Welcome to the Department of Mechanical Engineering Sciences

Dr Simão Marques

UNIVERSITY OF SURREY

Why Engineering?

A recent report…

‘Engineers are crucial to the economy and society as a whole.

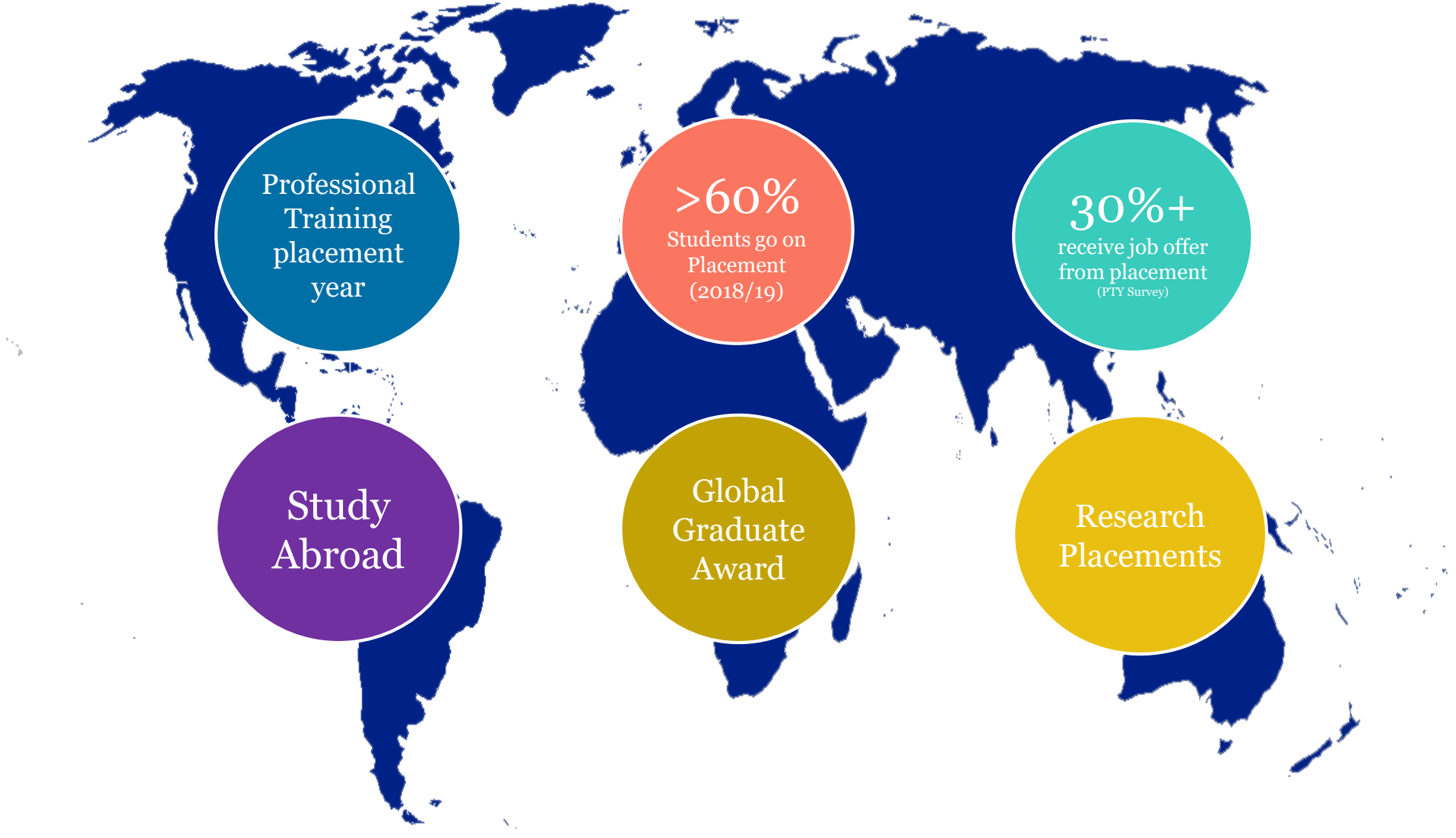
Engineers are the innovators and problem-solvers who really make a difference to people’s lives.

Engineers are the people behind innovations such as driverless cars, bionic limbs and space travel.

However the UK is facing an engineering skills shortage. Recent figures indicate that we need 69,000 more engineers in the UK every year just to meet industry demand.’

Award winning facilities

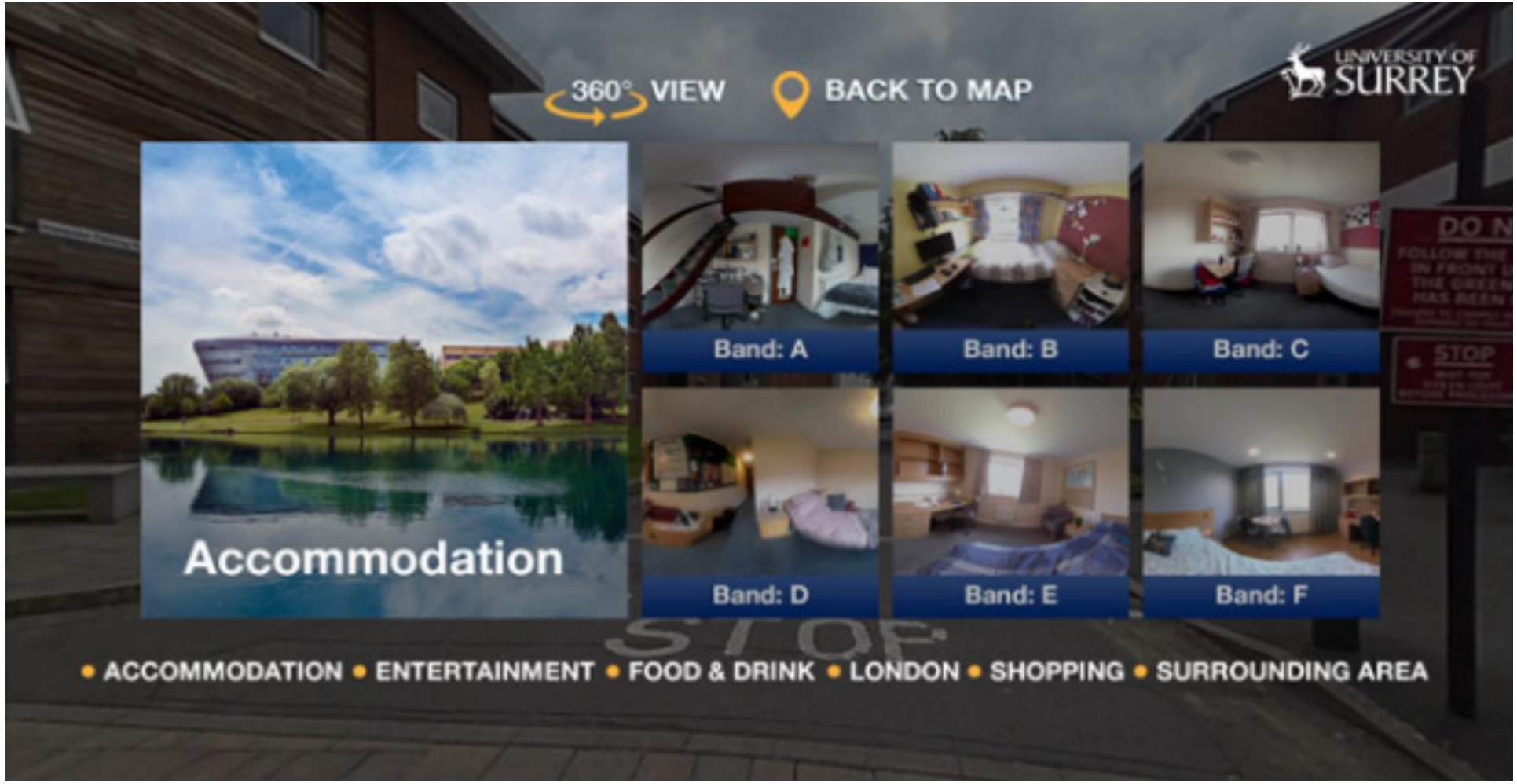
Opportunities at Surrey



Sports and Societies

Accommodation

https://www.surrey.ac.uk/accommodation and virtual tour app



Exploring Surrey – Guildford is only 34 minutes from London

Why Mechanical Engineering Sciences?

