Imperial College London

Department of Aeronautics

MSc in Advanced Computational Methods for Aeronautics, Flow Management and Fluid-Structure Interaction

Project Topics 2010-2011

January 2011

Project Supervisors Index

Supervisors in Fluid Dynamics

Prof S Chernyshenko [Room 259, RDHL]

1) Modelling of time evolution of turbulent flows. (Co-supervisor: Dr. A. Sharma)

Using simple finite-dimensional models, the student will investigate a relationship between the statistical description of turbulence on the basis of the probability density function, governed by the Liouville equation and/or Fokker–Planck equation, which are linear, and the ensemble-averaged description, based on the chain of moments equations, of which the first one is the Reynolds equation, and which are nominally nonlinear. This topic is a new development in the quickly expanding area of research on small perturbations of turbulent flows. The required skill is the ability to solve numerically ODE, using Matlab or any programming language. This project, while actually not very difficult, is more suitable for a student who loves and excels in mathematics.

2) Modernising a simple Navier-Stokes solver for fluid-structure interaction problems

In the preceding project a simple computer code for solving the Navier-Stokes equations was developed for using it in education. The major requirement of this code was simplicity. This year the student will modify the code in such a way that it will be possible to model galloping and vortex-induced vibrations. The student will then work on the interface so that the modifying code could be used in teaching fluid-structure interactions. A necessary requirement is a working knowledge of C, as the existing code is written in this language.

3) Modernising a simple Navier-Stokes solver for analysis of feedback control of bluff-body wake

In the preceding project a simple computer code for solving the Navier-Stokes equations was developed for using it in education. The major requirement of this code was simplicity. This year the student will modify the code in such a way that it will be possible to model a feedback control for stabilising vortex shedding from a bluff body. The student will then investigate various flow control strategies. A necessary requirement is a working knowledge of C, as the existing code is written in this language.

4) Converting Flow Illustrator into a stand-alone application

Description: Flow Illustrator ((http://chernyshenko.sesnet.soton.ac.uk/) is a web application allowing the user to upload a bitmap picture of a body and obtain a movie of a flow past this body. Its runs a Navier-Stokes computation using an immersed boundaries method. Many users request to develop a stand-alone version of Flow Illustrator, and this is the aim of the project. The code is written in C#, but there is also a specialised version of it which might be more close to a stand-alone application and which is written in C. The stand-alone version can be written in any language, but it should work (at least) under Windows operating system.

Type: computational.

5) Sum-Of-Squares analysis of the stability of a Kolmogorov flow (Co-supervised with Dr P Goulart)

Sum of squares (SOS) of polynomials is a recently (in 2000) developed tool, which has already been proven to be highly useful in many applications to control, and which is beginning to find its way into aerodynamics. The SOS approach provides a systematic way of constructing Lyapunov functions for systems with polynomial right-hand side, thus resolving the difficulty which stood out for more than a century. Kolmogorov flow is an especially simple flow proposed in 1959 as a testbed for tools and ideas related to turbulence and thoroughly studied since then. The student will apply SOS approach to the stability analysis of Kolmogorov flow using the ideas proposed in the latest work of the project supervisors. The project requires strong mathematical skills and good programming abilities.

Type: theoretical and computational.

Dr C J Cotter [Room E453A, ACEX]

6) High-order discontinuous Galerkin methods for traffic flow

This project will implement high-order discontinuous Galerkin (DG) methods for traffic flow, using the C++-based Nectar++ library developed in the department. The traffic equations are a simple 1D model of traffic density which supports waves, shocks and rarefactions that are observed in real traffic. The aim of this project is to investigate some methods for resolving shocks in high-order DG in a simple 1D environment. The Nectar++ library allows for rapid prototyping of high-order finite element methods since all of the low level algorithmic work is already coded. A possible extension is to consider a model of roads with junctions.

7) Numerical methods for speech analysis

A recent technique has been introduced in linguistics for analysing pronunciation of words. Given a short sound sample of someone saying a word, a function called a "covariance surface" is produced. The covariance surface is a symmetric function of two variables on a square domain. The aim is to compare nearby covariance surfaces. This is done by defining paths between covariance surfaces, each point on the path is a valid covariance surface. The path is specified in terms of a nonlinear partial differential equation, which can be approximated by an ordinary partial differential equation for large-dimensional symmetric positive-definite matrices. In this project, we shall investigate numerical methods for computing such paths between covariance surfaces, which will be tested on sample data from subjects speaking various dialects of Chinese, obtained from collaborators.

8) New horizontal grids for numerical weather prediction

A recent project has been started by the UK Met Office to design the next generation of the forecast model. One of the main issues is that the current model does not perform very well on parallel computers. This is mostly because a latitude-longitude grid is used, which leads to very thin elements near to the poles. We have recently proposed some approaches to horizontal discretisation in the forecast model, based on finite element methods, which allow for quasi-uniform resolution on the sphere, whilst satisfying a range of strict requirements specified by the UK Met Office. The aim of this project is to build a 2D rapid prototype on the sphere, using the FENICS library which automatically generates finite element code from prescriptions of the equations specified by the user in a Python script.

9) Seamlessly blending models and data

Numerical models can be combined with data to produce estimates of the state of a physical system. For example, it is very difficult to observe dynamics below the surface of the ocean (because the ocean is opaque to radiation) and so surface data must be combined with ocean models to produce an estimate of the full ocean circulation (see http://www-pord.ucsd.edu/~mmazloff/SOSE.html). The problem amounts to a weighting problem: we want to combine model output and data according to which we believe the most. One approach to this is the Ensemble Kalman Filter, in which one integrates forward an ensemble of model runs with slightly different initial conditions until the next data observation time. The mean of the ensemble represents our best guess of the current system state and the variance represents how certain we are of this state. After observing some more data, we modify all the members of the ensemble to take account of this information. This "kick" to the system often causes problematic artifacts, and we have recently developed a new "seamless" approach in which the update to the ensemble members is instead performed smoothly over some segment of time after the observation is made. In this project we shall apply this technique to some simple low-dimensional model problems and investigate its properties.

10) Numerical methods for deforming images

Image deformation or warping has many medical applications such as surgical planning and assisted diagnosis. In image deformation, the image is deformed by a fluid flow by the usual advection equation of fluid mechanics. The fluid flow itself solves an equation called EPDiff that represents the minimal amount of deformation that is required to take one image to another. In this project we shall develop discontinuous Galerkin methods for these equations; these equations result in very compact, local, high-order discretisations which are suitable for parallelisation on GPUs, for example.

Prof D J Doorly [Room 258, RDHL]

11) Aerosol deposition in the nasal passages

The project involves the measurement of the deposition patterns of aerosols in the human nasal passages using a combination of software from in-house and commercial sources, supplemented by program modifications performed by the student. The transport of aerosol particles and their deposition in the respiratory airways is of great importance, both to develop devices to deliver therapeutic drugs, and to assess the hazards of environmental and industrial pollutants. The results can be compared with experiments on aerosol deposition in highly accurate replica models, created using rapid prototyping and silicone casting. The project will provide a good training in the development and application of computational methods for flow and transport prediction, with wide application to a host of industries.

12) Modelling of ciliary motion

The project is concerned with computational modelling of ciliary motion. The first part of the work is concerned with a definition of an investigation of the process to determine an appropriate model. Next a 3D CFD code will be applied to investigate the induced flow field with prescribed boundary motion. Finally, if time permits, flow-structure coupled analysis will be applied. There is a possibility of conducting some experiments to complement the work.

13) Computational modelling of flow in respiratory networks

The project will investigate the coupling of 1-D network models of flow in the small airways to 3-D CFD simulations of flow in the principal respiratory conduits. A 1D model of an airway admits variation in the flow only along the airway length and in time. Although the air flows relatively slowly in the airways, their walls are distensible. A 1-D model of a single airway is thus described by an equation analogous to the 1D gas dynamic equations, though with area taking the place of density and sometimes augmented by an equation relating the internal and external pressures. The project will involve an analysis of flow in such networks and thus derive appropriate inflow/outflow boundary conditions to couple the 3D and 1-D flow computations.

