Final Year H401, H415 & H420 Internal Project List 2022-2023

Department of Aeronautics

May 2022

*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 H401, H415 & H420 Project 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 structures 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: Dynamic Fracture Mechanics (S)

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

The aim of this project is to investigate the influence of dynamic loading such as impact on crack growth in metallic structures. Two-dimensional in house boundary element code will be used to study mixed mode fracture and evaluate stress intensity factors.
Good programing knowledge is required. The in house code has been written in Fortran.

Aliabadi, Ferri Prof

Project no: ***LRFA05 ****
Project title: Fracture Toughness of multilayer materials (S)

Supervisor: Aliabadi, Ferri Prof
Co-supervisor(s):
Category: Experimental;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: Cost of Doing Business: quantifying the impact of collision avoidance manoeuvres on satellite constellations (S)

Supervisor: Amato, Davide Dr
Co-supervisor(s): Mylvaganam, Thulasi Dr
Category: Computational;Theoretical;Numerical
Software: MATLAB
Confidential: No

Satellite constellations are being increasingly used to satisfy coverage and redundancy requirements for Earth observation and telecommunications missions. Recently, constellations of several hundreds or thousands of satellites, such as the Starlink and Planet constellations, have been placed into orbit. Each of the constellation elements must be controlled through station-keeping manoeuvres to counteract perturbations such as those arising from Earth oblateness and atmospheric drag, and executes collision avoidance manoeuvres to minimise collision risk with other objects.
This project is centred on modelling the impact of the constellation orbit maintenance on the mission requirements. Constellation elements need to manoeuvre often to avoid collisions with other Earth-orbiting satellites. Every manoeuvre executed by a constellation element modifies the

constellation geometry; for instance, the result of a collision avoidance manoeuvre will in general be a change in inter-satellite distance and in ground coverage quantities. Therefore, it is important to understand what the total cost of any collision avoidance manoeuvre over the entire mission is.
In addition, results from this project will be used to devise efficient control policies for collision avoidance based on optimal control and game theory.
You will 1) model these effects through either numerical or analytical methods, and 2) quantify the cost of collision avoidance manoeuvres for mission operations. Depending on available time, you will also use public ephemerides for the Starlink constellation to model operational collision avoidance policies through inverse optimal control.
The project will involve advanced topics in orbital mechanics (in particular, motion under the effect of perturbations and linear approximations to orbital motion) and dynamical systems (linear and nonlinear). In order to complete the project to a good standard an excellent background in mathematics and dynamical systems is essential. A solid grasp of MATLAB (which will be used for simulations) is also required.

Amato, Davide Dr

Project no: ***LRDA02 ****
Project title: Reverse engineering of the Starlink satellite constellation (S)

Supervisor: Amato, Davide Dr
Co-supervisor(s):
Category: Computational;Design;Literature
Software: MATLAB, Python, Blender
Confidential: No

With the advent of inexpensive launch services through commercial companies in the United States, the Low Earth Orbit (LEO) environment is changing rapidly and will continue to change in the future due to the introduction of large satellite constellations providing broadband internet services to ground users. Three constellations are in an advanced stage of development: Amazon's Kuiper, OneWeb, and SpaceX's Starlink.
As of April 2022, Starlink is the only constellation that has achieved operational capability. The constellation consists of about 2150 satellites (out of a planned total of 12,000), placed on several orbit planes at the inclination of 53� and at an altitude of 550 km. Almost 40% of all active Earth satellites belong to the constellation.

Given the importance of the Starlink constellation, it is essential to characterise its mission architecture and concept of operations to better understand its current and future impacts on the LEO environment. You will:

- Perform a literature a review based on available open source data
- Characterise the Starlink concept of operations and mission architecture through state-of-the-art mission engineering practices
- Model ground coverage
- Characterise the Starlink spacecraft in terms of subsystems, dimensions, mass, inertia, and propulsion capability

- Model and simulate constellation operations by analysing existing ephemerides

In order to complete the project, a solid background in Spacecraft Systems and Orbital Mechanics (in particular regarding the propagation of spacecraft motion under perturbations and thrust with six degrees of freedom) is essential, besides knowledge of MATLAB and basic Python. Familiarity with Blender or other CAD software is desired.

Amato, Davide Dr

Project no: ***LRDA03 ****
Project title: Regularised numerical integration in orbital mechanics (S)

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

Confidential: No

Orbit propagation consists of calculating the trajectory of a spacecraft at any future time from given initial position and velocity. This is a computationally intensive task for many orbits in the presence of perturbations. Besides using efficient numerical schemes, it is possible to speed up orbit propagation by employing regularisation techniques.

Regularisation consists in removing singularities from the equations of motion for a spacecraft through analytical manipulations [1]. The independent variable is changed from physical time to a “fictitious time”, which is an angle-like quantity, through a differential transformation called the Sundman transformation. A variety of choices for the set of dependent variables exist, among which are non-classical orbital elements that are particularly advantageous in the case of weak perturbations (as for most Earth satellite orbits).

The core advantage of regularisation is that the resulting non-singular equations of motion are “smoother”, that is to say, their higher derivatives are smaller.

Recently, a numerical method relying on Taylor series has been proposed for the efficient numerical integration of ordinary differential equations [2]. The scheme relies on automatic differentiation to approximate solutions to ODEs through Taylor series. The scheme has shown excellent computational efficiency compared to classical Runge-Kutta numerical methods.

In this project, you will evaluate the numerical performance of regularised formulations when coupled with numerical integration methods using Taylor series. Because orbital motion is more linear in regularised space, using these methods with Taylor series can bring significant computational advantages.

The project requires an excellent mathematical background, willingness to go beyond the course curriculum, and a solid background in Orbital Mechanics and Computing and Numerical Methods. Knowledge of C++ and Python is essential. Knowledge of Julia is desired.

[1] J. Roa, Regularization in Orbital Mechanics: Theory and Practice. De Gruyter, 2017. Accessed: Nov. 10, 2020. [Online]. Available: https://www.degruyter.com/view/title/533907
[2] F. Biscani and D. Izzo, ‘Revisiting high-order Taylor methods for astrodynamics and celestial mechanics’, Monthly Notices of the Royal Astronomical Society, vol. 504, no. 2, pp. 2614–2628, Jun. 2021, doi: 10.1093/mnras/stab1032.

Amato, Davide Dr

Project no: ***LRDA04 ****
Project title: Closed-form solutions for planetary capture, entry, and descent (S)

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

Confidential: No

Future Solar System exploration architectures require novel mission concepts to drastically increase payload mass [1]. Therefore, there is a strong need for novel guidance algorithms that are able to deal with navigation and dynamical uncertainties. This is a particularly difficult task, as the dynamics of planetary capture and entry, descent, and landing (EDL) are strongly non-linear. In this context, analytical solutions for the dynamics of planetary capture and entry are particularly helpful to speed up preliminary mission analysis and to make robust onboard guidance algorithms possible.

You will devise closed-form approximated solutions for planetary capture and EDL dynamics [2], or implement existing solutions within onboard guidance methods while satisfying constraints on mechanical and heat loads. Depending on the state of ongoing research at the start of the project and on your interests, you will consider one of the following problems:

1) Analytical solutions for aerocapture dynamics. Aerocapture consists of an orbital manoeuvre in which the delta-V required for a spacecraft to achieve orbit insertion at a planet with an atmosphere is provided by aerodynamic forces. The task consists of improving approximate analytical maps sending the state of a spacecraft on an incoming hyperbolic trajectory to final conditions resulting in an elliptical orbit, escape, or collision. This may be achieved by employing perturbation methods such as matched asymptotic expansions and boundary layer methods.

2) Higher-order solutions for atmospheric entry. During atmospheric entry, the vehicle guidance must dissipate kinetic energy while satisfying constraints on the delivery location, mechanical, and heat loads. The task consists of generating high-order closed-form solutions for the entry dynamics by means of state transition tensors. These will be implemented in existing predictor-corrector/MPC guidance algorithms in order to improve their computational efficiency.

3) Generation of preliminary atmospheric entry / powered descent trajectories through multiple shooting methods, or direct optimal control methods (with a focus on sequential convexification methods).

Novel guidance algorithms for planetary entry based on parametric control laws, sequential convexification, or indirect optimal control.

The project requires an excellent mathematical background, willingness to go beyond the course curriculum, and a solid background in Orbital Mechanics and Computing and Numerical Methods.

[1] R. D. Braun and R. M. Manning, ‘Mars exploration entry, descent and landing challenges’, in 2006 IEEE Aerospace Conference, Mar. 2006, p. 18. doi: 10.1109/AERO.2006.1655790.

[2] N. X. Vinh, A. Busemann, and R. D. Culp, Hypersonic and Planetary Entry Flight Mechanics. Ann Arbor, MI, USA: The University of Michigan Press, 1980.

Amato, Davide Dr

Project no: ***LRDA05 ****
Project title: Analysis of near-Earth spacecraft dynamics in the frequency domain (S)

Supervisor: Amato, Davide Dr
Co-supervisor(s):
Category: Computational;Theoretical;Numerical
Software: MATLAB, Julia

Confidential: No

Spacecraft orbits are usually described and analysed in the time domain, although there are strong connections to the frequency domain approach to dynamical systems. For instance, a mean trajectory obtained through the method of averaging can be interpreted as a high-pass filtered osculating trajectory. Frequency analysis methods offer deep insights into the dynamics of objects in near-Earth space [1]. By exploiting the frequency spectrum of the trajectory expressed in an appropriate state vector form it is possible to easily perform averaging and understand long-term trends. This has important implications, for instance to associate fragments of a collision to their parent bodies, devise spectral numerical integration schemes, and to transform between mean and osculating trajectories.

You will explore the application of classical frequency analysis methods (such as the Discrete Fourier Transform [2]) and time frequency analysis methods (short-time Fourier Transforms, wavelet transforms) to characterise Earth satellite orbits in the frequency domain. Depending on the state of ongoing research at the start of the project and on your interests, you will consider one or more of the following problems:

1) Transformation from osculating to mean elements and recovery of short-periodic terms through the DFT [3]
2) Analysis of orbits in the frequency domain under conservative (time-invariant) perturbations.
3) Time frequency analysis of orbits under dissipative and time-varying perturbations.

The project requires an excellent mathematical background, willingness to go beyond the course curriculum, and a solid background in Orbital Mechanics and Computing and Numerical Methods.

[1] I. A. Araya and D. Amato, ‘Spectral analysis of US Space Catalog ephemerides for LAGEOS-1’, presented at the AIAA SCITECH 2022 Forum, Jan. 2022. doi: 10.2514/6.2022-1772.
[2] A. Oppenheim and R. Schafer, Discrete-Time Signal Processing, 3rd ed., 2013.
[3] T. A. Ely, ‘Transforming Mean and Osculating Elements Using Numerical Methods’, J of Astronaut Sci, vol. 62, no. 1, pp. 21–43, Mar. 2015, doi: 10.1007/s40295-015-0036-2.

Bilotti, Emiliano Dr

Project no: ***LREB01***
Project title: Safe batteries with built-in over-current/over-temperature protection (S)

Supervisor: Bilotti, Emiliano Dr
Co-supervisor(s):
Category: Literature Review, Experimental
Software:

Confidential: No

How many of you have noticed a loss in performance in your mobile device lithium-ion batteries (LIBs) during a hot summer day?

The aim of this project is to develop new conductive polymer (nano)composites (CPCs), to be utilised as an internal protecting component in lithium-ion batteries, to increase not only their performances but also their safety and long-term stability.

LIBs are currently the most promising energy storage solution for electric vehicles, portable electric devices and green grid energy storage. However, LIBs are hindered by safety issues such as high flammability of liquid electrolytes, showing flash points around room temperature (between 16 and 33 °C) as well as relatively narrow optimum operation temperatures.

We aim at using CPCs, in particular pyroresistive CPCs, as a reversible internal protecting component in LIBs, to prevent over-current and over-heating.

Pyroresistivity manifests itself, in certain CPCs (and other materials), as a unique change of their electrical resistance with temperature. In particular, PTC (positive temperature coefficient) pyroresistive CPCs show a sudden increase in electrical resistance in correspondence of a critical temperature. Thanks to this feature, PTC CPCs are used in self-regulating heating devices (self-regulating at the critical temperature of switch) - like the commercial product Grafheat codeveloped by Dr. Bilotti's group - and resettable fuses.

You will be developing a bespoke PTC CPCs for over-current and over-temperature protection in Li-ion batteries. The working principle can be briefly described as follow. During normal operating conditions, the electrical conductive pathways in the PTC layer are connected, while above the switching temperature (abnormal conditions), the PTC layer becomes instantaneously electrically insulating and shuts down the battery. This safety switch allows a fast, but still reversible, shut-off of the LIB before battery damage.

During this project, you will need to overcome a number of challenges. The most important one will be how to create sufficiently high electrically conductive PTC layers so to favour charge extraction/injection. This could be achieved by a suitable selection of conductive (nano)particles (e.g. graphitic and metal nanoparticles) in the CPC and their surface modification, by controlling the morphology of the conductive network, as well as by tuning the thickness of the PTC layer, so to reduce the distance between electrode and current collectors. A suitable selection of the polymer matrix will address the additional challenge of environmental stability of the CPC over long operating cycles and times.

Bilotti, Emiliano Dr

Project no: ***LREB02***
Project title: Learning from Nature: from silk fibre to high performance materials

Supervisor: Bilotti, Emiliano Dr
Co-supervisor(s):
Category: Literature Review, Experimental l
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 extract 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 (345-450 W/mK), 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: ***LREB03***
Project title: Edible Electronics

Supervisor: Bilotti, Emiliano Dr
Co-supervisor(s):
Category: Literature Review, 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 in 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.

Bruce, Paul Dr

Project no: ***LRPB01***
Project title: Shock wave - boundary layer interaction (S)

Supervisor: Bruce, Paul Dr
Co-supervisor(s):
Category: Computational;Theoretical;Analysis;Survey
Software:
Confidential: No

Shock wave - boundary layer interaction (SBLI) is an important and complex flow feature encountered in practically all high speed vehicles and flow systems. This project builds on the material covered in your Aerothermodynamics course (AERO97011) with the aim of pushing the boundary of our understanding of SBLI. The scope of the project will focus on one or more of the following broad topic areas: (1) impact of surface flexibility on SBLI; (2) prediction of heat transfer in a hypersonic SBLI; (3) computational methods for modelling SBLI; (4) SBLI flow control.

Bruce, Paul Dr

Project no: ***LRPB02***
Project title: Computational study of SBLI (S)

Supervisor: Bruce, Paul Dr
Co-supervisor(s):
Category: Computational
Software: PyFR (have agreed support to be given by Peter Vincent and his group)

Confidential: No

Developments in computational tools using high order methods - such as PyFR - offer great potential for exploring the flow physics of unsteady compressible flows. However, the ability of such methods to accurately predict the properties of shock / boundary layer interactions (SBLI) is unproven. This project will build on the foundations of previous studies in the department to apply PyFR to a number of classical SBLI-specific test cases including one or both of the following:
(a) a natural laminar flow (NLF) supercritical aerofoil,
(b) an isolator for a ramjet engine.

Bruce, Paul Dr

Project no: ***LRPB03***
Project title: Hypersonic foldable Aeroshell for THermal protection using ORigami (HATHOR) - Aerothermal analysis (S) - 2 projects available

Supervisor: Bruce, Paul Dr
Co-supervisor(s): Santer, Matthew Dr
Category: Experimental: Ready-made experiment;Computational;Theoretical;Design
Software: Abaqus, Matlab, OpenFOAM
Confidential: No

To land a payload on an extra-terrestrial body with an atmosphere is an immense challenge. To achieve sufficiently small ballistic coefficients, large braking areas are required which are greater than the diameters of available rocket fairings. This necessitates the use of deployable structures. Interaction of the atmosphere with the aeroshell at hypersonic velocities leads to high thermal loads which in turn requires the design of adequate thermal protection systems (TPS). There are numerous other interconnected aspects of the aeroshell design which much be addressed.
In the Department of Aeronautics, we are developing the Hypersonic foldable Aeroshell for THermal protection using Origami (HATHOR) concept. This consists of rigid folding TPS panels supported by a series of umbrella-like deployable ribs which lock upon deployment into a faceted aeroshell geometry. We are carrying out an analytical programme which will be validated by an experimental campaign consisting of wind-tunnel tests at both sub- and supersonic velocities, dynamic deployment tests, TPS structural testing, and others as appropriate.
Two projects are available, including 1 experimental project, to work on the structural and aero-thermal aspects, and their mutual interaction, of the HATHOR lander. Students allocated one of these projects will join the HATHOR research team. The project is intrinsically related to the project of same name supervised by Dr Santer.

