, T. & Baroutaji, A. (2018) Crashworthiness optimal design of multi-cell triangular tubes under axial and oblique impact loading. Engineering Failure Analysis, vol. 93, pp. 241-256, ISSN 1350-6307; doi: 10.1016/j.engfailanal.2018.07.003.
Abramowicz, W., & Jones, N. (1984). Dynamic axial crushing of circular tubes. International Journal of Impact Engineering, 2(3), 263–281. DOI: 10.1016/0734-743X(84)90010-1.

Vincent, Peter Prof.

Project no: ***LRPV01***
Project title: Investigating Flow over Martian Helicopter Rotor Blades using PyFR (S)

Supervisor: Vincent, Peter Prof.
Co-supervisor(s):
Category: Computational
Software: PyFR

Confidential: No
This project will involve using PyFR (www.pyfr.org) to simulate and analyse flow over novel aerofoil profiles for Martian rotorcraft blades. The project will build on work published in https://arc.aiaa.org/doi/10.2514/1.J061454. The student should have a strong mathematics and

coding background, and a passion for computational fluid dynamics. This project will run in coordination with a sister project, supervised by Prof. Oliver Buxton, that will develop experimental capabilities for Martian rotorcraft aerofoils.

Vincent, Peter Prof.

Project no: ***LRPV02 ****
Project title: Characterising Synthetic Turbulence

Supervisor: Vincent, Peter Prof.
Co-supervisor(s):
Category: Computational;Numerical;Theoretical
Software: PyFR

Confidential: No

The project will involve applying a new synthetic eddy turbulence injection approach that has been implemented in PyFR (www.pyfr.org), and formally characterising the properties of the turbulence that is produced, with a focus on determining the length scales of the turbulence, and the rate at which it delcays with distance from the injection site. The project will build on work in https://arc.aiaa.org/doi/abs/10.2514/1.J061046. The student should have a strong mathematics and coding background, and a passion for computational fluid dynamics.

Vincent, Peter Prof.

Project no: ***LRPV03 ****
Project title: Searching for Vortices

Supervisor: Vincent, Peter Prof.
Co-supervisor(s):
Category: Numerical;Theoretical;Computational
Software: PyFRParaview

Confidential: No

The project will involve applying PyFR (www.pyfr.org) to generate high-fidelity turbulent flow solutions in e.g. channels and pipes, followed by development of new strategies for automatically identifying and extracting specific vortical structures from the flow solutions. These new strategies will be based on extending machine learning approaches for image recognition. The student should have a strong mathematics and coding background, and a passion for computational fluid dynamics. There will be significant scope for the student to define their own research objectives.

Vincent, Peter Prof.

Project no: ***LRPV04***

Project title: Compressible Flow Simulations with PyFR (S) - 2 projects available

Supervisor: Vincent, Peter Prof.
Co-supervisor(s):
Category: Numerical;Computational
Software: PyFR

Confidential: No
Two projects are available, each will involve applying PyFR (www.pyfr.org) to a problem defined by the student. The acts of choosing the problem space, defining the associated research questions, and creating a plan of action to address them will form part of the project. Past students have used PyFR to simulate flow over high-rise buildings, flow in mixing layers, flow over novel aerofoils for model aeroplanes, and flow over Martian entry vehicles. The student should have a strong mathematics and coding background, and a passion for computational fluid dynamics. There will be significant scope for the student to define their own research objectives.

Wynn, Andrew Dr

Project no: ***LRAW01***
Project title: Data-driven modelling, estimation and control of turbulent fluids - 2 projects available

Supervisor: Wynn, Andrew Dr
Co-supervisor(s):
Category: Computational;Theoretical;Analysis
Software: Matlab / Python.

Confidential: No
Creating a reduced-order model of a fluid flow is often the first step towards the design of a flow control strategy to improve performance (e.g. reduce drag). Due to the complexity of the Navier-Stokes equations, it is instead desirable to extract flow models directly from large ensembles of fluid flow data (e.g. from numerical simulations or experiments). In this data-driven approach, model construction is achieved using computational optimization. Many strategies are available, ranging from classical linear programming to deep neural networks.
The main open research question, which will be investigated in these FYPs, is to enable boundary sensor or estimation of a full fluid flow field from only limited sensor information. In practice, real-time measurements of a flow are only available at certain locations, such as pressure of shear-stress sensors embedded in the flow boundary. This project will create data-driven algorithms which can estimate the full velocity field using only this sensor information. Such a step is vital to the implementation of many flow control techniques. Flows to be considered include turbulent boundary layers and bluff body wakes.

