Institution: University of Oxford

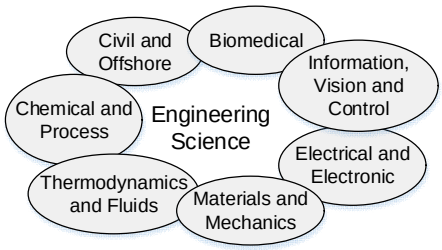
Unit of Assessment: 15, General Engineering

a. Overview

The Department of Engineering Science is one of ten Departments in the Mathematical, Physical and Life Sciences (MPLS) Division, one of four academic Divisions at the University of Oxford. Corresponding precisely to REF UOA 15 (General Engineering), the entire spectrum of work undertaken by the Department is summarised in this document.

The Department is currently led by Prof. Guy Houlsby, FREng, closely supported by Prof. Dominic O'Brien (Deputy Head) and Prof. Alison Noble, OBE, FREng (Director of the Institute of Biomedical Engineering). Whilst there is no formal sub-Departmental structure, we recognise the following seven, strongly overlapping research groupings:

- Biomedical Engineering.
- Chemical and Process Engineering.
- Civil and Offshore Engineering.
- Electrical and Electronic Engineering.
- Information, Vision and Control.
- Materials and Mechanics.
- Thermodynamics and Fluids.



Both our teaching and research are underpinned by a commitment to engineering as a unified discipline. To achieve this, we go much further than simply grouping every branch of engineering 'under one roof'. Our core belief is that Engineering Science is rooted in three guiding principles:

1. Excellent engineering depends critically on a sound mathematical and scientific foundation.
2. Problem-solving and innovation are best achieved by recognising that key concepts and techniques recur across many branches of engineering.
3. Many of today's technological challenges demand an interdisciplinary approach that crosses traditional engineering boundaries. For that reason we recognise and resource a number of broad themes, such as energy, transport, healthcare, water and the environment, that transcend traditional discipline-based groupings. These groupings are deliberately focused on key societal issues where engineering science can have significant impact.

b. Research Strategy

Our over-arching strategy is to apply intellectual rigour to the most challenging engineering problems, ensuring timeliness and relevance of research so that it best benefits society, and fostering interdisciplinarity where appropriate.

Key elements of our implementation plans in RAE 2008 were to increase academic staff numbers by approximately 20%, to open two new buildings (for biomedical engineering and for turbomachinery research) and to focus particularly on the research themes of biomedical engineering, energy and the environment. These ambitions have all been achieved, as detailed in later sections.

Throughout the REF period, we have pursued a consistent policy of research-led recruitment, reinforcing activities where we have existing strengths, but also pinpointing new areas where future applications of engineering science can make a distinctive impact at a national and international level. We believe that this twin-track approach provides a healthy basis for innovation, continued achievement and a contribution that will benefit society, boost economies and improve lives.

In this Section, we outline how this top-level strategy has been put into effect for each research grouping. This must be seen, however, in the context of the cross-sector research that is a core strength of our Department. To take three examples: Prof. Cui and Dr Ye (Chemical and Process Engineering) are currently working with Dr Payne (Biomedical Engineering) and Dr Collins (Electrical and Electronic Engineering) on "Engineering Human Neural Networks"; Dr Howey (Electrical) and Prof. Ireland (Turbomachinery) are studying the thermal response of lithium ion batteries; and Dr Burd (Civil and Offshore Engineering) collaborates with Prof. Edwards and Dr Stevens (Electrical and Electronic Engineering) on electromagnetic detection methods for buried pipelines – work that has already led to patents and the formation of a spin-out company. These and similar interactions thrive in our broadly-based Department.

Biomedical Engineering

The Institute of Biomedical Engineering (IBME), deliberately co-located with hospitals on the Old Road Campus, has been pivotal in delivering the rapid yet sustainable expansion that has been a striking feature of the REF period. We opened the £12M IBME in 2008 with 110 researchers and 8 academics. Today, it houses 220 researchers and 15 academics, who over the REF period have raised £33M of research funding, produced over 300 peer-reviewed publications and filed 21 patents. Our policy of co-locating engineers with medical professionals has generated a critical mass of expertise, enabling us not just to pursue major research initiatives but also to secure the substantial funding vital to driving forward the discipline. The IBME's impact has already been felt locally (through translational work with hospitals), nationally (through the Centre of Excellence in Medical Engineering and Centre for Doctoral Training in Healthcare Innovation), and internationally (*e.g.* collaborations with the US, India and China).

We organise our biomedical engineering research into four main clusters: biomedical signal processing and e-health; biomedical image analysis; therapeutic ultrasound and drug delivery; and regenerative medicine. Our underpinning strategy – to recruit acknowledged world leaders in this field – has resulted in each cluster being led by a Statutory Professor, with two out of four appointed within the current REF period. This approach has been vindicated by the success of all four clusters in terms of funding secured, expansion achieved and international impact delivered. Our objective is now to consolidate this expansion and continue integrating biomedical engineering into clinical practice through our rapidly expanding portfolio of spin-out companies (7 created since 2008, see Impact Template) and clinical trials (20 initiated since 2008).

Chemical and Process Engineering

Our strategy is to develop chemical engineering science and applications in the two main areas: individual health and environmental sustainability.

In **individual health,** which is integrated with Biomedical Engineering at the IBME, we conduct research at the interface with life and clinical sciences, linking with biomedical engineering in the field of regenerative medicine. Key areas of our research in the last few years have been advanced bioreactors for tissue engineering, stem cell bioprocessing, banking of stem cells and engineered tissues. Our research has attracted major research funding from research councils (*e.g.* BBSRC LOLA) and industry, and has led to the establishment of the spin-out company Zyoxel.

In **environmental sustainability** our strategy is to focus on water and sustainability – topics of global significance that will become increasingly crucial in the 21st century. We have an established reputation in membrane technology and its application in water and wastewater treatment, and have initiated major international research collaborations with Singapore, China, Spain and Mexico, *e.g.* the Singapore Peking Oxford Research Enterprise (SPORE). Research in the biological treatment of industrial waste water has led to the development of novel processes such as transformation of oil wastes to bioenergy, recovery of valuable metals from industrial waste streams, and controlled delivery of anti-microbial agents in water systems. We have formed partnerships with key industrial stakeholders (*e.g*. Ford, BP, Castrol) whose manufacturing activities generate large amounts of waste that are hard to treat sustainably. In collaboration with Thames Water, we are developing membrane technologies that can deliver significant cuts in energy use and aid emergency water supply in developing countries.

Our future strategy will focus on resource engineering and sustainability, where we will continue to develop designs and processes at nano, micro and mega-scale and apply them where they can make a substantive impact.

Civil and Offshore Engineering

We have maintained our strategy of focusing on the offshore energy sector, as it presents one of the most promising and sustainable means of meeting energy needs. Reflecting the continuing importance of oil and gas, we undertake extensive research on offshore structures, foundations and pipelines, but have complemented this with a strategic move into support for the marine renewables sector, working for the offshore wind industry and establishing a strong focus on tidal power. Separately, we maintain significant strength in structural dynamics and earthquake engineering. To nurture diversity, however, we place a key emphasis on giving our academics the freedom to pursue research beyond our core themes.

We cluster research around four main topics: marine renewables; ocean engineering; geotechnical

engineering; and structures. Our tidal energy group, for example, conducts both fundamental and applied research into tidal stream energy; initiated during the REF period, this has grown rapidly with around £2.6m in funding, including a major £1.5M grant from the ETI Performance Assessment of Wave and Tidal Array Systems (PerAWaT) project. New lines of research on wave power are also being pursued, and work on extreme waves is directed towards a major update of design guidance for the offshore industry.

Our geotechnics work has delivered major advances (*e.g.* software solutions to plastic collapse problems) that have secured extensive industrial take-up. Strong industrial links ensure our work has high impact and feeds directly into national and international design and practice: we are leading the Carbon Trust PISA project on foundations for offshore wind farms, building on earlier work in collaboration with DONG Energy, and extensions funded by EDF Energy.

As well as impacting at European level through EU-funded work, our structural dynamics research has contributed directly to UK guidelines on grandstand dynamics, whilst since 2008 Dr You has carried out pioneering work in the new field of origami structures, which has already made its mark in fields ranging from energy-absorbing structures to biomedical devices (stents).

Electrical and Electronic Engineering

Our research targets seven themes where Oxford University has a proven track record of significant, measurable impact: communications; microscopy; microelectronic circuits and analogue systems; sensor systems; optoelectronic and liquid crystal materials; nanotechnology; and electrical power systems. Electrical engineering has been strengthened by a series of key appointments during the REF period; for example, in 2012 we appointed Jong-Min Kim (formerly Director of the Samsung Display Laboratory) as Professor of Electrical Engineering. Interdisciplinary collaboration is central to our philosophy, not just within the team and Department (*e.g.* between electromagnetics and medicine in the field of medical imaging) but across the University (*e.g.* Dr Booth holds a joint appointment with the Centre for Neural Circuits and Behaviour, Dr Collins is developing novel cameras to be used for plant health diagnosis in collaboration with Plant Sciences, Prof. Edwards is working to repurpose the Goonhilly satellite earth-station for astronomy, together with colleagues in Physics).

Our strategy's effectiveness is reflected several successes, such as breaking the 'world speed record' for optical wireless systems, the development of new medical imaging techniques and production of a metamaterial-based wireless power and data transmission system, as well as the world's first metamaterial motor. Extensive interactions with organisations such as Sharp, DSTL, and Samsung ensure that we tackle significant problems of national/international importance (*e.g.* battery management for electrical vehicle use – where our results have provided key input to national policy briefings produced by NESTA). There have been 42 patents and applications, and three spin-outs set up since 2008 (including YASA Motors, whose novel technology was used in the car that holds the FIA electric world speed record, and Oxems, whose buried asset detection system is currently in trials with major utilities such as Veolia).

Photonics is a major strength, and our staff play a leading role in Oxford Photonics – a University-wide initiative – and we are currently leading the development of a specialist centre focusing on the mobile devices of the future. Looking ahead, we will strengthen strategic areas, including further investment in nanotechnology led by Prof. Kim, who is already playing a leading role in establishing University-wide research centres and fostering international collaboration, especially with Korea (£817k of contracts from KETEP/KIER and 5 Samsung GRO awards already secured).

Information, Vision and Control

We group research around four main fields: computer vision and image understanding; mobile robotics and automation; machine learning; and control engineering and systems. We address a wide array of information engineering questions, exploring both fundamental research and high impact applications. For example, our work on image understanding will make the entire BBC photo archive searchable, with the ultimate aim of categorising every image on the internet. Robotics research is delivering high impact in autonomous transport and warehouse automation, while work on machine learning and big data is tackling problems as diverse as water management and exo-planet detection. Our active-vision research has, through the pioneering PTAM virtual reality system, moved real-time computer vision from the desktop into the pocket. Our dynamics and optimal control work has resulted in collaboration with, and support from Ferrari Formula One on minimum lap-time simulation, driver simulator design and the control of the 2014 power train.

Research on complex network systems is advancing our understanding and control of cell signalling pathways, paving the way towards personalised medicine and better drugs.

Over the REF period, this grouping secured some 35 grants with a total value exceeding £20M, published over 300 papers and filed over 14 patents. Importantly, further advances were achieved in industrial engagement, including funding from (and joint exploitation with) major enterprises such as Nissan, BAE and Google, and SMEs such as SciSys, Guidance and MIRA. Indeed, extensive collaboration with companies, other Departments and other Universities has been a key characteristic of the last five years. Our strategy is now to consolidate Oxford's strengths in this area, expanding our expertise around key leaders in in machine learning (Roberts), vision (Zisserman, Torr), control (Limebeer) and field robotics (Newman). Growth is an essential component (recent appointments include three Professors and four University Lecturers), as is our drive to build on our wide-ranging, highly productive engagement with industry.

Materials and Mechanics

Our research spans topics from microstructural phenomena to the design and use of exotic materials. An unusual hallmark is that every facet of our work includes both experimental and analytical considerations – a dual approach that delivers the intellectual rigour critical to genuine, sustained progress in this centrally important field of engineering.

The Rolls-Royce University Technology Centre (UTC) in Solid Mechanics, founded nearly 25 years ago as one of the pilots for the UTC network that now spans the UK and worldwide, is at the centre of our activities. Our research reputation and close relationship with the aircraft propulsion industry have enabled us, during the REF period, to tackle an array of high-priority technical challenges, such as sand ingestion problems in the wake of the Icelandic eruption of 2010, and the need for safety-related advice to secure compliance with Civil Aviation Authority requirements. We are also inaugural members of the Bristol-Oxford Nuclear Research Centre, aiming to deliver research to support safe operation of the future nuclear plant.

During this period, our support exceeded £2.3M from Rolls-Royce, £8.8M from EPSRC and the EU, and £3.4M from other sources. The group has an impressive collection of state-of-the-art test facilities for structural impact, servo hydraulic mechanical testing and micromechanical testing: this has recently been expanded through a £3.4M Capital "Great Technologies" grant from EPSRC. Our active strategy of nurturing this highly successful field led us to move our major experimental assets to Begbroke Science Park just outside Oxford (see Section d), helping us to achieve impact in an area of research where the UK has only a limited number of facilities.

Our main plans for further expansion are in nanomaterials, nuclear engineering, numerical modelling and materials design. In this context, we have appointed two Professorial Research Fellows, two ULs and one Senior Research Fellow, and continue to interact extensively with the Department of Materials, whilst pursuing a lively programme of international collaboration.

Thermodynamics and Fluids

Our main activities in this area are jet engine research at the Osney Thermo-Fluids Laboratory (see Section d) and applied thermodynamics research. In the first, we continue to make a distinctive contribution to cutting fuel burn in aircraft and in gas turbines for power generation. We opened the new Southwell Building in 2010 for this research (see Section d) and have invested heavily in turbomachinery research. To reinforce the Department's strategy of supporting highest impact research, we have re-located major national experimental facilities to the new lab, including the acquisition in 2010 of the Oxford Turbine Research Facility (OTRF), one of the most sophisticated turbine test rigs worldwide (see Impact Case Study UOA15-01). Our Turbomachinery Research Group continues to attract significant industrial funding (with current grants worth over £12M) and, in addition to the Rolls-Royce UTC, now embraces a wider range of sponsors, *e.g.* MHI.

Our work on applied thermodynamics focuses on internal combustion engines and on cryogenics, with funding for on-going projects exceeding £1.5M; additional funds from industry (NGAS, Honeywell Hymatic) support other projects (*e.g.* developing a cooler for the James Webb Space Telescope). Close collaboration with the Department of Physics has made it possible to develop unique capability in advanced combustion measurement methods and, over the REF period, work has also been initiated on Stirling engines powered by radioisotopes, low temperature difference heat engines for pumping water, and oil-free refrigeration compressors. We plan to develop further our capability in optical modelling for solar concentrators as efficient sustainable heat sources.

Overall Future Strategic Plans

We have structured our Department to be free of internal boundaries, so that we were best able to adapt quickly to new challenges and opportunities that arose during the REF period. We will retain this structure, and continue our expansion programme, carefully targeting key research areas:

- We will build on our successes in **Biomedical Engineering**, translating engineering techniques directly into medical practice; this will include building further partnerships with clinical colleagues in areas such as oncology. Another key aim is to exploit cross-departmental expertise in nanotechnology for biomedical applications.
- **Chemical and Process Engineering** will extend its interaction with biomedical sciences and expand its sustainability-related research in the key fields of water treatment, resource recovery, energy and bio-processing.
- **Civil and Offshore Engineering** will further extend its support for the energy industry, especially the offshore sector. Recent strategic moves to support marine renewables will be expanded and strength in structural dynamics will be maintained.
- In **Electrical and Electronic Engineering**, we will lead broad consortia across the MPLS Division working on nanotechnology, electronics and photonics. This will deliver products and benefits built on our fundamental research (*e.g.* graphene, quantum and nano-technology).
- In **Information, Vision and Control** we shall build on our existing strengths in vision, imaging, control theory and complex model development. Expansion will focus on autonomous intelligent systems and the dynamics of biological, vehicular and energy systems. We intend to establish a centre for Data Analytics.
- In **Materials and Mechanics**, we will develop our capability in nanomaterials as well as in numerical modelling, whilst growing our portfolio of nuclear energy projects at the Bristol-Oxford Nuclear Research Centre. We will further build our relationship with the Materials Department through recently awarded capital equipment (£3.4M) and Programme (£5.4M) grants.
- We will further diversify our activities in **Thermodynamics and Fluids** to complement our collaboration with Rolls-Royce. We will reinforce our research on internal combustion engines, and extend into areas such as power electronic cooling, system thermal management, hypersonic flow and the re-emerging UK nuclear industry.
- We will take a lead in the MPLS Division's **energy programmes**, addressing an extremely varied set of challenges that encompass power generation, storage, distribution and use. Specifically we plan to grow our work in electrical energy storage, linking this to the appointment of Prof. Peter Bruce (specialist in batteries) to a Professorship in the Dept. of Materials.
- Importantly, we will continue to place special emphasis on actively supporting **interdisciplinary projects** that reach across our Department and beyond.

c. People

i. Staffing Strategy and Staff Development

Our strategy during the next 6-year period is to continue our expansion, to grow to between 100 and 110 academic staff from our current base of 89. We will appoint staff with a wider range of job specifications and give both new and existing staff a more flexible research/teaching balance. Our recruitment policy is to focus some posts in key strategic areas (evidenced by recent appointments in information engineering and in electrical engineering) whilst implementing an underpinning philosophy of 'advertise broadly, appoint the best'. This will result in critical mass in strategic areas as well as research led by inspired – and inspiring – individuals.

Every academic is supported as an independent, self-motivated researcher empowered to drive an individual agenda. Our unified departmental structure and broad overlapping groupings allow collaborations between academics to thrive, leading to impact and engineering innovation.

Notes: University Lecturer (UL) at Oxford includes both Lecturer and Senior Lecturer grades. Most academic staff hold College Fellowships as well as Departmental posts.

New academic appointees benefit from:

- Generous relocation assistance, plus an established newcomers' support network.
- An automatic start-up allowance of £10k for ULs, usually with substantial further investment (recent examples include £110k for engine analysis equipment, and £40k for a high speed camera). Professors receive a much more substantial start-up allowance, subject to negotiation.
- An academic mentor (for all ULs).

- Personalised teaching/administrative duties, as appropriate to the experience of the appointee.
- Extensive courses delivered by the Oxford Learning Institute, addressing teaching skills, interviewing skills, and staff management and research leadership.
- A structured five-year probationary period, with an initial review after two years and a final review involving three external referees (at least one from overseas).

In addition, **all our academic staff:**

- Are supported by a dedicated team of administrative staff throughout the process of seeking grant funding, application, contract negotiation/set-up, administration and accounting, through to final reporting. Larger research groups have dedicated support staff and all academics receive support from the University's central Research Services Office.
- Receive a research allowance (reviewed annually and including a proportion of overhead earned from their research) to be spent at their discretion. Most also receive research allowances from their College.
- Enjoy access to grants from the Oxford University Press John Fell Fund, an internal but competitive University fund providing grants typically up to £100k.
- Have an annual written appraisal, and a formal appraisal meeting at least every five years.
- Are entitled to (and are actively encouraged to take) one term's sabbatical for every six taught.
- Are eligible to apply for the title 'Professor' under Oxford's Recognition of Distinction exercise. Our Department actively encourages this (26 of our academics currently hold the title) and all who do so have the opportunity to apply for a more research-intensive role (Professorial Research Fellow) as part of our established strategy of enabling flexible career paths.

Research Staff: Recruitment and Career Development

Support for research staff is of key importance to the Department. Oxford has been awarded the EC's 'HR Excellence in Research' badge, recognising the systems/practices in place to support our researchers' careers and their professional development in line with the national Concordat for Researchers. We implement all aspects of the Concordat through University codes of practice and a strong HR team.

Every appointment is made following an openly advertised competition, with processes monitored and applicants entitled to seek feedback. Interview panel chairs undergo training through the Oxford Learning Institute and every new research staff member undergoes formal induction plus a formal probation process. Supervisors receive guidance on management, and all research positions have formal specifications with required tasks set out clearly and transparently.

Researchers have an annual Professional Development Review with their supervisors (a process currently being redesigned using researcher focus groups to identify their needs better). Individual career advice is provided by supervisors. Researchers are further supported through courses at the Oxford Learning Institute on subjects such as teaching and learning, personal development and research management; the MPLS Division also runs more specialised training courses. Researchers are encouraged to undertake some teaching, with many holding College Lecturer positions that allow them to gain experience relevant to securing permanent academic posts.

Post-Doctoral Research Assistants (PDRAs) are encouraged to apply for permanent posts – six UL appointees since 2008 have been from our PDRAs. Some researchers have long-term contracts, while for large grants we commit to making long-term senior PDRA posts permanent. We host College Junior Research Fellowships (career development posts) and strongly encourage applications for EPSRC, RAEng, 1851 and Royal Society Fellowships: at present we have 2 Royal Society, 1 RAEng, 1 ERC Starting Grant and 3 ERC Advanced Grant holders in the Department. Researchers near the end of fixed-term contracts are helped to seek opportunities across the University and beyond, with exit questionnaires used to improve the environment for researchers.

Equality and Diversity

The University has an action plan for race equality, and a strong support for staff with disabilities, as well as a recently launched £1M Vice-Chancellor's fund to support diversity. The Department is actively engaged in these programmes, and has applied to the VC's fund to run a University pilot project to redevelop our recruitment website to encourage more diverse applications.

Our commitment to equality was acknowledged by an Athena SWAN Bronze Award in 2013. Key policies include: flexible working for researchers and support staff; planning of individual academic working patterns; a generous University maternity leave policy; focus groups for female staff;

leadership training for women through Oxford's Springboard programme; and recruitment training for panel chairs. A working group led by our Deputy Head of Department meets three times a year to drive implementation of our action plan geared to securing an Athena SWAN Silver Award.

Academic Staff Appointments and Major Promotions

The REF period has seen invigorating change and expansion. In RAE 2008, we said we would:

- Increase academic staff by 20%; this has been achieved, with numbers growing from 72 to 89.
- Appoint to chairs in mechanical, electrical and control engineering; this was also accomplished.

We have also appointed Professors in other areas (see below): of 13 currently in post, eight took up office during the REF period. Some came with extensive experience and an established track record; others were relatively young researchers in whom we recognised the potential to become tomorrow's research leaders. Some were internal appointments; others were eminent arrivals from elsewhere. All were appointed through open international competition.

Biomedical Engineering – **Constantin Coussios** was appointed Professor of Biomedical Engineering; the youngest of our Statutory Professors (aged 33 when appointed) and a previous holder of an EPSRC Challenging Engineering Award, he brings extraordinary talent and energy to his field. **Prof. Alison Noble, OBE, FREng,** was appointed Technikos Professor of Biomedical Engineering, recognising her superb track record in medical imaging and her ambitious vision for the future. We have built substantial teams around these two appointees and Professors Cui and Tarassenko, including seven new ULs: **Prof. Robin Cleveland** (from Boston University), recognising his world-renowned achievements in acoustics; **Dr Gari Clifford** (from MIT), who adds a global dimension to our mobile health research and has won several international awards; **Dr Eleanor Stride** (from UCL), holder of an EPSRC Challenging Engineering Award and an expert in drug delivery systems engineering; **Dr Vicente Grau** (biomedical imaging and analysis) promoted from RCUK Fellow; **Dr Michael Chappell**, appointed to support Professor Noble; **Dr Bob Carlisle** (from the Department of Oncology), appointed to support Professor Coussios and whose expertise in biomedical nanotechnology, pharmacology and oncology demonstrates our commitment to interdisciplinary excellence; **Dr Jens Rittscher**, who comes from GE in America, bringing expertise in biological image analysis and informatics. **Dr David Clifton** takes up an RAEng Research Fellowship focussing on biomedical signal processing.

Chemical and Process Engineering enjoyed strong expansion during the RAE 2008 period. Since 2008, three additional University Lecturer appointments have been made: **Dr Cathy Ye** (tissue engineering), promoted from RCUK Fellow, **Dr Alfonso Castrejon-Pita** (from Cambridge, also holding a Royal Society Research Fellowship) is an expert in inkjet printing technology, and **Dr Aidong Yang**, who will join us from Surrey University on 1st January 2014.

Civil and Offshore Engineering – Our four UL appointments have galvanised this area, as well as providing a strong focus on energy: **Dr Richard Willden** was promoted from RCUK Fellow; **Dr Tom Adcock** is an expert in marine energy and large waves; **Dr Chris MacMinn** (from Yale University) is an expert in porous media, focusing on carbon capture and storage; and **Dr Manolis Chatzis** (from Purdue University) further strengthens our established structural dynamics team.

Electrical and Electronic Engineering – The key development has been appointing **Jong-Min Kim** as Professor of Electrical Engineering. An electronics and nanotechnology expert, he was previously a Samsung Senior Vice President and one of only 11 Samsung Fellows. With his extraordinary record of scientific publication and over 200 patents, he adds a new dimension to our activities. Complementary UL appointments include: **Dr Bhaskar Choubey** (from Glasgow University) in microelectronics; **Dr Stephen Morris** (from Cambridge University and holder of a Royal Society Research Fellowship) in photonics; and **Dr Justin Coon** (from Bristol University/Toshiba) and **Prof. Katya Shamonina** (from Imperial College London) in communications. We have also appointed **Dr David Howey** (from Imperial) to our Electrical Power Group and promoted microscopy expert **Dr Martin Booth** to Senior Research Fellow, jointly with the Centre for Neural Circuits and Behaviour.