» *The department in numbers*

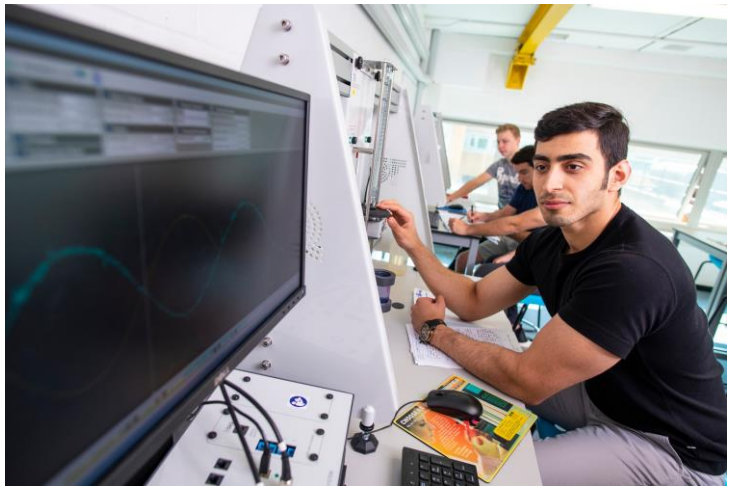
» ~40 academic staff; 18 research fellows

» 7 technical staff and 4 administrators

» **~750 undergraduates studying:**
- BEng/MEng Aerospace Engineering
- BEng/MEng Automotive Engineering
- BEng/MEng Mechanical Engineering
- BEng/MEng Biomedical Engineering

» **~30 full-time PGT students studying:**
- MSc in Biomedical Engineering

» ~30 PhD and ~20 EngD research students



Research at Surrey

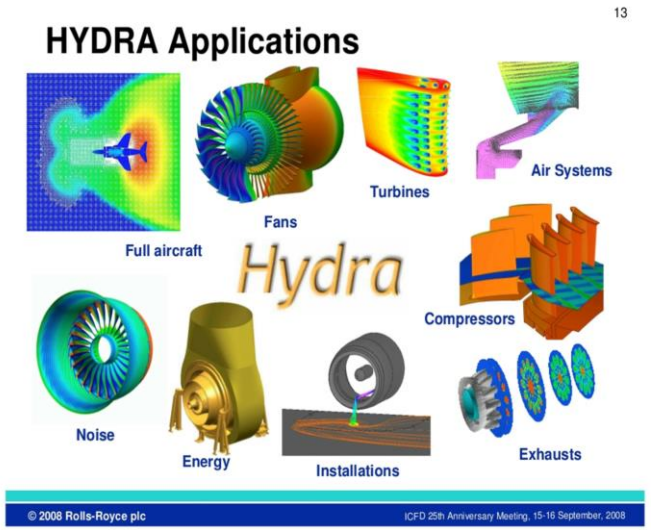
Mechanical Engineering Sciences

» *Engineering is about making the world a better place.*

Centre for Aerodynamics & Environmental Flow

» Part of the Rolls-Royce network of research centres – Thermo-Fluid Systems University Technology Centre, which was established in 2003.

» EnFlo, the Environmental Flow Research Centre, opened in 1993 as a focus for UK research activities based on laboratory scale simulation of atmospheric flow and pollutant dispersion. Its unique capabilities are recognised by its status as a NERC-NCAS (National Centre for Atmospheric Sciences) facility.



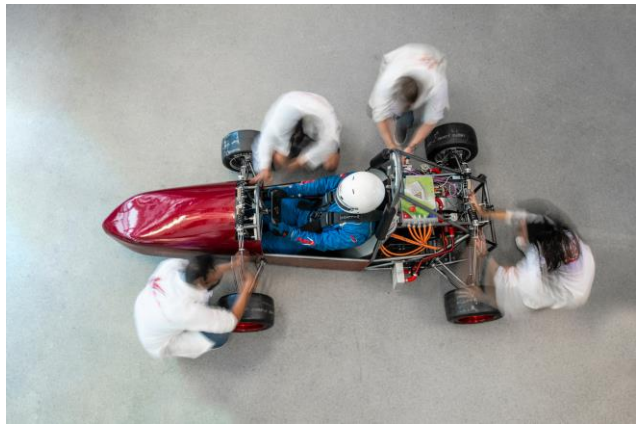
NERC Centres for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

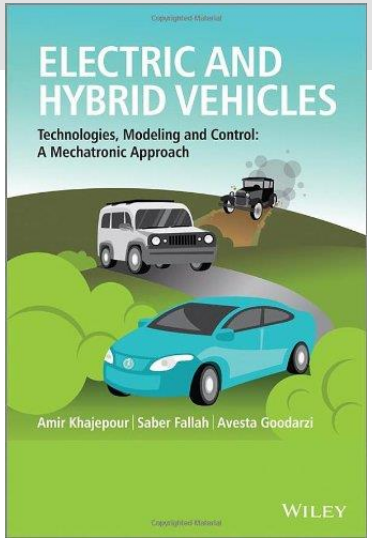
Mechanical Engineering Sciences

» *Engineering is about making the world a better place.*

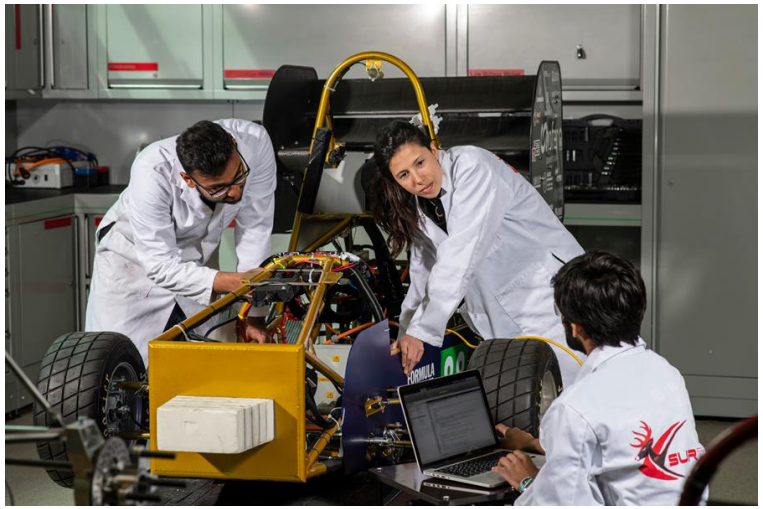
» **Centre for Automotive Engineering**

» The group has research interests in hybrid vehicles, vehicle dynamics and control, and terrestrial mobile and space robotics. We are working with colleagues in the 5G Innovation Centre on autonomous driving.





» The group also oversees the Formula Student activity.

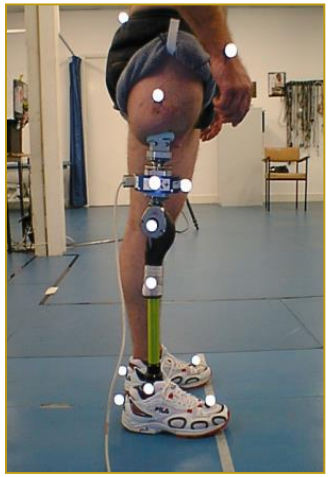


Mechanical Engineering Sciences

» *Engineering is about making the world a better place.*

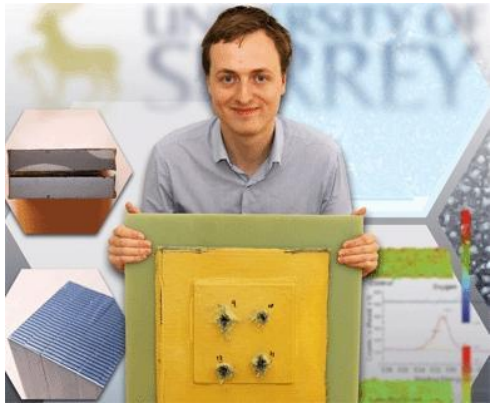
Centre for Biomedical Engineering

» We are working with amputees to develop better outcomes, developing equipment and technologies to give early detection of cancer and Alzheimer's disease.



Centre for Engineering Materials

» Our activities range from saving lives through better armour to designing and manufacturing bespoke miniature energy harvesting devices for the internet of things.



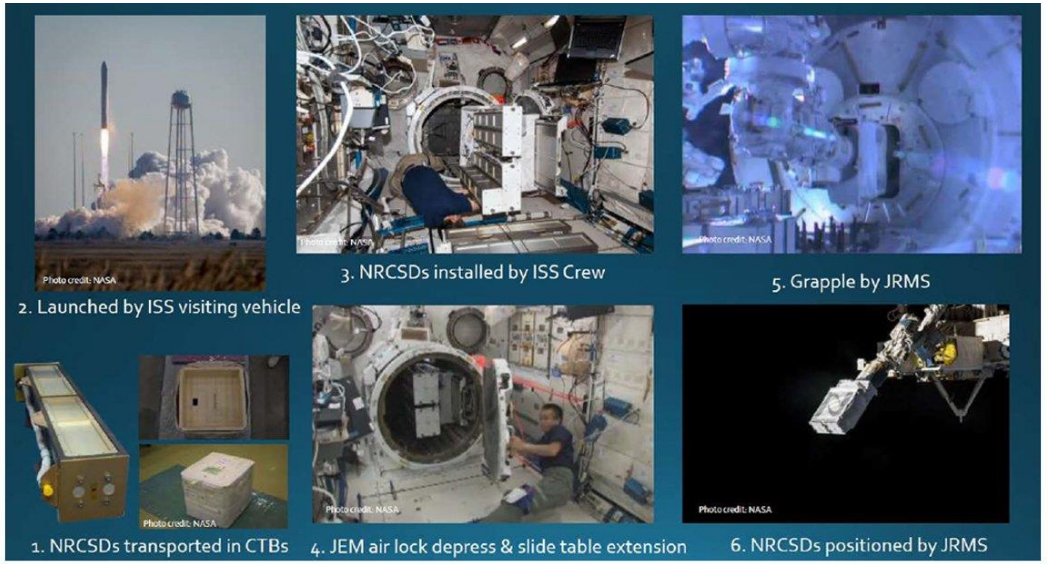
» Home to the EPSRC Centre for Doctoral Training in Micro- and NanoMaterials and Technologies

Mechanical Engineering Sciences

» *Engineering is about making the world a better place.*

Surrey Space Centre

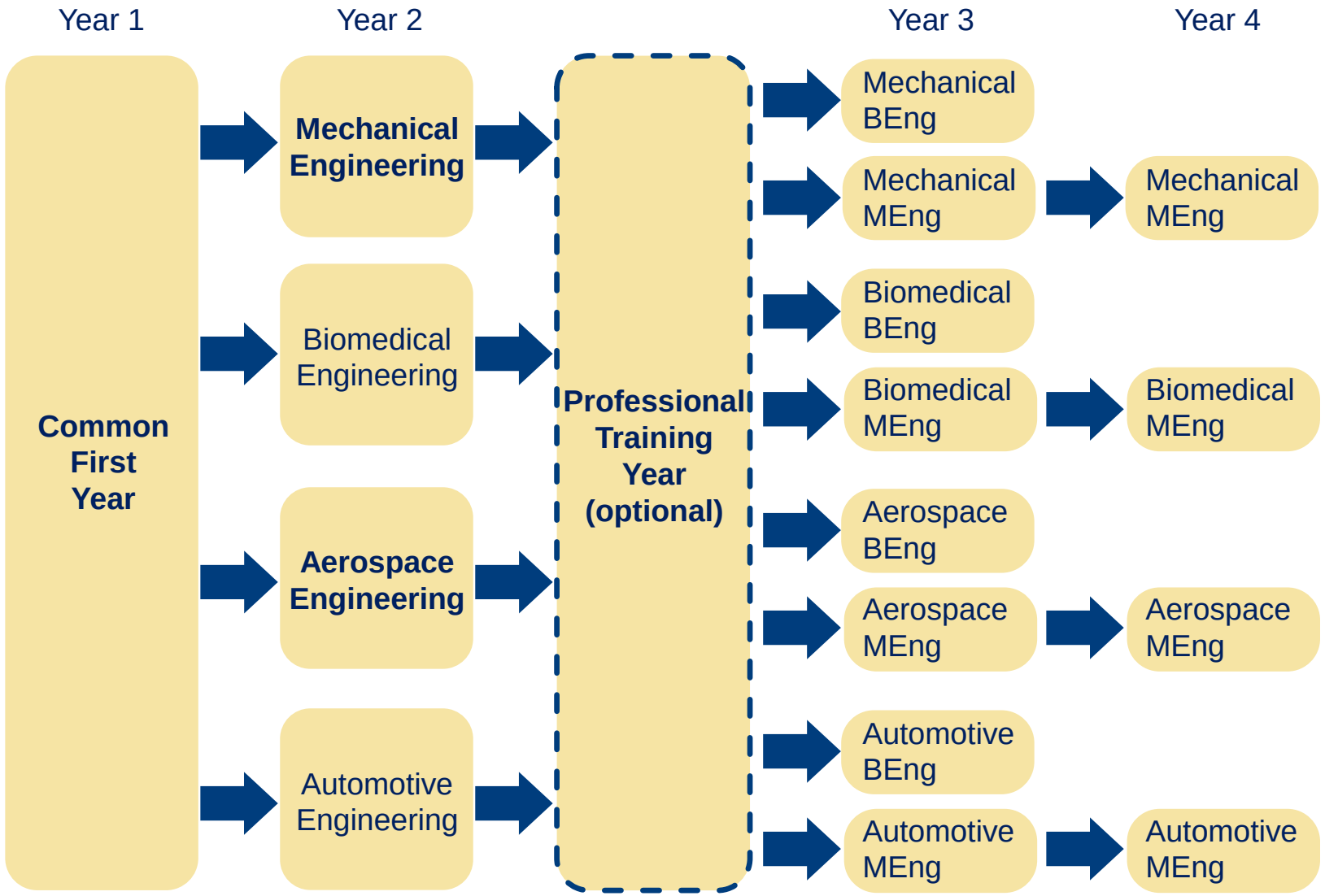
- Pioneers of modern "Small Satellites" since 1979, we have taken part in numerous missions. Spacecraft technology requires a broad range of backgrounds from Physics and Engineering to Mathematics and Software systems, this broad range is reflected in our research.



UNIVERSITY OF SURREY

Automotive and Mechanical Engineering Programmes

Programme organisation



Degree Programmes

Choosing between MEng and BEng

MEng *Master of Engineering, 4 or 5 years*

- More analytical: greater breadth and depth in support of R&D roles
- Fastest route to chartered status
- Fuller preparation for the workplace

BEng *Bachelor of Engineering, 3 or 4 years*

- Fastest degree completion
- Shortest path to industry
- Good if you're planning a further degree such as a specialist M.Sc. or M.B.A.

Programme Detail

» *Common First Year*

Later Years

Year 1 (FHEQ level 4)

Modules include:

- Mathematics 1 and 2
- Experimental and Transferable Skills
- Fluid Mechanics and Thermodynamics
- Materials and Statics
- Design and Component Production
- Solid Mechanics 1
- Electronic Instrumentation 1

Year 2+ (FHEQ level 5+)

Modules include:

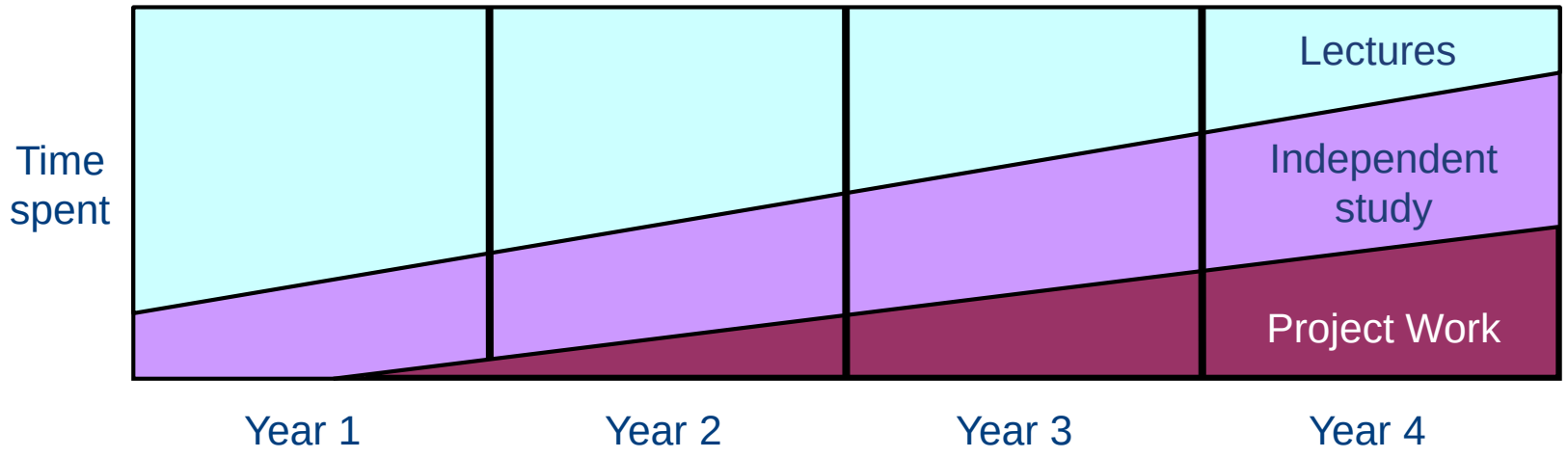
- Control & Dynamics
- Modern Vehicle Design
- Numerical and Experimental Methods
- Vehicle Aerodynamics
- Turbomachinery and Aircraft Propulsion
- Spacecraft Structures and Mechanisms
- Space Systems Design
- Composite Materials Technology
- Mechanics of Vehicles & Machines
- Advanced Stress Analysis

You will be enrolled in 120 credits of modules each year. This roughly equates to four modules per semester.

Learning and Teaching

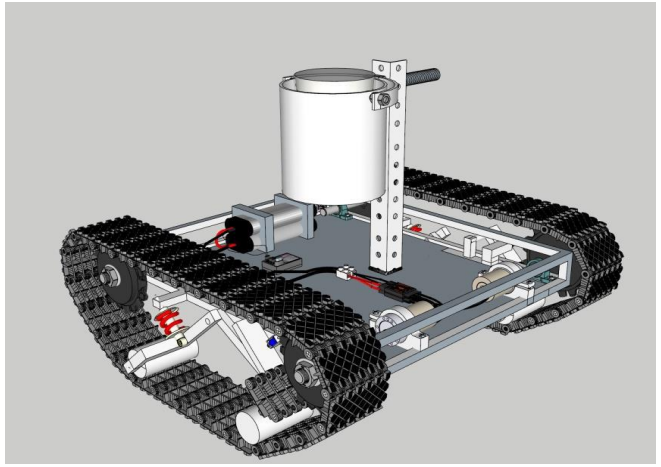
» **Learning and Teaching is by a Variety of Approaches**

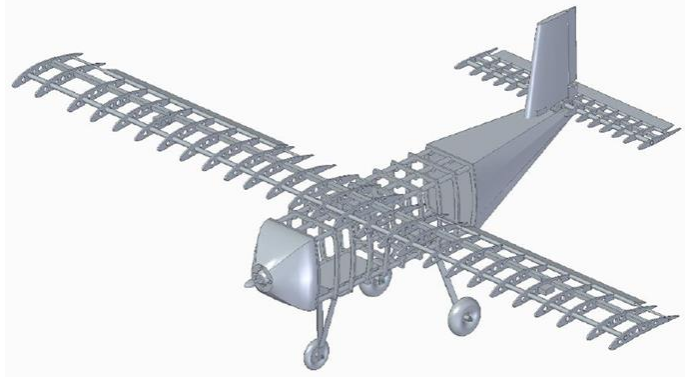
- Lectures
- Workshops and laboratory work
- Team design projects
- Virtual learning environment



Programme Detail

» Year 2 Design Project (Group Project: Design, Make, and Evaluate)

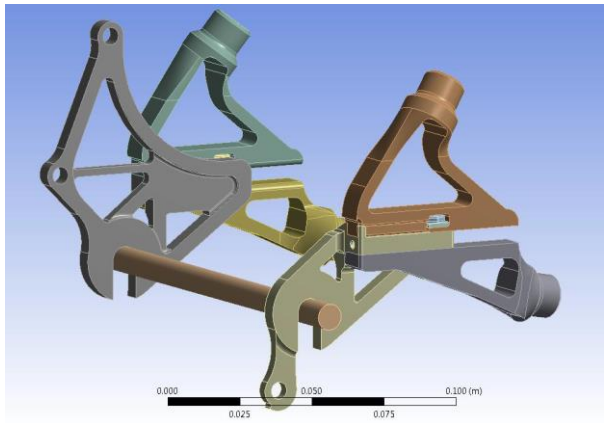


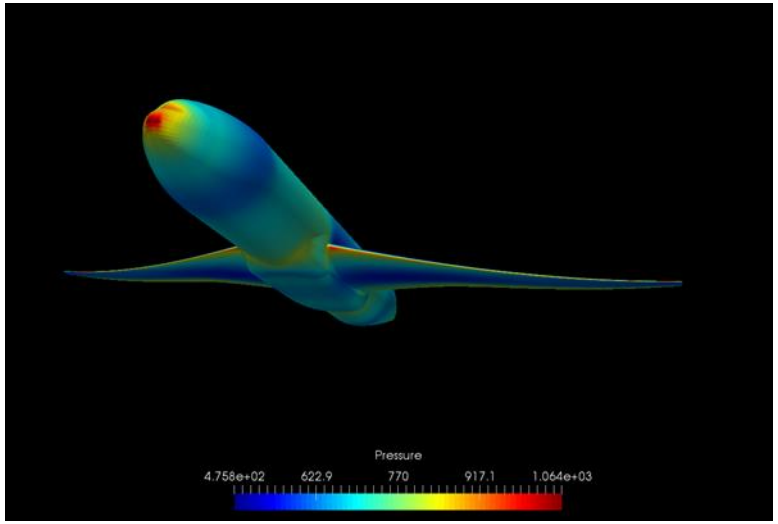


Learning and Teaching

» *Individual Projects: Some current titles*

- *Mechanical properties of metal-polymer composite materials for space applications*
- *Design and modelling of vibrating piezoelectric energy harvesters*
- *Microstructure-property relationships in additively manufactured AA2319*
- *Additive manufacture of maraging steel by laser powder-bed process*
- *Effect of the understeer characteristic on the energy consumption of a fully electric vehicle with multiple motors*
- *Design of an optimal omnidirectional velocity probe*
- *Multi-element high-lift aerodynamics*
- *F1 rear wing aerodynamic study*
- *Ducted fan propulsion installation*
- *Hot gas ingestion in turbine air systems*
- *Small satellite propulsion system*
- *Harpoon Target Deployment Device for In-orbit Demonstration*

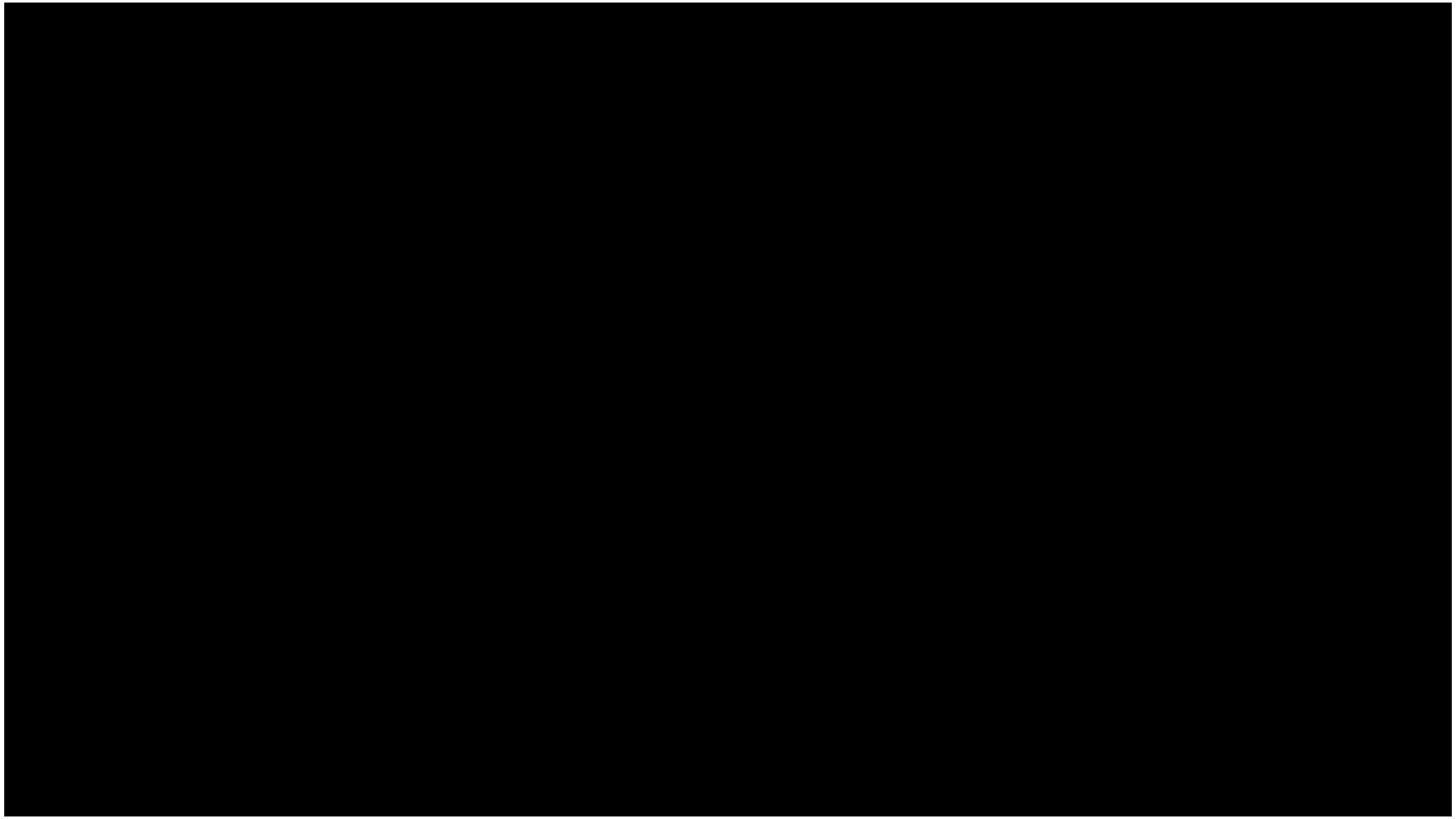




Formula Student (IMechE competition)

University of Surrey - Formula Student team (since 2008)

Participation possible from Day 1 through FS Society



An exciting new activity

IMechE Unmanned Aircraft Challenge

Advantages of a Surrey degree

Teaching quality is our priority:

» You are our future!

TEF Gold Teaching Excellence Framework

Focus on graduate employability:

» One of the very highest graduate employment rates

Programmes are fully accredited

» Institution of Mechanical Engineers

» Royal Aeronautical Society

Institution of MECHANICAL ENGINEERS

ROYAL AERONAUTICAL SOCIETY

Engineering Council accredited degree

Integrated professional training

» For those things you just can't learn in a lecture

Global Graduate Award

- Arabic
- British Sign Language
- Chinese Mandarin
- French
- German
- Italian
- Japanese
- Korean
- Portuguese
- Russian
- Spanish

- Free language courses open to all students.
- Sustainability module.
- Starts every year in October and run for 19 weeks, two hours per weekly session, over two semesters.
- Are assessed modules, and the final module mark is based on assessed coursework tasks (60%) and a final test (40%).
- Award 15 co-curricular credits to undergraduate students, which will appear on UG student records.

Professional training year

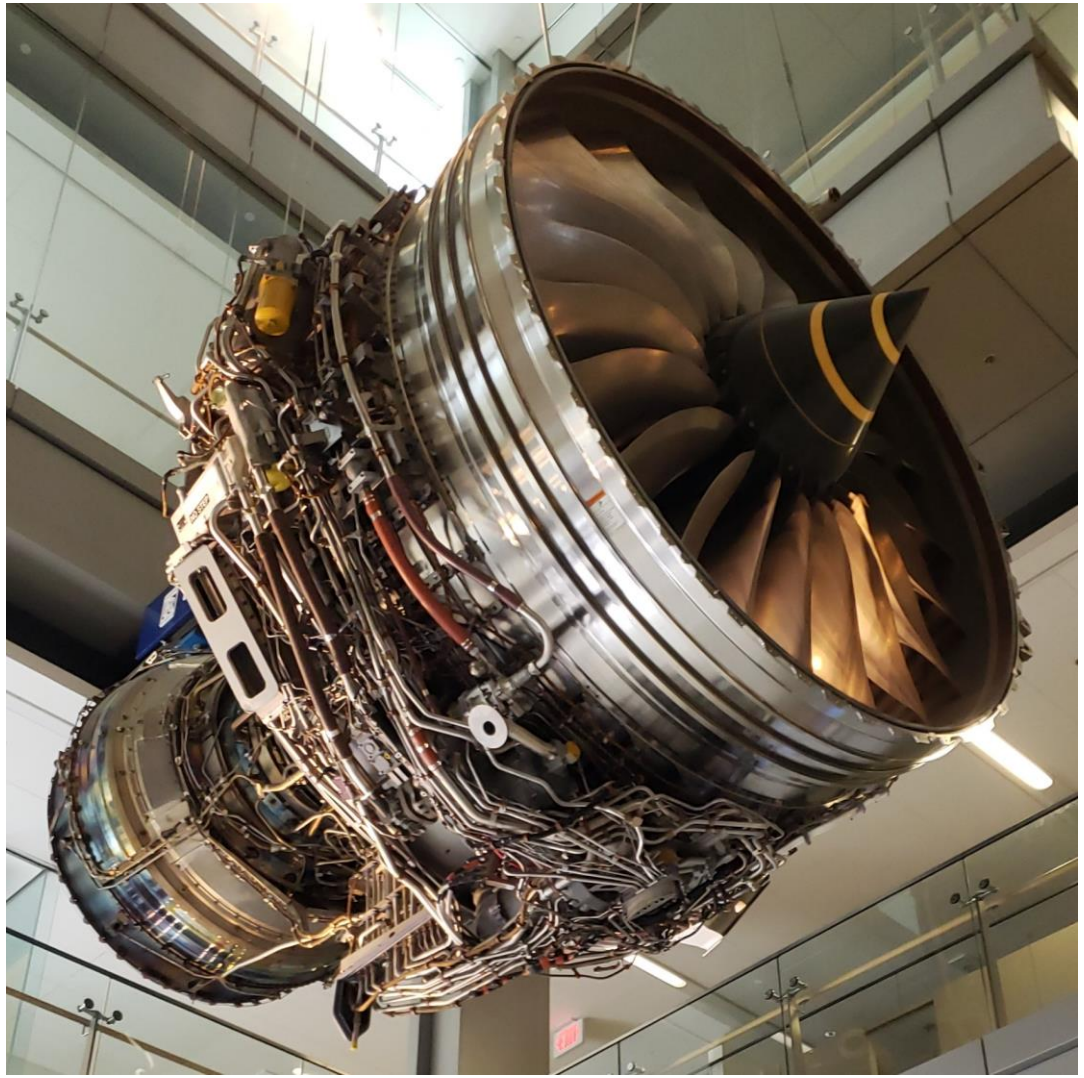
- Normally done between second and third year of study
- Salaried positions: typically £16K - £21K
- Substantially reduced student fees during placement year
- A member of academic staff visits the student on-site
- Placements made at more than 100 companies in UK & overseas

Our students

- *Hamza Chaudhry, MEng Mechanical Engineering*

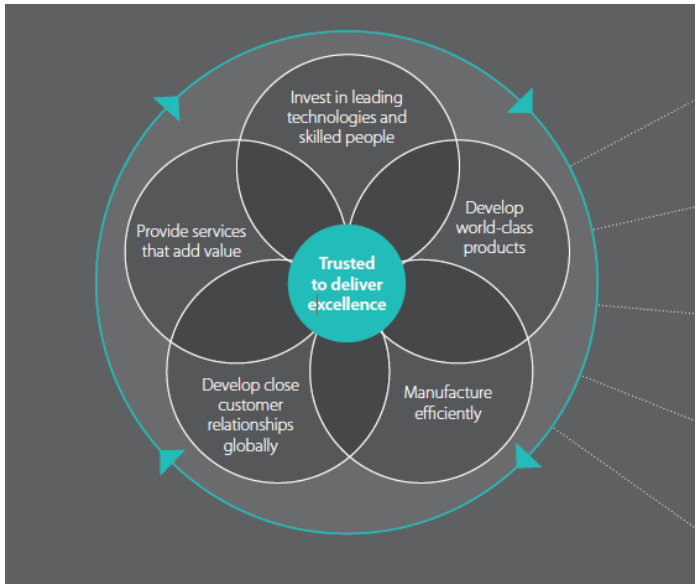
Rolls-Royce Industrial Placement

Trent7000 Performance



Rolls-Royce plc

Trusted to Deliver Excellence



DISCOVER OUR WORLD

We employ over 50,000 people across more than 40 countries

Rolls-Royce is a global organisation in every sense. Over half of our workforce is based outside the UK and we have customers in over 150 countries. These include more than 380 airlines and leasing customers, 160 armed forces, 4,000 marine customers including 70 navies, and thousands of power and nuclear customers.

While the expertise and facilities we have in each country varies, it's the pursuit of excellence that's the unifying force across every single one of them.

Everything we do is about delivering excellence; both for our customers and for the people who work for us. That's why we invest more than £1.2 billion in research and development every year, two-thirds of which we spend on improving the environmental performance of our products and services. It's also why we invest millions in training and developing our people, offering online resources as well as dedicated training facilities in our key hubs.

Over **50,000** employees

Operations in more than **40** countries

Customers in over **150** countries

Global order book stands at over **£75** billion

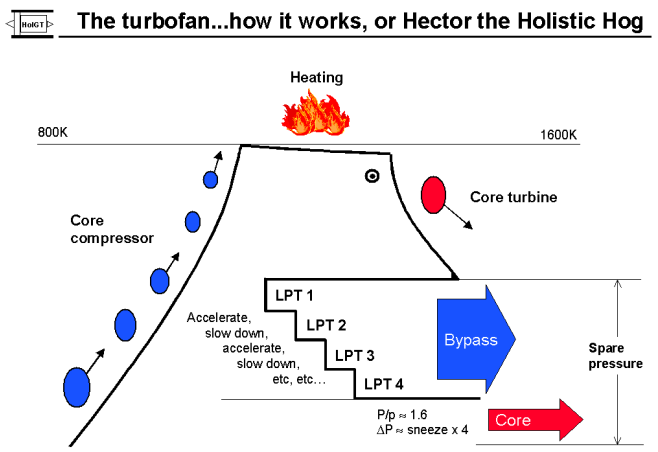
Global revenue of **£13.35** billion

Summary of Rolls-Royce plc

Performance – What is it?

Gas Turbine Performance

- Rolls-Royce design Turbofan gas turbine engines.
- $\eta_{overall} = \frac{Vo}{FHV \; X \; SFC}$
- Therefore obsession in SFC reduction

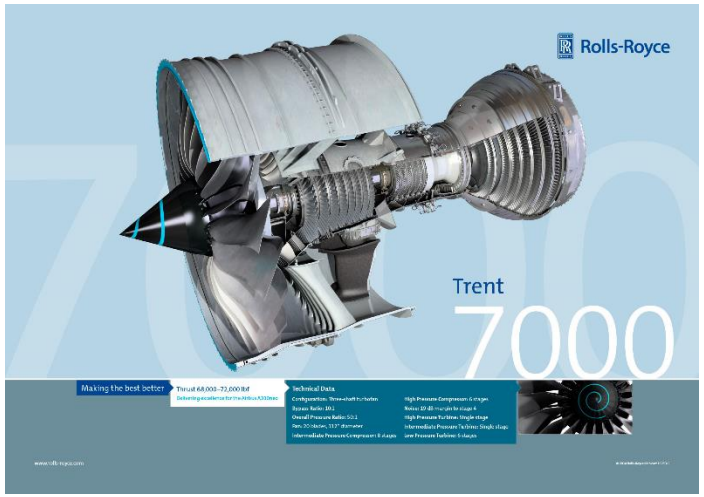


Performance is the functional behaviour of the entire engine

It assembles the understanding of individual components and systems into the whole engine view

Performance (as a function):

- Own whole engine attributes such as thrust, SFC, surge margin, speed margins, etc.
- Design the engine thermodynamic cycles
- Produce models of the behaviour and thermodynamics of the engines to provide design conditions
- Verify and validate steady state and transient behaviours
- Monitor engine behaviour and investigate problems
- Covers the entire lifecycle of the engine



What do our customers (Airframers) want?

Summary of Performance Engineering

Burst Duct Failure

- Event was modelled using a thermodynamic deck
- Following a Burst Duct there is a loss of pressure
- Resulting in a loss of work from the engine
- Given this loss in work, the engine would rematch
- Analysis predicted this would lead to a hazardous failure
- Decision was made to investigate a control system solution

LPT under Burst Duct

- Supported customer System Design and Integration in clearing aircraft certification requirement CS25.1103 (d), which states:

“for bleed air systems no hazard may result if a duct rupture or failure occurs at any point between the engine port and the aeroplane unit served by the bleed air”.