14) Combined Computational Fluid Dynamics and Magnetic Resonance Flow Mapping

This project is about the development of efficient techniques to combine the prediction of time-varying flow in arterial geometries with a solution for the magnetisation properties of the flow.

Currently, Magnetic Resonance Imaging (MRI) can be used to image and to measure the geometry and the flow in the cardiovascular system, though at present with limited accuracy, particularly in the coronary arteries and in the heart muscle (the myocardium). The specialist Cardiovascular Magnetic Resonance group at the Brompton Hospital, with whom this project will be linked, are pioneering methods to improve accuracy of flow measurement using novel imaging techniques. These techniques apply a rapidly varying pulse sequence of radiofrequency and magnetic field excitation to recover a signal which provides a temporal and spatial map of the flow. The complexity of pulse sequences has now advanced to a stage where it is difficult to predict the effects of uncertainty or possible measurement artefacts, and there is a pressing need to develop computational tools to advance this promising medical imaging technology.

A recent joint project between Aeronautics and the Brompton CMR unit led to the development of a hybrid Eulerian-Lagrangian numerical scheme. The project task will be to test this and investigate how to link it to matlab routines used to specify the magnetisation sequence and image reconstruction. It is envisaged that there will be some collaboration with Professor Frirmin and Dr. Gatehouse at the Brompton Hospital. This project requires a strong background in mathematics and facility with programming.

15) Investigation of the SPH (Smooth particle hydrodynamics) method to model deformable bodies at low Reynolds number.

The project will investigate the application of the above computational method to study how cells are transported by a flow near a boundary and how they become adherent. The work will begin with the use of an existing open-source library to investigate the capabilities and limitations of the method, and then progress to the implementation and validation of models for the cell boundary.

16) Evolutionary methods for airfoil optimisation

The project will investigate the application of parallel and multi-layer genetic algorithms for airfoil optimisation.

Dr P Goulart [Room E360, ACEX]

17) The effect of observability on Moving Horizon Estimation

A dynamical system with a measurement process is called observable if it is possible to reconstruct the true state of the system using only the measurement data. Moving Horizon Estimation (MHE) is a technique used to perform the state reconstruction. It has the advantage of being computationally efficient and can be easily applied to non-linear systems. In theory, the performance of the MHE estimator depends upon the system's observability and the aim of this project is to analyze this link. Different notions of observability are available, which can provide measures of observability at each point in the state space. A further goal of the project will be to use this information to create a modified MHE observer which outperforms the standard implementation. If successful, this will have important consequences for state estimation of non-linear systems.

This project will have both theoretical and computational components, and a high level of mathematical ability will be required.

18) State Estimation of Fluid Systems

A fundamental question in fluid mechanics is whether the full velocity field of a flow can be reconstructed from incomplete measurement data, for example, pressure readings on the flow's boundary. A related question, important for the implementation of flow control techniques, is whether state estimation can be achieved in real time.

The aim of this project is to code, in C++, a high speed algorithm to estimate the state of a fluid system. The algorithm will implement the Moving Horizon Estimation technique, which requires the efficient minimization of a nonlinear least squares function. A possible approach may be to use a Gauss-Newton algorithm coupled with multiple shooting techniques, but a balance will need to be found between accuracy and algorithm speed. Once an algorithm has been developed, its performance will be assessed by applying it to both theoretical models and experimental data.

This project requires a good working knowledge of C++.

Dr E Kerrigan [Room E366, ACEX]

19) Control of a Wave Energy Farm

The mechanical energy present in ocean waves can be used to generate electricity, but despite the enormous potential of wave power, its uptake has not yet been as fast as, for example, wind power. This project will therefore look at the various control engineering aspects to do with running a wave power farm. This project will involve the modelling and simulation of a wave farm in Matlab, as well as developing and testing a variety of existing and new control algorithms in Matlab. This project will assess the advantages and disadvantages of both current and future wave power systems, as well as propose new conceptual designs. See en.wikipedia.org/wiki/Wave_power for background material.

List software licence(s) required for computational project: Matlab, Simulink, Matlab Control Systems Toolbox, Matlab Optimization Toolbox

20) Control of a Small Satellite

Imperial College is intending to design, build and launch a CubeSat, which is a small satellite based on a 30cm x 10cm x 10cm framework developed by CalPoly in the USA (see cubesat.atl.calpoly.edu). The CubeSat controller will be required to run several algorithms to control the CubeSat, e.g. to acquire data from the payload, perform basic attitude measurement and actively control the attitude of the CubeSat through use of magneto-torquers or other attitude control systems. This project will involve the modelling and simulation of the CubeSat in Matlab, as well as developing and testing a variety of control algorithms in Matlab.

List software licence(s) required for computational project: Matlab, Simulink, Matlab Control Systems Toolbox, Matlab Optimization Toolbox

21) Parallel Computing for Control

Modern control methods, particularly those that rely on solving optimization problems, require significant computation power if real-time requirements are to be met. The goal of this project is therefore to investigate the use of parallel computing architectures for accelerating the computation of the control input. This project will also investigate and formulate new control techniques that can only be implemented if parallel computing is available, and quantify the performance improvements that such techniques could bring over existing control methods. The project will involve a mixture of control theory and a lot of linear algebra. You should be able to program in Matlab, C/C++ and be willing to learn new programming languages and mathematics.

List software licence(s) required for computational project: Matlab, Simulink, Matlab Control Systems Toolbox, Matlab Optimization Toolbox

Dr A Morgans [RoomE458, ACEX]

22) Simulation of Thermoacoustic Instability using Simulink (Computational)

Thermoacoustic instabilities occur in the combustors of aero-engines and gas turbines. They are particularly problematic for low-NOx combustors. They are caused by a positive feedback between unsteady combustion and acoustic waves: unsteady heat release generates acoustic waves, these propagate with the combustor and reflect from boundaries to arrive at the flame, where they give rise to more unsteady heat release. Under some conditions, this cycle results in successively increasing amplitudes and a thermoacoustic instability occurs. This project aims to develop a Simulink model of thermoacoustic instabilities in a simple combustor. The model will include the generation of acoustic waves by the flame, the propagation and reflection of the acoustic waves in the combustor and the response of the unsteady heat release when these acoustic waves arrive back at the flame. The project will involve working with Matlab and Simulink work, and will provide a tool on which to test active control strategies for suppressing instability.

Prof Jonathan Morrison [Room 260, ACEX]

23) Wavenumber/frequency spectra of wall pressure fluctuations and inner-outer interactions in turbulent boundary layers (experimental)

We have a novel drag balance that uses a frictionless air bearing to obtain independent measurements of the wall shear stress over an area of about 250x250 mm2. This is to be used to examine the interaction generated by surface roughness. Here, a specific form of ‘known’ roughness is set up with a long fetch, the novelty being that a drag balance is used to measure the surface shear stress (accuracy ± 2%) independently of the velocity field. This is vital for meaningful scaling. A thick boundary layer would ensure good hot-wire probe resolution. Then the downstream roughness is removed to produce a rough-to-smooth change in surface roughness – a strongly perturbed boundary layer – in which the development is dominated by an inner-outer interaction. A key question is the extent to which the viscous sublayer (principally the pressure and wall-normal velocity fields) may be described as “wave-like”. By extension, further experiments can be proposed, in which the ‘roughness’ takes the form of time-dependent surface waves, which DNS indicates, are known to reduce skin friction significantly. Such a fundamental study is of direct interest to Airbus and EADS – IW.

Objectives

1. Familiarisation with drag balance and check of drag balance accuracy.
2. Hot-wire measurements on grit roughness: comparison of shear-stress estimates with drag-balance measurements.
3. Comparison of u-wire and x-wire data.
4. Remove roughness strips such that drag balance now measures downstream of a rough-to-smooth change in surface roughness.
5. Hot-wire measurements in rough-to-smooth configuration.
6. Inclusion of two-point wall-pressure correlation measurements for estimates of two-dimensional wavenumber phase velocity spectra.

Measurements are to be undertaken in the 30”x30” tunnel in the Flow Control lab. The rig is more-or-less extant except for the roughness elements. The traverse gear for hot-wire measurements is in place. Extensive hot-wire data analysis using MATLAB – time domain statistics and spectral analysis.