Bruce, Paul Dr

Project no: ***LRPB04***
Project title: Low-temperature ablation experiments for re-entry vehicle applications (S)

Supervisor: Bruce, Paul Dr
Co-supervisor(s): Lee, Koonyang Dr
Category: Experimental

Software:
Confidential: No

This multi-disciplinary research project will combine aerodynamics and materials science to study the behaviour of re-entry vehicles as they enter the Earth's atmosphere from space. These vehicles are responsible for the safe return of payloads (including astronauts!) from space and thus our ability to reliably predict and characterize their performance is essential. Ordinarily, the study of these vehicles necessitates the use of advanced (read: extremely expensive!) materials and wind tunnels to recreate the extreme conditions (very high temperatures) experienced during a real re-entry mission. The primary aim of this project is to establish a capability within Imperial to study the physics of re-entry vehicles without the need to use exotic materials or generate such extreme conditions. This will be achieved through experiments in Imperial's new Mach 5 Supersonic Wind Tunnel using a scale model of a re-entry vehicle made of the organic compound naphthalene. It is postulated that the unique properties of naphthalene – a safe and widely available material – will allow us to recreate some of the key physics of a real re-entry vehicle mission at a fraction of the cost and complexity of previous studies.

Bruce, Paul Dr

Project no: ***LRPB05***
Project title: Heat transfer analysis of a deployable heat shield (S)

Supervisor: Bruce, Paul Dr
Co-supervisor(s):
Category: Experimental;Computational
Software: MatLab

Confidential: No

Currently, the maximum mass that can be landed on Mars (or other celestial bodies) is limited by the entry vehicle heat shield size, which is constrained by the space available in the launch vehicle fairing (4.5 m diameter for Ariane 5). Future inter-planetary exploration missions necessitate the development of entry vehicles which can fit inside the available launch vehicle and then deploy to a larger size once in space by mechanical deployment. This project complements ongoing work and expertise at Imperial to consider the design and optimisation of the heat shield for such a vehicle. The scope is flexible (negotiable), but will likely include: (1) Literature review to develop an understanding of the re-entry environment; (2) computational work in MATLAB to develop an engineering model of heat transfer to a complex-geometry heat shield; (3) infra-red-thermography experiments in the Imperial College supersonic wind tunnel for validation.

Bruce, Paul Dr

Project no: ***LRPB06***
Project title: Heat flux sensor for robust aerobraking missions (S)

Supervisor: Bruce, Paul Dr

Co-supervisor(s): Rodriguez Marinas, Sara Dr (Airbus D&S engineer)
Category: Computational;Design;Analysis
Software:
Confidential: No

Aerobraking involves using a planet's atmosphere to slow down an incoming spacecraft to circularise its orbit minimising the need for retro-propulsion. Such manoeuvres offer the potential to reduce inter-planetary spacecraft mass and ultimately cost. However, the uncertainties associated with such operations can be significant, especially those that impact the heat flux experienced by the vehicle. On-board, real-time measurement of heat flux during aerobraking is a highly attractive option for reducing uncertainty and enabling a spacecraft to more efficiently perform a corridor control at periapsis. This project will involve a comprehensive review of relevant literature and modelling work using MATLAB in order to provide answers to the following questions: (1) what are the most promising candidate technologies for capturing (direct and indirect) heat transfer measurements in free-molecular flow and transitional flow regimes? (2) what are the characteristics (accuracy/reliability/response time) of such a heat transfer sensor? (3) what is the (quantifiable) advantage of implementing such a sensor on an aerobraking mission?

This project is in collaboration with Airbus Defence and Space and will be co-supervised by Sara Rodriguez Marinas (AOCS/GNC engineer in Airbus D&S).

Bruce, Paul Dr

Project no: ***LRPB07***
Project title: Aero-structural analysis of a grid-fin (S)

Supervisor: Bruce, Paul Dr
Co-supervisor(s): Hayes, David (MBDA)
Category: Experimental
Software: As a contingency (expts unavailable) this project could run as a computational version using one of more of: Star-CCM+, OpenFOAM, Abaqus.

Confidential: No

Grid-fins offer a robust and efficient method for the control and stabilisation of high-speed objects such as guided missiles and reusable rocket stages. The unique geometry of a grid-fin – which comprises multiple slender aerodynamic surfaces in close proximity – makes it susceptible to high-speed fluid-structure interaction, but this aspect of their performance has not been widely studied. This project aims to target this deficit in understanding by undertaking the following tasks: (1) design and build a scale model of a grid-fin for testing in Imperial's supersonic wind tunnel; (2) perform aerodynamic testing of the grid-fin model to validate (steady) aerodynamic performance predictions from CFD and literature; (3) perform (steady and unsteady) aero-structural measurements of the grid-fin model at supersonic conditions, focusing on the impact of flexibility on steady and unsteady aerodynamic performance; (4) validate results through comparison with predictions of aero-structural performance from an in-house coupled aero-structural (FEA/CFD) tool. This project builds on previous research into grid-fins in the Aeronautics

Department at Imperial and will be co-supervised by David Hayes, an engineer in the Mechanical Future Concepts department at MBDA Systems

Bruce, Paul Dr

Project no: ***LRPB08 ****
Project title: Aerodynamics in high-performance sports

Supervisor: Bruce, Paul Dr
Co-supervisor(s): Hale, John (ext)
Category: Computational;Analysis;Literature
Software: Star-CCM+

Confidential: No
This project focuses on the important role of aerodynamics in the competitive high-performance sports of cycling and rowing. The project specification is broad and flexible (negotiable) depending on the interests of the selected student, who will ideally have a strong interest in cycling and/or rowing. This project aims to advance the state-of-the-art in sports aerodynamics and its relationship with athlete physiology and race strategy. The project will comprise some or all of the following tasks: (1) literature review to establish the state-of-the-art in technologies to minimise aerodynamic drag, together with tools for the measurement and estimation of drag using data from real-world tests and wind tunnel experiments, reduced-order models, and CFD; (2) select a suitable methodology/tool/framework for predicting aerodynamic drag; (3) identify a small number of promising novel technologies and quantitatively assess/predict any anticipated performance benefit; (4) identify optimal strategies for improving practical (rapid-turnaround) techniques for drag analysis. The project will be co-supervised by John Hale – an elite athlete and engineer and founder of Hale Dynamics.

Buxton, Oliver Dr

Project no: ***LROB01***
Project title: Coherence in a wind turbine wake

Supervisor: Buxton, Oliver Dr
Co-supervisor(s):
Category: Computational;Theoretical;Analysis
Software: MATLAB or any other prgramming language the student is comfortable with using.

Confidential: No
Many flows fluctuate in a periodic fashion - an example being the wake of a regular cylinder. For such flows a simple Reynolds decomposition of the velocity into a time-invariant mean flow and a fluctuation is insufficient. Instead a triple decomposition is more satisfactory in which the velocity fluctuations are further decomposed into a coherent (periodic) part and a stochastic/residul

fluctuation (caused by smal-scale turbulence within the flow). Recently, we introduced the multi-scale triple decomposition for flows in which periodic fluctuations are introduced at different frequencies. This is typical of flows such as those through an urban environment or the wake produced by a wind turbine. In this case periodic fluctuations may be introduced from the wind turbine tower, nacelle and the tip vortices shed by the individual blades - all of which occur at different frequencies. In this project we have access to the most advanced numerical simulations of wind turbines provided to us by Stony Brook University. We will try and apply our multi-scale triple decomposition to these data sets in order to try and understand the importance of the various coherent (periodic) structures present in a wind turbine wake. In addition we have data acquired in our own laboratory for comparison against the numerical data.

Buxton, Oliver Dr

Project no: ***LROB02 ****
Project title: Fluctuating wind gusts in a representative wind turbine array

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

Wind turbines located in the wake of an upstream machine are markedly less efficient and suffer from fatigue damage due to the fluctuating (turbulent) inflow casued by the wake of the upstream machine. In this project we will simulate a wind farm with an array of porous discs - the wakes of which are shown to resemble those of a real rotor from about three disc (rotor) diameters downstream of the wake generator. We will then arrange the porous discs in various fashions and measure the fluctuating loads and inflow velocities in order to try and determine an efficient farm layout.

Buxton, Oliver Dr

Project no: ***LROB03 ****
Project title: Aerodynamic measurements for Martian flight (S)

Supervisor: Buxton, Oliver Dr
Co-supervisor(s): Bruce, Paul Dr
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.

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: Data-driven modelling of dynamical systems using graph neural networks - 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 exploring the performance of graph neural networks for the prediction of fluid dynamics or biomedical problems. 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: Development of a web portal for interrogating high-order finite element datasets

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

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 scientific challenge and financial cost of generating rich datasets on large supercomputers is substantial. While these are of great value to other scientists around the world, sharing terabytes of data is not practical. Researchers typically need to apply operations such as extracting subsets of the data, interpolating onto different grids, computing auxiliary quantities and computing isocontours of particular quantities of interest which only requires a fraction of the total dataset. This project will investigate and prototype a web-based system for the remote analysis of high-order finite element datasets using cloud computing resources. It will allow the user to stipulate analysis protocols, and visualise the result through a web interface, or download the analysis in an open data format for local visualisation. This project has a strong focus on software engineering and knowledge of Python is essential.

Cantwell, Chris Dr

Project no: ***LRCC06***
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: The modulation of near-wall turbulence by outer large-scale structures

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

The work on this project has to be done full-time without distractions and has, therefore, to be mostly concentrated in one term only. Please do not select this project if you plan to take more than one exam in spring.

Direct numerical simulations of turbulent flows can be done only at moderate Reynolds numbers Re. Experiments on near-wall turbulence is also limited to moderate Re, because at high Re the viscous sublayer becomes too thin to be resolved by existing instruments. As a result, industry is constantly concerned with results obtained within academia not being transferrable to high Re typical of flight regime. Until recently, the hope of overcoming this difficulty was based on the idea of the universality (Re-independence) of near-wall turbulence. This hope suffered a serious blow with the discovery of a second, "outer", peak of the energy spectra at large Re, suggesting that at high Re more turbulence kinetic energy is contained in large-scale structures than in the near-wall region. The hope was restored when the theory, now called Quasi-Steady Quasi-Homogeneous (QSQH) theory, of the effect of large scales on near-wall turbulence was proposed. Recently, the theory was extended to the case when the direction of the large-scale friction fluctuates [https://doi.org/10.1017/jfm.2021.180]. This project is part of the ongoing research: further details of the project will be determined at its start. High-performance language (Fortran for example) and/or Matlab programming are likely be required, but the project can also be restricted to analytic mathematical analysis.

Chernyshenko, Sergei Prof

Project no: ***LRSC02***
Project title: Sum-of-squares of polynomials optimisation in fluid dynamics and related problems. - 4 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. The same description applies to all.
The work on this project has to be done full-time without distractions and has, therefore, to be mostly concentrated in one term only. Please do not select this project if you plan to take more than one exam in spring.
Sum of squares of polynomials technique is a recent breakthrough in mathematics, which allowed checking and constructing positive-definite multivariate polynomials in a computationally efficient way. The method proved to be highly efficient in many areas, in particular in control theory. In fluid mechanics, it offered new opportunities in global stability theory, flow control, and bounds on various quantities related to turbulent flows, for example lift and drag. Further developments branched into a variety of areas. This is a new and exciting area of theoretical research in fluid dynamics. The projects are likely tol be done using Matlab, and the student will be expected to use the Matlab toolbox YALMIP. Have a look at “A Tutorial on Sum of Squares Techniques for Systems Analysis” by Antonis Papachristodoulou and Stephen Prajna (http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1470374), and at Chernyshenko SI, Goulart P, Huang D, et al., 2014, Polynomial sum of squares in fluid dynamics: a review with a look ahead, Royal Society of London. Philosophical Transactions A. Mathematical, Physical and Engineering Sciences, Vol:372, ISSN:1364-503X http://hdl.handle.net/10044/1/15496

A purely theoretical versions of the project are also possible.
All the students taking this project will start with the same literature review and exercises, and then will branch into the particular area they will like most. This project is a part of the ongoing research in the department.
Students applying for this project should have programming skills (at least MATLAB) and a strong background in mathematics.
There are several short videos that might give a better idea of this group of projects. The videos are highlighted in yellow at
https://www.imperial.ac.uk/aeronautics/fluiddynamics/ChernyshenkoResearch/misc.php
More, and more serious, video is at
https://www.youtube.com/watch?v=NrF7n3MyCy4&list=PLf_ipOSbWC86n18q4JMn_1J04S90FpdeE&index=8

Chernyshenko, Sergei Prof

Project no: ***LRSC03***
Project title: Finding orbits in space (S)

Supervisor: Chernyshenko, Sergei Prof
Co-supervisor(s):
Category: Computational;Theoretical;Numerical
Software: Matlab

Confidential: No
This project is closely related to the group of projects on application of sum-of-squares of polynomial optimisation to fluid dynamics: in this project, the same techniques will be applied to a three-body problem in astronavigation. Please read in full the description of the Sum of squares of polynomials project first.
Then have a look at the paper “Finding extremal periodic orbits with polynomial optimisation, with application to a nine-mode model of shear flow” by Mayur Lakshmi et al, SIAM Journal on Applied Dynamical Systems 19(2):763-787, 2020. This project is a part of the ongoing research in the department.
Students applying for this project should have programming skills (at least MATLAB) and a strong background in mathematics. The work on this project has to be done full-time without distractions and has, therefore, to be mostly concentrated in one term only. Do not apply for this project if you plan to take more than one exam in spring.

Doorly, Denis Prof

Project no: ***LRDD01 ****
Project title: Diffusion in complex domains: application to MR imaging

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. Depending on progress, it may be possible to incorporate the effects of perfusion on the measurements. The project will ideally suit those with a good grasp of mathematics and computational skills, and who also has an interest in broader applications of science and engineering.

Doorly, Denis Prof

Project no: ***LRDD02 ****
Project title: Modelling exhaled aerosol spreading (S) - 4 projects available

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

Confidential: No

Up to 5 projects can be offered on aerosol transport in external flows, where the aerosols are generated by exhalation. Threre of these may be primarily computational and one could be experimentally focussed. The objective of the group of projects is to characterise the spread of aerosols of different sizes, produced under a variety of conditions: speech, coughing/sneezing, CPR, during vigorous exercise, in a wind flow - e.g. by a cyclist or runner and to consider means to contain or limit aerosol spread. Some of these scenarios have received little attention and the area of protective shielding is comparatively new.
It is expected that the computational projects will rely mostly on Star-CCM, though the use of Open Foam may be considered for comparison in one of these. 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, these projects are ideal for several students to work in complementary areas.

Doorly, Denis Prof

Project no: ***LRDD03 ****
Project title: Simulation of a quantum computer - 2 projects available

Supervisor: Doorly, Denis Prof
Co-supervisor(s):
Category: Experimental;Numerical
Software: Matlab, Anaconda (Python)

Confidential: No
Simulation of a quantum computer: The project will investigate methods to simulate the execution of an algorithm on a quantum computer. A starting point could be an existing matlab package - see https://fr.mathworks.com/matlabcentral/fileexchange/73035-quantum-computer-simulator.

Doorly, Denis Prof

Project no: ***LRDD04 ****
Project title: Random walk methods to solve diffusion equation

Supervisor: Doorly, Denis Prof
Co-supervisor(s):
Category: Computational;Theoretical;Numerical
Software:
Confidential: No
Random walk methods to solve diffusion equation: The project will investigate the application of random walk methods to solve problems involving permeable boundaries and jumps in diffusion coefficient. This has application in many areas, but particularly in diffusion tensor imaging. See for example Powles et al PRoySoc A 1996, 436 391-403; Fieremans et al, NMR Biomed 2010, DOI:10.1002/nbm.1577

Doorly, Denis Prof

Project no: ***LRDD05 ****
Project title: Aerosol transport in the airways - 2 projects available

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

Confidential: No
Aerosol transport in the airways

The project will apply computational modelling to study aerosol transport in the upper airways. If experiemental work resumes as normal, it may be possible to perform some experiments in an experimental project

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, in the first instance to data on grades, sole scores and experience of aeronautics students to test whether data supports various hypotheses. Depending on avalability, data from other contexts, (industrial or medical) may be included. Also, depending on progress, there may be an opportunity for some data gathering. The student should become familiar with R, which is the de facto standard for statistical analysis.

Fantuzzi, Giovanni Dr

Project no: ***LRGF01***
Project title: Studying fluid flows via convex optimization - 2 projects available

Supervisor: Fantuzzi, Giovanni Dr
Co-supervisor(s):
Category: Computational;Theoretical;Analysis;Numerical
Software: MATLAB, Julia or Python + open-source optimization toolboxes (e.g., https://github.com/aeroimperial-optimization/aeroimperial-yalmip)

Confidential: No
Can one predict the properties of turbulent flows without running expensive numerical simulations? Excitingly, the answer is yes: it is often possible to estimate flow properties of interest using the “background method” by Doering & Constantin. Rather than requiring flow simulations, this method is based on the solution of convex optimization problems. Up to two projects are offered to develop new computational techniques to solve these optimization problems efficiently, which will enable the application of the background method to industrially relevant flows. The computational techniques will be used to study convective flows driven by spatially-varying heating and cooling, which along other applications determine the efficiency of heat exchangers. Since these projects require a combination of mathematical analysis and

computations, they are recommended to students with an interest in mathematics and programming.
References:
[1] Doering & Constantin, "Energy dissipation in shear driven turbulence", http://doi.org/10.1103/PhysRevLett.69.1648
[2] Fantuzzi et al, "Bounds on heat transfer for Bénard-Marangoni convection at infinite Prandtl number", https://doi.org/10.1017/jfm.2017.858

Fantuzzi, Giovanni Dr

Project no:	***LRGF02 ****
Project title:	Relax and...solve PDE-constrained optimization problems - 2 projects available
Supervisor:	Fantuzzi, Giovanni Dr
Co-supervisor(s):	
Category:	Computational;Theoretical;Analysis;Numerical
Software:	MATLAB + open-source software toolboxes (https://github.com/aeroimperial-optimization/aeroimperial-yalmip)
Confidential:	No

PDE-constrained optimization problems are ubiquitous in physics and engineering. Examples include the design of lightweight stiff structural beam, or of efficient heat exchangers. Solving PDE-constrained optimization problems is usually a challenge because there exist many solutions that are locally but not globally optimal. Traditional numerical approaches are extremely effective at finding local optimizers, but cannot certify global optimality even when they supported by the latest data-driven methods. Up to two projects are offered to pursue a completely different approach, based on a strategy called "relaxation". Loosely speaking, this strategy approximates hard PDE-constrained problems via much simpler optimization problems. The projects can focus either on the development of numerical solvers for these simpler problems, or on their applications to problems in fluid or structural mechanics (e.g., the optimization of steady flows in heat exchangers and the identification of buckling modes).
These projects require a strong background in mathematics and programming. Interested students are encouraged to look at the references below and to discuss the project with the supervisor before applying.
[1] Mevissen et al., "Solving partial differential equations via sparse SDP relaxations", https://pdfs.semanticscholar.org/a42b/aa38135abd58d083ca669e611ae7ba099de6.pdf
[2] Lasserre, "Convergent SDP relaxations in polynomial optimization with sparsity", https://dx.doi.org/10.1137/05064504X
[3] Waki et al., "Sums of squares and semidefinite program relaxations for polynomial optimzation problems with structured sparsity", https://doi.org/10.1137/050623802

Fantuzzi, Giovanni Dr

Project no: ***LRGF03***
Project title: Uncertainty propagation for nonlineary dynamical systems (S)

Supervisor: Fantuzzi, Giovanni Dr
Co-supervisor(s):
Category: Theoretical;Analysis;Numerical
Software: MATLAB + open-source optimization toolbox (https://github.com/aeroimperial-optimization/aeroimperial-yalmip)

Confidential: No

The amount of debris orbiting around the Earth is growing rapidly, but the number of sensors available for debris tracking is not. Since the number of observations for a particular piece of debris is limited, predictions of its orbit over very long times are needed in order to ensure that collisions with spacecrafts are avoided. Such predictions are strongly affected by measurement and/or model uncertainty, and one must account for the effects of this uncertainty over long time horizons. This project will use polynomial optimization to rigorously propagate uncertainty in nonlinear dynamical systems, even when only limited information about measurement and/or model errors is available. The method is very similar to techniques described in the paper "Bounding Extreme Events in Nonlinear Dynamics Using Convex Optimization" by Fantuzzi & Goluskin (https://doi.org/10.1137/19M1277953) and in the paper "Convex computation of the region of attraction of polynomial control systems" by Henrion & Korda (http://doi.org/10.1109/TAC.2013.2283095). Interested students are advised to look at these references and discuss their intention to apply for this project with the supervisor. Strong mathematical skills are required.

Fasel, Urban Dr

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

Supervisor: Fasel, Urban Dr
Co-supervisor(s): Brunton, Steven L. Prof (University of Washington)
Category: Computational; Theoretical
Software: Matlab; Python
Confidential: No

The sparse identification of nonlinear dynamics (SINDy) method enables the discovery of nonlinear dynamical systems 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 project, we used E-SINDy [3] (an extension to the SINDy algorithm) for active learning, leveraging the ensemble statistics of E-SINDy to identify and sample high-uncertainty regions of the state space that maximally inform the sparse regression. Here, 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: ***LRUG02***
Project title: Optimization and control of reprogrammable structures (S)

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

Greenhalgh, Emile Prof

Project no: ***LREG01 ****
Project title: Analysis of system performance of structural power for future air vehicles (and beyond) (S)

Supervisor: Greenhalgh, Emile Prof

Co-supervisor(s):
Category: Theoretical;Design;Analysis
Software: Matlab and Abaqus
Confidential: No

There is considerable interest in the development of structural power systems, either multifunctional structures (in which battery/supercapacitor devices are embedded with conventional composite materials) or multifunctional materials (in which the material itself is imbued with dual (or more) functionalities. The focus of this research is to investigate and model the potential weight, volume or cost saving associated with such structural power systems for future aerostructures, using both analytical and numerical modelling techniques. This research will build on research completed by a previous MSc student who modelled using these materials on the Airbus E-fan aircraft. The aim of the current project will be to extend this model to larger aircraft, such as single aisle passenger aircraft. Ultimately the research should extend to investigate whether such structural power materials could impact on the concepts/configurations for future aircraft designs. It is anticipate that the models and methodologies developed could also be utilised to investigate other platforms, such as automotive and mobile electronics.

Greenhalgh, Emile Prof

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

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

Prof Greenhalgh has a team of six researchers working on structural power materials, principally structural supercapacitors. The aim of this research project will be to work with one or more of these researchers in the development of new reinforcement constituents and device architectures.

Hewson, Robert Dr

Project no: ***LRRH01***
Project title: Hyper-reduction methods for multiscale structural analysis (S) - 2 projects available

Supervisor: Hewson, Robert Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Numerical
Software: Unix, Python and FEniCS - all open source.

Confidential: No

Additive manufacturing now permits the design of complex hierarchical structures to be manufactured. One of the challenges in analysing such structures using conventional finite element approaches is the computational requirements of solving the problem on a mesh fine enough to capture the finer details of complex structures.
One was finite element analysis has been solved more efficiently is using a hyper-reduction approach, whereby Proper Orthogonal Decomposition is used to extract modes from which a course mesh with POD-Galerkin elements are constructed (see for example https://doi.org/10.1016/j.cma.2021.113723).
This project will couple this approach hyper-reduction approach with a multiscale analysis to construct POD modes on a single unit lattice, from which the element of a large scale problem will be constructed.
This work is part of the structural-metamaterials group (https://www.imperial.ac.uk/structural-metamaterials) and will be mainly computational with some parts printed as demonstration components if appropriate.
The python based open source FE module FEniCS will be used. Experience of python programming is not essential, but you should enjoy programming if you want to do this project!

Hewson, Robert Dr

Project no: ***LRRH02***
Project title: Pressure sensor Diaphragm Optimisation (S)

Supervisor: Hewson, Robert Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Analysis;Numerical
Software: Unix, python and FEniCS - all supported locally by my group.
Confidential: Yes

Pressure sensors are found all over aircraft, whether they are measuring pressures to calculate speed or form part of an aircraft system - such as fuel, hydraulic, pneumatic, air conditioning etc they are critical components.
One of the critical components of a pressure sensor is the diaphragm, which separates the working media - like the air, from the oil filled cavity which transfers the pressure to the sensing component - typically a tiny piece of silicon with piezoresistive properties.
This diaphragm has to be flexible, so all the pressure is transferred to the oil, but not so flexible that it deforms too much that it touches sensitive sub-components or fails, and it must be manufacturable and able to operate across a range of temperatures and pressures. To achieve this a set of corrugations are stamped into a thin metal sheet, the design of which has been developed and refined over the years.
This project will take a more formal optimisation approach to the design of the component. We will use a similar approach to that developed for topology optimisation but instead of specifying material density to produce a final shape we will use the local diaphagm height as the design variable. Hopefully we will end up with some weird and counter intuitive designs that years of experience has not been able to come up with. The project will make a thin-shell approximation and use the adjoint method to calculate design sensitivities. This is implemented in the python

based open source finite element toolkit FEniCS. You don't have to have experience of using python, but you should enjoy programming if you take this project.
This project is based on a challenge set me by a colleague working in the R&D division of a pressure sensor company. As part of this project we will have meetings with colleagues from the company and hopefully present the final results of the work there.

Hewson, Robert Dr

Project no: ***LRRH03***
Project title: Adapting space reflectors and mirrors using 2D metamaterials (S)

Supervisor: Hewson, Robert Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Numerical
Software: Unix, python and FEniCS - supported locally and all open source.
Confidential: No

The design of large antenna for space applications often requires the out of plane motion of the antenna/reflector in order to provide local focusing. This project will apply 2D structural meta-materials (https://www.imperial.ac.uk/structural-metamaterials/research/shell-metamaterials/) to develop tunable and adjustable antenna structures which can be actuated simply, but produce complex surface shapes.
The project will use a multiscale approach which will exploit a set of small scale unit lattice geomtry simulations, which are then homogenised and represented using response surface methods. We will then use the adjoint method - similar to that used by topology optimisation - to produce the optimum small scale paramter distribution to produce complex deformations.
Finally, we will do some printing and test example parts.

Hewson, Robert Dr

Project no: ***LRRH04***
Project title: Fluid-Structure Topology Optimisation (S)

Supervisor: Hewson, Robert Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Numerical
Software: Ubuntu, Python, FEniCS (all supported locally).
Confidential: No

This project will develop and apply topology optimisation methods to the optimisation of fluid-structural problems, such as that of a multiphase heat exchanger. This is a challenging problem to undertaken as it requires that the two fluid phases are kept separate and the solid boundary between the two fluid phases does not fail due to the pressure difference in the fluids.
A topology optimisation approach will be taken which will account for the stresses in the solids and lead to an optimum channel design for both heat transfer and structural integrity. We may even extend the project to include structural loading to result in a multifunctional component.

The project will use open source finite element code (FEnicCS) which is able to automatically differentiate the problem to obtain optimisation sensitivities. It requires programming in Python. Python experience is nor required, but an enjoyment of programming is!
We will hopefully present the outputs of the work to Airbus R&T towards the end of the project and will print example components.

Hewson, Robert Dr

Project no: ***LRRH05***
Project title: Structural metamaterial optimisation (S)

Supervisor: Hewson, Robert Dr
Co-supervisor(s):
Category: Experimental;Computational;Theoretical;Design;Numerical
Software: Ubuntu, Python, FEniCS - all supported locally by research group.
Confidential: No

We have a range of activities in the area of structural metamaterials (https://www.imperial.ac.uk/structural-metamaterials) where we optimise structural components across scales using a topology optimisation type of approach (what product designers tend to call generative design).
All of our lattices are aligned with fixed orthogonal axes. This project will extend the work to include complex curved lattices to further improve the performance (stiffness, unusual resposne to loading etc) of the components we design. A new small scale database of more than 135,000 small scale finite element simulations will be used to generate the large scale designs using formal optimisation approaches (most notably enabled using the adjoint sensitivity method). We will use an open source finite element package called FEniCS which is extremely powerful and can be automatically differentiated for optimisation purposes. This is GUI-less code and is quite low level so you should be prepared and enjoy programming!
We will then do some printing of the design parts!

Hewson, Robert Dr

Project no: ***LRRH06***
Project title: Structural metamaterial flow control

Supervisor: Hewson, Robert Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Numerical
Software: ubuntu, python and FEniCS - all locally supported by research group.
Confidential: No

The structural metamaterials group has been developing multiscale approaches for structural optimisation where there are two distinct scales present. Grading of these structures using formal optimisation approaches can lead to improves responses, for example lightweight structures, optimised frequency response or resistance to failure.

This project will apply methods used to design shell like multiscale structures (https://www.imperial.ac.uk/structural-metamaterials/research/shell-metamaterials/) to design aerodynamic surfaces which deform in an optimum way when subjected to aerodynamic loading. The project will advance the multiscale framework already developed. This will require coding in python (in a unix environment) and the use of a number of python modules, including the open source finite element code FEniCS. You don't need extensive python experience to undertake the project, but you do need to enjoy programming.
We will try to finish the project by printing components and test them.

Hwang, Yongyun Dr

Project no: ***LRYH01 ****
Project title: Data-driven low-dimensional modelling of turbulent flow - 2 projects available

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

The project is aimed to examine novel technique that construct a nonlinear dynamical system using the data obtained by direct numerical simulation. The 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: Quasi-linear approximation of turbulent flow - 2 projects available

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

Quasi-linear approximation is a new approach that simulates only the essential part of dynamics of flows. The key idea is to take only important part of nonlinearity, while neglecting all the other nonlinear terms in analysing flows. The goal of this project is to test this idea using in-house numerical simulation tools. Strong mathematical capability and interest in scientific computation are required.

Hwang, Yongyun Dr

Project no: ***LRYH03 ****
Project title: Fluid dynamics of bioreactors - 2 projects available

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

Harvesting biofuel from aquatic microalgae is currently understood to be the most promising way to replace petrolume-based fuel. Bioreactor is an enegineering device used for the biofuel harvesting, but fluid dynamics involving a huge number of microalgae inside bioreactor is very poorly understood. In this project, we will study a specific instability and pattern formation arising in a flow of a model bioreactor. This project requires strong mathematical capability.

Hwang, Yongyun Dr

Project no: ***LRYH04 ****
Project title: Transition in stratified shear flows

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

Flows with density stratification are very common in atmosphere and oceans. However, their transition to turbulence in shear flows has not been very well understood. The project will be to study the early stage of transition to turbulence in stratified shear flows using linear dynamical systems theory. The student needs to be equipped with good unerstanding on fluid mechanics, mathematics, numerical method and control theory

Hwang, Yongyun Dr

Project no: ***LRYH05 ****
Project title: Data-driven 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 to apply 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.

Iannucci, Lorenzo Prof

Project no: ***LRLI01 ****
Project title: Electrohydrodynamic propulsion for UAV

Supervisor: Iannucci, Lorenzo Prof
Co-supervisor(s):
Category: Numerical
Software: OpenFoam

Confidential: No

This project involves the design and validation of a potential novel UAV propulsion system which has no moving parts. The concept uses the principal that partially ionized fluids can gain net momentum under an electric field, as charged particles undergo momentum-transfer collisions with neutral molecules in a phenomenon termed an ionic wind. Electrohydrodynamic (EHD) thrusters generate thrust by using two or more electrodes to ionize the ambient fluid and create an electric field. This thrust or wind has been confirmed by many researchers over the past 80 years, most noticeably Brown in the 1950s. It is expected that the student will built such a device and measure the observed thrust-to-power ratio, which has been recorded as high as 100N/kW which is very high. Parameter studies will also be performed to investigate critical features within the thruster. This will be purely computational using OpenFoam or other multi-physics code.

Iannucci, Lorenzo Prof

Project no: ***LRLI02 ****
Project title: Modelling Composite Manufacture - 2 projects available

Supervisor: Iannucci, Lorenzo Prof
Co-supervisor(s):
Category: Numerical
Software: OpenFoam and ls-dyna(LSTC)

Confidential: No

Manufacture Process Simulation(MPS) is now a key step in the design process of complex composite components. This project involves modelling a number of key stages during the manufacturing process for simple generic scenarios. The envisaged sub-projects, which typical would be per FYP would be expected to be:

(1) Preform Draping Simulation which can be performed using the ls-dyna explicit FE codes.

(2) Use of simple RVE models of the composite preforms will be developed to determine permeability and preform behaviour for input into the higher scale models.

(3) Resin Infusion Simulation using OpenFoam or the ls-dyna (LSTC) software.

(4) Cure and spring-back/distortion to determine all properties during the infusion and cure cycle. Expected software to be ls-dyna (LSTC).

Iannucci, Lorenzo Prof

Project no: ***LRLI03 ****

Project title: Full-size drone – computational project (S)

Supervisor: Iannucci, Lorenzo Prof

Co-supervisor(s):

Category: Experimental: Ready-made experiment;Theoretical;Design

Software:

Confidential: No

To understand the vulnerability of aircraft to drone impacts a detailed model of a drone is required. This project involves building a detailed CAD and Finite Element which can be used in a simple impact simulation with the ls-dyna explicit code. The CAD model is available, but the exact internal structure is not included. The project will require the disassembly of a phantom 3 drone and appropriate geometrical and material determination.

