Institution: Newcastle University

Unit of Assessment: UoA 13 Electrical and Electronic Engineering, Metallurgy and Materials

a. Overview

Expertise in the School of Electrical and Electronic Engineering (EEE) ranges from electrical machines to nanotechnology and encompasses significant inter-disciplinary research. Academics belong to one of four Research Groups: Communications, Sensors and Signal Processing (CSSP: **Boussakta, Ding, Dlay, Neasham, Sharif, Tian, Tsimenidis, Woo**), Emerging Technology and Materials (ETM: **Briddon, Cowern, Goss, Horsfall, Olsen, O'Neill, Wright**), Microsystems (µSys: **Degenaar, Mokhov, Nazarpour, Yakovlev**) and Power Electronics, Drives and Machines (PEDM: **Armstrong, D Atkinson, G Atkinson, Baker, Cao, Dahidah, Gadoue, Mecrow, Pickert, Taylor, Wade, Widmer, Zahawi**).

b. Research strategy

The UoA's vision of "research excellence with purpose" is achieved by a strategy that seeks to meet societal challenges with a continuous improvement of unique strengths. We lead the Newcastle Institute for Research on Sustainability, NIReS (**Taylor**), our Faculty's Societal Challenge Theme. Our strategy to grow biomedical engineering research supports the Medical Faculty Societal Challenge Theme of Changing Age, while digital systems research supports the Humanities Faculty Societal Challenge Theme of Social Renewal. Regarding continuous improvement, we lead the University Research Centre for Nano Science and Technology, nanoLAB (**O'Neill**), which has housed the UK national facility for XPS since 2012 and received £3M from the EPSRC Great Technologies Advanced Materials Capital Bid in 2013; we have raised and invested well over £3M in dedicated facilities for electric drives; the Sensors, Electromagnetics and Acoustics Lab (SEALAB) and recently awarded Neptune National Centre for Subsea and Offshore Engineering represent >£9M investment for electronic systems within extreme environments.

It is our strategy to focus research around four areas of strength, which consolidates our expertise as evidenced by the following highlights since 2008:

- **CSSP** has been creating new algorithms and techniques for wireless communications and signal processing which have led to a reduction beyond well-known limits for Bit Error Rate (by 10x), Peak-to-Average Power Ratio (by 3x) and complexity (IEEE Trans Sig Proc **59** 5994 (2011)). Additionally, we have devised key communication methodologies for hostile underwater and through-metal channels (e.g. 1 Mbit/s through 8cm metal), which resulted in a spin off device for cheap medical ultrasound (IEEE Trans Ind Elec **58** 4972 (2011)). Our eddy current pulsed thermography was subsequently used commercially by Rolls Royce in Malaysia, India and China (Appl Phys Lett **103** 084104 (2013)). New pathways for artificially simulated human stereo hearing have led to performances gains 3x better for signal separation accuracy and 5x faster than state-of-the-art methods (IEEE Trans Neur Net & Learn Sys **23** 703 (2012)).
- **ETM** produced the world's first strained silicon heterojunction bipolar transistor, with 27x improved gain over conventional devices (IEEE Trans **ED 57** 1243 (2010)). A step change in the speed of quantum-mechanical materials modelling was achieved with 'basis set filtration', so first principles atomistic calculations may be performed as fast as semi-empirical methods (Phys RevB **80** 205104 (2009)). Our copper nanowire studies using a DNA template produced the first < 3nm diameter wires with true metallic copper properties (Langmuir **26**, 2068 (2010)). Furthermore, work on contact properties of graphene led to the first manufacturable contact technologies for high temperature graphene devices (Appl Phys Lett **99** 073506 (2011)).
- **µSYS** is developing new microprocessors and biomedical microsystems. We pioneered new patented concepts in energy modulated, clockless, digital computing with the world's first self-timed SRAM working down to 0.2V (J Low Power Electr **7** 274 (2011)) and a self-powered voltage sensor based on charge to digital conversion (IEEE JETCAS **3**, 35 (2013)). Advancing globally asynchronous and locally synchronous (GALS) systems design has led to 10x improvement in speed in many-core microprocessors manufactured by Intel and Oracle (IEEE J SSC **42** 550 (2008)). In tandem, we have pioneered the development of CMOS driven micro-

LED arrays for optogenetic neural stimulation, demonstrating a world first in the use of a microdevice for optical neural stimulation (J Neur Eng **7** 016004 (2010)).

- **PEDM** has demonstrated new power electronic and machine topologies and construction methods to increase torque density, power density and efficiency (IEEE Trans Ind App **45** 1460 (2012)). The group has recently extended to encompass a large Smart Grids and energy storage team. Our impact ranges from an ultra-high efficiency drive for solar aircraft to a kinetic energy recovery system (KERS) in a race winning Honda Zytek racing car (IEEE Trans Ind Elec **57** 457(2010)). We have also established a major Dyson Research Centre co-located with the PEDM group, with patented concepts now implemented in commercial products. Our research into network power flow has included looking at the effects of environmental conditions and real time rating estimation (IME J Power &Energy **223** 743 (2009)). Commercialisation of our research has also been undertaken by PM Power, GE, Northern PowerGrid, Siemens and Scottish Power.

Research is managed and supported within the School at a range of levels. Each Research Group meets on a fortnightly basis to agree priorities, identify new opportunities and discuss lab issues. Group leaders meet to discuss strategy and review progress with the Director of Research and the Head of School at monthly Research Committee meetings. The School also holds Research Away Days twice a year to review and revise our research strategy and direction. The Director of Research ultimately takes responsibility for the School's research, sitting on the School Executive Group with the Head of School, Director of Teaching, Director of Engagement and School Manager. The Director of Research also sits on the Faculty Research Committee, which provides a direct line to the central University Research Committee.

Our vision is for the UoA's research to be sustainable, relevant and of international standing. Our strategy is to attract, appoint and invest in highly research active staff. We recruit internationally in order to build strength in priority areas rather than replacing staff in the same field. Moreover, our strategy is to collaborate with world leaders in industry (Intel, Dyson) and academia (Cambridge, MIT, Princeton), participate in consortia and networks (NMI, SiNANO, eFutures) and to secure funding from many sources (EPSRC, TSB, EU, industry). Engagement with industry is vital to translate our research into commercial products and we have been successful in embedding staff and equipment from industry within the UoA (Dyson, CPI, Högänas). Going forward, success in new research initiatives already gives us secured funding of more than £20M over the next 7 years

Relationship to RAE 2008

We have met or exceeded our 2008 Research Strategy objectives in terms of impact and income:

1. *Industry interaction*: Has increased since 2008, with 11 Dyson, CPI and Högänas staff embedded in EEE. Industry research partners invested £4.6M support and included ARM, Intel, Raytheon, QinetiQ, Northern PowerGrid, UK Power Networks and Siemens.
2. *Nanoelectronics:* Has been strengthened through greater use of new EEE clean rooms for both electronics (e.g. EP/J010944) and biomedical devices (e.g.Wellcome/EPSRC CANDO, EP/K50340X). Two new members of staff (**Briddon, Goss**) have also transferred from another academic school at Newcastle University.
3. *Electric Drives Research*: Has grown since 2008 through the recruitment of 5 new academic staff, 18 RAs, and 37 current PhD students, with funding to the value of £8M (EU, TSB and EPSRC) in collaboration with the automotive and other industries. We lead research into advanced motor concepts and manufacturing methods and have worked with over 20 OEMs, Tier 1 and 2 suppliers. We lead the University's Greener Transport research theme, steering cross-cutting projects within this area.
4. *Electrical Energy research:* has expanded in renewables, energy management, smart grids and energy storage, achieved through 3 new appointments (**Baker, Taylor, Wade**) and many new research projects. e.g. the UK's largest Smart Grid project (Ofgen), and 2 EPSRC Grand Challenge projects, (£8.9M EP/I031650, EP/K002252).
5. *Biomedical research:* has expanded with 2 new EEE staff (**Degenaar, Nazarpour**) and grants worth over £15M. These projects have involved internal collaboration with the Institute for Ageing and Health (G1001828), Cell and Molecular Biosciences (BB/J020176) and Neuroscience (Wellcome/EPSRC, EP/K50340X, FP7 249867 , BB/F021127).
6. *Extreme environment research*: has been extended since 2008. This was achieved for SiC electronic systems and underwater communications with £2M regional funding, the £7M

Neptune National Centre and support from Raytheon, EPSRC (EP/I037660).
7. *Collaboration with Newcastle's School of Computer Science* has been extended with the appointment of a new lecturer (**Mokhov**) and several joint EPSRC grants totalling £2.5M in energy-aware computing, power-reliability-performance interplay, complex concurrent systems modelling, and elastic logic (EP/K001698, EP/I038551).
8. Science Central is a £50M investment led by EEE (**Taylor**) to attract and grow knowledge-intensive businesses. The 24 acre site will be the university's demonstration of urban sustainability.

Future Research Strategy

Our research focus over the next 10 years will expand on our achievements and concentrate on the following key areas:

- **Biomedical Engineering**: New academic staff with expertise in this area will help extend our research links with the University's Institute of Neuroscience. For example, through current projects in synthetic biology (BB/J020176) and electronic systems for healthy ageing (G1001828), neural stimulation and detection (EP/K028421) and a major new grant on optogenetic implants (Wellcome/EPSRC, EP/K50340X).
- **Sustainability:** The Science Central project will incorporate monitoring and control features to allow Smart Grid operation and research. This integrates electric vehicle charging infrastructure, energy storage, voltage control, low-carbon technologies and real-time monitoring. We will utilise our leadership of a key EPSRC Underpinning Power Electronics 'Drives' programme to be transformative in the field.
- **Digital Systems:** We will extend our research into embedded autonomous electronic systems, where traditional power sources are insufficient. We aim to reduce computation energy together with improving energy harvesting and storage, while maintaining reliability. We will conduct research into efficient ultra-low power algorithms for embedded devices with limited computational power.
- **Interface engineering and characterisation:** We will invest in materials growth and characterisation facilities to improve existing silicon based devices, investigate materials such as ferroelectrics to extend functionality in integrated circuits, and investigate devices exploiting materials engineered at a nanometer scale.
- **Hostile Environment Electronics**. The £7M Neptune National Centre for Subsea and Offshore Engineering will extend this work into the ocean environment by developing pressure tolerant electronics.
- **Wireless communications**: We will conduct research in enabling 5G technologies and develop advanced algorithms encompassing high data rate and seamless mobility within future wireless applications. These include new multicarrier and modulation schemes, network coding, massive MIMO, communications in extreme environments and underwater acoustics. We will build upon our current encryption and signal processing research to tackle the important and unsolved problem of how to process data in the encrypted domain.
- **Electric Drives:** New staff will investigate variable speed drives which offer increased functionality and may replace over 50% of all fixed speed motors within the next 30 years. Our research will also focus on new materials and devices; faster, more sophisticated controllers and advanced design and construction techniques. We will continue to lead research into new reluctance and permanent magnet motor concepts with increased speed, power and torque density, and implement radical new design techniques to realise ultra-high power dense DC/DC converters without increased switching losses.

c. People, including:

i. Staffing strategy and staff development

Staffing Strategy

The recruitment and retention of excellent staff forms a key part of our strategic plan. Although a number of senior research staff have retired since RAE 2008 (12), the School has recruited more new academics during the current REF period, including:

- **Neasham, Ding** to expand wireless communications, Network Coding and Large MIMO.
- **Briddon** and **Goss** to strengthen emerging technology and materials.

- **Atkinson, Cao, Dahidah, Gadoue** and **Widmer** to grow electric drives research.
- **Taylor, Wade** (bringing in 18 additional researchers) and **Baker** to make us one of the largest UK research centres for Smart Grid, Low Carbon and sustainability research .
- **Degenaar** and **Nazarpour** to build capacity in biomedical research.
- **Mokhov** to strengthen research collaboration with the School of Computing Science.

New research support administrators/managers have been appointed in groups as well as for the school.

We actively celebrate diversity and engage with the Newcastle Athena Swan (Scientific Women's Academic Network) Committee to ensure the maintenance and upgrading of our University Athena Swan award. Procedures ensure no discrimination on the basis of ethnicity, gender or creed, reflected in the international mix of staff and female research staff in a male-dominated discipline.

Staff exchanges internationally and with business are facilitated by our Industry Advisory Group and by promoting an active programme of exchange visits:
1. **Briddon** was Visiting Professor at Nantes, France; **O'Neill** was Visiting Professor at EPFL, Switzerland; **Yakovlev** was Visiting Professor at TU Vienna, Austria, **Degenaar** was a Visiting Professor at SEU University, Nanjing, China.
2. Leverhulme Visiting Professorships were awarded to J-P Raskin (UCL, Belgium) and A Sayed (UCLA); an RAE Distinguished Visitor Fellowship was awarded to A Jamalipour (Sydney).
3. Visiting Professors in EEE: 35 including D Robbins (CPI); R Kennel (T.U. Munich); J Kirtley (MIT); W Drury (Emerson); L Grant (Globoco); G Yin, Z Su (Sichuan, China), T He (NUAA, China); E Spooner (ex. OpenHydro); D Allen (ex Alstom), J Shen (Zhejiang, China), V. Poor (Princeton), P. Fan (Jiaotong University, China), C Balloner (Franhaufer). We also had 51 visiting fellows.

Staff Development
Our commitment to staff development is demonstrated by 3 internal RA promotions to Lecturer (**Mokhov, Atkinson, Nazarpour**), 3 promotions to Senior Lecturer (**Woo, Neasham, Goss**), 3 promotions to Reader (**Horsfall, Degenaar, Ding**), and 2 promotions to Professor (**Briddon, Pickert**) since RAE 2008. New staff follow an induction programme, introducing them to key staff, EEE procedures and the concordat. Regular meetings with line managers and Performance Development Reviews (PDR) help identify training needs and targets to enable career progression. The PDR includes a personal research plan, requiring mandatory setting of research targets (research outputs, funding applications, PhD completions) for all staff, with research group leaders also having group performance targets. Established staff are entitled to one semester of research leave every seven semesters, planned through the PDR.

Early career academics are given a light teaching load (<30 contact hours p.a.) and administrative duties, allowing them to focus on building their research portfolio. They have a senior academic (professor or group head) as mentor. The Director of Research and other senior staff give support for first grant applications. Staff are invited to self-nominate for an 8 month PI development programme provided by the university, focussing on research team leadership, people and project management, strategic planning, funding and research assessment. Funds are available from the school to attend important research conferences in addition to a start up account for consumable items and open access to all school laboratories and equipment, which has an on-line booking facility.

Career development opportunities are available to research active staff at all career stages within the School, University and beyond, according to need. For example, School research away days and Faculty-led workshops on pursuing commercialisation and research grant applications. The University's Staff Development Unit has a broad range of transferable skills training and academic leadership programmes. All staff are invited to monthly staff meetings and to apply for annual promotion. Staff are also encouraged to take up fellowships and secondments. Half of our staff have held fellowships or secondments: RCUK/EU (5), IET (5), Faculty fellowships (2), industrial secondments (2), and outgoing visiting professorships (4). This is achieved through our large portfolio of international and industrial collaborations. Our Industrial Advisory Group actively promotes staff exchange visits. For RAs, other career development opportunities following the Concordat include career development workshops, attending conferences, co-supervision of PhD students, managing labs and equipment, lecturing and leading research grants where this is allowed e.g. Leverhulme (**Vasilevskiy** – Senior RA) and TSB (**Widmer** – Principal RA). The success of our strategy is linked to the awarding of Faculty Research Fellowships (**Vasilevskiy, Mokhov, Sokolov**). Some of our former RAs have also progressed to senior appointments within the University (e.g. **Wright**, PVC Research and Innovation) and industry (e.g.

Clothier, Director of Motors & Power Systems, Dyson).

ii. Research students

Our research environment is enhanced by a large number of postgraduate research students. We have graduated 169 students over this REF period. In particular, we have been able to attract a large cohort of students with international scholarships, and industrially sponsored students through our strong industrial links. Our continuing ability to attract high quality students with scholarships/sponsorships to support them attests to our international reputation in PGR supervision and training.

Of particular note are our 21 industrially funded students during this REF period, resulting from our long history of successful industrial collaborations. Such studentships provide commercial experience and often lead to direct employment or enhanced career opportunities. These projects have been supported by companies such as Intel, BAE Systems, Raytheon UK, Dyson, Scottish Power, Siemens, Högänas, Parsons Brinkerhoff, and Northern PowerGrid. Furthermore, we have been able to attract a large cohort of Chinese and Middle Eastern students who have funding from their respective governments, or are supported via the Overseas Research Student (ORS) scheme. In particular, many of our Middle Eastern students are already academics in their home countries and are looking to upgrade their research capabilities via a PhD. Finally, we have supported UK students via our EPSRC Doctoral Training Award (DTA), and Doctoral Training Centre (DTC) in Power Electronics, Drives and Machines (16 students).

Recruitment and coordination of the research student cohort is managed centrally by a Director of Postgraduate Studies, who works closely with the Faculty on strategic issues such as quality and the student experience. We believe a good relationship between the student and the supervisory team is crucial to success. A high level of support is provided during the period of registration on a PhD programme, as set out in a work agreement between the student and their supervisors. Every PhD student is allocated at least 2 academic supervisors, who work with the student to produce an initial research proposal within the first 3 months and supervise their progress. University policy is to provide at least 10 formal meetings a year, however, our PhD students are encouraged to meet their supervisors more frequently. Additional support is also provided by other students and RAs who are working on related topics within the Research Group. The University provides generic research skills training and monitors the number of courses attended. Training credits are awarded for completion of these training modules and a minimum score is needed before students can proceed to further years of study. A panel comprising 2 other academic staff monitor progress throughout the PhD. This includes interviewing the student and reviewing progress reports.

The School holds an Annual Research Conference (ARC) which is organised and led by PhD students. The conference provides a platform for students to learn about current research in the School, as well as gaining experience in technical writing and presentation skills. The event also attracts keynote speakers and financial sponsorship from Intel, BAE Systems, Siemens, Imagination Technologies and the IET. First year students must present a poster, whereas students in the subsequent years of their studies must present a technical paper and a presentation. As an incentive, the School awards best-student prizes in designated categories.

A Research Student-Staff Committee meets regularly with key staff within the School, offering a direct route to raise concerns, or to discuss ideas for continuous improvement of the student experience. Minority groups are well represented and students from each Research Group are encouraged to attend. The Committee also organises a number of social events and team building activities such as football games and quiz nights. Our PhD students are also represented on the Faculty Student–Staff Committee.

d. Income, infrastructure and facilities

Continuing investment in world class facilities can be seen in our 4 Research Groups:

- **CSSP:** (i) Sensors, Electromagnetics and Acoustics Lab (SEALAB): £1 M invested in anechoic water tank calibrated hydrophones and high performance data acquisition systems; 3 remotely operated underwater vehicles for deployment of sonar/ comms devices; dedicated test rigs for mixed media (water, air, metal) communication channels.
  (ii) Non Destructive Evaluation Lab: pulsed eddy current scanner systems; pulsed magnetic flux leakage; eddy current pulsed thermography; Instron stress measurement and IR cameras;

(iii) Wireless Lab and Anechoic Chamber: £0.5 M invested in wireless sensor nodes ; MIMO signal generators and synchronisation units; vector analysers for 3/4G and WLAN/WPAN comms broadband horns for antenna characterisation; automated waveguide scanner.

- **ETM:** Fabrication facilities include two class 1000 clean rooms, housing a 200 mm cluster tool for Atomic Layer Deposition (ALD), sputter deposition, chemical stations, Rapid Thermal Processing (RTP), special tools for SiC processing, lithography, sputtering, evaporation, and device bonding, together with metrology tools such as an ellipsometer and microscopes. In addition, we also have access to a 400 m^2 class 100 clean-room for device fabrication, packaging and evaluation on campus (INEX) and nanoLAB's shared facilities. These include the EPSRC national facility for X-ray Photoemission Spectroscopy (XPS), a £3M EPSRC Great Technologies Advanced Materials Capital award (desktop SEM, XRD, TOF-SIMS, He ion microscope and a second ALD tool), nanoindenter, quartz-crystal nanobalance and an Omicron UHV nanoprobe.
  Climate controlled electrical and material characterisation facilities include: DC and RF 200mm probe stations for varied C-V and I-V analysis to 67GHz, low and high frequency noise measurement, Deep Level Transient Spectroscopy, Hall effect, specialist facilities in electrical measurement for hostile environments, accelerated test ovens, Atomic Force Microscope (AFM) and an AFM/Raman system with optical and UV lasers. A computer controlled polishing system for ultra-shallow bevel angle sample preparation was donated by Atmel (£130k). The Group also invested in a dedicated computer cluster (100s cores). We also use the N8 (network of 8 most research intensive universities in the north of England) super-computer (>5000 cores) and the £100M national super-computer, HECToR (>90,000 cores). **Briddon** was one of 5 UK academics who oversaw the purchase of this national facility. Software includes AIMPRO, developed by **Briddon**, a density functional code for materials modelling, leading to 125 papers published in this REF period; Technology CAD software for device and process simulation (Synopsys).
- **µSYS:** A total of 10 chip designs were manufactured during the REF period. The Asynchronous Circuits and Neuroprosthesis labs have been used for testing these chips, as well as experiments with Field Programmable Gate Array (FPGA) designs. µSYS has a significant server estate operating most of the major chip design and simulation packages (Cadence, Synopsys, Mentor Graphics, Altera (inc. Quartus II and Nios IDE for FPGA implementation of run-time thermal management) and Xilinx). Open Source tools in use include Balsa (Manchester University) and NOXIM - locally modified for modelling 3D Network-on-Chip and integrated with 'Hotspot' for thermal simulation. The Group also invests significant time in creating its own software tools (http://async.org.uk/tools.html) and makes some available to the wider community: Workcraft, RMMixed, Check Hazard, VARMA (not public). Biomedical engineering uses lab facilities within EEE and the Institute of Neuroscience, including wet biology culturing facilities (linked to genetically engineered colonies), advanced genetic viral/non-viral engineering tools, and incorporates our unique optoelectronic stimulation arrays. A prosthetic hand (iLimb) is used in motor prosthesis experiments and we have a high end psychophysics trial projection system for simulation trials of visual disorders.
- **PEDM**: Dedicated facilities for electric drives have been completely refurbished and extended to encompass lab, workshop and office space covering over 800m^2 for electric drives and machines. Our modern, specialist equipment includes 13 dynamometers, worth more than £1.5M, spanning powers of up to 500kW and speeds up to 100,000 rpm. We also have an environmental chamber, new instrumentation including DC and variable frequency AC supplies up to 60KVA, totalling more than £1M. Furthermore, our Mechanical Workshop has the capability to manufacture a full range of prototypes. New equipment includes wire erosion machines, CNC milling, lathes, winding machine, balancing machine and magnetiser totalling over £500k. In this REF period, we have raised and invested well over £3M in new test cells, equipment and power supply busses. We have undertaken further research infrastructure spending on industrially focussed research facilities within our Centre for Advanced Electrical Drives. This facility offers secure office, meeting and lab facilities allowing us to conduct confidential research for our industrial research partners. We have the UK's largest Smart Grid project funded by Ofgen through the Low Carbon Networks fund, Customer Led Network Revolution (£54M), Smarter Network Storage (£13M) and 2 EPSRC Grand Challenge projects, (£8.9M EP/I031650, EP/K002252). We have also secured £0.5M from Siemens in order to build a Smart Grid laboratory in the School in early 2014. This will combine distribution

network devices (including energy storage, embedded generators, low-carbon technologies and voltage controllers), monitoring and control equipment with field trial data and computer models to test advanced network management techniques.

The future EEE Strategic Plan will extend our biomedical research theme and achieve continuous improvement in all research laboratories through RCUK and ongoing partnerships with industry (e.g. Dyson, CPI, Siemens). The investment in our infrastructure and facilities has resulted in a rise in research spend to £16.7M during the REF period. Highlights from our current portfolio include:

- **CSSP:** the £4M EPSRC programme "Pervasive Mobile Environmental Sensor grid" (EP/E002129), to develop wireless sensor networks for use in urban air quality/traffic management in collaboration with researchers in transport, E-science and atmospheric chemistry. This work was selected by EPSRC to be exhibited as an exemplar project at its 'Pioneers 09' event and received follow-on funding for industry collaboration workshops. