Second Uncertainty Quantification & Management for High Value Manufacturing Study Group with Industry

8th - 10th March 2017

Innovate UK
Knowledge Transfer Network

University of Liverpool
Institute for Risk and Uncertainty

Contents

Problems posed by:

> It is a great pleasure to welcome people back to the Liverpool Institute for Risk and Uncertainty for the Second UQ&M Study Group with Industry.
>
> Last July we held the first such Study Group and we, the organisers, were delighted with the results - three great case studies and more importantly new collaborations which can make real impact for all involved.
>
> We believe that this approach works, and given its growing interest has the potential to become a recurring activity in the UK calendar for engineers, statisticians and mathematicians alike.
>
> Attracting more problems and more participants, we hope that this Study Group is as successful and enjoyable as the first and look forward to working with you all over the next three-days

Marco de Angelis, Francisco Alejandro Diaz De la O, Matt Butchers, John Mottershead

1 Study Group Information

The Study Group is an opportunity for industry to gain access to UK excellence in the fields of mathematics, statistics, engineering, and computer science. The structure of the Group allows for this to be done in a structured, intense session over three days.

1.1 Background

This Study Group with Industry is being run by the Institute for Risk and Uncertainty, and the Knowledge Transfer Network (KTN). In the KTN, the Uncertainty Quantification and Management (UQ&M) Special Interest Group (SIG) looks to draw together a UQ&M community and provide a structured meeting space where all the players can share their aspirations, knowledge and expertise.

The SIG was founded in 2014 by the late Prof. Tony Hutton at Airbus Operations Ltd. The SIG is a joint venture between KTN, Innovate UK, Government, industry, and academia. Our First Year Report highlights progress to date. It is expected that much tangible value will be created, such as:

- Collaborative groupings that identify real benefit in working together,
- The development and refinement of challenges and aspirations,
- The emergence of a clutch of industry pulled projects that make significant advances against the wider challenges within given industrial High Value Manufacturing (HVM) sectors,
- An increasingly statistics-savvy engineering design and assessment community,
- A highly visible joined up and holistic UK based UQ&M capability that can respond positively to end-user aspirations and requirements.

This Study Group represents a vital part of the SIG's progress in identifying state of the art approaches to deal with industry problems and identify where there are UK strengths and weaknesses. It is expected that the outputs of the Study Group will be of great use to the industries posing specific problems, but also in the approaches generated, wider industry can get a sense of 'good practice' in an industrial context.

1.2 Who will be attending?

The Study Group will consist of researchers from various fields, including, but not limited to mathematics, statistics, computer scientists, and engineers. As well as university researchers, we strongly encourage registrations from Ph.D students, postdoctoral researchers and early-stage researchers.

As well as these researchers, the Study Group will be attended by industrial representatives limited to those offering problems to the group. **We are not accepting registrations from any industry not directly involved in the problems**. In addition to these attendees the Study Group will host a number of Public Sector representatives from the Research Councils, and Department of Business, Energy and Industrial Strategy. We expect to host around 60 people to this Study Group from across these sectors. Attendees can be found in Section 3.

1.3 How does it work?

The format of the Study Group will be following the highly successful European Study Groups with Industry. Industry present their problems on the morning of the first day to the Group. The researchers ask questions and choose which group they may be able to help with.

The groups (10 - 15 researchers per group) will move to their own working space. An academic Project Lead will be nominated. They will discuss with the group what aspects of the problem should be addressed, and how these may be approached. It is likely that the group will subdivide, but this will depend on the problem.

It is expected that the industry representatives will be on hand to answer questions, provide access to codes, data and generally ensure that the problem context is clear throughout the Study Group.

Conversations often continue during the evening, and as such the Study Group provides dinner for all delegates. This often provides an environment for cross-fertilisation of ideas between groups and disciplines.

Group work continues until the Friday afternoon for final presentations. It is likely that the Project Lead will provide these presentations. Following the Study Group, the industry presenters will receive a report detailing what was done during the three days. Again, the Project Lead will coordinate this and draw on assistance from members of their team. The Project Lead will aim to get this report to the industrialist by the end of March 2017.

After review from the industrialist, we wish for this report to be made public as the Sponsoring parties have a responsibility to distribute good practice to the wider community. Thus, it is important for the industrialists to check for sensitive outcomes to be redacted within a month of receiving their report.

1.4 Agenda

	Tuesday 07	Wednesday 08	Thursday 09	Friday 10
09:00 onwards		**Registration** (Inst. Risk & Uncertainty)	**Group Work** (See Floor Plan)	**Group Work** (See Floor Plan)
10:00		**Welcome, Introductions and Problem Presentations** (Seminar Room. Inst. Risk & Uncertainty)		
11:00			**Tea and Coffee** (Corridor. Inst. Risk & Uncertainty)	**Tea and Coffee** (Corridor. Inst. Risk & Uncertainty)
11:30		**Group Work** (See Floor Plan)	**Group Work** (See Floor Plan)	**Group Work** (See Floor Plan)
13:00		**Lunch** (Corridor. Inst. Risk & Uncertainty)	**Lunch** (Corridor. Inst. Risk & Uncertainty)	**Lunch** (Corridor. Inst. Risk & Uncertainty)
14:00		**Group Work** (See Floor Plan)	**Group Work** (See Floor Plan)	**Final Presentations** (Seminar Room. Inst. Risk & Uncertainty)
15:30		**Tea and Coffee** (Corridor. Inst. Risk & Uncertainty)	**Tea and Coffee** (Corridor. Inst. Risk & Uncertainty)	**Tea and Coffee** (Corridor. Inst. Risk & Uncertainty)
16:00		**Group Work** (See Floor Plan)	**Group Work** (See Floor Plan)	**FINISH**
17:00		**Dinner** (Vine Court Café, University of Liverpool Campus)		
18:30 onwards	**Drinks Reception** (Philharmonic Dining Rooms)		**Pre-Dinner Talk by Professor John Ockendon FRS and Conference Dinner** (60 Hope Street, City of Liverpool)	

1.5 Do I need to pay?

The sponsoring parties (Institute for Risk and Uncertainty and the Knowledge Transfer Network) are grateful to Innovate UK who have sponsored the Study Group as such we are pleased to cover for **all** delegates accommodation on the 7th - 10th March, including breakfast and lunches. We do however ask for a nominal payment of £30 to cover dinners. Additionally, we do ask that researchers and industrialists cover their own costs for travel to and from the venue

1.6 Pre-Study Group Actions

To make sure the group progresses well, it is important that researchers read and study the problem statements provided by industry prior to the Study Group. It would be helpful for the researchers to have ideas on how they might approach **all** of the problems and be willing to work in any of the groups in case adjustments need to be made to balance capability and numbers in each group.