Information, Vision and Control – In control the key appointment is **David Limebeer**, FREng, (from Imperial) as Professor of Control Engineering, bringing a wealth of experience in leading and co-ordinating research, with **Dr Antonis Papachristodoulou** appointed UL in Control Engineering to support him. **Paul Newman** was appointed as BP Professor of Information Engineering, bringing energetic entrepreneurship to robotics and automation; this post has been supported by appointing

Dr Ingmar Posner (robotics) and **Dr Andrea Vedaldi** (vision). **Prof. Stephen Roberts** was promoted to Professorial Research Fellow, with a brief to focus on machine learning research, supported by **Dr Michael Osborne** (big data) and **Dr Frank Wood** (machine learning, from Columbia University). Finally, **Prof. Philip Torr** (from Oxford Brookes University) joined us as Professorial Research Fellow (and ERC Advanced Grant holder) further strengthening our imaging and vision engineering team.

Materials and Mechanics – Significant appointments have included: high-strength alloy expert **Prof. Roger Reed** (from Birmingham University) as Professorial Research Fellow (50:50 with the Dept. of Materials); promotion of **Prof. Nik Petrinic** to Professorial Research Fellow to focus on research into impact, mainly for the Rolls-Royce UTC; promotion of **Dr Clive Siviour** to UL; and appointment of **Dr Jin-Chong Tan** (from Cambridge University), **Dr Antoine Jerusalem** (from IMDEA) as ULs and **Dr Felix Hofmann** (from MIT) as Senior Research Fellow support our growth in materials research.

Thermodynamics and Fluids – appointments were made to two key Professorships: **Li He** (from Durham University) became RAEng/Rolls-Royce Professor of Computational Aerothermal Engineering, bringing new skills in numerical analysis, while **Peter Ireland** (from Rolls-Royce) became Donald Schultz Professor of Turbomachinery, bringing a commercial, application-based edge to this critical area. These have been supported by further appointments: **Dr Budimir Rosic** (from Cambridge University) as a UL, pursuing experimental and numerical research mainly supported by Mitsubishi Heavy Industries (MHI); **Dr Ed Walsh** (from Limerick University) as a UL in Heat Transfer, working on power electronic cooling; **Dr Matt McGilvray**, as Senior Research Fellow in hypersonics, broadening the scope of our thermo-fluids work. **Kam Chana** (formerly a Fellow at QinetiQ) is playing a key role as OTRF Commercial and Technical Director. Rolls-Royce have seconded **Dr Marco Bacic** to us as a University Research Lecturer. The appointment in 2013 of **Ron Roy** (previously Head of Mechanical Engineering at Boston University, and an expert in acoustics) as Professor of Mechanical Engineering is key to our strategy of broadening our portfolio of research. Our Internal Combustion Engine research group, led by Prof. Richard Stone was strengthened by the appointment as a UL of **Dr Martin Davy**, from Loughborough.

In parallel, only a few of our ULs have left to take on Professorships at other Universities: they include **Fionn Dunne** (Imperial), **Ian Reid** (Adelaide University), **Alistair Borthwick** (University College, Cork) and **Yiannis Ventikos** (UCL), with the last two appointed directly as Heads of Department.

ii. Research Students

The Department is fortunate in that it is able to attract applications from students of the very highest calibre. As a result, we can be extremely selective in the research students taken. In return, we place ambitious, challenging demands on them. They represent a vital component in our team and we expect them to take an unusually high level of responsibility for their studies. During the REF period, an average of 55.9 doctoral students graduated each year – up by 61% from the 34.8 average in RAE 2008. In the Department, conduct of admissions is the responsibility of the Director of Graduate Admissions, while progression at Oxford is the responsibility of the Director of Graduate Studies. Both posts are held by academics, supported by a dedicated graduate administrator.

To maximise their success, all of our research students are closely supported, with their progress carefully monitored by:

- An expert supervisor (often two co-supervisors), guiding them through their research and mentoring their development and training. All supervisors report termly through an online system that also requires students to report on their own progress. The Director of Graduate Studies, a College supervisor and a College Academic Board monitor these reports.
- A supervisory committee (comprising expert academics and the relevant supervisor) requiring 'milestones' such as a research paper, seminar, written research plan and viva at the end of the first year, and a poster at the end of the second. (This applies to most doctoral students; those on four-year Centre for Doctoral Training programmes have different arrangements.)

Research students also benefit from:

- Access to a wide range of courses and skills training (writing, speaking, entrepreneurship, career management) provided by the MPLS Graduate School and the Oxford Learning Institute.

- Access to the exceptional Radcliffe Science Library, online access to all mainstream journals, supercomputing through the Oxford Supercomputing Centre, a PC provided by the Department, support from a number of funding mechanisms to attend conferences/meetings.
- A powerful programme of group seminars, providing an ideal forum for skills development.
- Career development advice through the Careers Service and the Oxford Learning Institute.
- A strong peer support network via the Department, Colleges and international societies.

d. Income, Infrastructure and Facilities

Income

During the REF period, we successfully secured nearly 400 research grants and contracts worth £85.5M (51% from Government/Research Councils, 26% industry, 12% EU, 9% charities and 2% other). From 2008-09 to 2012-13, annual research income (excluding "in kind") grew 38% from £9.55M to £13.18M, a compound annual growth of 8.4%. We highlight below some major projects.

- We host one of four UK Centres of Excellence in Medical Engineering funded by the Wellcome Trust and EPSRC. Our £8M **Centre of Excellence in Personalised Healthcare** brings together engineers and medical researchers to develop solutions to unmet clinical needs and to translate research into real-world products that save and improve lives.
- Creation of an in-vitro model of elements of the human brain is the goal of BBSRC's £3.7M grant **'Engineering Human Neural Networks'**, which has built a team from engineering, maths and medical science at Oxford, biological science at Aston University and physiology at Cambridge. The focus is on developing a basic biological neural network capable of learning, memorising and regeneration.
- **ARTEMIS**, the world's fastest radio transient detection system, has been developed in a £1.4M collaboration between the Depts. of Engineering Science and Astrophysics and the Oxford e-Research Centre. This high-performance capability, sponsored by nVidia and Dell, has been successfully implemented at major radio telescope sites in the UK and other EU countries.
- EPSRC's £5.5M grant **'Control for Energy and Sustainability'** aims to develop the state-of-the-art control systems. Through a consortium of Oxford, Cambridge and Imperial College, this research is addressing challenges of integrating renewables into electrical power systems, developing air traffic management systems to cut congestion, and enabling design/operation of a new generation of energy-efficient vehicles.
- The objective of the £10.5M EPSRC/industry grant **'Human-Agent Collectives: Project ORCHID'** is to develop the science of human-agent collectives and to address applications relating to the smart grid, disaster response and citizen science. It is underpinned by collaboration with Southampton University, Nottingham University and BAE.
- EPSRC's £3.2M **'UltraSpine'** award, secured jointly with Leeds University, is developing a minimally invasive ultrasound-based method of rehabilitating spinal discs.
- A £1.2M EPSRC grant on **micromechanical modelling and experimentation** in partnership with the Materials Department is devising new techniques and modelling strategies capable of evaluating and modelling the behaviour of materials at the meso-scale. EPSRCs £3.4M Great Technologies Capital Equipment grant (also with the Materials Dept.) in Advanced Materials will allow us to develop new **Multifunctional high performance alloys for extreme environments**. An EPSRC £5.4M Programme Grant led by Oxford in partnership with Cambridge, Imperial, Kings College London and Sheffield will provide new fundamental understanding of the mechanisms of Hydrogen Embrittlement in steels which will enable us to design new alloys that are resistant to such embrittlement.
- The £2.3M **Rolls-Royce UTC in Solid Mechanics** conducts strategic and applied research relevant to the company's engine technologies, with particular emphasis on the structural integrity of engine components.
- The **Rolls-Royce UTC in Aerodynamics and Heat Transfer** houses some of the UK's most sophisticated turbine and high-speed flow facilities and includes outstanding expertise in computational fluid dynamics, flow and heat transfer experiments and instrumentation. The average research income in this area exceeds £2.2M p.a., with grants awarded over the REF period exceeding £14M.
- The **Invensys UTC for Advanced Instrumentation** (£3.8M awarded during REF period) supports exploitation of Coriolis multi-phase flow measurement technologies, developed in our Department and leading to a substantial suite of patents (see Impact Case UOA14-04).

- In October 2012, at Begbroke Science Park, **Scuderia Ferrari** opened a research facility focused on developing racing car technologies. Ferrari currently supports three doctoral students, including access to data, facilities and in-house expertise. Current projects include development of driver-training simulator motion platforms, heat transfer and control studies for Ferrari's 2014 F1 drivetrain, and development of algorithms for driver training, car design optimisation and car set-up.
- We work at the leading edge of research into high-efficiency, low-weight motors, power electronics and control systems for the **clean road transport of tomorrow**, working with manufacturers and developers on specific projects such as the development of power trains for hydrogen-fuelled vehicles including the BOC Ech2o eco-marathon car, LifeCar and Hyrban.
- There are three significant European Research Council projects. The €1.8M European Research Council **VisRec** initiative aims to develop a 'Visual Google', a search engine enabling retrieval of objects, people and human actions from image databases and videos simply by specifying a query visually. The €2.0M **UniQDS** project aims to create a universal framework for the understanding of charge transport in Quantum Dot systems. The €1.2M project COMEM focuses on Computational Multiscale Neuron Mechanics.
- The department was awarded a £3M Great Technologies Capital Grant for robotics from EPSRC. This funding will underpin the creation of a new robotics centre at Oxford.

Buildings and Infrastructure

We occupy 23,700m^2 of laboratory and office space, with almost two-thirds (15,700m^2 including almost all our teaching space) located on the 'Keble Road Triangle' in the heart of Oxford. As anticipated in RAE 2008, the REF period has seen heavy investment in new buildings and infrastructure, with £22M targeted at new-build projects. Consequently, we now have three annexes (two opened during the REF period) that are key to our work: the IBME, the Osney Thermo-Fluids Laboratory and premises at Begbroke Science Park.

The Institute for Biomedical Engineering (IBME, see also Section b)

The IBME, opened 2008, has no equivalent anywhere in the UK. Providing 1855m^2 of dedicated research space in a purpose-built building on the Churchill Hospital site, opposite the new £109M NHS Cancer Centre and close to the world-leading Nuffield Orthopaedic Centre, its underlying philosophy is clear-cut: translational research applying engineering to medicine can only be achieved by co-locating engineers with medics – so we have located engineers in a unique multi-disciplinary engineering institute as part of an internationally recognised medical sciences campus.

Initially funded through a £13M Intellectual Property exploitation agreement with Technikos (£12M for the building, £1M for a Professorship), the IBME shares space in the Old Road Campus Research Building with four other biomedical departments (the Jenner Institute for Vaccine Development, Dept. of Oncology, the Structural Genomics Consortium and the Nuffield Dept. of Surgical Science). There are no physical boundaries between the five, and each is split on at least two levels to nurture interaction. Driven partly by University investment in new academic posts, the IBME's rapid growth has been secured mainly through £33M in Research Council and EU grants. Moreover, both UK and international companies actively sponsor research there.

The IBME hosts a Centre of Excellence in Medical Engineering, a Centre for Doctoral Training in Healthcare Technology, a National Centre in Cancer Imaging, a Bio-engineering and Technology Theme (part of a National Institute of Health Research Comprehensive Biomedical Research Centre) and a Grand Challenges in Healthcare IT centre. It provides access to specialised shared facilities (*e.g.* microscopy and histology), enabling translational and applied research normally beyond the reach of an engineering department. In addition, a 160m^2 biomedical workshop is shared with the Dept. of Oncology, specialising in the prototyping of devices for medical research and clinical trials – an excellent example of the IBME's fundamental mission to meet ever more challenging real-world needs in the field of healthcare.

Osney Thermo-Fluids Laboratory

In 2010, we opened the Osney Thermo-Fluids Laboratory in the new Southwell Building (4900m^2), replacing ageing and smaller premises and providing a specially equipped, fit-for-purpose space capable of meeting the evolving needs of our Turbomachinery Research Group. Financed mainly by £10M of inward University investment, the building hosts the Rolls-Royce UTC for Fluid Mechanics and Heat Transfer, established in 1989 and playing a pivotal role in implementing Rolls-Royce's R&D strategy for turbines – a key part of its drive to maintain its position as a world-

leading engine manufacturer; significant sponsors also include Alstom, Siemens, QinetiQ and MHI. The Laboratory houses some of the UK's most sophisticated turbine and high-speed flow facilities, such as the OTRF (see below and Impact Case UOA15-01).