Iannucci, Lorenzo Prof

Project no: ***LRLI04 ****

Project title: Bolted holes testing - experimental (S)

Supervisor: Iannucci, Lorenzo Prof

Co-supervisor(s):

Category: Experimental;Experimental: Structures

Software:

Confidential: No

The design of a large-scale composite wing requires sub-component parts, such as covers and spars to be bolted and bonded together. The bolting allows for inspection and repair and transfer of loads between covers and spars. This project will investigate different bolting configurations and different bolt preloads to understand how the ultimate strength changes. The bolting of two laminates will be two simple laminates that would be bolted together as a lap joint. The department's high-fidelity video and strain recording apparatus will be used to provide detailed feedback on each possible configuration of bolts and preload.

Iannucci, Lorenzo Prof

Project no: ***LRLI05 ****
Project title: Blockchain and bloom filters - computational (S)

Supervisor: Iannucci, Lorenzo Prof
Co-supervisor(s):
Category: Computational
Software: C compiler

Confidential: No
Modern finite element analysis of an aircraft loads case can generate several hundred Tbytes of data. This project will investigate the use of bloom filters to store information in a probabilistic manner coupled with a blockchain to effectively store the evolution of such large finite element models. Both bloom filters and blockchains are extensively used in bitcoin and other cryptocurrencies.

Iannucci, Lorenzo Prof

Project no: ***LRLI06 ****
Project title: Mapping of the probabilities of drone to aircraft collisions – computational project

Supervisor: Iannucci, Lorenzo Prof
Co-supervisor(s):
Category: Computational
Software: Suitable compiler

Confidential: No
The key objective of the project is to determine a risk matrix for the effects of collisions between drones and typical CS-25/CS-23 based aircraft. To determine the relative impact velocity between a potential drone and target aircraft requires knowledge of both the drone and target aircraft velocities.
Firstly, the performance details of typical drones can be determined as a function of MTOM, while the target aircraft flight envelope including take-off used to determine the aircraft velocity. Thus, a net impact velocity can be calculated. An approach could use detailed information on the probabilistic distribution of potential target aircraft ground speeds and can be calculated as a function of altitude using Automatic Dependent Surveillance-Broadcast data for the aircraft using historical transponder data for various aircraft within each Certification category defined by CS-23 and CS-25. The target aircraft velocity could be combined with drone altitude data and used to generate probabilistic impact maps including relative velocities as a function of altitude. While the

endurance, altitude, and maximum speed capabilities of all drones are usually available from datasheets. The actual velocities typically observed during flight could be derived from the flight data which includes near-misses and is organised by the Aviation Safety Network (ASN) as a function of altitude.

Kerrigan, Eric Prof

Project no: ***LREK01 ****
Project title: Advanced gyro-less spacecraft attitude estimation (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
Modern space missions require high levels of accuracy in the attitude estimate, so that fine pointing is achieved and payload data is post-processed with sufficient precision. For this reason several missions employ high-precision gyroscopes which complement star tracker measurements via data fusion. Accurate gyroscopes are however notoriously expensive, therefore efforts towards gyro-less attitude estimators have been made by industry and research (see https://doi.org/10.2514/2.4071). For high-precision applications, effects such as structural flexibilities (due to solar arrays or instrument booms) and model uncertainty play a significant role in the degradation of the attitude estimate. On the other hand, advanced techniques such as machine learning and dynamic programming have shown promising results in control and estimation tasks (e.g. https://doi.org/10.1109/TNN.2005.863458).

The aim of the project is to evaluate the effectiveness of modern estimation techniques in the frame of gyro-less attitude estimation. An algorithm for attitude estimation will be developed and tested on the defined use case, starting from the model of a spacecraft equipped with star tracker and reaction wheels, The use of all available signals is advised: star tracker attitude measurement, reaction wheels commanded torques, reaction wheel speeds and any other useful signal. 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.

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: ***LREK02 ****

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: ***LREK03 ****
Project title: Algorithmic financial trading using optimization in the Julia programming language

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

Confidential: No

Many financial trading algorithms are based on solving optimization problems. The aim of this project is to develop a software package for algorithmic trading in the Julia programming language.

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 one day overtake C/C++ as the language of choice for high-performance scientific computing. See julialang.org and the paper doi.org/10.1137/141000671 for more details. If you have not yet heard of Julia, you will definitely hear a lot about it in the future!

This project will involve integrating existing packages for financial trading and optimization in Julia with optimization solvers developed by my research group. The goal will be to have a software package that can automatically download financial data, analyse the data and make recommendations in real-time as to whether an investor should buy or sell shares.

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: 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: ***LREK05 ****
Project title: Dynamic optimization in the Julia programming language (S)

Supervisor: Kerrigan, Eric Prof
Co-supervisor(s): Vila, Eduardo
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 a well-documented and unit-tested direct collocation method 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.

Knoll, Aaron Dr

Project no: ***LRAK01***
Project title: Development of a hydrogen fuelled cathode for electric propulsion applications (S)

Supervisor: Knoll, Aaron Dr
Co-supervisor(s):
Category: Experimental;Experimental: Manufacturing intensive
Software:

Autodesk Fusion 360
Finite Element Methods Magnetics (FEMM)

Confidential: No
Hollow cathode neutralizers are an essential component of almost every electric propulsion (plasma thruster) technology on the market. The purpose of the hollow cathode is to neutralize the outgoing ion beam to prevent charge accumulation on the satellite and, in the case of Hall Effect Thrusters, to provide the electron current to sustain the discharge. Despite their relative importance, these devices continue to be the 'weak link' in terms of the reliability and cost of the overall system. Additionally, the working gas for spacecraft Hollow Cathodes is limited to Xenon, a very expensive and rare propellant.
The Imperial Plasma Propulsion Lab is currently investigating a next generation plasma propulsion system fuelled by water electrolysis, where the thruster is supplied oxygen and the neutralizing cathode is supplied hydrogen. While much work has been conducted on the oxygen fuelled thruster, there has so far been no development of the hydrogen fuelled cathode. The purpose of this project is to build a first laboratory prototype and demonstrate its successful operation within the large vacuum chamber facility (Boltzmann Chamber). 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 plasma thrusters, so it's an ideal opportunity for those interested in becoming involved in the field of spacecraft electric propulsion.

Knoll, Aaron Dr

Project no: ***LRAK02***
Project title: Preliminary design of a solar sail propelled spacecraft for extrasolar trajectories (S)

Supervisor: Knoll, Aaron Dr
Co-supervisor(s):
Category: Theoretical;Design;Analysis
Software: Matlab
NASA GMAT

Confidential: No
Imperial College has a particular strength in Deep Space engineering and science (cis-lunar space, interplanetary space and beyond). As part of this vision, an Imperial CubeSat platform is under consideration to address the unique challenges associated with deep space exploration: extreme radiation and temperature environment, low solar irradiance, long mission durations and challenging RF communications requirements. This project considers the preliminary design of the CubeSat scale spacecraft, propelled by a solar sail, with the capability to exit the solar system. This project builds on three previous final year projects (2019/20, 2020/21 and 2021/22) and one MSc project (2020/21) that have established the feasibility of the concept and developed a baseline design. The focus of this current project will be on the dynamics of the solar sail deployment in zero-g, and the long-term stability of the deployed sail during the extra-solar transfer.

Knoll, Aaron Dr

Project no: ***LRAK03***
Project title: Design of a compact plasma toroid generator

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 two previous MSc projects (2020/21 and 2021/22). 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;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;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 two prior MSc projects (2019-20 and 2020-21) 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.

Kovac, Mirko Prof

Project no: ***LRMK01 ****
Project title: Aerial Bio-Printing (S) - 2 projects available

Supervisor: Kovac, Mirko Dr
Co-supervisor(s): Kocer, Bahdir
Category: Experimental;Experimental: Structures;Experimental: Manufacturing intensive;Design
Software:
Confidential: Yes

This project aims to develop new techniques for bio printing from a drone. Leveraging an in-situ deposition of various materials can provide a federated manufacturing process on the environment. The project will explore various materials considering microfibrillated cellulose based ink and fungi that will be deposited with a stabilized mechanism on the drone. The first phase will be focusing on the tests for the material and the second phase of the project will be the integration for the drone deployment on-site.

Kovac, Mirko Prof

Project no: ***LRMK02 ****
Project title: Learning-based Soft Grasping for Aerial Robots (S) - 2 projects available

Supervisor: Kovac, Mirko Dr
Co-supervisor(s): Nguyen, Pham Huy
Category: Experimental;Experimental: Structures;Experimental: Manufacturing intensive;Theoretical;Design

Software:
Confidential: Yes
The project aims to develop a drone endowed by a soft grasping mechanism which can be used to grasp various shapes for sample collection, perching and transportation. When the soft extension mechanism is added from the bottom side, the drone can utilize multiple tasks and minimize the impact forces during the interaction. The project is defined in a balance between the mechanical design and the control design. The first phase will be based on developing the soft grasp mechanism and the control approach. The second phase is the integration phase and the system will be tested in the laboratory environment.

Kovac, Mirko Prof

Project no: ***LRMK03 ****
Project title: Tactile Navigation in Narrow Surroundings (S) - 2 projects available

Supervisor: Kovac, Mirko Dr
Co-supervisor(s): Stephens, Brett
Category: Experimental;Experimental: Structures;Theoretical;Design
Software:
Confidential: Yes
The project aims to develop an aerial physical interaction framework that can achieve a flight in a tunnel like environment. The system will exploit the interaction forces to move and find a route with contact forces. The drone will be endowed with the geometrically placed mechanical extensions that will use the developed soft force sensors. The initial phase will be based on the mechanical design, sensor characterization and the simulations for the navigation with the force feedback. The second phase will be mostly based on the experimental evaluation in the flight arena.

Kovac, Mirko Prof

Project no: ***LRMK04 ****
Project title: Simulation of an interactive aerial manipulator (S) - 2 projects available

Supervisor: Kovac, Mirko Dr
Co-supervisor(s): Stephens, Brett
Category: Experimental;Experimental: Structures;Computational;Theoretical;Design
Software:
Confidential: Yes
Develop a Gazebo simulation that incorporates on-board sensors (visual, depth, etc.) that allows for the Software-In-The-Loop testing of various interactice control and motion planning strategies. The simulation will be based on a hexaxopter platform which needs to be developed within a Gazebo environment. The simulation environment should include objects of various sizes and geometries to which the hexacopter can interact with via a delta-arm manipulator, of which also needs to be modelled appropiately within the simulation.

Kovac, Mirko Prof

Project no: ***LRMK05 ****
Project title: Motion optimisation for Aerial Manufacturing (S)

Supervisor: Kovac, Mirko Dr
Co-supervisor(s): Gortat, Daniel
Category: Experimental;Experimental: Structures;Design
Software:
Confidential: Yes

The ARL is working on various methods of additive manufacturing using multi-modal drones. This project will study and implement the motion planning and path optimisation solutions for manufacturing using drones. In particular, it will look at mitigating risk situations the drone might encounter during its task execution and providing it with sufficient intelligence and the ability to solve problems. This can be called the development of an artificial intelligence capable of learning, reasoning and problem solving. If the environment changes, the robot adapts. Gradually, the drone is expected to build a library of risk mitigation protocols for different categories of situations. The project will include simulation based work and experimental verification.

Laizet, Sylvain Prof

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

Supervisor: Laizet, Sylvain Dr
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 FORTRAN flow solver on multiple CPUs and GPUs.

Laizet, Sylvain Prof

Project no: ***LRSL02 ****
Project title: 2D compressible flow solver for GPU hardware

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

This project consists in writing from scratch flow solvers designed for GPU hardware. The solvers will deal with the 2D compressible Navier-Stokes equations and will be based on finite-difference methods on a Cartesian mesh. The aim is to investigate the robustness and performance of OpenMP, OpenACC and CUDA as parallel paradigms. Comparisons will be made with an equivalent Fortran solver dedicated to CPU hardware. The flow configuration of interest is the wake generated by a circular cylinder for low Reynolds numbers. Previous experience in GPU programming would be extremely useful but is not mandatory.

Laizet, Sylvain Prof

Project no: ***LRSL03 ****
Project title: Real-time fluid simulations with Julia

Supervisor: Laizet, Sylvain Dr
Co-supervisor(s):
Category: Computational;Numerical
Software: Julia, Pluto

Confidential: No

This project consists in writing from scratch a flow solver in Julia which will allow for real-time visualisations. The solver will deal with the 2D compressible Navier-Stokes equations on a Cartesian mesh and will use an immersed boundary method to deal with fluid-structure interactions. Visualisations will be performed in real time via Pluto, a simple reactive notebooks for Julia. The flow configuration of interest is the wake generated by a circular cylinder for low Reynolds numbers. Previous experience in Julia would be extremely 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? - 2 projects available

Supervisor: Laizet, Sylvain Dr
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 Dr
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.

Laizet, Sylvain Prof

Project no: ***LRSL06***
Project title: Computational Fluid Dynamics with augmented reality

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

The main idea behind this project is to investigate the possibility of using augmented reality in computational fluid dynamics dataset to help conveying important information and results in a more efficient and rather intuitive way. The behaviour of fluid flow is often a complex paradigm for visualisation and cognitive interpretation. Mixed reality related technology can be a solution for enhanced virtual interactive learning environment. However, there are limited augmented reality platforms on fluid flow interactive learning. The project is aiming at developing an interactive education application for students to interact and understand the complexity of fluid flows, with a focus on the turbulence generated by wind turbines.

Laizet, Sylvain Prof

Project no: ***LRSL07 ****
Project title: Influence of the rotation speed for a 2D circular cylinder at low Reynolds numbers

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

Confidential: No

A 2D numerical study on the laminar flow past a circular cylinder rotating with a constant angular velocity will be carried out. The objective is to obtain a consistent set of data for the drag and lift coefficients for a wide range of rotation rates and a deeper insight into the flow field and vortex development behind the cylinder. The incompressible 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 cylinder 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 cylinder. Previous experience using Fortran would be very useful but not mandatory.

Laizet, Sylvain Prof

Project no: ***LRSL08***
Project title: Quantum algorithms to solver PDEs

Supervisor: Laizet, Sylvain Dr
Co-supervisor(s):

Category: Computational;Theoretical;Numerical;Literature
Software:
Confidential: No

With the advent of quantum computing (QC), a plethora of quantum algorithms have demonstrated, both theoretically and experimentally, more powerful computational possibilities than their classical counterparts. The project will investigate methods to solve linear and non-linear PDEs. The project will be using the Quantum Exact Simulation Toolkit, which is a high performance simulator of universal quantum circuits, state vectors and density matrices. QuEST can be used by both C and C++, is open source, multithreaded, distributed and GPU-accelerated. Needing only compilation, QuEST is easy to run both on laptops and supercomputers, where it can take advantage of multicore and networked machines to quickly simulate circuits on many qubits.

Lee, Koon-Yang Prof

Project no: ***LRKL01 ****
Project title: Optically transparent material derived from cellulose nanofibres

Supervisor: Lee, Koon-Yang Dr
Co-supervisor(s): Wloch, Daniela
Category: Experimental;Design;Analysis;Survey;Literature
Software:
Confidential: No

Bacterial cellulose (BC) is synthesised as a tough and continuous nanofibre network with high specific surface area, with single fibre tensile modulus and strength of up to 160 GPa and 6 GPa, respectively. We hypothesise that this continuous BC nanofibre network will serve as excellent nano-reinforcement for polymers with similar refractive indices, such as acrylic resin, for the production lightweight polymeric transparent armour with specific energy absorption higher than the state-of-the-art (e.g. impact-modified acrylic and polycarbonate-impact-modified acrylic resin laminates), thereby bridging the gap between monolithic polymer and glass-clad polycarbonate. The introduction of such continuous nanofibre network into acrylic resin will introduce additional energy-absorbing mechanisms, including fibre de-bonding (due to an increase in fibre-polymer matrix interface), fibre re-orientation and fracture, enhancing the impact resistant of the resulting BC-reinforced acrylic resin without sacrificing optical transparency (due to its refractive index matching with acrylic resin and small length scale of 50 nm). This proposed research aims to interface BC engineering and polymer sciences with materials engineering and processing. Through this interface, this project will explore challenging and high-impact methods for the development of new large-scale processes in order to manipulate the microstructure of BC and efficiently utilise them as nano-reinforcement for novel lightweight transparent armour. One position is available for this project and potential students are encouraged to contact Dr Lee for more information to discuss workload and research directions.