1.7 Computer Access

Access to the servers at the Institute will be granted to industrial participants, and group leaders. Also, there will be plenty of space in our facilities to meet, talk and discuss the challenge problems. However, desktop workplaces are limited and we **strongly recommend participants to bring and use their own laptops wherever possible**.

1.8 Check-in, Accommodation and Dinners

The organisers have arranged for a number of rooms to be held for Study Group members, for the Tuesday, Wednesday and Thursday nights - requests for these should be indicated at Registration. These (en-suite) rooms include breakfast. Check-in time on the Tuesday is 16:00 and delegates should go to the Best Western Hallmark Hotel (Blue Bed Icon on the map in Section 4). Buffet lunches will be provided at the Institute, a buffet dinner will be available on the Wednesday night at Vine Court (Green Knife & Fork Icon on the map in Section. 4), and a conference dinner will be held on the Thursday evening (below).

For those traveling down on Tuesday, there will be an informal reception in the evening starting at 18:30 at the Philharmonic Dining Rooms (Purple Pint Icon in Section 4), where drinks and light snacks will be available. It will also be a good opportunity to discuss research ideas and how problems may be addressed in an informal manner.

1.9 Conference Dinner

The dinner on Thursday will be held at 60 Hope Street (Yellow Cocktail Glass Icon on the map in Section 4). There is no dress code, and no cost associated with the dinner. We would ask that people arrive promptly by 18:00 (for a 18:30 start). Additionally, if you have not indicated to the organisers in your registration any allergies, we request that you do so as soon as possible.

1.10 Pre-Dinner Speaker - Prof. John Ockendon FRS

We are delighted to have Professor John Ockendon FRS deliver a pre-dinner talk on the history of Industrial Mathematics in the UK, Study Groups and in particular the trends of industrial problems over the decades. Professor Ockendon is an applied mathematician noted especially for his contribution to fluid dynamics and novel applications of mathematics to real world problems. He is an Emeritus Professor at Oxford University, an Emeritus Fellow of St Catherine's College, the first Director of the Oxford Centre for Collaborative Applied Mathematics (OCCAM) and Chief Mathematician and Technical Director of the Smith Institute for Industrial Mathematics and System Engineering and Chairs the Scientific Board.

His initial fluid mechanics interests included hypersonic aerodynamics, creeping flow, sloshing and channel flows and leading to flows in porous media, ship hydrodynamics and models for flow separation. He moved on to free and moving boundary problems. He pioneered the study of diffusion-controlled moving boundary problems in the 1970s his involvement centring on models for phase changes and elastic contact problems all built around the paradigm of the Hele-Shaw free boundary problem. Other industrial collaboration has led to new ideas for lens design, fibre manufacture, extensional and surface-tension-driven flows and glass manufacture, fluidised-bed models, semiconductor device modelling and a range of other problems in mechanics and heat and mass transfer, especially scattering and ray theory, nonlinear wave propagation, nonlinear oscillations, nonlinear diffusion and impact in solids and liquids.

His academic career has been built around mathematics-in-industry, beginning with the first-ever Maths-in-Industry Study Group in 1968. He has been deeply involved in setting up Study Groups in many countries including Australia, Canada, USA, India, China, where he is an Advisory Professor at Fudan University, Shanghai, and elsewhere. John is a Fellow of the Royal Society and was awarded the Gold Medal of the IMA in 2006.

2 Problems

2.1 Uncertainties in Robot Machine Dynamics Characterisation

mtc Manufacturing Technology Centre

Presenting Institution: Manufacturing Technology Centre

Problem Presenter: Silvia Estelles-Martinez, Alejandra Matamoros

Abstract (Technical Topics and Desired Outcomes): A computer assisted system modelling deterministic approach has been recently implemented at the MTC for estimating the dynamic stiffness of an industrial parallel robot machine, the Exechon Parallel Kinematic Machine (PKM) - shown in Figure 1. For modeling purposes, it is treated as a multi-body system externally excited at the tooltip position.

Objectives: The ultimate objective of this modelling work is to identify the dynamic stiffness of the machine to improve its accuracy via real-time feedback control design. The aim of this use case is to increase the maturity of the model by quantifying the effects of known sources of uncertainty

Time domain measurement data was used to estimate a model for the robot drives. Experimental acceleration data of vibration transmissibility at certain locations on the machine whilst exciting it with random forces was recorded. Forces were applied through a shaker table via the tooltip and the recorded data corresponds to only two machine positions along the X-axis.

