Institution: Oxford Brookes University

Unit of Assessment: 15

a. Overview

The UoA comprises staff from within the Department of Mechanical Engineering and Mathematical Sciences (MEMS), and the School of Architecture, which are both in the recently formed Faculty of Technology, Design and Environment. Research within MEMS is organised within three cross-cutting themes: Sustainable Engineering and Innovation; Advanced Engines, Propulsion and Vehicles; and, Simulation, Modelling and Systems Integration. The Architectural Engineering Research Group (which was not returned in this UoA in RAE2008) contains staff from both the School of Architecture and MEMS.

b. Research strategy

The 2008-2013 Strategy for this UoA (as described in the RAE2008 submission) focussed on achieving further increases in the quality of research and in external funding, and sought to capitalise on the:

a. Excellent research environment provided by the new Engineering building constructed for the UoA, and the associated good quality laboratories and equipment.
b. Networks and collaborations developed through knowledge transfer activities and HEIF funding.
c. Opportunities associated with the Motorsport Engineering Centre funded by SEEDA.

Specific strategic objectives were to:

1. Increase the number of post-doctoral researchers, and continue to actively recruit early-career academic research staff.
2. Increase the number of CASE industrial students through Faraday Advance, SEEDA and new academic appointments.
3. Initiate a Doctoral Engineering programme in motorsport technology through the Motorsport Engineering Centre.
4. Further expand collaborative research through, for example, Faraday Partnerships, the Materials KTN and the Motorsport Engineering Centre.
5. Increase the income from knowledge transfer activities (excluding research income) to £250k p.a. to support post-doc and research technician appointments.
6. Develop major 'breakthrough' projects with the automotive industry, in novel and fuel-efficient engine design, and in hybrid vehicle power-plants and lightweight autobodies;
7. Develop leadership in end-of-life vehicle issues and materials sustainability and build upon the success of DRIVENet by creating a new *Sustainable Transport Engineering Group* to tackle economic, environmental, legislative and technical issues.

These objectives have been realised with notable advancement being achieved across a wide range of areas. At the last RAE, 13 staff (12.2FTE) were submitted to this UoA. Since then one member of staff has left to pursue another career, one has reduced their fraction from 1.0 FTE to 0.5 FTE, and one is being returned in another UoA (a reduction of 1.8 FTE overall). Despite this the number of staff returned to the REF has significantly increased. 27 staff (25.9 FTE) are being returned including five early career researchers. This reflects a strategy for growth that includes a positive commitment to early career research posts.

During this REF period, the UoA has funded 11 post-doctoral researchers (PI in brackets) in the areas of: Risk and Reliability (Marie Curie Fellowship) (**Todinov)**, Joining Technology (EPSRC) (**Hutchinson, Broughton)**, Structural-Acoustic Modelling (**Morrey**), Stress Analysis and Materials (**Fellows**), Advanced Engines (**Samuel)**, Slender Structures (**Beale**), Vehicle Dynamics (Leverhulme) (**Morrey**), Life Cycle Analysis (EPSRC) (**Morrey**), Sustainable Engineering (**Hutchinson**) and Architectural Engineering (**Ogden**). Two of these posts are permanent and are part-funded through income from knowledge transfer activities.

The UoA was successful in securing industrially funded PhD students during the period from various companies including Honda, Jaguar Land Rover, Texas Instruments, Tata Steel, Calex, and Norbar Torque Tools.

Morrey submitted a joint bid to EPSRC with Oxford University, to establish a Centre for Doctoral Training in Reducing End-use Energy in Transport. The bid built on the strong activity with the Automotive/Motorsport Industry, and was supported by 17 letters of industrial support, two from F1 Teams. The bid was not successful but collaborations are underway to fund this activity from other sources.

In 2008, the Sustainable Vehicle Engineering Centre (SVEC) was established. Examples of 'major breakthrough' projects are the flagship £6.4m TSB-supported MINI E project, the eight partner, £5m, four year, EPSRC project supporting the TSB low carbon vehicles innovation platform, 'Towards Affordable, Closed-Loop Recyclable Future Low Carbon Vehicle Structures' (TARF-LCV), and a project with Transport for London on the monitoring and modelling of hybrid buses in London.