Lee, Koon-Yang Prof

Project no: ***LRKL02 ****

Project title: Upgrading waste: Design and manufacturing of novel polymer composites reinforced with waste materials - 2 projects available

Supervisor: Lee, Koon-Yang Dr
Co-supervisor(s): Gaduan, Andre
Category: Experimental;Design;Analysis;Survey;Literature
Software:
Confidential: No

Consumer plastics are highly-engineered products with well-defined physical properties in order to meet their stringent design specification, which includes the use of additives and multi-polymer products. These must be separated into recognisable plastic grades prior to recycling. Melt reprocessing of mixed plastic waste leads to products with inferior properties due to incompatibility between the different plastics; these are instead down-cycled as fillers for building materials. To bridge this property-performance gap, we propose a composite approach combining mixed plastic waste with waste material to produce high performance engineering materials, upgrading the value of mixed plastics for advanced engineering applications. In this project, the student(s) will study the structure-property relationship of mixed plastic waste (if applicable) and identify novel suitable processing/reinforcement, as well as its architecture that will upgrade waste plastics. The grand vision of this project is to develop material solutions that will contribute to a more sustainable future. Up to two positions are available for this project. Students are encouraged to contact Dr Lee for more information to discuss workload and research directions.

Lee, Koon-Yang Prof

Project no: ***LRKL03 ****
Project title: Upgrading individual protective clothing with nanocellulose - 2 projects available

Supervisor: Lee, Koon-Yang Dr
Co-supervisor(s): Li, Joanne
Category: Experimental;Design;Analysis;Survey;Literature
Software:
Confidential: Yes

Individual protective equipment (IPE) is used to protect personnel from the effects of chemical, biological and radiological (CBR) warfare agents. The technology used in IPE clothing provides a very high level of protection against CBR warfare agents for the military personnel. However, the physiological burden of wearing such clothing can be high in some circumstances. One major challenge is the removal of body heat, which is facilitated by the use of air-permeable fabrics as these allow water vapour derived from sweat to escape the microclimate of the suit. However, if the air-permeability is too high the levels of protection can fall significantly. Consequently, there is an interest in developing protective technologies that could provide protection without impeding the permeation of water vapour out of the suit. It is anticipated that the application of nanocellulose in IPE clothing will foster the development of lighter, multifunctional IPE garment with reduced physiological burden to the user by providing filtration within the outer shell textile. As nanocellulose is hydrophilic in nature it is anticipated that this will also facilitate the passage of moisture from the inner layers to the exterior of the garment, allowing for efficient body heat removal. Therefore, the aim of this proposed project is to produce nanocellulose-enhanced IPE and to demonstrate the scale of the resulting performance improvements over the state-of-the-art. It should be noted that no chemical, biological and radiological agents will be used in our experiments. Up to two positions are available for this project and potential students are encouraged to contact Dr Lee for more information to discuss workload and research directions.

Lee, Koon-Yang Prof

Project no: ***LRKL04 ****

Project title: Manufacturing "artificial wood" from low cost ionic liquids - 2 projects available

Supervisor: Lee, Koon-Yang Dr

Co-supervisor(s): Barr, Meredith

Category: Experimental;Design;Analysis;Survey;Literature

Software:

Confidential: No

There is currently a timely need to design and manufacture renewable materials for high volume structural applications and decouple our
economy from fossil-derived non-renewable resources. Cellulose-based natural fibres are the prime candidate for the production of low-cost high-performance renewable composites. However, there is still a property-performance gap between natural fibre-reinforced polymers and traditional fossil-derived engineering materials, as the high tensile stiffness (up to 165 GPa) and strength (at least 1 GPa) of cellulose microfibrils have yet to be fully exploited in a composite setting. 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 the world's first "artificial wood", i.e. cellulose microfibril-reinforced lignin composites with the native cellulose-I structure preserved (mimicking wood cell wall), using simple and intrinsically scalable manufacturing concepts. The proposed research activities are structured around (i) manufacturing "artificial wood" from (low cost) ionic liquid, (ii) design and manufacture of unidirectional and continuous "artificial wood" fibre-reinforced renewable composites and (iii) optimising the techno-economics and lifecycle of "artificial wood" manufacturing. 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 and potential students are encouraged to contact Dr Lee for more information to discuss workload and research directions.

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;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: Graphene based thermalplastic composites via hot pressing (S)

Supervisor: Li, Qianqian Dr
Co-supervisor(s): Tagarielli, Vito Dr
Category: Experimental;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 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.

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;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.

The aim of this project is therefore to design, build and test a simple proof of concept experimental prototype of a practical cycling/sports helmet that is able to filter out harmful air particles (ideally to FFP2 standard) without causing breathing discomfort or affecting the wearers vision.
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.

Please note, I also welcome students who wish to propose their own FYP project. For further details please see my project proposal entitled "Propose your own FYP project".

Lubbock, Roderick Dr

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

Supervisor: Lubbock, Roderick Dr
Co-supervisor(s):
Category: Experimental;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.
Please note, I also welcome students who wish to propose their own FYP project. For further details please see my project proposal entitled "Propose your own FYP project".

Lubbock, Roderick Dr

Project no: ***LRRL03 ****
Project title: A spatial impulse response technique for improving the frequency response of thermocouple probes

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

Thermocouple probes are ubiquitous in the field flow temperature measurement however they are limited by their low frequency response due to the large thermal inertia of the bead. This experimental project looks at improving the probe frequency response for a given flow by deriving the probe impulse response by traversing it through a spatially varying temperature field at

different known velocities. This technique has already been shown to work for pressure probes [1].
Experimental aspects of the project and will involve building a simple experimental rig for traversing thermocouple probes across a hot flow (e.g. from a heat gun) at different velocities, along with a simple PC-based DAQ system. Theoretical aspects will include developing a solid understanding of thermocouple-probe based flow temperature measurements, whilst analytical aspects will include time-frequency analysis (impulse response, deconvolution, FFTs etc.).
[1] Burdett, Lubbock & Povey, 2018. AN IMPULSE RESPONSE TECHNIQUE TO IMPROVE THE EFFECTIVE FREQUENCY RESPONSE OF PRESSURE PROBES. XXIV Biennial Symposium on Measuring Techniques in Turbomachinery, Prague, Czech Republic, 29 - 31 August 2018. Paper No MTT2418B23. Available from: https://meastechturbo.com/paper-archives/2418-prague-2018/item/download/466_1bdd5c50c7ece7b207acee25244b0fac
Please note, I also welcome students who wish to propose their own FYP project. For further details please see my project proposal entitled "Propose your own FYP project".

Lubbock, Roderick Dr

Project no:	***LRRL04 ****
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).
Please note, I also welcome students who wish to propose their own FYP project. For further details please see my project proposal entitled "Propose your own FYP project".

Lubbock, Roderick Dr

Project no: *LRRL05 **

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.
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.
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).
Please note, I also welcome students who wish to propose their own FYP project. For further details please see my project proposal entitled "Propose your own FYP project".

Lubbock, Roderick Dr

Project no: *LRRL06 **

Project title: Integrated helmet - breathing apparatus for avalanche survival - computational - 2 projects available

Supervisor: Lubbock, Roderick Dr

Co-supervisor(s):

Category: Computational;Theoretical;Design;Analysis

Software: CFD software e.g. Ansys or 3DExperience (Simulia), Matlab, CAD.

Confidential: No

85% of avalanche deaths are caused by asphyxiation due to the inability of the victim to evacuate exhaled CO_2 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

CO_2. 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 CO_2 away from the user's airways - appears to be sound. This project seeks to overcome the impracticalities of the Avalung by integrating some sort of avalanche breathing apparatus into a helmet. 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.

The challenges associated with this project include modelling air flow under conditions of snow burial, as well as modelling air flows through the device itself.

[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].

Please note, I also welcome students who wish to propose their own FYP project. For further details please see my project proposal entitled "Propose your own FYP project".

Magri, Luca Dr

Project no: ***LRLM01 ****

Project title: Physics-constrained turbulence learning with quantum computing (S)

Supervisor: Magri, Luca Dr

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 Dr

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

Supervisor: Magri, Luca Dr
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
Emphasis will be put on quantum algorithms.

Montomoli, Francesco Prof

Project no: ***LRFM01 ****
Project title: Optimization of gas turbine component (S) - 2 projects available

Supervisor: Montomoli, Francesco Prof
Co-supervisor(s):
Category: Computational;Design
Software: Matlab, OpenFoam
Confidential: Yes
The aim of this project is to study and optimize a realistic model of gas turbine component with the open source CFD solver OpenFoam. This project requires a high level of mathematical ability and experience using Matlab and ideally openfoam

Montomoli, Francesco Prof

Project no: ***LRFM02 ****
Project title: Machine Learning and Turbulence models (S) - 2 projects available

Supervisor: Montomoli, Francesco Prof
Co-supervisor(s):
Category: Computational
Software: Matlab, OpenFoam
Confidential: Yes

The project will involve Genetic Programming, high fidelity simulations and ML methods. The work will be applied to optimization problems.
This project requires a good knowledge of CFD and ideally a previous experience using OpenFoam.

Montomoli, Francesco Prof

Project no: ***LRFM03 ****
Project title: Non Intrusive Polynomial Chaos for transonic/supersonic flows (S) - 2 projects available

Supervisor: Montomoli, Francesco Prof
Co-supervisor(s):
Category: Computational
Software: Matlab, OpenFoam
Confidential: No

The aim of the project is to develop non intrusive polynomial chaos for transonic flows based on stochastic collocation methods. Uncertainty plays a key role in many modern applications and it is important to have a reliable method to account such uncertainty. A stochastic collocation methodology with Pade's polynomials will be used to simulate the stochastic field. This project requires a high level of mathematical ability and experience using Matlab.

Montomoli, Francesco Prof

Project no: ***LRFM04 ****
Project title: AI for CFD (S) - 2 projects available

Supervisor: Montomoli, Francesco Prof
Co-supervisor(s):
Category: Computational
Software: Matlab, OpenFoam
Confidential: Yes

The aim of this work is to investigate Active Learning for CFD models. Meshgraphnet applied to hydrogen explosion to characterize the pressure load on Oil&Gas and Aerospace components. The student will use OpenFoam and Meshgraphnet to simulate realistic explosions

Montomoli, Francesco Prof

Project no: ***LRFM05 ****
Project title: Machine Learning for Design for Additive Manufacturing - 4 projects available

Supervisor: Montomoli, Francesco Prof
Co-supervisor(s):
Category: Computational
Software:
Confidential: Yes

The project will investigate by using Tensorflow the possible application of machine learning to additive manufacturing, from defect detection to material selection. In particular the work will investigate how deep neural networks can be used to identify the right parameters in AM.

Morrison, Jonathan Prof

Project no: ***LRJM01 ****
Project title: Membrane-Substrate buckling for boundary layer control.

Supervisor: Morrison, Jonathan Prof
Co-supervisor(s):
Category: Experimental
Software:
Confidential: No

We wish to design an experiment to test the use of dynamic roughness for the control of turbulent boundary layers. The dynamic roughness will be implemented through controlled actuation of chequerboard bifurcations in compliant membrane-substrate structures. This highly novel approach enables the simultaneous change in the time-dependent surface conditions so that the moving surface may be characterised by both an imposed lengthscale (wavenumbers) and a timescale (frequency), with the added motivation of identifying the drag-altering behaviour. Such an approach replicates many practical examples of time-dependent surface change used for boundary layer control in such as the delay of separation. The project would initially involve a design of the boundary layer experiment followed by a bench top experiment in, for example, fully developed turbulent channel flow. The project is intrinsically related to the project of same name supervised by Dr. Santer and focusing on the design and construction of the chequerboard.

Morrison, Jonathan Prof

Project no: ***LRJM02 ****
Project title: Inertial subrange in turbulent pipe and channel flow - 2 projects available

Supervisor: Morrison, Jonathan Prof
Co-supervisor(s):
Category: Experimental;Analysis
Software: Matlab

Confidential: No

Using Princeton superpipe data, we have been looking at the behaviour of the inertial subrange in high-Reynolds-number turbulent pipe flow Re_lambda~1000. Even in a simple flow such as this, the energy transfer is not classical, as described by the -5/3 law in spectra, or the "4/5'ths" law in real space using structure functions. The goal is to investigate the effects of small shear in the mean velocity profile by extending the analysis to small distance from the pipe centre line as well as in the local equilibrium region. The data are single axial velocity component from the NSTAP probe at Re_\tau up to 98000.
The second database involves DNS data from a turbulent channel flow at Re_\tau=5200 which broadly has similar behaviour of the energy budget as that in pipe flow, http://journals.cambridge.org/article_S0022112015002682. Here we have the fully resolved 3D data and more ambitious approaches can be used, in particular using the Kármán-Howarth-Monin equation for low-order structure functions.

Morrison, Jonathan Prof

Project no: ***LRJM03 ****
Project title: Analysis of the effects of surface waves on turbulent boundary layers for drag reduction.

Supervisor: Morrison, Jonathan Prof
Co-supervisor(s):
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

Morrison, Jonathan Prof

Project no: ***LRJM04 ****
Project title: Instrumentation for CRM-HL testing - 2 projects available

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

A Boeing generated project based on the open-source Common Research Model - High Lift programme. Details will be determined by QinetiQ who test the CRM model in the 5m tunnel at Farnborough. A half-span model is due to come to the 10x5 tunnel next year. In the run-up to this, we expect two FYPs will support this activity.

Mylvaganam, Thulasi Dr

Project no: ***LRTM01 ****
Project title: Control strategies for satellite constellation maintenance via dynamic optimisation (S)

Supervisor: Mylvaganam, Thulasi Dr
Co-supervisor(s): Amato, Davide Dr
Category: Computational;Theoretical;Design;Analysis;Numerical;Literature
Software: Matlab

Confidential: No

Satellite constellations are being increasingly used to satisfy coverage and redundancy requirements for Earth observation and telecommunications missions. Recently, constellations of several hundreds or thousands of satellites, such as the Starlink and Planet constellations, have been placed into orbit. To operate the constellation correctly and to prevent collisions, each of its elements must be controlled through station-keeping manoeuvres to counteract perturbations such as those arising from Earth oblateness and atmospheric drag, and execute collision avoidance manoeuvres to minimise collision risk with other objects.
This project will be centred about control of satellites. More precisely, you will study optimal control-based/game theory-based techniques for constellation maintenance. Such techniques have already proved highly beneficial for autonomous coordination of ground-based and aerial robots, providing a systematic technique for guaranteeing a specific task is achieved while avoiding collisions with obstacles/other robots. In this project you will explore whether similar results can be obtained in space!

The project will involve 1) gaining a solid understanding of optimal control and differential game theory; 2) reviewing trajectory planning and control techniques currently available for satellite constellations; and 3) applying optimal control/game theory-based techniques to models describing satellite constellations. The overall control objective will be to ensure efficient constellation maintenance.
The project will involve advanced topics in control engineering (linear and nonlinear), dynamical systems (linear and nonlinear) and orbital mechanics. In order to complete the project to a good standard an excellent background in mathematics and control engineering is essential. A solid grasp of Matlab (which will be used for simulations) is also required.

Mylvaganam, Thulasi Dr

Project no: *LRTM02 **
Project title: Optimal Control of wind turbines

Supervisor: Mylvaganam, Thulasi Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Analysis;Numerical;Literature
Software: Matlab and NREL simulation tools (or other similar tools)

Confidential: No
As we strive to minimise the use of fossil fuels, renewable energy is becoming ever more important. For this reason, wind turbines (which may be on land or offshore) have gained (and continue to gain) interest. Both due to the environment in which they operate and due to their (nonlinear and often difficult to model) dynamics, controlling the operation of offshore wind turbines is challenging. However, for several reasons, it is of interest to ensure that a wind turbine remains at (or close to) specific operating conditions (to minimise structural damage and maximise energy generation). These objectives can be elegantly captured via the formulation of an optimal control problem. Nonlinear optimal control problems are notoriously difficult to solve, however. Therefore, most existing techniques for solving optimal control problems involving (offshore and land-based) wind turbines rely on a linear approximation of wind turbine dynamics, resulting in a so-called Linear Quadratic Regulator (LQR) problem.
Recently, we have developed an alternative technique to solve (nonlinear) optimal control problems approximately. The technique has been demonstrated (via simulations in Matlab) on a nonlinear (albeit simplified) model of an offshore wind turbine with promising results (i.e. improved performance with respect to an LQR approximation). This is a very recent and very exciting result and it would be very interesting to explore how the control technique will perform in more “realistic” settings, e.g. via the use of high-fidelity simulation tools.
In this project the student will consider optimal control of wind turbines. The first objective of the project will be modeling and simulation (of simplified models) of single/multiple wind turbines in MATLAB. The second objective of the project is then to simulate the behaviour of one/more wind turbine/turbines under the designed control action using existing high-fidelity simulation tools, e.g. those that have been developed by The National Renewable Energy Laboratory (NREL). The

performance of the different control strategies will be compared and contrasted using these simulation tools.
The project will involve the consideration of nonlinear dynamical systems and advanced control techniques. For this reason, an excellent background and a keen interest in mathematics and control theory is absolutely essential. The project will involve a programming in Matlab as well, as learning how to use existing simulation tools (such as those developed by NREL). A solid background/aptitude for programming is therefore also beneficial.

Mylvaganam, Thulasi Dr

Project no: ***LRTM03 ****
Project title: Optimal control of wave energy converters

Supervisor: Mylvaganam, Thulasi Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Analysis;Numerical;Literature
Software: Matlab

Confidential: No

As we strive to minimise the use of fossil fuels, renewable energy is becoming ever more important. In this project the student will consider wave energy converters. As suggested by the name, wave energy converters harvest wave energy to produce useful energy. This project will focus on control of wave energy converters, e.g. with the objective of maximising power generation. Optimal control techniques are particularly relevant in this regard. Wave energy converters are, however, described by nonlinear dynamics and, as a consequence, solving optimal control problems associated with such systems is tricky (as nonlinear optimal control problems are difficult to solve, in general). Various (systematic) techniques to approximate the solution of nonlinear optimal control problems exist and may be useful in overcoming the aforementioned hurdle.
In this project the student will consider wave energy converters.
The first objective of the project will be modeling and simulation of wave energy converters. Simulations will be run using Matlab. The second (and main) objective of the project is then to consider techniques available to approximate the solution of nonlinear optimal control problems and explore their application to wave energy converters. The performance of the controllers will be evaluated via simulations using Matlab.
The project will involve the consideration of nonlinear dynamical systems and advanced control techniques. For this reason, an excellent background and a keen interest in mathematics and control theory is absolutely essential. The project will involve a programming in Matlab. A solid background/aptitude for programming is therefore also beneficial.

Mylvaganam, Thulasi Dr

Project no: ***LRTM04 ****
Project title: Control of robotic systems for space applications (S)

Supervisor: Mylvaganam, Thulasi Dr
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).

Mylvaganam, Thulasi Dr

Project no: ***LRTM05 ****
Project title: Techniques to solve dynamic optimisation problems

Supervisor: Mylvaganam, Thulasi Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design
Software: Matlab

Confidential: No

Optimal control concerns the optimisation (i.e. minimisation/maximisation of a cost/reward) subject to a dynamic constraint (i.e. the dynamics of the system). Namely, given a dynamical system, one seeks to design its control input so that the resulting trajectory is optimal with

respect to a certain objective. A classical optimal control problem is the so-called Goddard Problem, which concerns the problem of maximising the peak altitude of a rocket. Differential games represent a similar class of problems, involving a dynamical system and multiple objectives/control inputs. Such problems – which involve optimisation and quantities that evolve in time - are known as dynamic optimisation problems.
With very few exceptions (e.g. the Linear Quadratic Regulator problem), solving dynamic optimisation problems is notoriously difficult. Different techniques to approximate their solution are therefore called for.
Recently two techniques have been proposed, that combine the complementary perspectives provided by the two main “machineries” to solve dynamic optimisation problems (i.e. Dynamic Programming and Pontryagin’s Minimum Principle), to construct (systematically) approximate solutions of (nonlinear) optimal control problems. In this project the student will consider in detail one/both of these techniques. The student may then delve into applications of these techniques into meaningful engineering problems and/or further developments (from a fundamental control theoretic perspective) of these techniques. The performance of designed controllers will be assessed via simulations in Matlab.
This is an ambitious project that is focused on fundamental control theory. The project will necessarily involve nonlinear dynamical systems and advanced nonlinear control techniques. For this reason, an excellent background and a keen interest in mathematics and control theory is absolutely essential. The student will be required to explore fundamental concepts and topics in nonlinear systems and nonlinear control. The project will involve a programming in Matlab. A solid background/aptitude for programming is therefore also beneficial.
Note that due to the focus of this project on fundamental control theory, it is well suited for a student with particular interests in this area and with a particular fondness of mathematics, with the relevant background as detailed above.

Mylvaganam, Thulasi Dr

Project no:	***LRTM06 ****
Project title:	Control strategies for robotic systems: ensuring reliable operation in uncertain environments
Supervisor:	Mylvaganam, Thulasi Dr
Co-supervisor(s):	
Category:	Computational;Theoretical;Design;Analysis;Numerical
Software:	Matlab
Confidential:	No

Robotic systems are ubiquitous. For certain types of applications, e.g. environmental monitoring, structural maintenance, etc., such systems are requried to operate in uncertain, challenging environments. As a results accurate models describing the behaviour of such robotic systems may be lacking (e.g. due unknown exogeneous disturbances).
Motivated by the above, in this project the student will consider data-driven and/or optimal/robust control of robotic systems. The student will explore existing models describing the

dynamics of robotic systems 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/robost control (treating unknown environmental effects as an exogenous disturbance) 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).

Mylvaganam, Thulasi Dr

Project no: ***LRTM07 ****
Project title: Optimal air traffic management for approach and landing

Supervisor: Mylvaganam, Thulasi Dr; Paranjape, Aditya Dr
Co-supervisor(s):
Category: Computational;Theoretical
Software: Matlab (preferred) or Python

Confidential: No
Sustainable aviation is a topic of significant interest at the moment, and for the foreseeable future. A big part of achieving sustainable aviation involves finding ways to minimize the environmental footprint of aircraft. The exact approach to be taken depends strongly on the flight phase. Towards that end, for instance, there are well-established strategies for managing the push-back times to minimize the time spent by aircraft on the ground while taxiing for take-off. More recently, Airbus has looked at formation flying to optimise fuel consumption during cruise.

In this project the student will consider an airport with archetypal airline and airliner models. More, precisely the project will revolve around the following problem. Given a list of incoming aircraft, design optimal laws for assigning landing slots while minimizing a joint environmental and economic metric. This involves solving the two sub-problems of slot assignment and approach path planning. As such the project will involve several topics in the fields of mathematical optimization, dynamical systems and control engineering. The project will involve a mix of theoretical work and coding in Python/Matlab, with a particularly strong emphasis on the former.

Students will learn about cutting edge topics in the fields of optimization, optimal control, dynamical systems and decision-making. These fields are of relevance to the contemporary industry, not limited to aviation and aerospace.

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 Mylvaganam.

Prior academic preparation: the project will involve work that is of a highly mathematical nature. It is therefore absolutely essential that the student has a strong background in mathematics, dynamical systems and control theory. Familiarity with using Matlab is also required.

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: Design and wind tunnel demonstration of flutter suppresion system

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 - 2 projects available

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: Data-driven model for wing loads under gusts

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

Confidential: No

A classical aerodynamic solution due to W. P. Sears describes the interactions between an airfoil and an incoming flow. It is however cumbersome to use directly for simulation and numerous approximations have been proposed, with mixed success. In this project we will explore data-driven solution using recently developed algorightms for sparse identifcation in nonlinear dynamics (SINDy). We will further seek extensions of the appraoch to wings in atmospheric turbulence. This is a computational project that can will need both python and matlab. Further reading: https://doi.org/10.2514/1.J060863

Palacios, Rafael Prof

Project no: ***LRRP05***
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

Panesar, Ajit Dr

Project no: ***LRAP01***
Project title: LatTess (Lattice Tessellator) – metamaterials design tool (software functionality)

Supervisor: Panesar, Ajit Dr
Co-supervisor(s):
Category: Computational;Design;Numerical
Software:
Confidential: No

The first use of the LatTess 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. Previous years have seen the migration from MATLAB to Python with the aim to reach a wider audience. The core 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: a) High-quality surface rendering for quick visualisation during design phase and for print-ready file for AM techniques, b) Quicker lattice generation by adopting e.g. GPUs, c) Generate the lattice infill within desired structure and d) Extensions to include non-planar slicing options.

Panesar, Ajit Dr

Project no: ***LRAP02***
Project title: Sustainability through Additive Manufacturing considering life cycle analysis

Supervisor: Panesar, Ajit Dr
Co-supervisor(s):
Category: Computational;Analysis;Literature
Software:
Confidential: No

There is a growing interest and even regulatory requirements for sustainable manufacturing. While AM has been hailed as the more sustainable option for its additive nature, there has not been much conclusive work in quantifying the impact of various design considerations over the whole product life cycle of AM parts.
This project will aim to develop the quantitative model that assesses the sustainability and economics of additive manufacturing. Potential considerations in the assessment include decentralised manufacturing, CO2 emissions, cost modelling, packing optimisation etc. Successful implementation will allow sustainability considerations to be incorporated into the design optimisation for additive manufacturing process, creating products that are more environmentally friendly and economical.
A strong interest in Machine Learning, Optimisation, and programming in Python is desirable.

Panesar, Ajit Dr

Project no: ***LRAP03***
Project title: Intelligent design tool to realise system embodied within a structure (S)

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

In collaboration with AMRC Catapult, this project aims to advance the area of multi-material AM. Development of the next generation of products, such as autonomous flying vehicles, require both optimised structures and system elements (https://www.youtube.com/watch?v=roB5wCr9ITo) which can be realised using multi-material multifunctional 3D printing to exhibit unrivalled performance.
A design framework has been developed for the creation of a routing system within the structure. This design tool is developed to enable fast and effective manufacturing using the approximation method along the medial axis interpolated by a series of piecewise Catmull-Rom splines.
The contribution of this project is to enhance the design tool to the front-end design tool in Jupyter Notebook, assessing the suitable routing method and generating the CAD model from the design tool ready to be realised. Depending on the student's interested applications, Finite Element analysis or experiment on printed samples can be conducted by considering a) the effect of the reinforcement's thickness b) heat dissipation of electronic components c) evaluating the design performance through conducting experiments on printed reinforced samples.
Programming Language/Software: Python, Abaqus

Panesar, Ajit Dr

Project no:	***LRAP04 ****
Project title:	LatTess (Lattice Tessellator) – metamaterials design tool (application focused) (S)
Supervisor:	Panesar, Ajit Dr
Co-supervisor(s):	
Category:	Computational;Analysis
Software:	
Confidential:	No

The first use of the LatTess 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. Previous years have seen the migration from MATLAB to Python with the aim to reach a wider audience. The core 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 extending the software to various functional applications: a) analyse the lattices' natural frequency and resistance to vibration, b) investigate the comprehensive response of lattice structures subject to impact loading, c) Lattice structural optimisation/tuning for multi-functions to achieve lattice designs with high-efficiency vibration isolation, high energy absorption capability and sufficient structural stiffness.

Panesar, Ajit Dr

Project no: ***LRAP05 ****

Project title: Fibre reinforced additive manufacturing (S)

Supervisor: Panesar, Ajit Dr
Co-supervisor(s):
Category: Experimental;Experimental: Structures;Design;Literature
Software:
Confidential: No

This project offers the student a unique opportunity to work on the state-of-the-art Anisoprint 3D printer to realise high performance fibre reinforced polymeric parts. It is envisaged that besides process parameter optimisation, the student in concultation with the supervisor will be exploring tool-path, infill strategies and fibre volume fractions to enhance the part performace. This experimental work will likely lead to a conference/journal paper.

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 superivisor, 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: 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: ***LRGP05 ****
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.

Papadakis, George Prof

Project no: ***LRGP06 ****
Project title: Flow inside a ventilated room to reduce the risk of disease transmission (S)

Supervisor: Papadakis, George Prof
Co-supervisor(s):
Category: Computational;Theoretical
Software: Star-ccm+, open foam

Confidential: No
Disease transmission in the interior of buildings has renewed the importance of ventilation. Ventilated rooms pose much lower risk of transmission compared to non-ventilated ones. In this project we will simulate the flow inside a ventilated room, and compare with available results in the literature. We will also investigate whether we can infer the flow inside a ventilated room from pressure measurements at the walls of the room. Where should these pressure transducers be placed to optimally reproduce the flow? Using this information from available wall measurements will allow one to compute the degree of risk of disease transmition in real time, without expensive and time consuming flow computations.

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: Computational;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 look to design output feedback control laws and determine their stability margins. While the PDEs can be helpful in deriving analytical stability guarantees, we will also look to use numerical continuation and bifurcation methods to determine the stability margins computationally. 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.

Prior academic preparation: control theory; partial differential equations; flight mechanics; aeroelasticity

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 - 6 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: Multiscale modelling of Aircraft structures - 4 projects available

Supervisor: Pinho, Silvestre Prof
Co-supervisor(s):
Category: Computational;Design;Analysis;Numerical
Software: Abaqus (necessarily); Python (depending on student aptitude); Fortran (only if student already has experience in object-oriented programming)

Confidential: No
We have developed advanced structural failure models in cooperation with NASA and Airbus. These models have now been incorporated into and are part of the commercial releases of the FE software packages Abaqus and LS-Dyna. You can find further details about these and other models by watching the videos in my website (http://tinyurl/pinholab) or by watching this keynote in youtube: https://www.youtube.com/watch?v=lBblnnF_lgw&t=1061s (the keynote starts at minute 1:20, the description of models relevant to this project are from 13:37 to 36:04).
In this project, you will use our FE models (and eventually develop them further) to make accurate Finite Element predictions of failure of an aircraft wing /wing-box using multiscale approaches. The objective is to predict not only the failure loads but also to achieve a detailed understanding of the failure process and sequence of events leading to complete structural collapse.
Students applying for this project should have a strong aptitude (at first class level) for Structural Mechanics, Finite Elements and Computational Mechanics (and eventually also programming).
Depending on your interest and aptitude for programming, there are various routes for this project: your project can be designed around using mostly the abaqus graphical interface, or it can also include significant coding in Python. If you already have a background in Fortran (object oriented) then there is also scope for making this a key part of the project.
By the end of this project, you will be proefficient in the use of Finite Element models actually used by Airbus.

Pinho, Silvestre Prof

Project no: ***LRSP02***
Project title: Bio-inspired solutions for improving the mechanical performance of composite structures via microstructure design - 3 projects available

Supervisor: Pinho, Silvestre Prof
Co-supervisor(s):
Category: Experimental;Design;Analysis
Software: N/A
Confidential: No
Nature has evolved fantastically intricate microstructures that have an excellent mechanical response. Examples include wood, bone, nacre, the gigas shell, the mantis shrimp, among others. Sor far, it has proved challenging to manufacture equivalent microstructures in human-made composite structures.
However, recent developments in tow spreading technologies and laser micro-machining allowed, for the first time, the manufacturing of complex CFRP microstructures, and an increase in translaminar fracture toughness of over 500% was demonstrated in our group. You can find

details about some recent results in this keynote in youtube:
https://www.youtube.com/watch?v=lBblnnF_lgw&t=1061s (from 36:05 until the end).
This project will explore new and exciting opportunities for the application of these high-tech materials in actual structural components under real-life test conditions.
In particular, the aim of this project is to use our new Automated Tape Placement machine to manufacture microstructures usibng the same manufacturing methods that are actually used in aerospace.
This is an experimental project; it requires strong practical skills along with a solid understanding of material science and solid mechanics.

Pinho, Silvestre Prof

Project no: ***LRSP03***
Project title: Structural design of a dry-wing / blended-wing for a Hydrogen-powered aircraft - 4 projects available

Supervisor: Pinho, Silvestre Prof
Co-supervisor(s):
Category: Computational;Design;Analysis;Numerical
Software: 3DX Catia / Abaqus

Confidential: No
Airbus's ZEROe project identified three NetZero aircraft concepts - all of them Hydrogen-powered. Airbus has now commited to have one flying by 2035. In its FlyZero project, the ATI also investigated NetZero concepts, also closed in on 3 concepts, and also all of them are Hydrogen-powered.
In this project, you will start from one of the FlyZero concepts, which are extensively documented in the FlyZero website, or ZEROe concepts, and carry out a preliminary structural design of a corresponding aircraft wing.
The project will involve overall structural calculations, creating CAD models, CAE models and running them in the college's computer cluster.
Students applying for this project should have a strong aptitude (at first class level) for Wing design, Structural Mechanics, Finite Elements and Computational Mechanics.
By the end of this project, you will be proefficient in the structural design of aircraft structures relevant for the NetZero target.

Quino, Gustavo Dr

Project no: ***LRGQ01***
Project title: Digital twinning of environmentally damaged composites

Supervisor: Quino, 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 has to 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, Gustavo Dr

Project no: ***LRGQ02***
Project title: Micro-mechanical study of damage propagation of aerospace composites under compression

Supervisor: Quino, Gustavo Dr
Co-supervisor(s):
Category: Experimental, Analysis, Design
Software: MATLAB

Confidential: No

Compression loads can be critical in certain aerospace components. Fibre composites normally underperform under compression, exhibiting a compressive strength of only 50-60% their tensile strength. The understanding of the underlying mechanisms taking place during compression failure still requires further exploration.
This project aims at studying the damage propagation in composites under compressive loads. In this project, the researcher will design and conduct compressive experiments on aerospace fibre composites. Advanced experimental techniques such as digital image correlation, in-Situ observations, micro-mechanical testing, and high resolution microscopy will be applied in this project. This project has the potential to produce a journal paper.

Ribera Vicent, Maria Dr

Project no: ***LRMRV01***
Project title: A panel method for rotor wake/fuselage aerodynamic interaction

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

Confidential: No

A free-vortex rotor wake model can improve the aerodynamic modelling of a helicopter and its predictions of the dynamic response using a comprehensive flight dynamics model. While CFD, and even more CFD/CSD, can very accurately capture the interaction between rotor and fuselage, it comes at a large computational cost, which might not be ideal for flight dynamics applications. The proposed project will consist of producing an aerodynamic model of the UH-60 helicopter using a panel method. The rotor wake shall be modelled with a free vortex wake. The effect of the rotor wake on the aerodynamics of the fuselage is to be determined at different flight conditions (hover, 60 kts, 120 kts, turning and climbing flight). A comparison of the trim predictions obtained with the flight dynamics code with wind tunnel data and the panel method should follow.

Ribera Vicent, Maria Dr

Project no: ***LRMRV02***

Project title: Validation of a comprehensive helicopter flight mechanics code with the HART-II campaign data

Supervisor: Ribera Vicent, Maria Dr

Co-supervisor(s):

Category: Computational;Analysis

Software: FORTRAN, Matlab

Confidential: No

The HART-II program was a test campaign with a 40% Mach-scaled model of the BO-105 helicopter that aimed to improve our understanding of rotor blade-vortex interaction noise with and without higher harmonic pitch control input. Data available from this program includes vortex visualisation, acoustics, wind tunnel data and much more.

A comprehensive helicopter flight dynamics simulation code with data for the BO-105 is available. This code can obtain both free flight trim as well as wind tunnel solutions. The purpose of this project is to scale the BO-105 data available and validate the model's wind tunnel trim solution and rotor aerodynamic data with the experimental data of the HART-II program.

Ribera Vicent, Maria Dr

Project no: ***LRMRV03***

Project title: Upgrade and validation of a helicopter flight dynamic simulation for stiff cases

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: ***LRMRV04 ****

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: ***LRMRV05***

Project title: Verification of Vortex Ring State avoidance diagram using a comprehensive flight dynamics helicopter model

Supervisor: Ribera Vicent, Maria Dr

Co-supervisor(s):

Category: Computational;Analysis

Software: FORTRAN, MATLAB

Confidential: No

The Vortex Ring State (VRS) is a dangerous flight condition that helicopters encounter when descending into their own wake. The rotor wake collapses into a ring-like vortical structure which, as it crosses the rotor plane, produces highly unsteady aerodynamic loads that cause a drop in thrust, unsteady flapping and loss of control.
Better understanding of the aerodynamic effects in the wake during VRS has led to improved understanding of the velocities (forward speed and rate of descent) at which VRS occurs. The proposed project will use a comprehensive helicopter flight dynamics code with an advanced free vortex wake model, capable of modelling the VRS, to explore how the predictions of this code compare to the latest VRS boundary models.

Rigas, Georgios Dr

Project no: ***LRGR01***
Project title: Particle Image Velocimetry using Machine Learning

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

Confidential: No
Particle Image Velocimetry (PIV) is an optical method of flow visualization to obtain instantaneous velocity measurements by seeding the flow with small particles. This is achieved by applying auto-correlation and cross-correlation techniques to the seeding particles in order to estimate their position and velocity. In this project, we will leverage modern image analysis techniques based on Variational Convolutional Neural Networks (V-CNN) to improve the computation time and execution of PIV analysis. The results will be compared against benchmarks from traditional PIV processing algorithms.

Rigas, Georgios Dr

Project no: ***LRGR02***
Project title: Data-driven hydrodynamic stability analysis using Variational Autoencoders

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: ***LRGR03***
Project title: Wind tunnel study of rotating/flapping wing flow

Supervisor: Rigas, Georgios Dr
Co-supervisor(s):
Category: Experimental;Analysis
Software: Labview, RobotStudio, Matlab

Confidential: No
Flapping wings possess mechanisms of lift generation beyond those of fixed wings, such as wake capture, rotational lift and delayed stall, and these unsteady effects have been found to provide a substantial portion of the lift during insect/bird flight. Using a novel wind tunnel experimental setup, this project aims to reveal and quantify the differences in the dynamics between fixed wings and flapping wings.
Recently, a ABB IRB-140 6 axis Robot has been acquired, which will be used to hold the wing, position it in the wind tunnel, and execute complex 3D motions in 3D, following realistic trajectories encountered in bird flight (i.e. figure 8 motion). The project will involve the rapid prototyping of the wing, the robot set-up and programming (using Robot-Studio) and wind tunnel measurements. Parameters such as the wing aspect ratio, Reynolds number, flapping frequency, will be varied and the effects on the natural instability modes (linked to leading edge vortices and vortex shedding, lift, drag) will be accessed.

Rigas, Georgios Dr

Project no: ***LRGR04***
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: ***LRGR05***

Project title: Eigenvalues of operators beyond 1 billion degrees of freedom: a Deep Spectral Network Decomposition approach

Supervisor: Rigas, Georgios Dr

Co-supervisor(s):

Category: Computational;Theoretical;Numerical

Software: Tensorflow

Confidential: No

In collaboration with Google, we apply a framework for learning eigenfunctions of linear operators by stochastic optimization and Deep Neural Networks. As such, they can be a powerful tool for unsupervised representation learning from extremely large datasets (i.e. from high-fidelity simulations) or large-dimensional operators (i.e Navier-Stokes equations). Three applications related to fluid mechanic problems that will be explored in this project are: (a) Eigenvalue decomposition of data-based covariance matrices (known as PCA, POD, or KL expansion) (b) Eigenvalue decomposition of the discretized Navier-Stokes operator for hydrodynamic stability analysis (c) Singular value decomposition of discretized Navier-Stokes operator for calculation of optimal forcing modes (resolvent analysis). The algorithm has been validated for a small problem belonging in (a). The goal of the project is to explore the capabilities of the proposed framework in a variety of datasets and operators already available.

Rigas, Georgios Dr

Project no: ***LRGR06 ****

Project title: Reinforcement learning for flow control of road-vehicle aerodynamics - 2 projects available

Supervisor: Rigas, Georgios Dr

Co-supervisor(s):

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 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). The demonstration will be performed using simplified 2D Direct Numerical Simulations.

Rigas, Georgios Dr

Project no: ***LRGR07 ****

Project title: Experimental reinforcement learning: application to road-vehicle flow control

Supervisor: Rigas, Georgios Dr

Co-supervisor(s):

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.

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: Development and Investigation of a novel Mode I interlaminar toughness test with improved stability

Supervisor: Robinson, Paul Prof

Co-supervisor(s):

Category: Experimental;Computational

Software: ABAQUS

Confidential: No

Interlaminar toughness testing of composites laminates is most commonly performed using the double cantilever beam method. This method works well for laminates which show no strong variations in toughness as the delamination front advances along the specimen. However some materials, such as woven reinforced composites, exhibit variations in toughness which can result in unstable crack growth in the standard DCB. For such materials it is difficult to measure the toughness variation correctly – often only the high toughness values are determined. A modified loading jig has been proposed to improve the crack growth stability and a previous project has performed some initial investigation. This modified loading jig will be further developed and investigated in this project. The investigations will include finite element modelling and experimental work.

The project is open to all courses but can only be taken by one UG student AND one MSc student

Robinson, Paul Prof

Project no: ***LRPR03 ****

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: ***LRPR04***
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 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. 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 Dr

Project no: ***LRMS01***
Project title: Deployable Whipple Shields for Nanosatellites (S)

Supervisor: Santer, Matthew Dr
Co-supervisor(s):
Category: Computational;Design
Software: Abaqus
matlab

Confidential: No

When satellites are in space they are subject to the permanent risk of micro-meteorite strike. Small particles travelling at several tens of thousands of kilometres per second have the potential to destroy a spacecraft through ballistic impact. The Whipple shield is a mitigation strategy in which thin armour is placed a distance from the spacecraft to absorb much of the energy of the impact before the mission critical components are hit. A common criticism of nanosatellites is that they are not robust due to a lack of shielding: this project will address that criticism.
This project will involve the design of deployable Whipple shields based around hinged tin armour plates that fit within a CubeSat body for launch and deploy around the satellite in orbit to form a completely encasing rigid polyhedral shield. Concepts will be evaluated using the abaqus

compliant multibody dynamic finite element solver to determine the deployment characteristics. Explicit analysis will also be used to provide a preliminary assessment of the shield effectiveness.

Santer, Matthew Dr

Project no: ***LRMS02***
Project title: Damage tolerant metamaterials for satellite components resistant to hypervelocity impact (S)

Supervisor: Santer, Matthew Dr
Co-supervisor(s):
Category: Numerical
Software:
Confidential: No

As low Earth orbit becomes increasingly congested and satellites have become increasingly vulnerable to both accidental and intentional hypervelocity collision, there is a great need to develop spacecraft components that are robust and resilient.
In the structural metamaterials group in the Department of Aeronautics we have developed optimized lattice microstructures that can achieve unexpected and beneficial properties. This can range from controlled anisotropy leading to optimal compliance and desired shape changes; tailored thermo-structural performance; frequency control; and other more esoteric behaviours.
In this computational project our developed python-based optimization framework incorporating the open source Fenics finite element solver will be augmented and used to design a structure that is resistant to hypervelocity impact. This will include probability-based techniques as the precise location of impact would be unknown a priori. This project would benefit from a strong familiarity with the python programming language and an interest in advanced optimization methodologies.

Santer, Matthew Dr

Project no: ***LRMS03***
Project title: Efficient numerical analysis of deployable tape springs (S)

Supervisor: Santer, Matthew Dr
Co-supervisor(s):
Category: Numerical
Software:
Confidential: No

Tape springs are a type of compliant hinge which are increasingly popular for deployable space applications due to the fact they combine self deployment with latching into a stiff configuration without the need for motors. Their structural behaviour is complex as they operate predominantly in a post-buckled regime. The simulation of tape springs is usually carried out using shell finite

elements which, although successful in predicting performance, quickly becomes intractable when analysing systems containing multiple tape spring components.
Recently in the Department of Aeronautics we have published for the first time an implementation of a new finite element, based on a so-called unified formulation, which enables accurate simulation of slender components. This has been implemented in c++ and validated against the commercial Abaqus FE solver. But there is much still to do.
This project will extend and refine the capability of this new approach. The scope is flexible but is expected to involve one of the following:

- Implementation as an Abaqus user element;
- Implementation of a contact algorithm;
- Implementation of a dynamic solver for deployment simulation;
- Incorporation with an optimization algorithm to achieved tailored deployment performance.

This computational project requires good programming competence and an interest in finite element techniques.

Santer, Matthew Dr

Project no: ***LRMS04 ****
Project title: Deployable boom design and fabrication for a CubeSat-scale magnetometer (S)

Supervisor: Santer, Matthew Dr
Co-supervisor(s):
Category: Experimental;Design;Analysis
Software: Abaqus

Confidential: No
CubeSats offer the potential to carry out science missions at a fraction of the launch cost of a larger satellite. To exploit the full potential of CubeSats, however, it is necessary to miniaturize deployable components so that science instruments and other ancillaries are stowed for launch and then deployed on-orbit. Of particular interest is the deployment of magnetometers as they need to be placed sufficiently far away from the magnetic field of the underlying spacecraft.
This project, which will combine design, analysis and experiment, will develop a tape spring boom that is capable of deploying a 50 g magnetometer >1 m from a CubeSat in a 1g environment and stowing into a 0.5U volume. The design will be based on simulations carried out using Abaqus and must satisfy all requirements in the CubeSat specification in addition to being sufficiently robust to survive launch.
As an additional requirement this project will also explore how the electrical harness may be integrated within the design so that risk of snagging and any parasitic dynamic effects are minimized.

Santer, Matthew Dr

Project no: ***LRMS05 ****
Project title: Membrane-substrate buckling for dynamic roughness

Supervisor: Santer, Matthew Dr
Co-supervisor(s):
Category: Numerical
Software:
Confidential: No

When a thin membrane is attached to a compliant substrate, the effect of stress in the substrate is to cause the membrane to buckle into interesting patterns. These patterns can be striped, dimpled, labyrinthine or combinations of these. This phenomenon has application as a flow control technology by enabling a skin with dynamic roughness in which, under actuation, the surface can transition elastically between smooth and rough.
In this computational project the first stage will be to investigate the instability landscape using the open source python-based finite element solver Fenics. A parametric study will be carried out to determine bifurcation diagrams for membrane-substrate systems at a scale appropriate for implementation in a wind tunnel experiment.
A second stage of this project will then explore the benefits of optimally varying the materials properties of the substrate so the distribution of the surface deformations can be controlled.

Shamsuddin, Siti Ros Dr

Project no: ***LRSRS01 ****
Project title: In-Plane and Out-of-Plane shear properties of thermoplastic PES interleaved UD carbon fibre reinforced thermosetting composites

Supervisor: Shamsuddin, Siti Ros Dr
Co-supervisor(s):
Category: Experimental;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 in-plane and out of plane shear properties.

Shamsuddin, Siti Ros Dr

Project no: ***LRSRS02 ****

Project title: Graphene reinforced toughened Epoxy composites

Supervisor: Shamsuddin, Siti Ros Dr

Co-supervisor(s):

Category: Experimental;Experimental: Manufacturing intensive;Theoretical;Design;Analysis

Software:

Confidential: No

Individual graphene flakes are an atomic thickness and possess excellent mechanical, thermal and electrical properties. Graphene also provides outstanding reinforcement for composite materials, providing a high specific surface area (2630 m2 /g), two-dimensional load bearing capacity and high aspect ratio. Epoxy matrices on the other hand are intrinsically brittle and causes catastrophic failure. To improve the brittleness of the epoxy matrix, thermoplastic PES will be added at a controlled loading fraction. The project is divided into two sections, the first is to investigate the best loading fraction of PES that provides the best toughening properties and then different loading fractions of graphene 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 Ros Dr

Project no: ***LRSRS03 ****

Project title: Compression and Compression After Impact of polyethersulfone (PES) Interleaved UD and [0/90]s CFRP

Supervisor: Shamsuddin, Siti Ros Dr

Co-supervisor(s):

Category: Experimental;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. Composite panels having gone through impact may not show any damages on its surface, but its compression strength would have significantly reduced. This study is aimed at studying the compression properties of pristine and interleaved composites. The results will be compared to those after impact.

Shamsuddin, Siti Ros Dr

Project no: ***LRSRS04 ****

Project title: Carbon fibres – Recycle and Repurpose for optimum composite application

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

Carbon fibre reinforced polymers (CFRPs) are used extensively in the aerospace, military, automobile, and sports industries due to their light weight and outstanding mechanical properties. More CFRP used in industry means that more waste are generated. The high carbon fibre price, rising landfill costs, legislation implementation, and environmental pressure have motivated to recycle and reuse the high-valued carbon fibre in CFRP waste. This study focuses on creating a CFRP and/or hybrid composite using only recycled fibres to manufacture new material that would retain as much as the fibre properties as possible. This project includes design experiments, as well as manufacturing and mechanical testing to validate the performance of recycled fibre composites.

Shamsuddin, Siti Ros Dr

Project no: ***LRSRS05 ****
Project title: Creep/recovery and stress relaxation of carbon fibre reinforced epoxy with thermoplastic Interleaving

Supervisor: Shamsuddin, Siti Ros Dr
Co-supervisor(s):
Category: Experimental;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.

Sharif Khodaei, Zahra Prof

Project no: ***LRZSK01***
Project title: Structural health monitoring of vertical launch vehicles (S)

Supervisor: Sharif Khodaei, Zahra Dr
Co-supervisor(s):

Category: Experimental;Computational;Analysis
Software: Abaqus, Matlab, Python

Confidential: No
The application of Structural Health Monitoring (SHM) to future space missions has the potential to significantly improve the safety and reliability of the flight and lower the cost of re-use vehicles. However, this application is extremely challenging for two main reasons: the harsh space environment and the high level of safety requirements imposed by the space industry. One of the areas that SHM can benefit directly, is the pre-launch integrity checks. For any non-destructive inspection (NDI) technique to be applicable to real structure, it must be demonstrated that it has acceptable levels of reliability and probability of detection. This not only includes the capability of the software to detect different types of damage and material degradation during the operation of the vehicle, but also the reliability and survivability of the hardware exposed in multiple missions. In thid project, the application of SHM hardware and software for the integrity assessment of re-usable launch vehicles will be tested under simulated harsh environments of flight. The existing sensor technologies that will be evaluated and tested are piezoelectric sensors and passive capasitance sensors. The type of structures to be evaluated include composite structures as well as metallic strucutures representative of different parts of launch vehicle. This project will be mostly computational, existing structures and experimental sensor data will be used for analysis.