Apart from sensor location, there are other sources of uncertainty associated to the model simplification. The model does not account for body flexibility or frictional effects in the machine joints. Additionally, internal mechanisms and drives control are represented via mathematical deterministic models The assessment of the machine vibrations focused on the dynamic response of the machine to a force excitation with a burst random frequency characteristic and a pre-set power value. This should suffice for designing advanced dynamic control algorithms, with no need for modelling the machining process, which reduces the number of uncertainties of the model for

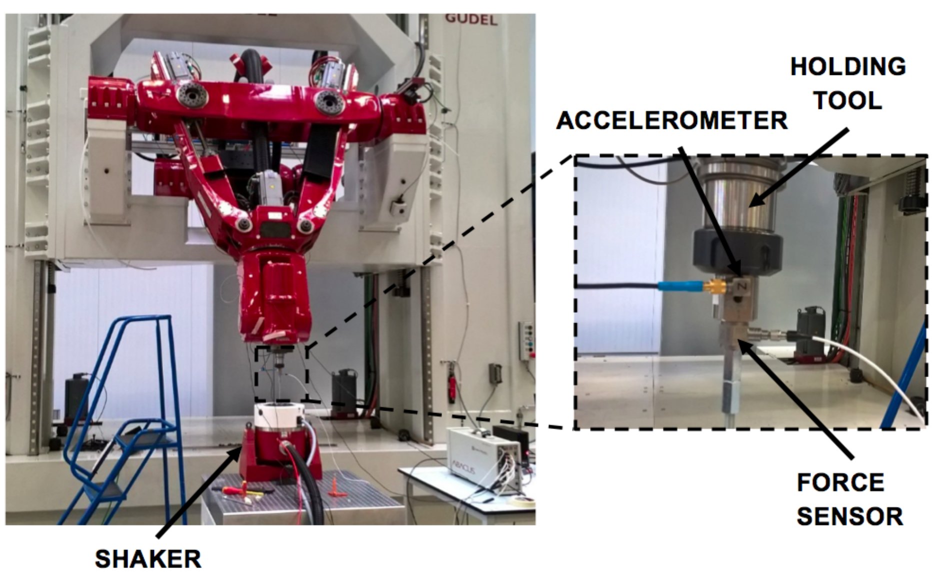


Figure 1: Image of the Exechon Parallel Kinematic Machine (PKM) and experimental set up.

control design purposes.

UQ&M Aspirations:

- The ambition is to obtain an estimation of uncertainties on the parameters described above. It is expected that the results will provide a better understanding on how the variations of these parameters may modify the frequency response of the machines model and increase its predictive capabilities.
- An UQ&M analysis could help to increase the Readiness Level of the machine dynamics by providing some characterisation of either the parameter uncertainty and / or directly in the robot dynamic stiffness mathematical model. This would also raise the confidence levels of the model and its usability for control design purposes and allow a more robust frequency-based control design in the future based on a more accurate estimation of the dynamic stiffness of the machine.

Resources Available for this Problem:

- Experts from the MTC
- Access to the multibody modelling approach

References:

1. Full problem details can be found here: Uncertainties in Robot Machine Dynamics Characterisation. A presentation will be given on the first morning of the Study Group
2. The Manufacturing Technology Centre. Simulation and Systems Integration Readiness Scale Development report for WP4. Use Case 2 - PKM Dynamics Model Validation (Internal Report). UK (2016)
3. The Manufacturing Technology Centre. SimReady (white paper in preparation). UK (2017)

2.2 Setting of Wing Target Loads

Presenting Institution: Airbus Operations Ltd.

Problem Presenter: Simon Coggon

Abstract (Technical Topics and Desired Outcomes): The aircraft design process proceeds through a series of maturity / decision gates. At the early stages of this process the design parameters are very fluid and uncertain and are progressively tightened and addressed in ever increasing detail as the design is converged. At maturity gate (MG) 5 the global parameters of the design (i.e. shape and structural layout) are converged. The concept is now validated and frozen. At this stage the aircraft (a/c) 'target' loads are set - see Fig. 2. Design loads are the limiting loads that an a/c (or a/c component) must be designed to withstand. Clearly it is important to limit the risk in setting these target loads. If the target loads are underestimated, then expensive re-design is often required incurring the costs and penalties arising from programme delay. If the target loads are overestimated then the a/c will be heavier than need be at the risk of not meeting customer performance guarantees.

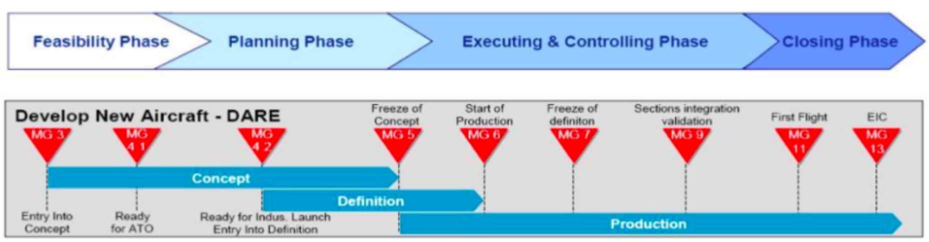


Figure 2: Airbus Aircraft Development Process.

Objectives: The process underlying this challenge is the Aero-Loads-Stress process, shown diagrammatically in Fig. 3. Each of the aerodynamic scenarios is analysed using a combination of low and high-fidelity CFD plus wind tunnel test results. The resulting loads for a specific design configuration are used to design the associated structure required to sustain the loads (in this case by varying the wing cover thickness. The internal structural layout is held fixed). This step alters the flexibility / stiffness of the wing and consequentially also the deformation of the wing under the applied forces (e.g. twist). For steady manoeuvres, the aeroelastic loop is iterated until it converges and the a/c is in equilibrium under the converged forces (lift and moment) and given mass distribution. This process must be performed in principle for all the loading conditions (although search algorithms may assist in converging rapidly onto the extreme region of loads

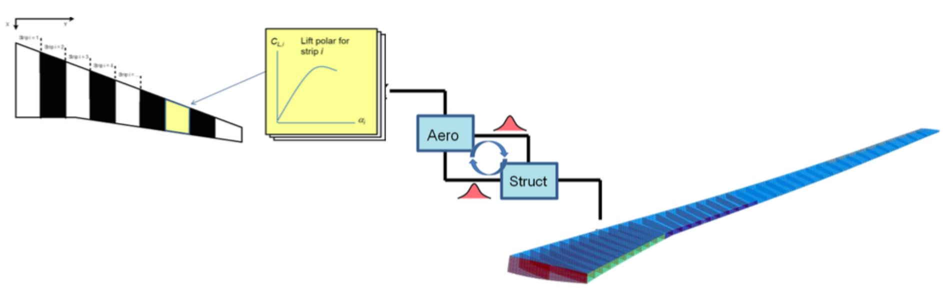


Figure 3: The Aero-Loads-Stress Process.

space) and the limit loads identified. The cover thickness is then optimised (minimal thickness) to sustain this loading resulting in a wing weight. The analysis process by which the limit loads on and a/c or component are established is very complex and computationally demanding. A very large number of conditions across the loads envelope must be considered.

UQ&M Aspirations: Can formal UQ&M methods be deployed to improve and underpin confidence in setting target loads thus reducing conservatism and the weight of the a/c or component? The key benefit to flow from a demonstrable UQ&M capability is improved confidence levels in the target load setting decision gates. The current use case has been designed to exercise most of the challenges of applying UQ&M to the setting of target loads whilst simplifying the range of conditions to be considered, i.e. it is not entirely realistic but is sufficiently testing. The focus is the setting of aircraft-in-flight target loads and the range of aerodynamic loading scenarios to be analysed is reduced by the following simplifications. Within Airbus it will not be acceptable to introduce intrusive methods, and thus the UQ&M capability must be able to wrap around existing processes.

Resources Available for this Problem:

- The simplified loads analysis model, GT-QHL, is constructed within MATLAB. It allows 'plugin' data and UQ&M methods.
- The reference aircraft model underlying the analysis is based upon the NASA developed Common Research Model (CRM), an open reference aircraft for CFD and wind tunnel validation studies.

References:

1. Full problem details can be found here: Setting of Wing Target Loads. A presentation will be given on the first morning of the Study Group.

2.3 Thermo-mechanical Analysis of a Turbine Disc

Presenting Institution: Rolls-Royce PLC.

Problem Presenter: Ron Bates, Cath Kindred

Abstract (Technical Topics and Desired Outcomes): In modern turbo-machinery, robustness to uncertain operating conditions, as well as geometrical and material variability is vital for performance and operational lifetimes.

Objectives: This Use Case concentrates on an adapted Rolls-Royce training example designed to assess the effect of component temperature distributions, stresses, tip clearance etc. on changes to model geometry, material and boundary conditions. The simulation is either a combined transient thermo-mechanical analysis or a thermal analysis followed by a series of single time point stress analyses using interpolated temperature distributions.

The model has been devised to represent a simple gas turbine spool. A single stage drilled rim high-pressure turbine, linked to a 3-stage axial compressor drum is assumed, with an internal cooling air system. As well as boundary conditions representing heat transfer coefficients, mass flows, and heat pick-up terms - a dozen or so - the Use Case aims to investigate the effect of component geometry with hundreds of user defined parameters.

UQ&M Aspirations: The UQ&M objective is to propagate the uncertainty on various input parameters (conceivably many hundreds) through the model to assess their impact on performance. There are benchmark results for some performance measures based on Monte Carlo analysis. The idea would be to contrast these with other methods. Key questions:

- How does variation in the boundary conditions affect the temperature at the rim (blue star in Fig. 4)? This value (and variation) affects the life of the disc.

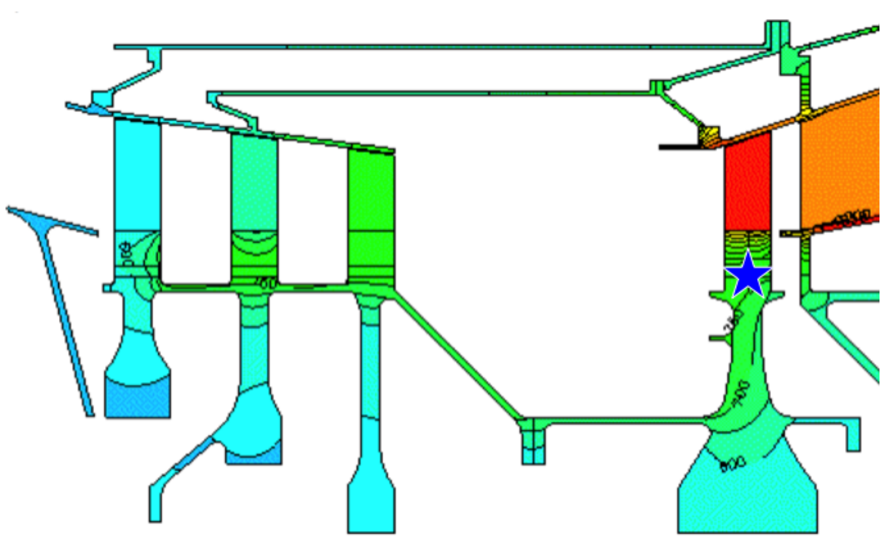


Figure 4: Simplified 2D Model and Rim Assessment Location

- What methods exist to examine the (potentially) very high dimensional problem the geometry / material variables introduce.
- What effect do 3D features have on the simplified model

Resources Available for this Problem:

- A 3D parametric model representing a simple gas turbine spool.
- Engineering experts from Rolls-Royce able to run the workflow (described above)
- Data on input uncertainties based on performance decks

References:

1. Full problem details can be found here: Thermo-mechanical Analysis of a Turbine Disc. A presentation will be given on the first morning of the Study Group.

2.4 Climb-Cruise Engine Matching - An Optimisation Approach

Presenting Institution: Airbus Operations Ltd.

Problem Presenter: Sanjiv Sharma

Abstract (Technical Topics and Desired Outcomes): Aircraft design involves optimising a multi-component system, where each system has sub-components. There are uncertainties in the physical parameters in models of each system, and each system is subject to noise from the environment and from other sub-systems. Many disciplines are involved. There is a large and evolving literature on what is sometimes called, 'bi-level' optimisation, where an optimisation problem involves one or more variables that are optimal for some other optimisation problem that is coupled by one or more variables to the higher-level problem. This Use Case - originally posed at the 2016 Study Group - might be a multi-level version of such bi-level problems generalised by including uncertainty from outside and from within the system [2]. The work at the 2016 Study Group, mainly with surrogates and emulators, could perhaps be usefully combined with ideas on bi-level optimisation.

Objectives: Consider a use case in the context of a 24-hour operation aircraft; a key implication is that aircraft can operate within noise curfews. Then, using a Set-Based Design approach, explore a multitude aircraft configurations with respect to their climb out Noise Levels, the Cruise Performances and Gaseous Emissions, under uncertainty. The basic concept is to generate data for a set of representative single aisle aircraft configurations by combining a multitude of airframes with a multitude of engines. Specific noise measurement criteria in terms of the location of the measurement system and the type of noise level need to be deduced. Then, using coupled analyses 'plug-ins', derive the performance models that enable an architect to explore the sensitivities amongst three exemplar measures of aptness. For this use case these are:

- Noise Levels (lower is better); conversely, Noise Level **Margin** (higher is better)
- Cruise Fuel Consumptions (lower is better)
- Gaseous Emissions (lower is better); conversely Gaseous Emissions **Margin** (higher is better)

Figure 5: Overall Concept of UQ&M in a Set-Based Design Approach

This provides a multi-dimensional challenge for determining, visualising and acting on the uncertainties that propagate through the analyses to these measures of aptness. The main objective is to narrow the set of possible aircraft configurations to a set of feasible ones using uncertain, multi-dimensional decision criteria. The process is then repeated, using analyses models closer to the laws of nature, to narrow the set of feasible aircraft configurations to a set that provides competitive advantages - process shown in Fig. 5.

UQ&M Aspirations: The UQ&M analyses will be used for:

- robust design-making to narrow a set of possible aircraft configurations
- discovering the parameters that strongly contribute to the variations in the measures of aptness
- managing key parameters to drive reliably towards the desired properties and behaviours

Resources Available for this Problem:

- Simulation experts from Airbus
- Data generated through CONGA project to support analysis for a multitude of airframes with a multitude of engines (provided in `.csv` format).
- Access to AirCADia environment - an interactive tool for the composition and exploration of aircraft computational studies at early design stage.

References:

1. Full problem details can be found here: Climb-Cruise Engine Matching. A presentation will be given on the first morning of the Study Group.
2. Final report: Climb-Cruise Engine Matching. Various Authors (2016)

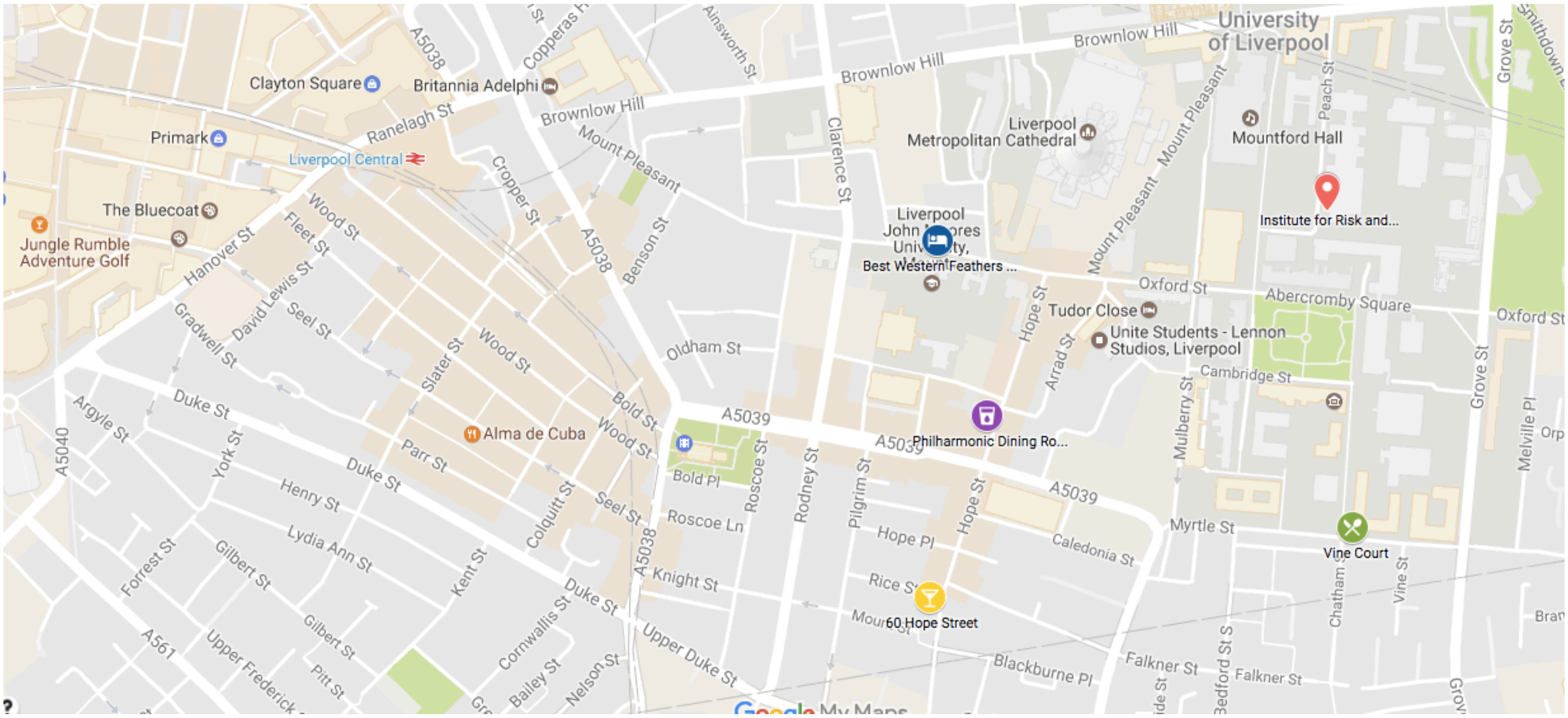
3 Participants

Surname	First Name	Institution	Capabilities
Adamou	Maria	University of Southampton	Design of Experiments
Adhikari	Sondipon	University of Swansea	Uncertainty problems in dynamics
Ahlfeld	Richard	Imperial College London	Uncertainty quantification for Computational Fluid Dynamics
Barons	Martine	University of Warwick	Graphical models for decision support incorporating uncertainty;
Bates	Ron	Rolls-Royce PLC.	Thermo-mechanical Analysis of a Turbine Disc
Batou	Anas	University of Liverpool	Uncertainty quantificationStructural and multibody dynamics
Brommer	Peter	University of Warwick	Computational Materials Science, Uncertainty Quantification, Gaussian Processes, Multiscale Materials Modelling.
Butchers	Matt	Knowledge Transfer Network	Organiser
Byrnes	Paul	University of Liverpool	Machine Learning
Calleja	Cominic	University of Liverpool	Uncertainty Quantification
Carter	Jonathan	Jonathan Carter	Uncertainty quantification in engineering
Chen	Xin	University of Cranfield	Uncertainty Propagation, Sensitivity Analysis
Coggon	Simon	Airbus	Setting of Wing Target Loads
Crowder	Adam	University of Manchester	Stochastic Galerkin methods, Adaptive methods, a posteriori error estimation
De Angelis	Marco	University of Liverpool	Uncertainty propagation, reliability and risk analysis, epistemic uncertainty, interval/fuzzy probability
Diaz De la O	Francisco Alejandro	University of Liverpool	Bayesian methods, calibration, reliability analysis, metamodelling.
Elsheikh	Ahmed	University of Liverpool	Head of School of Engineering. Professor of Biomaterial Mechanics.
Englezou	Yiolanda	University of Southampton	Design of Experiments
Estelles-Martinez	Silvia	MTC	Uncertainties in Robot Machine Dynamics Characterisation
Farmer	Chris	University of Oxford	UQ & M, simulation, inverse problems, control theory
Ferrer Fernández	Maria	University of Liverpool	Mathematics
Garbuno	Alfredo	University of Liverpool	Statistics, Machine Learning, MCMC methods, Surrogate modelling, Numerical Optimisation
Gong	Zitong	University of Liverpool	Model calibration and uncertainty quantification
Gower	Artur	University of Manchester	optimisation, mathematical modelling, signal processing and general pattern recognition in data.

Surname	First Name	Institution	Capabilities
Green	Peter	University of Liverpool	Structural dynamics, Bayesian inference
Haji-Ali	Abdul-Lateef	University of Oxford	Stochastic Differential Equation, Numerical methods for SDEs and PDEs, Multilevel Monte Carlo, Particle systems, Crowd modelling, Mean-field theory, Sparse Grids, Combination techniques, Multi-index techniques, Inverse problems.
Hernandez	Santiago	University of Coruna	Reliability based multidisciplinary size and topology optimization
Hristov	Peter	University of Liverpool	Gaussian process emulation, sensitivity and reliability analysis, fluid dynamics
Innocente	Mauro	University of Coventry	Structures & Heat Transfer. Applied Mathematical Modeling. Multidisciplinary Optimisation. Swarm Intelligence
Jeavons	Claire	University of Sheffield	I am in the final year of EngD in advanced cost engineering for application in industrial research - sponsored by Rolls-Royce and AMRC
Kawabata	Emily	University of Edinburgh	My current project is to quantify uncertainty in earthquake parameters. I would be very interested in learning about uncertainty in other contexts.
Khodadadyan	Atousa	University of Liverpool	Risk Management
Kindred	Cath	Rolls-Royce PLC	Thermo-mechanical Analysis of a Turbine Disc
Kipouros	Timoleon	University of Cambridge	Multi-disciplinary uncertainty quantification and management. Multi-dimensional data visualisation and analysis for uncertainty.
Kundu	Abhishek	University of Cardiff	Gaussian process, surrogate modeling, polynomial chaos, stochastic reduced order modelling
Loxham	Joseph	University of Cranfield	Uncertainty quantification and management in multidisciplinary design optimisation. Machine learning.
Matamoros	Alejandra	MTC	Uncertainties in Robot Machine Dynamics Characterisation
May	Gordon	Rolls-Royce PLC.	Thermo-mechanical Analysis of a Turbine Disc
McGregor	Lynne	Innovate UK	Funding through Innovate UK
Molina-Cristobal	Arturo	University of Cranfield	Uncertainty Quantification and Management in Multi-Disciplinary Design Optimisation
Mottershead	John	University of Liverpool	Director, Liverpool Institute for Risk and Uncertainty. Alexander Elder Professor of Applied Mechanics
Newsum	Craig	University of Manchester	Reduced basis methods for forward problems in uncertainty quantification
Ni	Tianyuan	University of Liverpool	Data analysis, Artificial intelligence and machine learning
Ockendon	John	University of Oxford	Mathematical Modeling
Paoletti	Paolo	University of Liverpool	Dynamic modeling and control, also in presence of uncertainty (in parameters) or noise (in measurements)