Begbroke Science Park

Our expanding footprint at Begbroke provides a perfect environment for commercial exploitation of our research at a location dedicated to the needs of high-tech start-ups. We occupy 1800m^2 of research space, representing a total investment of £4.2M and housing four main activities: impact engineering; autonomous guided vehicles; energy and power; and environmental engineering. It is home to a remarkable breadth of world-class experimental facilities.

Complementing these three major building developments, our other key focus has been on refurbishing and renewing our existing premises. During the REF period, we have made a number of investments in upgrading our infrastructure, most recently £600k to convert existing space in the Keble Road Triangle into nanotechnology laboratories. However, essential infrastructure extends beyond buildings and laboratories. IT, in particular, is of critical importance in enabling our work and we maintain a modern network with wired and wireless access and comprehensive fileserver, backup and other facilities. To supplement University facilities (*e.g.* email), we provide local resources (*e.g.* SharePoint) backed by a dedicated support team. Every researcher is provided with a desktop or laptop plus essential software, with most advanced scientific software centrally licensed. We resource high-throughput computing via a combination of seven dedicated PC clusters and access to the Oxford Supercomputing Centre, which provides 640 and 512 core MPI clusters, 64 core shared memory machines and access to e-Infrastructure South.

Facilities

We continue to maintain and extend a world-class array of specialised facilities, without which our research would not be possible. A few key examples are highlighted below:

- In 2011, the Turbomachinery Research Group acquired a unique national facility with the help of £1.8M in support from SEEDA (the South East England Development Agency) and Rolls-Royce. Originally designed and built by our Department for the MoD, the **Oxford Turbine Research Facility** (OTRF) offers capabilities unmatched in the UK for measuring, under engine-representative conditions, aerodynamic loss, turbine efficiency and surface heat transfer in high-pressure and intermediate-pressure turbines.
- We have invested in other major facilities, including **a nozzle guide vane (NGV) capacity rig** used to measure the capacity of Trent engine high-pressure NGVs, and with a £1M upgrade to allow it to measure engine part cooling effectiveness. A new (£1.1M) high-temperature, high-pressure flow facility is being built for Rolls-Royce to simulate HP turbine air system conditions at cruise. We operate three hypersonic wind tunnels, including the Oxford High Density Tunnel (a national facility acquired in 2011) and a Low Density Wind Tunnel recreating planetary re-entry conditions, used to develop an anemometer for the Mars probe Beagle II.
- In the area of solid mechanics, our **fretting fatigue equipment** has been copied worldwide while our **structural dynamics test facilities** are among the most powerful in the UK, with a range of actuators mounted on reconfigurable test frames. By coupling with custom IT systems, these offer capability for advanced hybrid physical-numerical tests, including real-time coupling with facilities in other EU laboratories.
- Our **impact engineering facilities** enable us to research strain-rate-dependent thermo-mechanical responses of advanced engineering materials across a huge range of rates and temperatures. We have unique loading, data acquisition and characterisation facilities for evaluating materials and systems subjected to explosions and/or collisions, with emphasis on ultra-high-frame-rate digital imaging. This is integrated with advanced computation to develop validated predictive numerical models for industrial use (*e.g.* by Rolls-Royce, MHI and DSTL).
- In 2013, we also installed new nanofabrication facilities to support Prof. Kim's growing research.
- Our **Mobile Robotics Group's field laboratory** is a key facility for our RobotCar UK project, with Begbroke's private roads providing a valuable resource for an initiative aimed at delivering ultra-low-cost autonomy for road vehicles. As part of this, we run three vehicles: an autonomous Wildcat (part of a £2M Intellectual Property agreement with BAE) and two all-electric Nissan LEAFs. This project has most recently benefitted from a £3M capital grant from EPSRC.
- Our **Energy and Power Group's facilities** include a back-to-back testing rig for dynamic and steady-state performance of motors, a thermal analysis facility where novel cooling mechanisms

for motors and power electronics are evaluated, and a new facility on insulation degradation.
- In environmental engineering, we have established a **specialised laboratory** for developing new technologies meeting key 21st Century challenges such as water desalination, contaminated water treatment, bioenergy generation and the development of sustainable biocides to prevent microbial growth in water systems.
- Complementing our development and use of in-house facilities, we make extensive use of **national research facilities** such as the Diamond Light Source a few miles south of Oxford; Professor Korsunsky was lead proposer for Diamond's engineering beamline JEEP (I12).

Our Future Plans

Our strategy for expansion means we will continue to increase and improve our laboratory and office space. Much of this will be delivered by further renewal within our Keble Road Triangle site, where a ~£35M refurbishment of the 8500m^2 Thom Building is our top priority. We will also continue to expand the IBME and extend our presence at the Begbroke Science Park.

e. Collaboration and contribution to the discipline

Vibrant interactions with industry, engineering researchers at other Universities, researchers in non-engineering fields, learned societies and UK and European funding bodies are all fundamentally important to our ability to deliver high quality research and beneficial impact. Critical features of our work include collaborative grants with other Departments, Universities and industry; jointly supported research students; consultancies and secondments.

We have a particularly strong culture of commercial exploitation through patents, licence agreements and spinouts. From 2008 to 2013, 14 companies were spun-out: Eykona, Farmware, Intelligent Ultrasound, Kepler Energy, Navetas Energy Management, OBS Medical, OrganOx, OxeHealth, OXEMS, Oxford NanoSystems, OxSonics, Oxyntix, YASA Motors and Zyoxel. Many maintain close collaborative links with us. In April 2010, Plink – a start-up formed by two ex-students and developer of the PlinkArt search engine – became Google's first UK acquisition.