Sharif Khodaei, Zahra Prof

Project no: ***LRZSK02 ****
Project title: Damage detection in metallic structure (S)

Supervisor: Sharif Khodaei, Zahra Dr
Co-supervisor(s):
Category: Experimental: Structures;Computational;Analysis;Numerical
Software: Matlab/Python, Abaqus

Confidential: No
Structural health monitoring technique involves detecting damage in a sensorized structure based on the sensor recorded data. This project in particular will focus is detection damage in metallic structures, i.e. corrosion, crack, bolt loosening, for aircraft parts under simulated operational and environmental conditions. It will use existing structure and existing experimental data, so no manufacturing will be done and existing data base will be used. The next step consists mainly of developing algorithms together with signal processing techniques to detect and identify damage in the structure, as well as optimisng the number and location of sensors. The project requires a good knowledge of Matlab or Python for signal processing and feature extraction.

Sharif Khodaei, Zahra Prof

Project no: ***LRZSK03 ****

Project title: Numerical Simulation of nonlinear ultrasonic guided wave for micro-crack detection in metallic structures (S)

Supervisor: Sharif Khodaei, Zahra Dr
Co-supervisor(s):
Category: Computational;Theoretical;Analysis;Numerical
Software: Abaqus, Python, Matlab

Confidential: No

The purpose of the project is to investigate the application of non-linear acoustic waves for damage detection in metallic structures. The conventional Lamb wave technique for plate structures are based on linear theory, and depend on measuring particular parameter, such as sound velocity, attenuation, or the transmission and reflection coefficients of the propagating waves. These parameters are sensitive only to gross defects, opened cracks, or macro-cracks within structures. Consequently, linear theory-based ultrasonic methods are unable to detect micro-cracks. Nonlinear ultrasonic behaviour include nonlinear resonance, mixed frequency response, sub-harmonics generation, and higher harmonics generation. The use of nonlinear ultrasonic theory will be investigated in this project as an approach to overcome the limitations of linear technologies. This project is numerical and will require very good knowledge of Abaqus for modelling and post-processing of the data will be done in Matlab or Python.

Sharif Khodaei, Zahra Prof

Project no: ***LRZSK04 ****
Project title: Structural prognosis based on structural health monoitoring (S)

Supervisor: Sharif Khodaei, Zahra Dr
Co-supervisor(s):
Category: Experimental: Ready-made experiment;Computational;Theoretical;Numerical
Software: Abaqus, Matlab or Python

Confidential: No

Prognosis refers to remaining useful life (RUL) prediction. Current practice for RUL estimation is based on historical load envelopes with large safety and reliability factors. Safe-life designs involve testing and analysis (typically fatigue analysis) to estimate how long the component can be in service before it will likely fail. Using historical load data in combination with safety and reliability factros often results in conservative design and service life which is not sustainbale. In tthis project probabilistic prognosis models will be developed (based on established cumulative damage for metallic structure). for RUL prediction. The RUL analysis will be based on simulated flight loads, rather than historical fatigue data. This involves running high fidelity numerical simulations in combination with machine elarning algorithms to develop surrogate models to estimate the RUL. The project is purely computational and it requires a good knowledge of finite element simulation using ABAQUS, good understanding of fracture mechanics and good knowledge of prgramming such as matlab or pything for machine learning application.

Sharif Khodaei, Zahra Prof

Project no: ***LRZSK05 ****
Project title: Advanced Analytics for structural health monitoring application (S)

Supervisor: Sharif Khodaei, Zahra Dr
Co-supervisor(s):
Category: Computational;Analysis;Numerical
Software:

Confidential: No

Structural health monitoring techniques are increasingly being used in evaluation and maintenance of existing structures. A critical aspect of these diagnosis and prognosis methods is the visualization and accessibility of large, heterogeneous data sets. The decision making will result in identifying which part of the structure is damaged and this requires data and metadata for the sensorized structure to be directly integrated into a user's viewing environment which visualizes the structure and the location of probable damage. The aim of this project is to take the initial step in developing a preliminary framework for documenting and visualizing data related to different monitored structures. Data fusion, machine learning and AI are at the core of big data handling and assessment. This project will use previous experimental and numerical data to create algorithms for data fusion and decision making, in real-time as new data becomes available. The project requires excellent knowledge of programming such as matlab or python and highly motivated in learning new advanced analytical tools.

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: ***LRSS03***
Project title: Financial Modelling using Machine Learning - 2 projects available

Supervisor: Sherwin, Spencer Prof
Co-supervisor(s): Karamanos, George Dr (KBW), Kirby, Mike Prof (Computing, Uni of Utah)
Category: Computational;Analysis
Software: Nektar++
Matlab

Confidential: Yes

We have been developing pricing models using propriety and commercially available data based on machine learning techniques in collaboration with KBW. In this project we would explore different optimisation and training strategies for prediction of European and US bank stock pricing as well as the portfolio development to apply the machine learning methods.

Steiros, Kostas Dr

Project no: ***LRKS01 ****
Project title: Non-equilibrium turbulence

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

Most turbulence models used in science and engineering are based on Kolmgogorov's theory of turbulence, also known as K41. According to that theory, turbulence is a cascade of energy, from large scales, which act as reservoirs of kinetic energy, to small ones, which act as sinks. However, recent results indicate that this cascading process is perturbed when large coherent structures exist in the flow. The result is a violation of the fundamental Kolmogorov laws and the generation of spontaneous regulatory dynamics in the cascade.
This project will aim in further investigating the fundamental physics behind the coherent structure - turbulence cascade interaction. The student will build a unique turbulence grid, to generate turbulence, equipped with vortex generators, to amplify coherent structures. The grid will be equipped in the T1 wind tunnel, and hot wire anemometry will then be used to characterize the turbulence energy spectrum, and observe how K41 is violated. The results will be analyzed using advanced signal analysis techniques.

Steiros, Kostas Dr

Project no: ***LRKS02 ****
Project title: Synchronization of vortex shedding

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

The formation of large vortices behind bluff bodies (vortex shedding) is of interest to the automobile, aeronautical and construction industries. Unfortunately, the physics of vortex shedding remain obscure. Recently, we have found a simple geometry that has the ability to organize and synchronize vortex shedding, and we would like to know why. This investigation would shed light on the mechanisms of formation and development of the large vortices. In this project, the student will conduct high speed Particle Image Velocimetry experiments of various bluff body geometries in the Aeronautics Flume.

Steiros, Kostas Dr

Project no: ***LRKS03 ****

Project title: Improving the performance of wind turbines on hilly terrain

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

The existence of hills is detrimental to the efficiency and maintenance costs of wind farms in the UK. Hills generate flow separation in their leeward side, lowering the performance of the turbines positioned there. Here, a novel idea on how to solve the above issue is proposed. By pitching the turbines at the top of the hill, the flow will be deflected towards the base of the hill, re-energizing its wake. In that manner turbines will be able to be positioned closer to the rear side of the hill, i.e. in locations hitherto inaccessible. The objective of this project is to act as proof of concept of the above idea, via wind tunnel measurements of a purposefully constructed experimental rig.

Steiros, Kostas Dr

Project no: ***LRKS04 ****
Project title: Design of a fractal dynamic mixer

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

Dynamic mixers are a paramount component of the process and pharmaceutical industries. However, their complex aerodynamics (combining rotating turbulence, wall effects and wake dynamics) have kept their design a purely empirical process resulting in major inefficiencies.
This project's goal will be the design of a dynamic mixer based on the novel concept of fractal turbulence. Fractal shapes have been shown to greatly enhance mixing, and thus a fractal impeller has the potential to generate a real breakthrough with industrial implications.
This project will be design-intensive. The student will have to be enthusiastic about R&D, as they will have to design the mixing tank, fractal impeller, and rotating shaft. Also, they will have to choose the appropriate machine elements (motor/bearings/seal etc.), and then, with the help of workshop technicians, construct and mount the assembly. The final step is a thorough characterization of the power consumption, losses, and velocity field of the mixer, the latter using laser advanced laser diagnostics.

Steiros, Kostas Dr

Project no: ***LRKS05 ****
Project title: Design of a wind tunnel gust generator

Supervisor: Steiros, Kostas Dr

Co-supervisor(s):
Category: Experimental;Design
Software:
Confidential: No

A major challenge of wind turbine aerodynamics is predicting the flow response after a gust has occured. Gusts cause power fluctuations and blade flutter, and as such are of paramount importance for the grid stability and turbine integrity. Unfortunately, gusts are very hard to simulate experimentally, as conventional wind tunnels can only produce steady and uniform inflows.
To resolve this issue, in this project the student will design a novel gust generator for the 18'' open-loop wind tunnel of the department of Aeronautics. A louvre system will be positioned on helical gears, which will be controlled using a motor. In that way, the inflow of the tunnel will be dynamically altered, leading to the generation of various types of gusts. The produced dynamic inflow will be characterized using hot wire anemometry.
This project will be design-intensive, as various components need to be designed and purchased or manufactured, including the gears, motor, shafts and holding frame. A real-time control system for the louvre rotation will also be designed. This project is ideal for an ethusiastic student, as the goal of this work is to lay the foundations for future groundbreaking wind turbine experiments in the department.

Tagarielli, Vito Dr

Project no: ***LRVT01 ****
Project title: Hydrocarbon deflagration inside a spherical deformable shell: a theoretical, numerical and experimental study (S)

Supervisor: Tagarielli, Vito Dr
Co-supervisor(s): Montomoli, Francesco Prof
Category: Experimental;Experimental: Ready-made experiment;Computational;Theoretical;Analysis;Numerical;Literature
Software:
Confidential: No

Please select this project only if you are willing and able to perform substantial work in the Autumn term. The main supervisor will be formally away from mid-February, so most of the supervision by Dr Tagarielli will take place in the early stages of the project.
Consider a mixture of air and a hydrocarbon, for example propane, contained at a certain pressure in a rubber balloon of given diameter. 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. We shall first write an analytical model for this problem (relying partly on existing models for the deflagration of a hydrocarbon); then, we will validate the theoretical predictions using numerical simulations in OpenFOAM. Third, and time permitting, we will conduct experiments reproducing this problem in a lab environment and measuring the flame speed and balloon diameter via high speed photography, possibly the pressure history at selected points.

It will be necessary to complete the theoretical work and to at least set-up the numerical and experimental work by the end of January.
The project will particularly suit a student who is confident to be able to tackle the theoretical predictions quickly, someone comfortable with maths and CFD, able to safely play with fire in a lab environment.

Tagarielli, Vito Dr

Project no: ***LRVT02 ****
Project title: Commissioning of a split pressure Hopkinson bar and high strain rate testing of materials (S) - 4 projects available

Supervisor: Tagarielli, Vito Dr
Co-supervisor(s): Lee, Koon-Yang Dr; Del Rosso, Stefano Dr; Iannucci, Lorenzo Prof
Category: Experimental;Experimental: Structures;Experimental: Manufacturing intensive;Experimental: Ready-made experiment;Theoretical;Design
Software:
Confidential: No
Please select this project only if you are willing and able to perform substantial work in the Autumn term. The main supervisor will be formally away from mid-February, so most of the (essential) supervision by Dr Tagarielli will take place in the early stages of the project.
The objective is to assemble a split Hopkinson pressure bar (SHPB), to commission and calibrate this apparatus, and to conduct tests with it. The project is open to up to 4 students; these will initially work as a group until the equipment is completely operational; then, each student will use the SHPB to conduct high-rate compresison tests on different types of high-performance materials, to be determined later in the project (we envisage these will be composites, foams or polymers).
It will be necessary to complete all the assembly/commissioning work before the end of 2022, to ensure a smooth second part of the project.
The activities will involve using different types of equipment competently and safely. Regular attendance of the college will be required throughout the project.
The project suits students with sound understanding of applied mechanics, capable of liaising effectively with colleagues and technicians, and willing to put some hard work in the activities, which could result in publishable research. The student will pick up a basic technique in experimental solid mechanics and learn the principles of high speed photograpy and data acquisition, along with the response of the particular material/structure tested.

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

Confidential: No
Creating a low-dimensional model of a fluid flow is often the first step towards the design of a flow control strategy to improve performace (e.g. reduce drag). Due to the complexity of the Navier-Stokes equations, it is often desirable to extract flow models directly from large ensembles of fluid flow data (e.g. from numberical 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 investiatged in these FYPs, is to find the appropriate balance between the complexity of the fitted model and its off-training-set predictive capability. The chaotic dynamics of turbulent flows have, to-date, prevented resolution of this question. In these projects, data from bluff body flows and turbulent boundary layers (among other flows) will be considered in an attempt to resolve it.
Experience of Matlab is necessary.

Wynn, Andrew Dr

Project no: ***LRAW02***
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: ***LRAW03***

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 optimziation 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.
This project will take a new approach by seeking to build simpler models for turbine wakes from existing complex models (e.g. the recent model doi:10.1017/jfm.2016.595). Models will be constructed which are specifically tailored to creating easy-to-sovle optimziation problems (e.g. those with polynomial cost fuctions and constraints), in order to find globally optimal wake steering strategies. Further extensions of this projet will consider wake unsteadiness and unsteady inflow conditions to wind arrays in an optimization context.

Yang, Daqing Dr

Project no: ***LRDY01 ****
Project title: Distributed electric-powered foot launch hang glider design - 2 projects available

Supervisor: Yang, Daqing Dr
Co-supervisor(s):
Category: Experimental;Computational;Design
Software: Catia, Fluent

Confidential: No
This project focus on physical development of a scaled electrically powered foot launch hang glider design. The development will utilize off-the-shelf model aircraft and drone components. Simulation is required as physical presentation of this vehicle in operation. Flight or wind tunnel experiments will be needed to verify the design outcome.

Yang, Daqing Dr

Project no: ***LRDY02 ****

Project title: e-VTOL aircraft design for urban air mobility - 2 projects available

Supervisor: Yang, Daqing Dr
Co-supervisor(s):
Category: Experimental;Theoretical;Design;Analysis;Literature
Software:
Confidential: No
Combination of vertical take-off and landing aircraft with electric propulsion has demonstrated huge potential in future urban air mobility applications, this project will review current design proposals, endeavor a novel design concept and test its feasibility with off-the-shelf drone components. Simulation is required as physical presentation of this vehicle in operation. Flight and wind tunnel experiments will be needed to verify the design outcome.

Yang, Daqing Dr

Project no: ***LRDY03 ****
Project title: Hybrid wing body transport aircraft conceptual and preliminary design - 2 projects available

Supervisor: Yang, Daqing Dr
Co-supervisor(s):
Category: Design;Analysis;Literature
Software:
Confidential: No
This project will investigate hybrid wing body aircraft design to maximize the aerodynamic benefit of blended wing body configuration while maintaining acceptable stability and control characteristics. Student will go through complete conceptual design process and focus preliminary design effort on one of the four key aspects of aircraft design, namely aerodynamics, structure, propulsion integration and flight control.

Yang, Daqing Dr

Project no: ***LRDY04 ****
Project title: Flying underwater glider conceptual and preliminary design - 2 projects available

Supervisor: Yang, Daqing Dr
Co-supervisor(s):
Category: Computational;Theoretical;Design;Analysis;Literature
Software:
Confidential: No
Underwater glider is a type of autonomous vehicle that employs variable-buoyancy propulsion with a pair of hydrofoils. It is widely used in ocean research organizations. This project will investigate the possibility of converting an underwater glider into a flying aircraft. This amphibious

vehicle will be able to deploy as an underwater glider, take-off from underwater, fly and loiter in atmosphere with a certain duration, land back to water and resume its underwater voyage. Student is expected to design both underwater and flying aero-hydrodynamic, structure, propulsion and control aspects of the vehicle. A flight simulation is also required for demonstration of this novel concept.

Yang, Daqing Dr

Project no: ***LRDY05 ****

Project title: Preliminary design of integrated hydrogen fuel tank for blended wing body aircraft - 2 projects available

Supervisor: Yang, Daqing Dr

Co-supervisor(s):

Category: Computational;Design;Analysis

Software: CATIA, Abacus, Fusion 360

Confidential: No

This project will investigate the feasibility of an integrated hydrogen fuel tank design for a blended wing body aircraft. The design will combine the tube-shaped hydrogen tank with load bearing structures to maximize structural efficiency and reduce airframe weight penalties due to adoption of hydrogen fuel. Student will be given a BWB aircraft conceptual design and focus on the design and optimization of the airframe and integrated fuel tank.