Wynn, Andrew Dr

Project no: ***LRAW02***
Project title: Modelling and control of geometrically nonlinear structures in aeroelastics - 2 projects available

Supervisor: Wynn, Andrew Dr
Co-supervisor(s):
Category: Computational;Theoretical
Software: Matlab / Python
Confidential: No

This project will develop modelling and control methodologies for aeroelastic systems underpinned by geometrically nonlinear structures. Such systems are relevant to the design of next-generation air vehicles and wind turbines in which require active control as a result of increased flexibility.
The project can either take a purely structural focus: control of nonlinear beam equations is a challenging and active topic for research. Alternatively, this research project may focus upon efficient (for low-order modelling to drive control design) integration of aerodynamic forces into the aeroelastic model, or may focus on nonlinear control synthesis.
Real time control techniques such as Model Predictive Control will are expect to be developed. Furthermore, due to the complex nonlinear structure of the underlying models, algorithmic acceleration using data-driven modelling can also be considered as part of the research project.
This project is of interest to those who want to research either fluids or structures, but who want to study either subject from the viewpoint of data-driven modelling and control.

Wynn, Andrew Dr

Project no: ***LRAW03***
Project title: Optimization-based analysis of polymer induced drag reduction in fluid flows

Supervisor: Wynn, Andrew Dr
Co-supervisor(s):
Category: Computational;Theoretical;Analysis
Software:
Confidential: No

It is well known that the addition of polymers to fluid flows can significantly reduce drag, achieving the state known as maximal drag reduction. Although this phenomenum has been observed experimentally, much less is known about why polymer-induced drag reduction occurs. This project will use compuational optimization to attempt to understand this property from a mathematical perspective. This will involve studing partial differential equation (PDE) models for polymer flows, such as Oldroyd-B and FENE-P models, which are adpatations of the Navier-Stokes equations.
Interested students should read: C. R. Doering, B. Eckhardt, and J. Schumacher. Failure of energy stability in Oldroyd-B fluids at arbitrarily low Reynolds numbers. J. Non-Newtonian Fluid Mech., 135(2–3):92–96, 2006.
This project is appropriate for students who enjoyed the mathematical aspects of fluid dynamics, PDEs and optimization. It requires a strong level of mathematical ability.

Wynn, Andrew Dr

Project no: ***LRAW04***
Project title: Wind farm optimization via efficient wake modelling - 2 projects available

Supervisor: Wynn, Andrew Dr
Co-supervisor(s):
Category: Computational;Theoretical;Analysis
Software: Matlab (or equivalent)

Confidential: No

The power output of a wind farm is highly dependent upon interactions of the wakes generated individual turbines. In particular, a downstream turbine which lies directly in the wake of an upstream machine may produce up to 45% less power, due to the lower inflow velocity that it experiences. To attempt to mitigate this effect "wake steering" can be used, which involves intentionally yawing each turbine in a farm to reduce the impact of low-momentum wakes on downstream machines. However, since yawing reduces the power of the upstream machine, there is necessary a trade-off, which leads to an optimization problem to maximize wind farm power. Due to the complexity of wind farm wakes, such optimization problems are challenging to solve and may possess many local maxima.
A number of open questions can be addressed as part of this project, including:
1) Wake Estimation: the development of real-time sensing algorithms to infer the current state of a wind turbine's wake using only limited sensor information. This will build on the notion of "observer design" from the Control System course, but will use real-time, data-driven, optimization techniques such as Moving Horizon Estimation to improve performance.
2) Wake model development: taking inspiration from recent approaches such as (doi:10.1017/jfm.2016.595), models will be constructed which are specifically tailored to creating easy-to-solve optimization problems (e.g. those with polynomial cost functions and constraints), in order to find globally optimal wake steering strategies.
3) Layout Optimization: a generalization to wake steering optimization is to also consider the location of wind turbines as an optimization variable. This is creates a significantly more challenging optimization problem and will require the development of physically-inspired constraints to solve it as part of this project.