A simple dimensional analysis suggests that the wall-pressure spectrum of a turbulent boundary layer has a region in which the spectral density follows a k-1 region (k is the streamwise wavenumber). More often than not, spectra are measured in the time/frequency domain and conversion of frequency information to wavenumber information requires knowledge of the frequency-dependent phase velocity. Recent measurements have suggested that the phase velocity is more constant than previously thought leading to a (frequency)-1 dependence in the pressure spectrum. The objective of the project is to make wavenumber/frequency surface pressure measurements in a turbulent boundary layer for a range of Reynolds numbers and assess the description of the near-wall pressure field as a “wave” i.e. motion for which a convection velocity is constant over the height of the viscous sublayer.
Reading: Sadr & Klewicki Meas. Sci. Technol. 11, 2000.
Morrison J. F. 2007 The interaction between inner outer regions of turbulent wall-bounded flow Phil Trans Soc. Ser. A 365, 683.

24) Shearless boundary layer

The essential dynamics of near-wall turbulence involve the mean shear determined by the "no-slip" condition and the blocking of the wall-normal velocity, roughly at wavenumbers inversely proportional to the distance from the wall. The aim of this =experiment is to set up a shearless boundary layer by use of the moving floor in the 10'x5' tunnel. Suction at the upstream edge of the moving floor is used to suck of the incoming boundary layer and the circulation =
generated by the moving floor. Much of the work involves setting up the floor so that the boundary layer orgin occurs at the leading edge of the moving floor. Pitot tube and hot-wire measurements.
Experimental. Prerequisite: Flow Control course.

25) Shearless mixing layer

Fundamental questions concerning turbulent transport are to be addressed by setting up a mixing layer generated by two turbulence grids that meet halfway across the tunnel entrance. The grids are designed (and will need to be made) so that the pressure drop across each half is the same. However, the grids generate different turbulence intensities. Therefore mixing proceeds without mean shear. Pitot tube and hot-wire measurements are used to determine the basic transport processes.
Experimental. Prerequisite: Flow Control course.

Dr J Peiró   [Room 456, ACEX]

26) Aeroelastic modelling of the typical aerofoil section including dynamic stall

We will consider the modelling of the motion of typical aerofoil section in pitch and plunge. The aerodynamics forces will be calculated using an empirical model of dynamic stall. The structural deformation will be represented by linear springs. The coupling of the aerodynamic and structural models will lead to a system of ODEs representing the dynamics of the aerofoil that will be solved numerically. These are a few of the projects proposed under this theme:

1. Calculation of stall flutter: To develop a method to calculate the critical air speed that leads to stall flutter at high incidences based on published semi-empirical models of dynamic stall. This will involve an eigenvalue analysis of a suitably linearized version of the system of ODEs.
2. Variable geometry aerofoil section: To devise a model of the aeroelastic behaviour and determine the flutter boundaries of a morphing wing section.
3. Non-smooth dynamical system analysis: To investigate the behaviour of the typical aerofoil section as a non-smooth dynamical system. The non-smoothness arises from the piecewise-continuous definition of the aerodynamic loading provided by the semi-empirical models of dynamic stall.

27) Simulation of the aerodynamic and heat transfer in networks of tunnels

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: To select the tunnel section so that the increase in pressure does not go beyond the threshold of discomfort.
2. Thermal effects during the transit of a high-speed train in a tunnel: To incorporate thermal effects, including fire and thermal conduction in tunnel linings, into an existing aerodynamic code to model thermal effects during normal operation and in the event of a fire.
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. Multiscale modelling of the flow in train stations: To combine a 1-D model of the network with a 3-D model of the station to produce a simulation of the airflow and temperature in a train station.
5. CFD calculation of pressure losses at junctions: To use the commercial code CFX to determine the values of the semi-empirical formulas currently used in industry to predict pressure losses at the junctions of a network of tunnels.

The following two projects will be carried out in collaboration with Ventilation, Aerodynamics, Fire Smoke Control and MEP Systems in Tunnels, Arup, London, and are based on the Subway Environment Simulation (SES).

The SES is a computer program (written in Fortran) is one of the tools used at Arup to assist in the planning, design, and construction of subway ventilation systems. The SES provides tunnel designers with the tools to: properly size and locate ventilation shafts, evaluate tunnel geometry and fan size, optimize temperature, and model the effects of heat and smoke resulting from fires and other sources.

The two projects proposed here concern the further development of the SES program to produce improved user interfaces, extension of existing capabilities, additional testing and validation, application to practical cases of interest to Arup:

1. Improvement of the heat sink model in SES: The heat sink model in SES is one of the major compromises in the code. Essentially, the heat sink model assumes smooth sinusoidal temperature behaviour at all times. The model does not work well for winter operations and cannot deal with short heatwaves that were preceded and followed by significantly cooler weather (often the case in UK for example). The objective of this project is to improve this model.

2. Simulation using SES of large models of subway systems: One of the main limitations of the SES program is the size of the model that it can handle. The main objectives of the project are to investigate the implementation of large size models in SES and to develop sophisticated input/output graphical user interfaces that will help speed up the model construction process, interrogate the SES output data, and reduce errors.

28) Simulation of flow in arterial and respiratory networks

The arterial and respiratory systems are networks made up of millions of vessels so 3-D flow simulations are just not feasible. Reduced 1-D models of the system 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 on 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. Multiscale model of the respiratory system: To couple 1-D network models of flow in the small airways to 3-D CFD simulations of flow in the principal respiratory conduits.

29) Modelling of cryogenic sloshing using smooth particle hydrodynamics (SPH)

The purpose of this work is to assess the suitability of a code, based on the smoothed particle hydrodynamics (SPH) methodology, for modelling cryogenic-fuel sloshing under micro-gravity environments; to validate it against available experimental data; and to investigate its use as a tool for assessing the risk of upper-stage boiled-off condition.

This work is highly relevant for the implementation of re-ignitable upper stages like in the case of the Ariane-5 ME or for the NGL. Today neither grid dependent or independent CFD techniques are available to target this type of problem. 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.

This work is highly relevant for the implementation of re-ignitable upper stages like in the case of the Ariane-5 ME or for the NGL. Today neither grid dependent or independent CFD techniques are available to target this type of problem.

Dr V C Serghides [Room 261, RDHL]

30) Design assessment of an advanced business jet aircraft

Type: Design / Computational

Conceptual and preliminary design methodologies will be employed to determine the aerodynamic lift, drag and stability characteristics of an existing advanced, business jet aircraft. These will then be used in combination with the aircraft's actual physical characteristics, to estimate its field and flight performance and finally the results will be compared to published figures. This study will involve iterative design computations that will be facilitated through the use of programming.

31) Design assessment of an advanced single-turboprop military trainer aircraft

Type: Design / Computational

Conceptual and preliminary design methodologies will be employed to determine the aerodynamic lift, drag and stability characteristics of an existing advanced, single-engine turboprop aircraft which is designed for basic military training. These will then be used in combination with the aircraft's actual physical characteristics, to estimate its field and flight performance and finally the results will be compared to published figures. This study will involve iterative design computations that will be facilitated through the use of programming.

32) Lifting Body concepts for small to medium-sized commercial transport aircraft

Type: Design / Computational

Previous work on this topic highlighted the potential performance improvements achievable through lifting body aircraft concepts. On the basis of that work, a further refinement of performance calculations and flight profiles will be the focus of the proposed project. The work shall be supported by a review of current and emerging manufacturing technologies and design methodologies which could be used for a more elaborate set of performance, weight and cost estimates, for such aircraft concepts.

Dr A S Sharma [148a, RDHL]

33) Reduced-order modelling of turbulent flows

The persistence and prominence of particular features in turbulent flows suggests that reduced-order models are possible. Rather than approximations based on the physics, the project will explore the systematic application of modern model reduction methods to channel flow.

The student must be confident in programming, and would benefit from an interest in control theory.

Prof S Sherwin [Room 262, RDHL]

34) Computational fluid dynamics using spectral/hp element methods

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 of these techniques to incompressible flow problem similar to those shown under www.imperial.ac.uk/bioflow and www.imperial.ac.uk/vortexflows. Although there are no specific prerequisites for the projects priority will be given to students with computing and coding skills. Experience in C++ programming is desirable.