During the REF period, we published approximately 2650 articles in peer-reviewed journals (data from Scopus/Web of Science) many in collaboration with industrial authors or colleagues overseas. Many of our academics are recognised through elected Fellowships, including those of the Royal Society, RAEng, Royal Society of Chemistry, IEEE, ASME, IMechE, IET, ICE, IChemE, IStructE, IoP and Acoustical Society of America. We believe that the quality of our research leadership over the period is demonstrated by the many successes, awards and honours achieved by our staff. Some highlights are:

- National honours: OBEs for **Prof. Richard Darton** (2011) and **Prof. Alison Noble** (2013) and a CBE for **Prof. Lionel Tarassenko** (2012), all for services to engineering.
- **Prof. Alison Noble** elected FREng in 2008 and **Prof. Zhanfeng Cui** in 2013.
- EPSRC Fellowships: a Leadership Fellowship for **Prof. Paul Newman** (2010-15), an Advanced Research Fellowship for **Dr Martin Booth** (2008-13), and Challenging Engineering Awards for **Prof. Constantin Coussios** (2007-12) and **Dr Eleanor Stride** (2011-16).
- ERC: Advanced Grants for **Prof. Andrew Zisserman**, **Prof. Philip Torr** and **Prof. Jong-Min Kim**, and a Starting Grant for **Dr Antoine Jerusalem**.
- Royal Society Research Fellowships for **Dr Stephen Morris** and **Dr Alfonso Castrajon-Pita**, and an RAEng Research Fellowship for **Dr David Clifton.** All three will take up permanent positions in the Department at the end of their Fellowships.
- **Prof. Andrew Zisserman:** British Machine Vision Distinguished Fellow (2008); Royal Society Wolfson Research Merit Award (2011-2015), and the £50k Rank Optoelectronics Prize (2012).
- PASCAL VOC Award for Best Object Recognition System (2009) and ACM Best Open-source Project Award (2010): **Dr Andrea Vedaldi**.
- IMechE Thomas Bernard Hall Prize (2008 and 2010) and ASME Tribology Division Award for Best Paper in Contact Mechanics (2010): **Prof. David Hills**.
- Four ASME Best Paper Awards in five years: **Dr Budimir Rosic**.
- Philip Leverhulme Prize, Parliamentary SET for Britain Engineering Medal and Royal Society Brian Mercer Innovation Feasibility Award (all 2009); Acoustical Society of America Bruce Lindsay Award 2012: **Dr Eleanor Stride**.
- International Society of Therapeutic Ultrasound Frederic Lizzi Award and Acoustical Society of America Bruce Lindsay Award (both 2012): **Prof. Constantin Coussios**.

- IoP Martin Black Prize (2008): **Dr Gari Clifford**.
- Institution of Chemical Engineers Basil Brennan Medal (2010): **Prof. Zhanfeng Cui**.
- Royal Aeronautical Society Silver Medal (2012): **Emeritus Professor Terry Jones**.
- **Dr Byron Byrne** gave the 2011 ICE/BGA Géotechnique Lecture and **Prof. Guy Houlsby** will deliver the 2014 Rankine Lecture, widely held as the most prestigious invited lecture in the field of geotechnics.

Our staff contribute actively and fully to learned society and associated activities. For example: **Prof. Tony Wilson** is President of the Royal Microscopical Society; in 2013, **Prof. Alison Noble** was elected President of the Medical Image Computing and Computer Assisted Interventions Society; **Prof. Richard Darton** was President of the Institute of Chemical Engineers (2009-2010), President of the European Federation of Chemical Engineering (2010-2014) and a current member of the World Chemical Engineering Council.

We are very actively engaged with the **Royal Academy of Engineering**: **Prof. Guy Houlsby** was a member of Research and Secondment Committee (2009-12); **Prof. Lionel Tarassenko** is on the Engineering Policy Committee, **Prof. Alison Noble** on the External Affairs and Enterprise Committees, **Prof. Tony Wilson** on the Membership Committee; **Prof. Richard Darton** on the MacRobert Award Committee and **Dr Eleanor Stride** sat on the Research Review Panel (2012).

Our staff participate in the management of many leading journals, some examples are: **Prof. David Hills** is Editor-in-Chief of the International Journal of Solids Structures; **Prof. Richard Stone** is Editor of the Proceedings of the IMechE Part A: Journal of Power and Energy. Many staff are Associate Editors: **Dr Julia Schnabel** for IEEE Transactions on Medical Imaging; **Dr Martin Booth** for of Optics Express; **Prof. Robin Cleveland** for the Journal of the Acoustical Society of America; **Dr Antonis Papachristodoulou** for Automatica and IEEE Transactions on Automatic Control; and **Prof. Li He** for the ASME Journal of Turbomachinery and Aeronautical Journal; **Dr John Huber** is the UK Associate Editor for the European Journal of Mechanics – A Solids.

Many serve the global engineering community by organising international conferences and participating in peer-review grant evaluation at home and abroad – 19 are currently members of the EPSRC Peer Review College. **Prof. David Limebeer** sits on the ERC Starter and Consolidator Grants PE7 Panel. **Prof. Alan Cocks** is on the Royal Society UK Panel on Theoretical and Applied Mechanics and is a member of the Rolls-Royce Materials, Manufacturing and Structures Advisory Board. **Prof. Alexander Korsunsky** is a member of the EPSRC Strategic Advisory Team on Large Scale Facilities, Chair of the Diamond Light Source Science Advisory Committee and a member of the Science Advisory Committee at the European Synchrotron Radiation Facility.

We encourage staff to develop direct interactions with industry, and many staff undertake consulting activities through Oxford University Consulting, including the following examples:

- **Profs David Limebeer** and **Peter Ireland** are retained consultants, in control engineering and aerothermal technology respectively, for the Scuderia Ferrari motor racing team.
- **Prof. Constantin Coussios** is a consultant to spinout OrganOx, which undertook the first human trial of normothermic liver perfusion.
- **Prof. Guy Houlsby** advises E.ON and Atkins on offshore wind farm foundations, and **Dr Byron Byrne** is a consultant to Advanced Geomechanics, Cathie Associates, Nuon and Repsol Nuevas Energias UK, offering expertise on a variety of aspects of offshore geotechnical engineering for the oil and gas and renewable energy sector.
- **Dr Malcolm McCulloch** is a consultant to the Government of Maldives on pathways to carbon-neutral energy solutions and to Oxfordshire Low Carbon Hub.
- In the aerospace and turbomachinery sector, **Cocks, Gillespie, Hills, Ireland, Korsunsky, Nowell, Petrinic, Povey** and **Roberts** have all acted as consultants for Rolls-Royce Aerospace. Kam Chana and Paul Beard are consultants for Alstom Power on engine instrumentation, and Kam Chana is also a consultant to QinetiQ. **Prof Li He** is a consultant to Siemens, offering expertise in unsteady flow and fluid / structure interaction.

Above all, our Department recognises that engineering is a fast-evolving discipline, Collaboration with scientists, clinicians and industrial users, home and abroad, is essential to meet the needs of society. We are determined to lead and influence the development of engineering nationally and internationally, making a special contribution because of our commitment to the principles that underpin our approach to Engineering Science.