Surname	First Name	Institution	Capabilities
Papanagnoi	Christos	University of Salford	Multivariate time-series, data analysis based on statistics, control theory, discrete event simulation, stochastic analysis
Powell	Catherine	University of Manchester	Numerical Analysis, Numerical Methods for forward and inverse UQ in PDE models with uncertain parameters.
Pryse	Sion Eilir	University of Swansea	Currently researching into reduced order methods for stochastic dynamic systems under the supervision of Prof. Sondipon Adhikari.
Riaz	Atif	University of Cranfield	Model-Based Systems Engineering, Multidisciplinary Design Optimisation, AirCADia (proprietary tool for system design and analysis)
Russell	Paul	University of Manchester	Bayesian Inverse problems. MCMC algorithm design. Resampling/Filtering methods.
Rynn	James	University of Manchester	Bayesian inverse uncertainty quantification for PDEs (including MCMC and FEM).
Sadeghi	Jonathan	University of Liverpool	History Matching, Monte Carlo Simulations, Interval Predictor Models, Nuclear Engineering/ Physics, High Performance Computing, Probabilistic Safety Analysis, Uncertainty Quantification
Scarth	Carl	University of Swansea	Uncertainty Quantification, Aeroelasticity, Composite Materials
Seshadri	Pranay	University of Cambridge	Uncertainty Quantification, Dimension Reduction. See effective-quadratures.org
Sharma	Sanjiv	Airbus	Climb-Cruise Engine Matching – An Optimisation Approach
Silla	Matti	University of Liverpool	Aerospace Engineering
Sistek	Jakub	University of Manchester	high performance computing, domain decomposition methods, parallel finite element methods, applications to structural mechanics and computational fluid dynamics, vortex identification and vizualization in fluid flows
van Heerden	Albert	University of Cranfield	MDO and MBSE. Will bring AirCADia Explorer software.
Wang	Simon	University of Liverpool	Numerical analysis, data analysis and coding.
Wang	Qiongli	University of Liverpool	Uncertainty quantification; Vibrations, modal analysis and inverse problems;
Wiegand	Martin	Martin Wolfgang Wiegand	Computational Statistics; Risk Assessment; Extreme Value Theory; Tail Modelling techniques
Yuan	Jie	University of Cranfield	Structural dynamics, Uncertainty quantification, Mistuned fan bladed disc analysis, Aircraft design

4 University of Liverpool Information



Blue Bed Icon	Hallmark Hotel	Accommodation
Purple Pint Icon	Philharmonic Dining Rooms	Reception, Tuesday Evening
Yellow Cocktail Icon	60 Hope Street	Dinner, Thursday Evening
Green Knife & Fork Icon	Vine Court	Dinner, Wednesday Evening
Red Marker Icon	Inst. for Risk and Uncertainty	Study Group Rooms

4.1 Travel to the University of Liverpool

Road

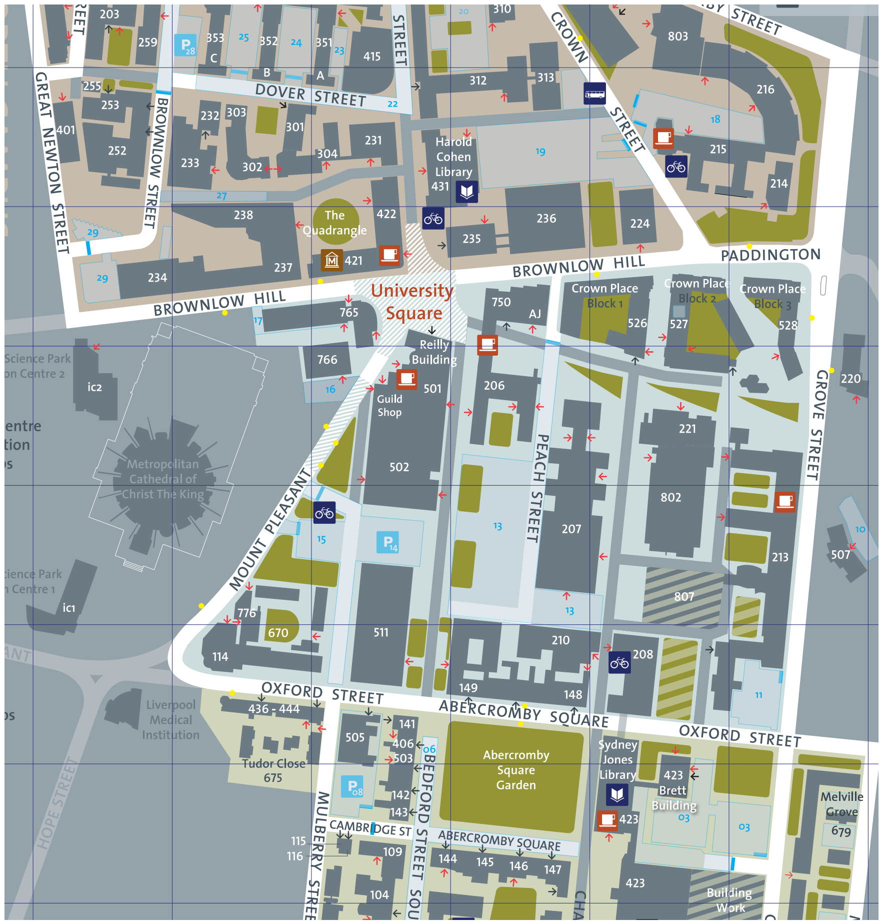
From the M62: at the end of the motorway continue straight ahead onto Edge Lane (A5080 then A5047) and follow signs for Liverpool City Centre and the University. Postcode for satellite navigation or online directions: L3 5TR.