The majority of active projects are collaborative, including the six partner TSB MiTRE project to develop a lightweight micro-turbine range extender (**Samuel**), the seven partner TSB Durastor project to develop a hydrogen storage vessel (**Hutchinson)**, the eight partner EPSRC TARF-LCV project (**Hutchinson**), the five partner EPSRC WISE-PV project (**Hayatleh**), the seventeen partner EU project MARS EV (Materials for Ageing Resistant Li-ion High Energy Storage) (**Winfield)** and the EU project TABASCO (Thermal Optimisation of Building Details) (**Ogden**).

The 2013-20 strategy for the UoA has the following objectives, to:

1. Further increase and diversify the funding portfolio, including that for collaborative research, by building on the strengths of the Sustainable Vehicle Engineering Centre and the reputation of the UoA in the areas of Motorsport Engineering and Architectural Engineering.
2. Increase the number of industrially funded PhD studentships through the UoA's strong network of industrial partnerships.
3. Maximise impact generated from research, and capture the benefits and outcomes particularly in the areas of Sustainable Mobility, Biomedical Instrumentation and Imaging, and Lightweight Structures;
4. Establish a collaborative Doctoral Training Centre in the area of energy reduction in transport, with a particular focus on high performance and motorsport engineering.
5. Continue to increase the number of post-doctoral researchers, and actively recruit early-career academic research staff.
6. Further expand collaborative research through engagement with initiatives such as Horizon 2020 and the TSB Catapult Centres.
7. Sustain and diversify income from knowledge transfer activities.
8. Establish additional collaborations with high quality overseas institutions, and support joint research student training and exchange.
9. Engage in further major 'breakthrough' projects, with the automotive and motorsport industry, particularly in the areas of hybrid vehicle power-plants, end-of-life vehicle issues, materials sustainability and vehicle dynamics.

c. People, including:

i. Staffing strategy and staff development

UoA strategic leadership is provided by a Research Lead based in MEMS, Prof **Morrey**. The Research Lead chairs the departmental Research and Knowledge Exchange Committee, which meets twice a semester. Research Theme Leads are members of the committee, and champion research within the themes.

At departmental level, individual researchers are allocated dedicated research time through a workload planning system, and supported by staff development funding (e.g. for research training). Staff prepare individual research plans (detailing their proposed research activities for a 3 – 5 year

period). These are monitored as part of an annual cycle of Personal Development Reviews and through regular progress meetings with the Research Lead. Externally funded research projects can, subject to workload planning approval, be used to increase the proportion of time spent by individuals on research and knowledge transfer activities. The University also operates a 'Central Research Fund' of around £800k-£1m per year which can be used to support projects with staff development goals as can QR funds from within the UoA. Examples of this latter use of QR are two awards of £12k given to **Knowles** and **Chidlow**, to fund MSc by Research projects, and a PhD Bursary awarded to **Bonatesta** (all ECRs).

The University provides support in the preparation of bids and research contracts, through the Research and Business Development Office (RBDO), and the Faculty's Research support team. During the census period, central funding has supported a specific Research Funding Officer for Mechanical Engineering and a Business Manager for Science and Technology (both based in RBDO). The Faculty has a Grant Panel, aimed at enhancing the quality of submitted proposals. All Research Leads are members of the Panel, and act as mentors to bid writers, along with other senior staff. Workload time is allocated for these roles. As an example, **Morrey** has recently acted as mentor to **Bonatesta**, in the preparation of his EPSRC First Grant application.

In terms of 'researcher development' the Faculty has instituted a 'Next 10' programme in Autumn 2012. This was a competitive call to allocate additional resource, senior mentoring and an associated PhD studentship (value £30k), to increase the personal research capacity of mid-career research staff. Of five successful bids in the Faculty, two were awarded to the UoA (**Broughton** and **Sebu)**.