- In line with this aircraft certification requirement it was decided to investigate a control system solution.
- Requirement of solution was to have no effect on engine operation in the event of a spurious trip

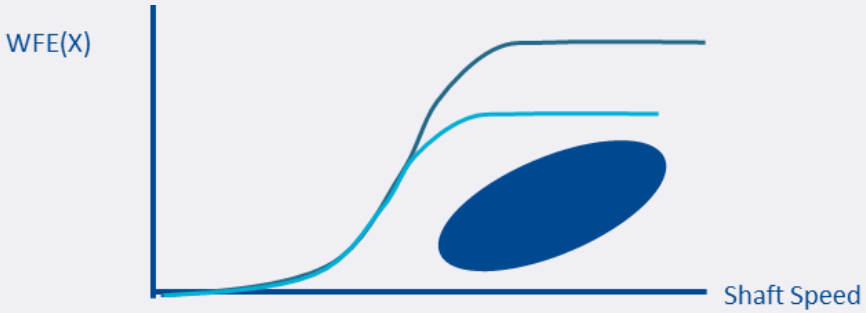


Figure 1: Optimised Controls System solution

Clearance of CS25.1103 (d)

Turbine Overspeed

QF32 suffered an uncontained engine failure on 4th November 2010

Figure 2: QF32 TOS failure

Low Pressure Turbine Overspeed

- The certification requirements for shaft failure are covered by the Certification Specifications CS-E 840 (Rotor Integrity) and CS-E 850 (Compressor, Fan and Turbine shafts).
- CS-E 850 can be summarised as requiring that any failure of the shaft system should not lead to a hazardous effect at a rate greater than Extremely Remote (ER).
- CS-E 840 (Rotor integrity) which requires that it be demonstrated that any engine rotor will not burst or grow unacceptably under a number of conditions which are summarised below:
- *The rotor shall not burst at 120% of the maximum permissible (redline) rotor speed.*
- *The rotor shall not burst at 105% of the highest rotor speed that would result from a failure of any component or system in the engine (unless failure can be demonstrated to be Extremely Remote).*
- *The rotor shall not grow unacceptably (to result in fire or release of debris, etc.) at 100% of the terminal speed resulting from failure of any component or system in the engine.*
- Historically, 105% of the maximum predicted terminal speed of the LP turbine following shaft break has been the limiting case, and the disc has been sized accordingly.

LPTOS ASSESSMENT

- Control System response upon detection of shaft break
- Intent to remove energy from system
- Event is modelled
- Previous methodology used worst case inputs
- New method uses a statistical approach

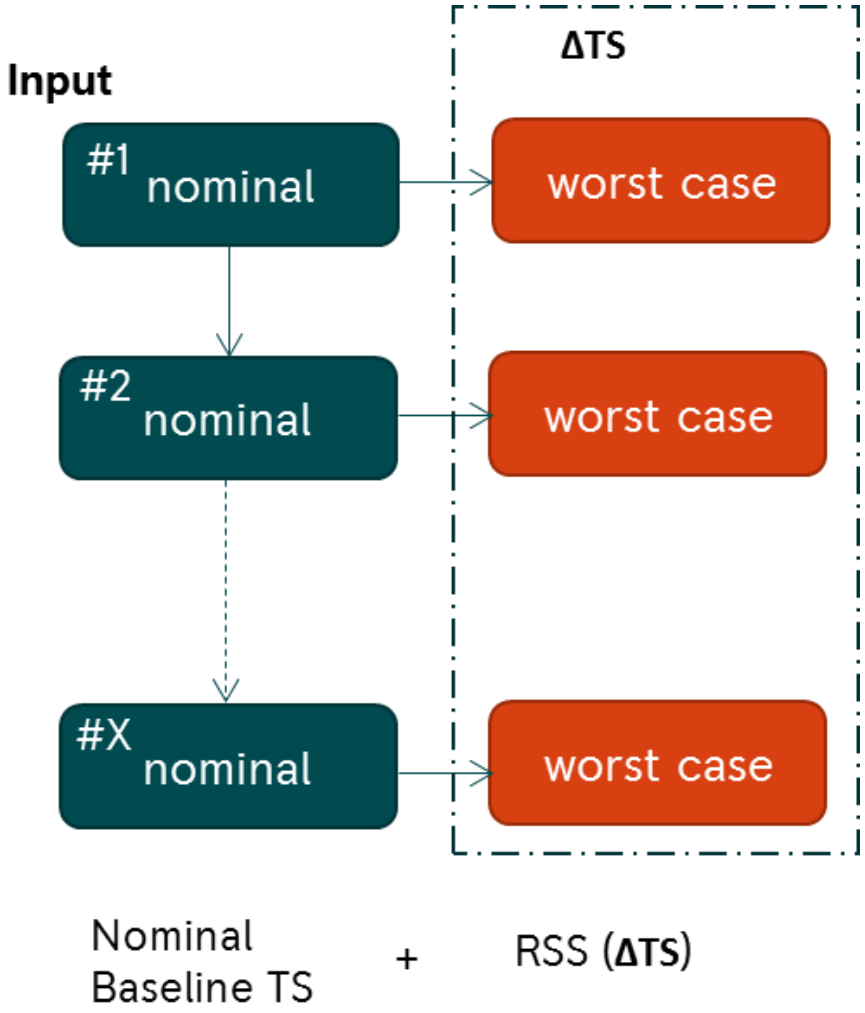


Figure 5: Statistical approach

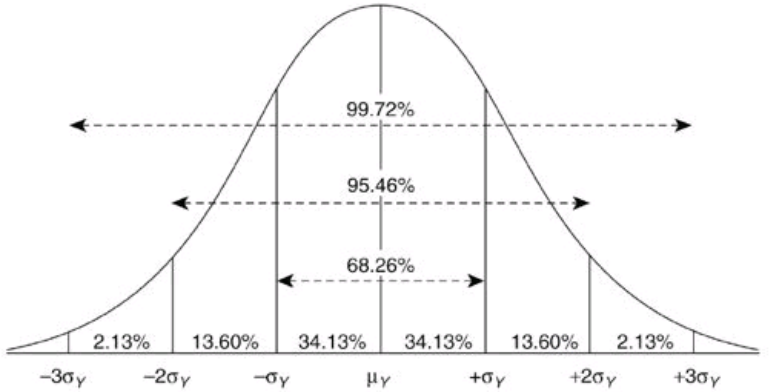


Figure 4: Normal Distribution Curve

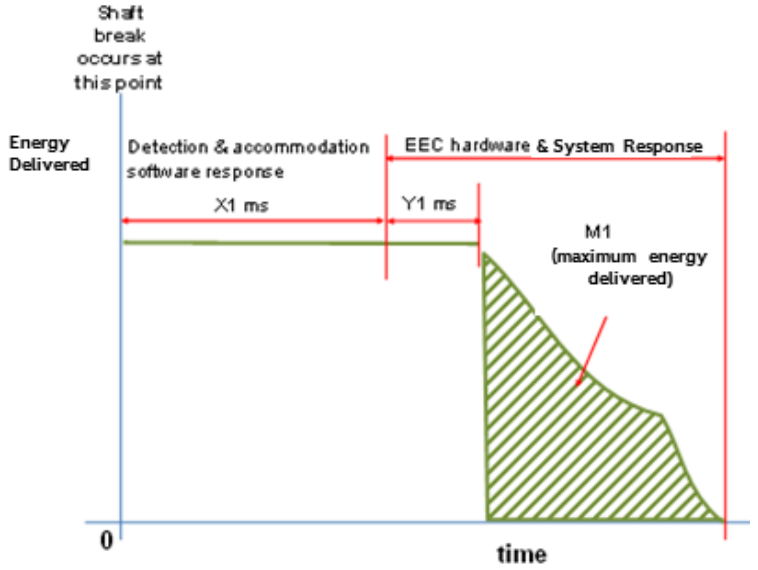


Figure 3: Control System Response

Engine Response and modelling of TOS event

IPC Operability Testing

Purpose of Testing

- CS-E 500: “Engine must be free from dangerous surge and instability throughout its operating range”
- Testing to provide an understanding of Trent7000 IPC operability under crosswind
- Understand the effect of EBAS on IPC Operability

- Assessing operability testing as it occurs in Stennis
- Providing support to the test team, to make fast decisions as and where it is necessary
- Technical support and guidance provided to other team members
- Analysis started to determine effect of crosswind on IPC operability

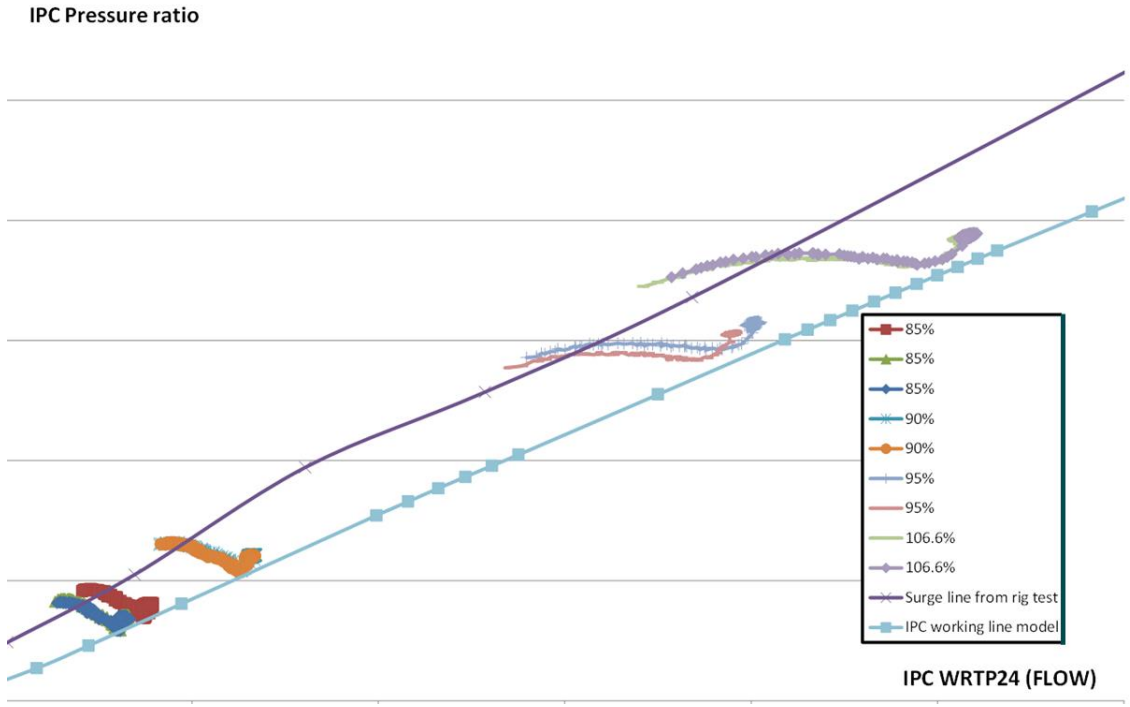


Figure 6: Surge line mapping

Supporting of IPC Operability testing on development engine

Software Data Transfer Process for EEC

Background

- Errors at previous software drop
- Initial aim was to improve the Alice Software Data Transfer Process
- Decision made not to improve upon an archaic system
- Decision made to create solution which has longevity
- Cross functional and cross project integration involved
- Kaizen event completed
- Conclusion was to use a shared database between both Controls and System Design
- Formalised buy-off received to progress with current strategy at CDE-Hi-Spots
- Creation of a Software Data Transfer IPT in January 2018

- Co-ordinated and led a team of engineers under programme milestones and tight deadlines
- 11 tools created from requirements I outlined
- Tools were validated inline with Rolls-Royce's validation process for tooling
- Process was trialled for previous software IPs
- Further presentation to CDE at CDE Hi-spots
- Resource and escalation achieved to create Controls tool
- Presented to the CPE at PTRM, concluding in process agreement
- Coordination with CPE in minimising risk to aircraft certification
- Presented to Airbus at FADEC Workshop for RR/AI Transverse WGs logics integration
- Coordination with Control Systems to define delivery dates
- All power management data delivered to Controls for EIS software on time
- Global Standard Software Data Transfer Process bought off

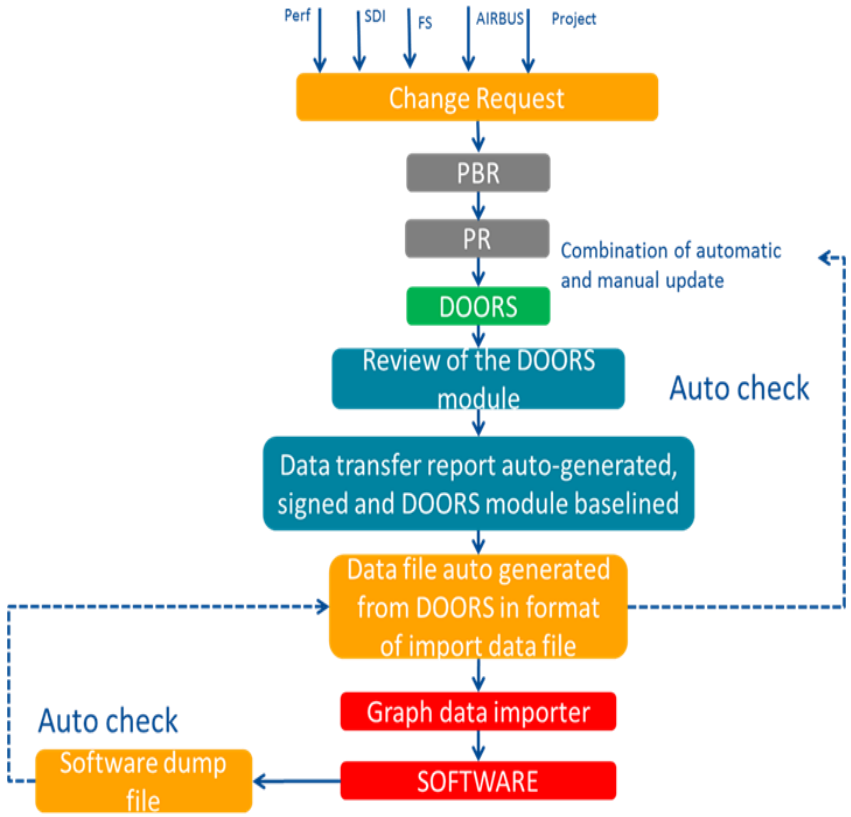


Figure 7: New Process for Software delivery

Advantages of new Process

Review of data	Allows easy peer reviews of data, in line with company working instruction
Reduced workload	As it combines three individual processes
Change control	The data transfer report can only be created when: All required attributes are populated. All reviews are completed.
Traceability	Version control, change history and accountability
Flexibility	Data can be updated manually or automatically
Efficiency	Database available to all functions at the same time Increased cohesion with controls
Annual Benefit	£70,000

Quantitative and Qualitative Benefits of New Process

Core Tasks Completed

1. LPT under Burst Duct
2. LPTOS Modelling
3. IPC operability testing
4. Software Data Transfer

Lessons Learnt

Knowledge is key:

- Create a baseline understanding
- Do not simply rely upon the information you are provided
- Rely upon the existing SMEs on the topic

Communication is fundamental:

- Be aware of the audience you are communicating and presenting to
- Relationships are forged on trust
- Consistency and clarity is king

Challenge not only yourself but also the people around you, including experts within the area

Performance is the definition of ambiguity

Lessons Learnt throughout the placement

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