List software licence(s) required for computational project: Tecplot, Access to Linux machiens

Prof JC Vassilicos [Room E362, ACEX]

35) Direct numerical simulations of turbulence generated by fractal grids

Over the past 60 years or so the efforts in turbulence have been mostly in ad hoc modelling of specific turbulent flows and the progress has been limited. An understanding of turbulence dynamics is needed, and for this a well-designed experiment is required where these turbulence dynamics are set out of joint so as to give us clues for understanding them. This is what has been achieved at Imperial College London where the first ever experiments on turbulence generated by fractal grids in wind tunnels have been conducted with impressive results. It is now necessary to develop computer simulations of these flows, and a fully parallelised code for very large such simulations has recently been developed. The challenge is to now use this code to understand fractal-generated turbulence, its fundamental dynamics but also its various engineering applications.

36) Particle agglomeration by turbulence in clouds

The Intergovernmental Panel on Climate Change (IPCC 1996) includes clouds (their distribution, dynamics and radiative characteristics) in its list of "most urgent scientific problems requiring attention". At any one time about half the earth is covered by clouds and one of the greatest difficulties in meteorological predictions concerns the whether, when and where it will rain. One of the intriguing aspects of the cloud-climate problem is the fundamental importance of processes occurring on extremely small scales in determining the macroscopic properties of clouds, including their lifetime, extent, precipitation efficiency and radiative properties. Thus, if we are to understand the impact of clouds on meteorological predictions and the global environment, we are obliged to understand processes occurring on seemingly unrelated scales, such as cloud-particle size distributions. The formation of cloud droplets on individual aerosol particles, the subsequent growth by vapour condensation and then the collision and coalescence of cloud droplets, all processes occurring on micrometer to millimetre scales, eventually take part in determining the macroscopic properties of a cloud such as its precipitation efficiency and optical properties. This project will be concerned with the agglomeration (collision) aspect of particles by small-scale turbulence. Some new developments will be required and use of the only Lagrangian model currently in existence which can take into account the interactions between coherent small-scale flow structure and dense particles/droplets, namely Kinematic Simulation.

37) Multiple-scale laminar flow controlled by electromagnetic forcing

In the past twenty years numerous works have used electromagnetic forcing to generate turbulent quasi-two-dimensional flows mostly for fundamental research into the nature of turbulence. Electromagnetically controlled flows have also been used to generate chaotic mixing in the laboratory (a type of mixing thought to be important in the stratosphere and in the earth's mantle) and may prove to be an efficient way to mix substances with limited power loss. This project will be either experimental, in which case it will involve taking films of the flow and perhaps also doing some Particle Image Velocimetry or Particle Tracking Velocimetry on the existing experimental set-up in the hydro-lab, or it will be computational, in which case an existing code will be provided to study multiple-scale laminar flow mixing.

38) Momentum and scalar dispersion and drag reduction in turbulent channel flow

Direct Numerical Simulations of turbulent channel flow will be used to probe the vortical and straining multi-scale coherent flow structure of the flow and its effects on fluid element trajectories and Lagrangian statistics which are important for understanding the physics of Reynolds stresses and turbulent momentum transport. The acceleration field will be a central component of this study which will therefore have implications for turbulent flow control. See P.S. Bernard & R.A. Handler, J. Fluid Mech. vol 220, pp. 99-124 (1990).

39) *Critical points in turbulent channel flows*.

There are two types of critical points which might be addressed. Stagnation points of the fluctuating velocity field, that is points where the fluid velocity is instantaneously equal to the mean flow velocity, and zero-acceleration points. The distribution of stagnation points has been shown over the past year to determine the mean flow profile in an intermediate equilibrium region of the flow. The distribution of zero-acceleration has been shown over the past 3 years or so to determine the demixing of small dense inertial particles by turbulence, even homogeneous isotropic turbulence. The exact topic of this project will be chosen in discussion with the student from various issues relating to either type of critical points, their relations dynamics and effects on various statistics of the turbulence, including Reynolds stresses, drag and mixing.

Supervisors in Structural Mechanics

Prof F Aliabadi [Room E459, ACEX]

40) Crack growth modelling in Aerostructures

The problem of fatigue crack propagation is of major concern in the design of structures for use in engineering applications, making the prediction of crack growth a challenging problem for structural engineers It is important to give an accurate estimate of the life expectancy of mechanical and structural components that can be expressed in a number of fatigue cycles. The problem is further complicated if crack interaction is considered. Weld joints are typical cases in which the fatigue crack interaction phenomena arise.

The aim is this project is to assess different computational methods for modelling crack growth.

List software licence(s) required for computational project: In house codes and Abaqus

41) Micromechanical Modelling for the Evaluation of Plain Woven Composites Elastic Modules

Between the major types of composites, woven fabric composites have long been recognized as more competitive than unidirectional composites. This is partly due to their ability to provide good reinforcement in all directions within a single layer, better impact resistance, better-balanced properties, easier handling and fabrication, good ability to conform to surfaces with complex curvatures. However, their complex architecture makes their analysis much more challenging. Many of the approaches for determining the properties of woven composites and predicting their behaviour use the representative volume element. The properties and behaviour of the composite are considered to be the same as the properties of the RVE.

List software licence(s) required for computational project: Abaqus and Matlab

42) Damage detection in composite materials using piezoelectric sensor/actuator

High performance composite structures are increasingly being adopted in many industrial areas, such as aerospace vehicles, due to their high strength and stiffness. However, good quality and reliability of the structure is an important concern. Structural Health Monitoring (SHM) involves systems with the ability to detect and interpret damage in a structure in order to improve reliability and efficiency during operation. This process consists of monitoring the structure over time during its service life. The detection of damage is determined by comparing the response of the structure by measuring data and comparing it to a base-line response. Due to increasingly high demands for safety and low cost maintenance, the use of built-in real-time SHM system for aircraft monitoring is becoming more and more attractive.

List software licence(s) required for computational project: Abaqus and Matlab

Dr P Baiz Villafranca [Room E456 ACEX]

43) Meshfree Method for Analysis of Laminated Composite Plates

Meshfree or element-free methods are gaining popularity as an alternative to the Finite Element technique for the simulation of fracture and large deformations. Their advantage is the lack of connectivity that greatly simplifies topology changes. The aim of this project will be to extend an available Element Free Galerkin (EFG) code, in order to include a new set of shape functions for the analysis of laminated composite plates. A good background in programming (e.g. Python/MATLAB, FORTRAN, C++) and a good theoretical understanding of the finite element method is required for this project.

List software licence(s) required for computational project: MATLAB, FORTRAN, C++

44) Analysis of Plate Structures by the eXtended Finite Element Method (XFEM)

The extended finite element method (XFEM) is an extension of the conventional FEM, in which a standard displacement based finite element approximation is enriched by additional (special) functions using the framework of partition of unity. Its advantage is that mesh refinement/updating is avoided when discontinuities (e.g. gaps, cracks, etc) are present. The aim of this project will be to extend an available plate bending XFEM code to model laminated

composite panels. A good background in programming (e.g. MATLAB, FORTRAN, C++) and a good theoretical understanding of the finite element method is required for this project.
List software licence(s) required for computational project: MATLAB, FORTRAN, C++

45) Development of Efficient Finite Elements with Drilling Rotations using Partition of Unity

When modelling 3D plate and shell assemblies (e.g. aircraft fuselage), a difficultly will arise on the assignment of the stiffness in the out-of-plane rotation of each plate because classical plate bending formulations do not include the equations associated with this rotational degree of freedom, also known as the drilling rotation. Recent developments in Partition of Unity Method (PUM) and drilling rotations have shown the potential of PUM for deriving new finite elements. The aim of this project will be to develop finite elements that include drilling rotations at selected nodes in order to improve the efficiency of classical plate bending FEM. A good background in programming (e.g. MATLAB, FORTRAN, C++) and a good theoretical understanding of the finite element method is required for this project.
List software licence(s) required for computational project: MATLAB, FORTRAN, C++

46) Residual Stress Fields in Aircraft Panels

Residual stress fields usually produce large tensile stresses, whose maximum value could reach the yield strength of the material, and therefore may reduce the performance of the structural component by increasing the rate of damage by fatigue. The aim of this project is to obtain process induced residual stresses in fibre reinforced composite panels. The study will be carried out with the commercial finite element software ABAQUS and its user subroutines. A good background in programming (FORTRAN and Python) is required for this project.
List software licence(s) required for computational project: ABAQUS, FORTRAN, Python

Dr E Greenhalgh [Room 362B, RDHL]

47) Aerodynamics of Runway Debris Lofting (Co-supervised with Prof Mike Graham)

One widely recognised threat to aircraft is that of runway debris. Debris is usually generated by thermal and climatic degradation of the runway surface, or by migration of material (by high winds, etc) from the surrounding environment. Another source of debris can be other aircraft or vehicles using the runway. The impact problem arises because debris can be thrown up towards the aircraft structure via a number of mechanisms. These include debris being picked-up by the tyres, sucked-up by the engine intakes or aerodynamic surfaces, or thrown up by adjacent aircraft.

The aim of this research is to work in conjunction with a PhD student (Sang Nguyen) to develop realistic models to understand and predict how runway debris can be thrown upwards by tyres and cause impact damage to aircraft structures. Research into this problem so far has mainly used a solid mechanics approach considering only the forces produced by the over-rolling tyre. This final year project focuses on taking into account the aerodynamics around an aircraft tyre and undercarriage to gain a full picture of the forces acting on an item of runway debris after the tyre passes over it. Information obtained about the maximum height to which the runway debris can be lofted will be used to predict the threat of impact, which will complement a corresponding project to investigate the subsequent damage to composite materials.

Task related to this project include:

1. Characterising the flow encountered by runway debris in the wake of an aircraft tyre during takeoff/landing and relating this flow to the forces on objects thrown up by aircraft tyres. This will involve creating computer models of a typical aircraft undercarriage and runway debris articles and using CFD software (Fluent) to analyse the interaction between the flow and debris. These simulations are likely to be sensitive to the aircraft speed, geometry of runway debris and geometry of the tyre.

2. In previous experiments where an aircraft tyre section was made to descend onto runway debris items, the debris was observed to leave the tyre at high rates of spin. Therefore the forces acting on spinning runway debris due to the Magnus Effect may be

significant enough to overcome the weight of the debris. This is the same phenomenon that explain explains the swerve encountered in certain sports, such as the curved path of a spinning football or baseball.

3. Considering how the ground effect caused by the passing aircraft undercarriage may influence runway debris lofting conditions.

4. Using calculated trajectories of lofted runway debris to predict likely impact zones on an aircraft structure based on the speed and geometry of the aircraft.

The results of this study will allow aerospace engineers to model and assess the potential severity of impact due to runway debris. These models will be invaluable for certification of current and future aircraft. These models are not only applicable to aircraft, but can be applied to any such lofting event with transport vehicles, such as Formula One racing cars.

Dr L Iannucci [Room 354B, RDHL]

48) PVDF impact sensor design

The project involves the development of a sensor technique to determine the location and nature of an impact on a structure. A number of different shapes will be impacted on PVDF film, with the corresponding force/impulse recorded. An algorithm will be developed to distinguish between different impacts. The process of turning PVDF from an inert polymer to a poled piezo-electric film is a complicated one. Partly due to this, and partly due to the inherent randomness of the semi-amorphous structure of PVDF, there can be considerable variation in the material properties of the final material. Hence commercial available PVDF film will be used with electrodes already placed on the film. Data acquisition systems will be used to record the information. The project is 70% experimental and 30% computational, perhaps using Matlab or Labview.

49) Hopkinson bar inverse modelling tests

A good overview is provided in Wikipedia. 'The Split-Hopkinson pressure bar, named after Bertram Hopkinson, sometimes also called a Kolsky bar, is an apparatus for testing the dynamic stress-strain response of materials. The split-Hopkinson pressure bar was first suggested by Bertram Hopkinson in 1914 as a way to measure stress pulse propagation in a metal bar. R.M. Davies and H. Kolsky refined Hopkinson's technique by using two Hopkinson bars in series, now known as the split-Hopkinson bar, to measure stress and strain. Later modifications have allowed for tensile, compression, and torsion testing.'The project involves developing a new technique to generate the dynamic stress strain curve using a high speed camera to record surface strains as a function of time on specimens. The department's tension bar will be used for all tests. An inverse approach will then be adopted to match the strain field on the specimen to Finite Element based calculation until a match is achieved. Materials such a Aluminum, Steel and composites will be investigated using the new technique. It is anticipated that the project will be 40% experimental and 60% computational using the ls-dyna software.

50) Bespoke MFC design and manufacture

The Macro Fiber Composite (MFC) is an innovative actuator. The MFC consists of rectangular piezo ceramic rods sandwiched between layers of adhesive and electroded polyimide film. This film contains interdigitated electrodes that transfer the applied voltage directly to and from the ribbon shaped rods. This assembly enables in-plane poling, actuation, and sensing in a sealed, durable, ready-to-use package. When embedded in a surface or attached to flexible structures, the MFC provides distributed solid-state deflection and vibration control or strain measurements. The project involves the manufacture of bespoke MFC using commercial available materials. The project is in conjunction with QinetiQ but manufacturing will take place in the department. The project is experimental in nature with some LABVIEW interfacing (10%).

51) Gauges for High Pressure Measurement Work

Manganin is a copper-manganese-nickel alloy with low strain sensitivity, but a relatively high sensitivity to hydrostatic pressure. Resistance change as a function of applied pressure is linear to extremely high pressures. This characteristic has been utilized in the construction of high range fluid pressure cells using manganin wire for many years. Manganin gauges are used extensively in high-pressure shock wave studies ranging from 1 to over 400 kilobars (1 bar = 14.5 psi = 100 000 N/m2). In conventional applications, the gauge is bonded between two flat metallic or polymer plates. In this project the gauges will be tested on the Aero small gas gun and modelled using the ls-dyna Finite Element software to understand the behaviour of the gauge under extreme pressure. The project is experimental in nature with some LABVIEW interfacing (10%).

52) Parachute wing design

The development of innovative adaptive structures for drag and lift based parachutes can potentially reduce system complexity by eliminating control surfaces and their auxiliary equipment. This technology has the potential of allowing high precision drops to be realised. The project involves a series of wind tunnel tests to characterise the behaviour of a model parachute with detailed instrumentation. The project is 80% experimental and 20%computational.

53) Development of a 3D Peridynamics code for crack propagation

Meshless techniques have been used successfully to design spacecraft-debris shields against ballistic impacts, and may be useful in the design of composite crush structures, which are very difficult to model using existing Finite Element techniques due to mesh entanglement. The Peridynamics (similar to Molecular Modelling) and SPH methods are meshless methods, but use a Lagrangian formulation, rather than a Eulerian formulation, with a corresponding Kernel function (like an interpolation function) between particles. This project involves the implementation of an orthotropic composite material model into a Peridynamics code and validation against experimental crack patterns. The project is purely computational. FORTRAN programming knowledge is required.

54) Characterisation of Graphite(co-sponsored with Dstl)

The project involves the mechanical characterisation of solid graphite using standard mechanical tests machines. Part of the project involves the understanding of the behaviour of the material under these tests.

Dr R Palacios [Room 355, RODH]

55) Aeroelastic optimization of flapping wing kinematics in forward flight.

Flapping flight is based on achieving net thrust and lift during each period of wing motions. Birds are known to achieve this with complex wing kinematics that include wing morphing during each cycle, and understanding those shape changes is an essential step to design successful ornithopters. This project will numerically investigate the effect of wing flexibility in the aeroelastic performance of bat-size flapping wings. A finite-element model will the wing kinematics and an existing three-dimensional unsteady vortex-lattice method will provide an approximation to the aerodynamic forces. An optimization problem will be then defined to determine the wing kinematics that gives the best overall propulsive performance. This project requires a good knowledge of Matlab.

56) Flight simulation of flexible aircraft using a partitioned aeroelastic solver

Load control systems are essential to achieve substantial weight reductions on aircraft with large wing spans, such as long-endurance observation UAVs. They help to reduce structural weight by reducing peak loads while in operation, but they also bring additional requirements to the vehicle flight control system. Their design is done using aeroservoelastic models of the aircraft which can account for structural dynamics, aerodynamics, sensor/actuators and feedback control algorithms. To that goal, this project will numerically investigate the aeroelastic response of flexible aircraft under atmospheric gusts using an existing partitioned aeroelastic solver. This project requires a good knowledge of Matlab.