The staff returned within the UoA are organised within three themes and one interdisciplinary research group as described below. Each has a lead and research students (numbers cited at the census date):

- **Sustainable Engineering and Innovation (SEI). Dr Broughton (Theme Lead and Head of the Joining Technology Research Centre (JTRC)); Prof Hutchinson (Head of the Sustainable Vehicle Engineering Centre (SVEC)); Dr Winfield (Deputy Head of SVEC); Prof Audebert; Prof Todinov**; **Dr Neighbour**; **Dr Raugei;** three other academics, two postgraduate research assistants and research students.
- **Advanced Engines, Propulsion and Vehicles (AEPV)**. **Dr Samuel (Theme lead); Prof Morrey; Dr Bonatesta; Dr Knowles; Dr Rhys-Tyler; Dr Thite.** Four other academics and research students.
- **Simulation, Modelling and Systems Integration (SMSI). Dr Fellows (Theme Lead); Prof Durodola; Prof Fitt; Prof Lidgey; Dr Bijura; Dr Chidlow; Dr Hayatleh; Dr Neves; Dr Oskrochi; Dr Sebu.** one other academic and research students.
- **Architectural Engineering (AE). Prof Ogden (Group Lead); Dr Beale; Dr Godley; Dr Wang.** Three other members of academic staff, one postgraduate research assistant and research students.

The themes are aimed at encouraging interdisciplinary research and addressing key issues of global external significance, building on the UoA's history as a strong externally-facing entity. Although individual staff members belong principally to one of the themes, the structure is matrix-based. Staff work across themes, according to their interests and expertise. For example both **Hayatleh** (SMSI theme) and **Raugei** (SEI theme) are involved in the recently awarded £1.4m EPSRC grant (EP/K022229/1) 'Whole System Impacts and Socio-Economics of Wide-Scale PV Integration' (WISE-PV).

ii. **Research students**

Research students have personal desk space, an individual networked personal computer, and access to dedicated research laboratories. Training for research students is provided at University and departmental level. Research students are given a full induction covering policies, procedures and health and safety, on commencement of their studies. A Postgraduate Tutor is responsible for

overseeing recruitment, induction, registration, monitoring of progress, and examinations. Administrative support for these processes is provided by the Faculty and the Graduate Office.

The UoA runs regular seminars for research students. Training includes research methods; thesis planning, preparation and writing; and formal procedural requirements such as registration, transfer and examination procedures. Students are encouraged and supported by their supervisory teams to publish in journals and to attend relevant conferences (funds are available for them to bid into in support of conference attendance) both to support their studies and their research career development.

Students are also supported to acquire specialist skills and competencies particular to their chosen field of study (such as use of software packages). They are required to attend a postgraduate Research Study Methods module which covers matters including library access, technical writing, plagiarism, risk management, social, legal and ethical issues, and presentation skills.

All research students are members of the Graduate College which is led by the P-VC Research and Knowledge Exchange. The College is student focused and oversees all matters related to the programmes and student experience.

The progress of all research students is monitored through interviews by a panel comprising two Post-Graduate Research Tutors and the Departmental Research Lead. These interviews take place at the time of submission of registrations and transfer applications, and also at the annual progress review where a written report is submitted (students in the 3rd year of their studies are required to submit two or three draft chapters from their thesis).

d. Income, infrastructure and facilities

Within the **Sustainable Engineering and Innovation Theme** eight different strands of research are undertaken:

Adhesion and adhesives research: includes (i) theoretical/experimental validation of novel joint design and adhesive bonding concepts for high performance joints (**Hutchinson, 8096, 9011, Broughton, 7144, 8033, 7521**) (ii) de-bonding techniques and the engineering performance of structures assembled with releasable adhesives/primers for automotive/aerospace applications (**Hutchinson, 7990**) (DTA studentship) , (iii) bonding of timber (**Winfield, 8088**), (v) development of rapid assembly joining technology [£140k KTP project KTP008914, 2012-2014].

Construction industry research: An examination of the durability of timber bonds and design rules for bonded metallic rods in repairs has included the development of a novel durability test rig for bonded-in rods and participation in the latest COST action FP1004 on bonding timber (**Broughton, 7714**). Sustainable bike frame technology (Bamboo Bike) has been developed, resulting in the first EN Certified (Certificate ALC P: 135841 : 0611/ S1) UK bamboo mountain bike, licensed to manufacture by Raw Bamboo (including Patent WO 2013/017872A1).

Automotive industry research: A CASE PhD studentship with Jaguar Land Rover (**Hutchinson)** investigated the behaviour of bonded joints in aluminium autobody structures under high strain rates for use with FE analysis (**Hutchinson, 8096**). A £142k TSB funded KTP [KTP008367, 2011-2013] project with YASA Motors (**Broughton**) was aimed at the development of sustainable joining technologies for a high volume low mass, high energy density electric motor. This has led to the funding of a follow on KTP project, the development of the next generation YASA electric motor for step change in performance through innovative thermal management (£160k KTP009161), which is about to start.

Aerospace industry research: **Broughton** received £1.4m TSB funding for the ACTS Project [TP/8/MAT/6/I/Q1505D, 2007-2011], in collaboration with Airbus UK, Bentley Motors, and Network Rail, continuing work on the development of a novel composite node for 3D truss structures. Consultancy and contract testing work carried out by JTRC (**Broughton**) generates around £ 50k per annum, which allows investment to support ongoing research in this area.

Energy and sustainability assessment research: A methodology for sustainable vehicle design, to enable evaluation of whole life energy, including different forms of drive-train, materials, processes and recycling techniques was reviewed by British Petroleum and published in 2012 (**Winfield,**

8608). A £140k TSB funded KTP project (KTP007523, graded outstanding) with Stannah Stairlifts (**Winfield**) examined whole life energy use and emissions from manufacturing, distribution, installation and de-commissioning. The DURASTOR £2m TSB multi-partner project (BH063L) including EPL, MERL, CTG, Crompton, Delta Motorsport, involved the design, development and whole-life assessment of a novel thermoplastic hydrogen storage vessel (**Hutchinson**).

A £44k TSB-supported feasibility study (130711) was undertaken by **Winfield** in conjunction with Axeon on the potential for a UK-based battery recycling centre. The recently awarded £6.6m EU MARS-EV (NMPS-LA-2013-609201) project (**Winfield**) will allow further development of end-of-life recycling techniques and business models for Li-ion batteries in a 17-partner project. **Hayatleh** has recently received an award from EPSRC (with Manchester, Sheffield and Loughborough) (£ 1.4M EP/K022229/1) to investigate Whole System Impacts and Socio-Economics of Wide-Scale Photo-voltaic Integration (WISE-PV). This work is further supported by the recent appointment of **Raugei**, who has worked on the theoretical improvement of existing methods for the net energy analysis and environmental assessment of renewable energy systems (**Raugei, 8609**, **8610** and **8611**).

A Leverhulme Trust award *(F/00 382/J,* 2009-2013, £91k, **Todinov**), built on earlier work on risk-based reliability analysis, and has led to the creation of theories of repairable flow networks and networks with disturbed flows (**Todinov, 6624**). A £30k British Petroleum funded project developed high-speed algorithms for the output flow in stochastic flow networks with tree topology (**Todinov, 7286**). These have since been incorporated in BP's simulations of the availability of their oil and gas production systems. **Todinov** has carried out work on the Weibull distribution for the probability of failure of brittle materials, proposing a new model, in collaboration with the HSE (**Todinov, 7222, 7941**).

Work conducted for British Energy Generation Ltd by **Neighbour** (**8622, 8623**) tackled sustainable and damage tolerant Reactor designs through the generation of complex 3D finite element models. This work has provided British Energy and Magnox with evidence to support life extension and higher confidence to underwrite the empirical relationships used in Statutory Safety Cases. A decision-making tool for material selection based on environmental factors was developed (**Neighbour, 8831**), and dysfunctional elements in the design process highlighted by neglecting sustainability as a functional requirement **(Neighbour, 8624**).

Vehicle light-weighting and design for disassembly research: **Hutchinson** has received funding as part of an eight partner, £5m, four year, EPSRC project supporting the TSB low carbon vehicles innovation platform (TARF-LCV). The research focuses on: (i) bonded joint design and disassembly concepts, and (ii) whole life assessments of the new manufacturing, materials and vehicle design concepts. Research has been undertaken on 'disbond-on-demand' adhesives using thermally-labile functional additives through a DTA studentship (**Winfield**, **7422, Hutchinson, 7990**). £30k of consultancy work has also been undertaken directly for General Motors by **Winfield** on this topic.

Electric vehicle (EV) and e-mobility research: Work undertaken by **Hutchinson** has focussed on energy requirements for electric vehicles (**Hutchinson, 8062)**. **Hutchinson** received funding as BMW's academic partner in the TSB-supported £6m MINI E project (BF045J) to engage in real-life trials to examine vehicle energy use and driver experiences. In the £700k EU Power Programme (INTERREG IVC) E-Mobility Accelerator project (**Hutchinson)**, business cases were developed for regions in UK, Holland, Sweden, Poland and Spain and these were show-cased as six short videos [http://bit.ly/nhgW6Z] for the UKTI. In the EU Atlantic Fund programme (2011-1/153), the BATTERIE project, involving seventeen partners across five countries, the intermodality implications for e-mobility are being explored through pilot studies that integrate road, rail, sea and air travel.

High strength nanostructured Al alloys for automotive and aeronautic applications: The studies of the molecular local order in rapid solidified Al alloys carried out by **Audebert** have led him to develop nanoquasicrystalline Al alloys for high temperature applications such as aerospace engines for improved efficiency (**Audebert, 9119**). A patent for using these alloys for producing "Metal Matrix Composite Material" (WO-2008050099-A1) was obtained jointly with the University

of Oxford (2008). Further studies confirmed the predicted stability and high strength at elevated temperature, five times higher than that of conventional Al alloys (**Audebert, 9120, 9121**). Recently, as a step toward industrial production the alloys have been produced at intermediate manufacturing scale (**Audebert, 9122**).

The **Advanced Engines, Propulsion and Vehicles** theme has four main areas of research:
Emission and Fuel economy research has focussed on the experimental investigation into particulate matter from Gasoline Direct Injected engines supported by BMW, Oxford (**Samuel, 7729, 7687**). **Samuel** has also received support from Ferrari for a PhD studentship (in collaboration with University College Dublin) in the area of nano-scale particulate matter. The outcomes published (**Samuel, 7600, 8553**) were directly utilised by Ferrari for the calibration of one of their recent vehicles. Combustion rates and duration were investigated experimentally in pent-roof spark-ignition engines by **Bonatesta**, in association with Jaguar UK. An innovative non-intrusive sampling system was used to determine the in-cylinder charge make-up (**Bonatesta, 8061**), and the investigation led to the development of a set of empirical correlations, which allow modelling of combustion using the Wiebe function approach (**Bonatesta, 7978**). **Samuel** has received funding from Transport for London and WSP (£42k) for an ongoing study to evaluate the fuel economy performance of Hybrid Buses in London. **Samuel** is a partner in the TSB IDP7 MiTRE project (£1.6M) with the responsibility for the design and testing of a low emission combustor for a prototype Microturbine range extender.

This group has received equipment donations from BMW, including new BMW Mini engines and a Full Vehicle emission bench with CVS system (value £200k) for vehicle emissions research. AVL, UK has donated an advanced combustion analysis system, and Gas exchange and combustion analysis software (value £56k) to evaluate combustion concepts for future engines.

Remote sensing and Air quality: The London Borough of Ealing and City of London Corporation provided DEFRA grant funding to **Rhys-Tyler** to implement roadside remote sensing surveys to measure pollutants in vehicle exhaust emissions, using absorption spectroscopy techniques. This work was informed significantly by previous findings (**Rhys-Tyler, 9070, 9071**). This has provided a crucial evidence base for government to inform future policy interventions to mitigate the nitrogen dioxide pollution problem. This has resulted in follow-on funding for Ealing from DEFRA for **Rhys-Tyler** to quantify time related changes in vehicle emissions, and to characterise the relationship between exhaust emissions and engine load.

Vibro-acoustics: This work has focussed on a) the development of SEA-like methods (**Thite, 7629)**, and b) combining boundary element and finite element methods to model vibro-acoustics of waveguides (**Thite, 8279)**. This work underpinned the MIDEA EU-project, undertaken by Southampton University, and the EPSRC project on Bayesian estimation of mid-frequency parameters was originally submitted by **Thite.**

Work undertaken as part of an earlier EPSRC project (GR/S27245/01) in collaboration with Ford, BI Composites, MIRA and Crompton Technology Group, focussed on the NVH performance of novel composite roof structures. Methods were developed for enhanced and efficient modelling of the structural-acoustic behaviour of the interior body cavity using model order reduction methods (**Morrey, 7902, 8604**), as well as optimised bonded joint geometries (**Hutchinson, 9011**). The structural-acoustic modelling was extended through a collaboration with Freiburg University and Adelaide University, and applied to a strongly-coupled ABAQUS benchmark problem (**Morrey, 8655**). Siemens Hydropower have used the techniques to model a hydropower turbine. Composite panel stacking-sequence optimisation for structural-acoustic behaviour was also undertaken (**Morrey, 7797**). The matrices developed as part of these simulations are part of the University of Florida Sparse Matrix collection.

Vehicle dynamics: Integrated biomechanical and vehicle system dynamic models have been developed to predict discomfort in vehicles, with parameters estimated using an elegant matrix inversion approach (**Thite, 7762**). Statistical approaches have been used to experimentally identify complex noise problems of vehicle suspension systems (**Thite, 7098**). Aircraft landing gear models

have been developed to investigate dynamic behaviour of a landing gear extension/retraction process (**Knowles, 8613)** in collaboration with the University of Auckland and Airbus.

Morrey supervised a PhD studentship funded by Honda, on the determination of vehicle dynamics parameters using a four post rig. A recently awarded £95k PhD studentship, funded by Norbar Torque Tools (**Morrey**), is focussed on dynamics and material optimisation for heavy-duty torque multipliers. A Leverhulme Fellowship (£32k) is working with **Morrey** on modelling for race car simulators in collaboration with Wirth Research. The group has a Multimatic four post rig (value £600k), and this is regularly used to carry out consultancy and contract research to test the vehicle dynamics of road and high performance vehicles.

The **Simulation, Modelling and Systems Integration** theme covers research within four areas:
Biomedical Imaging and Instrumentation: Calex Electronics Ltd and the 1851 Royal Commission provided funding (£90k, **Hayatleh**)) to develop of a non-contacting infra-red (IR) temperature sensor (**Hayatleh**, **7988**). The sensor is now in production (Patent held by Calex no. GB2476040). Texas instruments UK Ltd, Northants, funded a PhD studentship (£130k) with **Hayatleh** to develop high-speed inter-computer communication electronics.

Recent work on Electrical Impedance Tomography has focussed on the development of a novel non-iterative method, to enable rapid reconstructions in real-time monitoring in medicine (**Sebu, 7769**). A Daphne Jackson Postdoctoral research Fellow, partially funded by EPSRC (£36k), is working on Electrical Impedance Mammography (**Sebu**). (**Oskrochi**, **7228, 6299**) has employed a novel two stage mixed modelling approach to find the optimal solution to maximise the likelihood of high dimensional data, and applied this to three dimensional scapulothoracic motions of treated Breast cancer patients.

Stress and Materials: An EPSRC funded studentship (in collaboration with Instituto Politécnico Nacional in Mexico) applied artificial neural networks to the interpretation of signals during ultrasonic non-destructive evaluation (**Durodola, 8107**). Optimisation methods to determine forming loads, in spite of material springback problems (**Durodola, 7709**), were developed through a Mexican government funded PhD studentship. Stress intensity factors and crack growth rates in silicon carbide metal matrix composites were investigated with sponsorship from CONACyT (Mexican government) and Rolls Royce Ltd (**Fellows, 7982**). Research on bearing versus bypass failure in carbon composite bolted joints was carried out, sponsored by CONACyT and Airbus (UK) Ltd (**Fellows, 7794, 8090**). An investigation into the adhesive contact between an elastic stamp and an inhomogeneous elastic solid was funded by EPSRC in collaboration with Aston Martin (**Chidlow, 9008**).

Two TSB funded KTP projects, with Ice Energy Ltd (**Fellows**, £117k, DTI KTP6458) to develop novel ground source heat collector systems, and with Stockbridge Racing (Willans) (**Fellows**, £138k, DTI KTP8800) to develop motorsport vehicle fire extinguishant systems, produced new company products. Consultancy and contract testing work of £30-40K per annum is carried out with local companies, including Siemens Magnet Technology and Oxford PharmaGenesis.