Rail

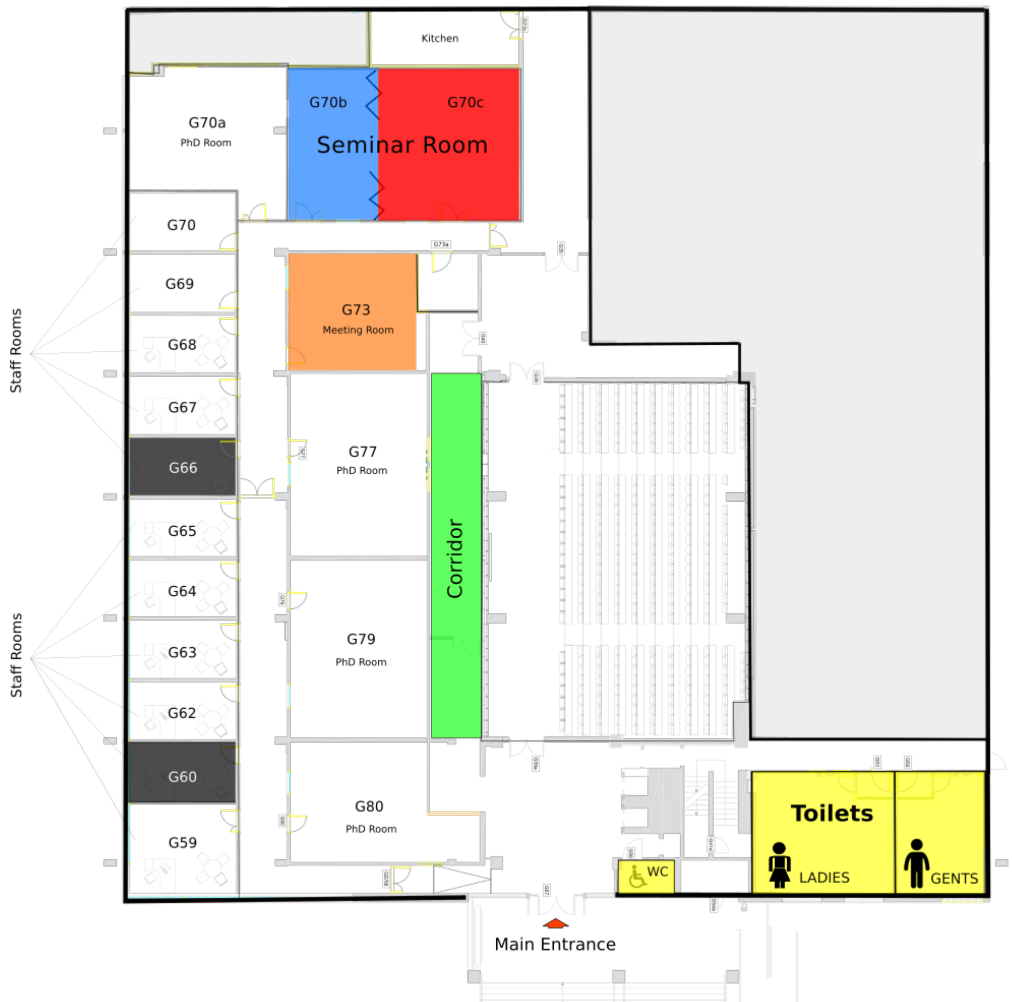
The Campus is just a ten-minute walk away from the nearest mainline station at Lime Street. Take the main exit and turn left into Lime Street. Then turn left again at the Britannia Adelphi Hotel and continue up Brownlow Hill towards the Metropolitan Catholic Cathedral and Red Brick Building with its clock tower.

4.2 Campus Map

The Study Group will take place in the Institute for Risk and Uncertainty (Building 207) on the Campus Map below - a 5 - 10 minute walk from the hotel. **Note: there is no guest car park, so delegates will be required to park in the University Visitor Car Parks on Campus.**



4.3 Floor Plan



Legend

(blue)	**Room G70b**	Presentations, Group work
(red)	**Room G70c**	Presentations, Group Work
(orange)	**Room G73**	Group Work
(dark grey)	**Room G60, G66**	Group Work
(green)	**Corridor**	Lunch, tea and coffee

4.4 Wi-Fi for Guests

If you are a guest at the University, you can use Wi-Fi whilst you are on campus. Choose the most appropriate option:

4.4.1 Visitor from Another Academic Institution

If you are visiting from an institution that participates in the eduroam scheme, you will be able to login to the secure eduroam wifi service using your own username and password.

If you require further information or support you should contact your own IT helpdesk.

https://www.eduroam.org/

4.4.2 Visiting for a number of days

GuestNet provides access to the Internet for guests and users who need authorised access for up to 7 days. You can get a GuestNet username and password from the department you are visiting.

If you are taking part at a conference at the University, GuestNet details will be included in your information pack or provided by the conference organiser on your arrival.

If you are a member of staff setting up a GuestNet account for visitors please note that accounts cannot be set up in advance - all GuestNet accounts must be created on the day of the users arrival.

https://wifi.liverpool.ac.uk/guest-wifi/connect-to-guestnet/

4.4.3 Public Wi-Fi

If you are are here for a short visit such as an Open Day or to attend a meeting, you can use the WiFi Guest service, powered by The Cloud. It is just like when you use The Cloud in other public places or hotels - just provide you email address and use The Cloud public WiFi.

To connect to Wifi Guest (The Cloud):

1. Select WiFi Guest from the list of available WiFi networks
2. Open your web browser - The Cloud landing page will appear. Click Get Online
3. Log in, or register if you're a first time user, to gain internet access.

If you need any help to get connected to the Wifi Guest option, visit The Cloud FAQs and Support website https://www.thecloud.net/faqs-support/.

5 Supporting Organisations

5.1 Knowledge Transfer Network

Innovate UK
Knowledge Transfer Network

KTN Connects people. To speed up innovation, solve problems and find markets for new ideas. Established to foster better collaboration between science, creativity and business, KTN has specialist teams covering all sectors of the economy - from defence and aerospace to the creative industries, the built environment to biotechnology and robotics. KTN has helped thousands of businesses secure funding to drive innovation. And we support them through their business cycle to see that investment through to success.

Contact(s): Matt Butchers
Website: http://www.ktn-uk.co.uk

5.2 Institute for Risk and Uncertainty, University of Liverpool

UNIVERSITY OF LIVERPOOL | Institute for Risk and Uncertainty

A centre for research and education. The University's Institute for Risk and Uncertainty is dedicated to helping people and organisations create a safer world. Large scale funding totalling £ 21 m has been secured to establish an EPSRC and ESRC Centre for Doctoral Training (CDT) on Quantification and Management of Risk & Uncertainty in Complex Systems & Environments within the Institute for Risk and Uncertainty.

Contact(s): Francisco Alejandro De La O, and Marco De Angelis
Website: https://www.liverpool.ac.uk/risk-and-uncertainty/