57) Spoilerons for aircraft control

The word “spoileron” comes from combining “spoiler” and “aileron” and that certainly describes its function. They have been used in different aircraft as a way to produce asymmetric wing loading by dropping lift on one wing, although their use is limited to situations in which ailerons cannot operate (e.g., in wings subject to control reversal). This project will provide a first estimate of the dynamic performance of spoilerons by using a vortex particle model in 2-D. System identification techniques will be then used to describe the dynamics of the system and the resulting transfer function will be integrated into an aeroelastic model for roll control of a full wing. This project requires a good knowledge of Matlab.

58) Robust control of aeroelastic instabilities on a tailored composite wing.

The widespread use of composite materials in aircraft primary structures not only reduces weight but also allows for new (and often ingenious) design concepts. One such idea is the use of the material anisotropy to improve the aeroelastic performance of the vehicle. This is known as aeroelastic tailoring and is the driver behind the successful design of forward-swept-wing planes like the X-29 fighter. This work will first model the robust aeroelastic margins of composite wings, accounting for model uncertainty, using existing industry-level computational tools (finite-element structural modelling, panel methods for unsteady aerodynamics modelling, and the Matlab robust control toolbox), which will then be used to define a stability augmentation strategies to be implemented in an existing wind tunnel model. This project requires a good knowledge of Matlab.

Dr S Pinho, [Room E457, ACEX]

59) Fractal Models for Strength and Toughness of Structural Materials

The project will focus on the application of fractal mathematical theories to the understanding and prediction of the mechanical response of materials. Fractals are structures with self-similar complex features: each part of a fractal is a reduced-size copy of the whole, so the same pattern appears when the fractal is studied at different magnifications. Although fractals were first theorised as a mathematical concept, many fractals exist in nature; such as coast lines and human blood vessels. Furthermore they possess various interesting properties. For instance, a fractal structure can lead to enhanced strength and toughness, which is extremely important for many Engineering applications, such as in Aeronautics. The study will be carried out with the commercial software Maple. Students applying for this project should have a strong interest in structural mechanics and mathematics.

60) Molecular dynamics simulation of graphene composites

The recent discovery of graphene has an enormous transformative potential: to engineer polymer-matrix composites where the reinforcement is a planar, 1 to 30μm-thick sheet made of graphene crystals. Graphene is a free-standing single-atomic plane of Carbon, with a Young's modulus ~1 TPa and tensile strength ~130 GPa. Achieving similar properties with graphene paper has not been attained yet, but it is not far from reality – graphene was only first reported in 2004 (also in the UK), and graphene paper has already been manufactured with Young's modulus 41.8 GPa and tensile strength 293.3 MPa. In comparison, quasi-isotropic carbon-fibre epoxy composites have Young's modulus ~70 GPa and tensile strength ~280 MPa. The objective of this project is to carry out molecular dynamic simulations of graphene composites using Matlab.

61) Multiscale modelling of aircraft structures

Advanced structural failure models have been developed in the department in cooperation with NASA. These models are currently implemented in a custom version of the FE software Abaqus. In this project, the student will use these models and develop them further to make accurate FE predictions of failure of typical structural components of interest to Airbus. 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.

This project will be carried out in the framework of an existing project with Airbus, which aims at assisting Airbus Engineers with the virtual design of the A350 composite wing. Students applying for this project should have a strong interest in structural mechanics and good knowledge of FE.

62) Theoretical modelling of toughening mechanisms

A key problem for aircraft industry is currently to accurately predict the strength and damage tolerance of large composite components from a sound understanding of the failure process at the micromechanical level, of the corresponding energy absorbing mechanisms, and of the different scales involved in the fracture process. The overall aim of the proposal is to obtain such a model, by developing an analytical model which relates the fracture toughness of a laminate in a component of a given scale to the micromechanics of the failure process. This model is to be built from an existing model recently developed in the department. The study will be carried out with the commercial software Maple. Students applying for this project should have a strong interest in structural mechanics and mathematics.

63) WorldFirst Formula 3 recycled car

As part of the WorldFirst project , Warwick University designed a Formula 3 car with environmentally sustainable components. The Formula 3 car features recycled carbon-fibre bodywork, as well as a several specially constructed recycled parts.

In this project, the student will use structural finite element models in Abaqus to design specific components from the recycled carbon-fibre bodywork. 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. This project will be carried out in the framework of an existing project on Structural models for recycled composites at Imperial and the WorldFirst project in Warwick University.

Dr P Robinson [Room 357, RDHL]

64) Investigation of multi-crack DCB tests

Results are available from a series of double cantilever beam tests performed on specimens containing a mid-plane delamination (as in the conventional Mode I fracture toughness test) and an additional secondary delamination a few plies below the mid-plane. The behaviour of these specimens is a good validation test for delamination modelling tools. This project will examine the effectiveness of available tools in finite element programmes to predict the observed behaviour.

65) Exploring the potential of the virtual fields methods for determining the elastic constants for composite plates

The virtual fields techniques holds the potential to deliver all the elastic constants for a composite laminate from a single laboratory test. The method requires the strain field in a loaded laminate to be measured and then virtual work equations are written using a series of suitably chosen virtual strain fields. The virtual work equations will contain the elastic constants of the laminate and so, provided a sufficient number of these equations are formed, then the elastic constants can be determined. A previous project has explored the concept of the virtual fields approach and has identified its potential and limitations. This new project will focus on strategies for selecting virtual strain fields which provide results that are relatively insensitive to errors in the real strain field.

Dr M Santer [Room 354, ACEX]

66) Optimization of Flapping Articulated Wing Kinematics in Forward Flight** (**Co-supervised with Dr. Rafael Palacios)

Computational, Internal

Flapping flight is based on achieving net thrust and lift during each period of wing motion. Birds and bats are known to achieve this with complex wing kinematics and fluid/structure interactions during each cycle. Understanding these shape changes is an essential step to enable the design of successful ornithopters. This project will numerically investigate the aeroelastic effects in the aerodynamic performance of bat-size flapping wings. Using existing unsteady vortex lattice and structural finite element codes, an optimization problem will be defined to determine the wing kinematics that give the best overall performance for an articulated flapping wing. The numerical simulations will be carried out in a Matlab environment.

67) Three-dimensional Digital Image Correlation

Computational, Internal

Digital Image Correlation (DIC) is a process by which displacements and strains are recovered from sequential images. Equivalences between speckles on the specimen being observed are determined by correlating the intensity matrices of the digital images. In two dimensions this is straightforward, but the aim of this project is to write a program using Matlab's digital image processing toolbox which enables the recovery of three-dimensional displacement and strain to a known accuracy. This necessitates overcoming several challenges, in particular the need to determine point correspondances between stereo image pairs. All work will be carried out in the Matlab environment.

Supervisors in Mathematics

Professor A Ruban [Room 6M45, HXLY]

68) Hypersonic Flow Past Slender Cone

When dealing with inviscid hypersonic flows past slender bodies three flow regimes (weak interaction, moderate interaction and strong interaction) are possible depending on the hypersonic interaction parameter $\chi = M_\infty \tau$; here M_∞ is the free-stream Mach number assumed large, and τ is the relative thickness of the body assumed small. This project is concerned with theoretical analysis of the circular cone flow at moderate values of χ . The task is to determine the temperature and density distributions between the front shock and cone surface based on appropriately simplified Euler equations.

If time permits the viscous boundary layer on the cone surface will be also studied.

69) Generation of Taylor-G¨ortler Vortices by Wall Roughness

The laminar-turbulent transition in the boundary layer on an aircraft wing is a complicated process which starts with transformation of “external perturbations” into natural instability modes of the boundary layer. This transformation is the subject of the Receptivity Theory. In this project a particular example of the receptivity will be considered, namely, the formation of the Taylor-G¨ortler vortices in the boundary layer will be studied by means of theoretical analysis of the linearised Euler equations. It will be assumed that the flow is incompressible and that there is a small imperfection of the surface of the wing. The first task will be to identify appropriate size (and shape) of the imperfection that is likely to create resonance with the Taylor-G¨ortler instability modes in the boundary layer. Then simplified equations of motions have to be formulated. Finally, a relationship between the shape of the wall roughness and the amplitude of the Taylor-G¨ortler vortices (generated in the boundary layer) has to be established.

It is expected that the solution of the governing equations can be found using the Laplace Transform technique.

Prof X Wu [Room 637, Huxley Building]

70) Large-scale coherent structures in turbulent free shear layers

While turbulent flows are usually characterised as being random and chaotic, an amazing feature is that structures exhibiting a high degree of order, or coherence, can also be detected. Among these, the most remarkable are large-scale, roller-like coherent vortical structures observed in free shear layers such as mixing layers and jets. It has long been suggested that these structures are closely related to instability modes supported by the background mean flow, and recent experiments show convincingly that many of gross characteristics of these structures can indeed be predicted by a linear instability theory. However, the roll-up of vorticity field is a highly nonlinear process. The aim of this project is to extend nonlinear instability theory for laminar flows to a turbulent mixing layer. A key issue to be addressed is the parameterisation of effects of small-scale turbulence on the large-scale structures. An appropriate closure model that accounts for the non-equilibrium nature of the flow will be adapted and tested.

71) The trailing-edge flow: triple-deck theory and instability property

The classical boundary layer theory is based on the hierarchical structure: the invisid solution provides the pressure gradient and slip velocity which drive the viscous flow in the boundary with the latter producing a negligible effect on the in the inviscid part of the flow field. This scheme is no longer valid when some form of abrupt change over a short scale is present. This scenario occurs in the case of the flow in the vicinity of the trailing edge of airfoil. The exact manner in which the classical boundary layer theory breaks down can be analysed in detail, and the scaling argument would then point to a new flow structure and theory --the triple deck theory, in which the inviscid and viscous motions are mutually coupled. The instability property of the trailing edge flow, which is yet to be full understood, will be investigated. The project is primarily theoretical / mathematical, but would also involve some numerical calculations.

72) Flame-acoustic interaction in premixed combustion

A premixed flame usually excites acoustic modes of a combustion chamber through unsteady heat release. The spontaneously emitted sound waves in turn modulate the flame. Such a two-way coupling may lead to combustion instability, which has many detrimental effects. In many previous studies, the spontaneous acoustic field of a flame was (artificially) suppressed, or the coupling was modelled in a rather ad-hoc empirical manner. We have recently developed a general first-principle flame-acoustic interaction theory. The aim of this project is to develop an appropriate numerical algorithm for solving the flame-acoustic interaction system. Alternatively, the general system may be simplified in certain special cases of interest, and the resulting reduced system may then be solved numerically. In particular, we would like to investigate if a family of well-known steady solutions, which are stable when spontaneous acoustic field is ignored, are in fact unstable.

External Projects

Airbus Bristol Projects

AB1) Uncertainty evaluation in aircraft loads.

The application of uncertainty management techniques with the aircraft design process is a current high profile research topic and of particular industrial interest. This project aims to provide more robust aircraft designs and to correctly balance the risks and opportunities within the non-specific design convergence process to shorten the specific design and manufacturing process. The student will further develop an existing project in conjunction with EADS Innovation Works to apply uncertainty management techniques to the loads calculation process to quantify the statistical variation of the output loads to the uncertainty in the A/C definition. The particular application area of this project is within the calculation of the loads due to ground manoeuvres (landing, turning, braking etc). A successful placement student would be able to work with key experts in this area from EADS IW as well as gaining direct knowledge of the ground loads calculation process, the details of the design drivers, knowledge of response surface techniques (polynomial chaos), and uncertainty analysis theory.

Aircraft Research Association Projects

Students are expected to do the work in ARA.

ARA1) Investigation of mesh/solver performance

ARA's standard CFD toolkit includes SOLAR meshing and the Tau flow solver. Although best practice guidelines in mesh generation do exist, tuned by examination of the flow solver results, there are still many issues related to the precise dependency of Tau predictions on SOLAR meshing which remain to be answered.

The project would be based around a number of relevant medium complexity aircraft configurations at representative onset flow conditions. A number of key mesh generation issues, dependent upon geometrical and flow features, would be chosen for investigation and a sequence of related meshes generated. Results obtained on the meshes would help to provide a quantitative view of the dependency of the flow predictions on the meshes. This information would then drive improved best practice. A further possible task could be to investigate tuning of Tau to achieve faster convergence for particular classes of problem.

The student would gain knowledge in: the use of industry standard CFD tools; the quality demanded by industry of CFD tools; fluid dynamics; aircraft aerodynamics; the interdependency of CFD meshes & flow solvers.

[Several projects are possible under this heading.]

ARA2) Noise prediction

ARA is in the process of putting together a capability to predict aerodynamically generated noise from external airframes – high-lift devices, propellers, landing gear. The emphasis is on creating a capability which is affordable and hence one which is based on steady or pseudo-steady RANS.

The project will focus either on extension of the current capability or further evaluation of the current capability, depending on the skills and interests of the student. The capability development component would revolve around embedding existing technology in an efficient process chain and potentially extending the functionality in a limited way. The evaluation would necessitate the generation of appropriate RANS solutions using SOLAR/Tau and then the application of existing acoustic methods to these solutions to generate the noise predictions. These would be compared with other available data to assess quality.

The student would gain knowledge in: the use of industry standard CFD tools; aircraft aerodynamics; aerodynamic noise generation.

ARA3) Evaluation of Wind Turbine Methods
ARA has developed a capability for analysing propeller aerodynamics using simple analytical methods. The method can also be used for designing propeller blades using a family of aerofoil sections. There is a requirement to assess the use of this capability for the design and analysis of wind turbine blades.

The project would involve extension of the method, as required, for application to wind turbine blades and the design of a wind turbine blade, with given planform and operating constraints. The design would be analysed over a range on flow conditions. It is expected that improvements to the capability will be generated: these could be enabled by the student or by ARA, depending on the complexity of the improvement and the skill of the student.

The student would gain knowledge in: the use and development of industry standard CFD tools; wind turbine aerodynamics.

ARA4) Investigation of open source CFD
Today, ARA makes active use of Paraview, an open source post-processing and visualisation tool, and limited use of the open source CFD tool, OpenFoam. The latter in particular possesses a vast range of functionality, only a tiny fraction of which has been used.

The project would involve investigation of currently unused functionality in one or both of these codes, with a view to establishing new capability which could be used by ARA in the future. Depending on the skill of the student, some capability creation involving software development (e.g. scripting) could be undertaken.

The student would gain knowledge in: the use of open source CFD tools; fluid dynamics; aircraft aerodynamics.

Anaglyph

A1) Curved Panel analytical solutions
External Supervisor: Dr. G. Kretsis; Internal supervisor: Dr P Baiz Villafranca
A literature survey of available equations and numerical solutions for composite curved panels and cylinders (thin shells) in compression, bending and pressure will be undertaken. Relative merits of methods will be quantified and experimental evidence will be referenced where possible. Local buckling effects will be considered wherever applicable. The extension of the available theories to include stiffeners or to thick shells will also be investigated, focusing on the changes to buckling patterns or on the laminate stress field. Comparison to simple FE models for validation purposes is possible.
List software licence(s) required for computational project: Abaqus, Matlab

A2) Woven fabrics FE solver
External Supervisor: Dr. G. Kretsis; Internal supervisor: Dr S Pinho
The prediction of stiffness and strength for woven fabrics necessitates the use of FE methods for wider applicability and greater accuracy. A method has been developed within the department whereby a 3D FE model is generated given the fabric properties. This project requires the development of a basic FE solver for brick elements, including constraint equations, to solve the generated model.
List software licence(s) required for computational project: Abaqus

A3) Three-dimensional laminate stress fields
External Supervisor: Dr. G. Kretsis; Internal supervisor: Dr S Pinho
An investigation into available methods to calculate three-dimensional stress fields for laminates will be undertaken. In particular, the case of a laminated brick finite element under 3D loading will be considered, where the layer stresses need to be calculated in some detail, for the purposes of failure calculations following an FE analysis. Another case to be considered will be that of ply drop-off, where local stress concentrations can cause delamination.
List software licence(s) required for computational project: Abaqus

A4) Flat Panel FE model
External Supervisor: Dr. G. Kretsis; Internal supervisor: Dr S Pinho
A simple FE model for the solution of composite flat panels of arbitrary shape, boundary conditions and loading is necessary for rapid analysis of idealised structural components. From the user's point of view, properties are defined via a simple interface and results are given in the form of in-plane forces and bending moments at any point queried. Behind the scenes, a simple shell FE model is automatically generated and solved almost interactively.
List software licence(s) required for computational project: Abaqus

Bordeaux Project

Project in collaboration with the RENAULT car company

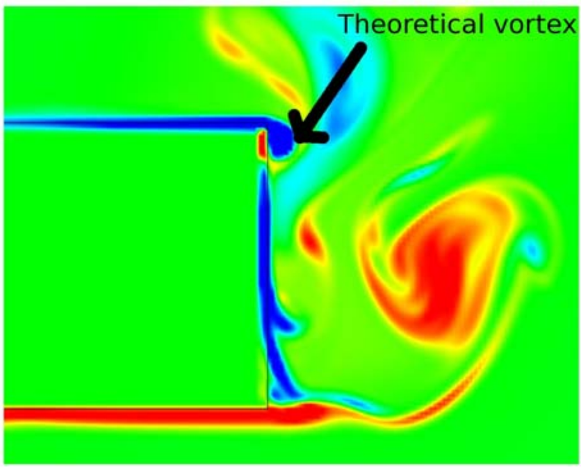
B&R1) Numerical study of the link between vortex kinematics and pressure drag on the back of a simplified truck model (with applications to the flow control)
Advisers: C.H. Bruneau, I. Mortazavi (INRIA) and P. Gillieron (Renault)
Contact: Iraj.Mortazavi@inria.fr
Schedule: spring - summer 2011

A large part of the drag coefficient around a bluff body is due to the pressure forces on the front and back walls. In particular the vortices generated on the sharp corners of the geometry are moved in the near wake, inducing strong pressure forces at the back. Consequently, each time a big vortex stand close to the wall the drag coefficient increases. A way to reduce this drag coefficient is to control the flow so that the vortices are convected away faster.

To convey faster the vortices, active control using blowing jets can be an efficient tool. In this project, the bluff body is a simplified car called the square-back Ahmed body. A theoretical study shows the strong relationship between the distance of an inviscid vortex and the pressure forces on the back wall. The results given by the active control process will be analysed to prove that this relationship is true in a real ow. Indeed, the variations of the drag coefficient are directly linked to the distance of the strong shedding vortices to the back wall. The placement schedule is planed as follows: a study will be performed using a vortex superimposed on a given viscous background flow as on the figure.

Then, the study of the trajectories of the vortices in the vicinity of the back wall for some real ows as well as the impact of the distance of the vortices to the pressure drag forces and thus on the whole drag coefficient will be carefully analysed.

The study will be performed using numerical approximations of the Navier-Stokes equations.



DSTL Projects

DSTL1) The Numerical Prediction of the Laminar and Turbulent Heat Transfer on a Flat Plate and On Spherical Surfaces

The aim of this research is to undertake a Computational Fluid Dynamic (CFD) simulation of the turbulence in hypersonic flows. The task will be the prediction of the local heat transfer on a flat plate and a spherically blunted conic surface for a range of turbulence models. Aims of the study will be to compare the numerical predictions with experimental measurement data where these are available and to evaluate the theoretical model developed under the Imperial College MSc studies on *Heat Transfer In Hypersonic Boundary Layers* under taken in 2010 under the guidance of Professor Ruban.

The study may be undertaken at the Defence Science Technical Laboratories (Dstl) Portsdown West site near Fareham in Hampshire or on-site at Imperial College. The study will use the Dstl Navier Stokes CFD model TINA and a copy of the Dstl code will be supplied for use on Imperial College computers.

The outputs required will be:
- a literature survey of turbulence models available for use in hypersonic flow modelling;
- a set of TINA code computational cases for the chosen turbulent models investigated.

The research will also allow the opportunity to interact with a leading UK software consultancy, the developers of the TINA software.

The research will be supervised by staff at Dstl and Imperial College (Prof. R Hillier). If based at Dstl, the researcher will have the opportunity to interact and gain knowledge and develop expertise by interacting with Dstl staff.

The latter option is however only open to students who hold UK nationality.

DSTL2) The Numerical Simulation of the Effects On The Local Heat Transfer Of Surface Porosity and Surface Blowing On A Flat Plate In Hypersonic Flow

The task will utilise the Dstl Portsdown West Navier Stokes solver TINA for the prediction of the effects of surface porosity and surface blowing on the local pressure field and heat transfer on a flat plate. The study will investigate the effects of ‘hole’ size, ‘hole’ density and ‘hole’ and location.

The study may be undertaken at the Defence Science Technical Laboratories (Dstl) Portsdown West site near Fareham in Hampshire or on-site at Imperial College. The study will use the Dstl Navier Stokes CFD model TINA and a copy of the Dstl code will be supplied for use on Imperial College computers.

The outputs required will be:
- a literature survey of surface porosity and surface blowing in hypersonic flows;
- a set of TINA code computational input files for the cases investigated.

The research will also allow the opportunity to interact with a leading UK software consultancy, the developers of the TINA software.

The research will be supervised by staff at Dstl and Imperial College (Prof. R Hillier). If based at Dstl, the researcher will have the opportunity to interact and gain knowledge and develop expertise by interacting with Dstl staff.

The latter option is however only open to students who hold UK nationality.

DSTL3) The Numerical Simulation Of The Flow Around Local Regular and Irregular Finite Scale Roughness Elements On A Flat Plate In A Hypersonic Freestream Using Navier Stokes Methods

The task will utilise the Dstl Portsdown West Navier Stokes solver TINA for the prediction of the effects on local heat transfer on a flat plate with local surface roughness. The study will encompass the development of Computational Fluid Dynamics meshes of local regular and irregular surface elements on a flat plate to simulate roughness. The study will look at the effects of different roughness height, spacing and location on a flat plate.

The study may be undertaken at the Defence Science Technical Laboratories (Dstl) Portsdown West site near Fareham in Hampshire or on-site at Imperial College. The study will use the Dstl Navier Stokes CFD model TINA and a copy of the Dstl code will be supplied for use on Imperial College computers.

The outputs required will be:

- a literature survey of surface roughness effects in hypersonic flows;
- a set of TINA code computational input files for the cases investigated.

The research will also allow the opportunity to interact with a leading UK software consultancy, the developers of the TINA software.

The research will be supervised by staff at Dstl and Imperial College (Prof. R Hillier). If based at Dstl, the researcher will have the opportunity to interact and gain knowledge and develop expertise by interacting with Dstl staff.

The latter option is however only open to students who hold UK nationality.

DSTL4) The Numerical Simulation Of The Flow Around Local Regular and Irregular Finite Scale Roughness Elements On A Flat Plate In A Hypersonic Freestream Using Direct Simulation Monte Carlo Methods

The task will utilise the Dstl Portsdown West Direct Simulation Monte Carlo (DSMC) solver DST for the prediction of the effects on local heat transfer on a flat plate with local surface roughness in rarefied flows. The study will encompass the development of Computational Fluid Dynamics meshes of local regular and irregular surface elements on a flat plate to simulate roughness and then use the DST code to predict the local heat transfer distribution. The study will look at the effects of different roughness height, spacing and location on a flat plate.

The study may be undertaken at the Defence Science Technical Laboratories (Dstl) Portsdown West site near Fareham in Hampshire or on-site at Imperial College. The study will use the Dstl DSMC model DST and a copy of the Dstl code will be supplied for use on Imperial College computers.

The outputs required will be:

- a literature survey of surface roughness effects in hypersonic flows;
- a set of DST code computational input files for the cases investigated.

The research will be supervised by staff at Dstl and Imperial College (Prof. R Hillier). If based at Dstl, the researcher will have the opportunity to interact and gain knowledge and develop expertise by interacting with Dstl staff.

The latter option is however only open to students who hold UK nationality.