Modelling and Analysis: The high dimensional data analysis technique has been used to compare fractal dimensions with perceptions of visual quality in street vistas (**Oskrochi**, **7876**); and to explore the relationship between leadership skills and a range of critical factors (**Oskrochi**, **7567**). Investigation of solutions of linear and non-linear systems of singularly perturbed fractional integral (and differential) equations has been conducted (**Bijura, 7910, 6584**). The development of mathematical models by **Fitt** to predict the flow of polluting thin molten glasses during glass manufacture has been implemented into Pilkington's code calculations (**Fitt**, **8616**, **8617**). Experimental testing has also shown excellent agreement with a mathematical model to predict glass fibre drawing with preform rotation (**Fitt**, **9013**). **Fitt** has shown mathematically and experimentally that motion decay in MEMS visocometers, used in the oil industry, decays algebraically and not exponentially as previously believed in the industry (**Fitt**, **8618**).

Intelligent Transport Systems: **Fellows** is the programme manager for a University multi-

disciplinary Doctoral Training Programme in Intelligent Transport Systems, developing an autonomous off-road vehicle.

The **Architectural Engineering Group** has been supported by significant investment in infrastructure including the construction of a new test facility for building cladding and structural components (value £1.5million) and investment in both building simulation modelling facilities and physical testing/monitoring capabilities (circa £200K).

The group is a strategic research partner of Tata Steel Europe with a major recurring annual research partnership (the baseline for which is currently £110K pa., £500K since 2008, and £1.2million since commencement in 2002). The group has major EU funded projects including Floodprobe (preservation of critical built infrastructure in flood scenarios), TABASCO (Thermal Optimisation of Building Details) and BATIMAS (Fabric Thermal Storage Systems), with other significant EU projects completed since 2008 including ROBUST (Thermal Renovation of Buildings). The combined value of EU projects is approximately £750K. The group maintains a dedicated strictures and building physics laboratory used both for research and to meet the development needs of the light steel, scaffold and off-site construction sectors. This is operating at full capacity with an annual turnover circa £200K.

Areas of research activity include: the development of vacuum and high performance insulation systems, building performance simulation using advanced computational techniques (**Ogden, 7617**), structural performance of light steel frames and light steel building cladding systems (**Ogden, 7812, 7560, 8649**), design and performance of scaffold and racking systems (**Beale, 7913, 8134, and Godley, 9123**), flood resilience of buildings, high performance transpired solar collectors, effective use of fabric thermal storage in buildings, low carbon building technology and combined operational /embodied energy analysis for minimum carbon standards (**Wang, 7971, 8650**). Specialist testing and research into the behaviour of scaffolding systems (**Beale, 7609, 8533**) also led to **Godley**'s membership of BS EN12811 technical committee which produced a series of Euronorms for scaffolding systems and components, and his authorship of the NASC design guide for access scaffolding. This design guide is now the basis for all access scaffolding design in the UK. The latest research into wind effects on scaffolding (**Godley, 9123**) has been used by the National Access and Scaffolding Confederation to produce a further revision of this design guide.

The group has obtained a contract from the Portuguese Research Council (*Fundação para a Ciência e a Tecnologia*) in conjunction with the National Civil Engineering Laboratory in Lisbonto determine revised risk analysis procedures for bridge scaffolding (**Beale**, £90k).

e. Collaboration or contribution to the discipline or research base

Within **the Sustainable Engineering and Innovation theme**, there are two established industry-facing Centres, the Joining Technology Research Centre (JTRC), and the Sustainable Vehicle Engineering Centre (SVEC). JTRC remains the principal UK construction test house for adhesive and composite materials (test protocols from www.brookes.ac.uk/jtrc). This and associated work led to the publication of several guidance documents for strengthening of existing structures including ICE Manual of Construction Materials (2009), TR55 (2012) and Construction Materials Reference Book (2013) (**Broughton, Hutchinson**).

SVEC's contribution to the industrial research base has been through the IOMMM Sustainable Materials committee work, SAE committee work on airbag safety and deployment, SMMT EV Group inputs to policy and reports (eg Electric Vehicle Guide 2011) and collaborative projects. International associations are held with academic colleagues and industrial partners across Europe, including BMW, Bentley Motors, Jaguar Land Rover, Network Rail, YASA Motors, Fibreline, Lisbon University and Sika (**Hutchinson, Winfield**).

Raugei has worked with the Brookhaven National Laboratory in the USA and the UNESCO Chair in Life Cycle and Climate Change in Spain working on Life Cycle Analysis of CdTe photovoltaic systems (**Raugei**, **8612**). **Raugei** is an Invited Visiting Scientist at Columbia University, USA. In

recognition of the industrial interest in the whole industrial chain for nanomaterial applications **Audebert** was awarded with the "*Pedro Vicien Medal*" by the National Academy of Science of Buenos Aires (2008) and the "*Roberto Cunningham Prize*" as Technology Leader by FUNPRECIT Foundation, Argentina (2012).

The Advanced Engines, Propulsion and Vehicles Theme maintains strong links with major automotive manufacturers (BMW, Jaguar, Honda, Ford), and motorsport companies (Lotus F1, Williams F1, Marussia F1, Prodrive, Swindon Engines, Delta Motorsport and Wirth Research), resulting in consultancy and equipment donations, and collaborative projects (**Samuel, Morrey, Bonatesta**). **Rhys-Tyler** has developed a collaboration with King's College London, resulting in the production of key publications for national air quality policy.

The Simulation, Modelling and Systems Integration Theme
Sebu has an ongoing collaboration with the University of Mainz which has generated two reconstruction methods to be used for conductivity imaging for a planar EIT device for breast cancer detection (**Sebu, 7659, 6732**). (**Sebu, 7900**) is the result of an interdisciplinary collaboration with Ciulli (Montpellier) and identified for the first time, potential accretions of dark matter around the stable Lagrange points of large planets in our solar system.

Hayatleh has a strong collaboration with the Bio-inspired Technology Centre at Imperial College, working on biomedical electronics, specifically ISFET sensors applications including bionic chemical synapse and rapid DNA sequencing (**Hayatleh, 8093**), measurement of urea and creatinine with an enzyme based chemical current conveyor ((**Hayatleh, 7627**) and buffer index/capacity measurements (**Lidgey, 8009**). **Hayatleh** and **Lidgey** are visiting researchers at Imperial College, London. Work on current feedback operational amplifier (CFOA) designs have arisen from an ongoing collaboration with Elantec Inc, USA, including analysis of the input stage of the CFOA (**Hayatleh, 8109**).

Durodola is a visiting Fellow at IPN, Mexico. **Neves** has carried out work on the characterisation and testing of functionally graded materials, in collaboration with Politecnito di Torino, Italy and the University of Porto, Portugal (**Neves, 9236**). **Oskrochi** collaborates with Liverpool University, the University of Gloucestershire, JR Hospital Oxford, Medical University Rotterdam, and the Medical School at University of Cape Town.

The Architectural Engineering Group has had 2 sponsored chairs (**Ogden**) in place throughout the census period: Tata Steel Europe Chair of the Building Envelope, and the Steel construction Institute Chair of Architectural Technology**. Ogden** was chair of the Scientific Committee of the International Vacuum Insulation Symposium from 2009 to 2011.**Ogden** and **Wang** received the Howard Medal from the Institution of Civil Engineers for their paper '*VIP and their applications in buildings: a review*' in October 2008.

The group has three visiting Professors. Bernd Doring of Fachhochschule University of Applied sciences, Markus Kuhnhenne of RWTH University (both in Aachen, Germany), and Nicholas Whitehouse MBE. The former two are highly regarded academics whose work is the closest international comparator of that of the Architectural Engineering Group. Nicholas **Whitehouse** is one of the foremost UK authorities in the field of off-site construction and a regular advisor to Government, industry and sector bodies such as Buildoffsite.

Editorial Positions
Editor of Carbon, Elsevier (**Neighbour**), Associate Editor: International Journal of Electronics and communications, Journal of Circuits, Systems, and Computers (**Hayatleh**).

Editorial Board Members: Journal of Analog Integrated Circuits and Signal Processing (**Lidgey**), ISRN Applied Mathematics (**Durodola**), International Journal of Adhesion and Adhesives (**Broughton**), Journal of Environmental Accounting and Management (**Raugei**), Advances in Mechanical Engineering (**Thite**), International Journal of Performability Engineering (**Todinov**).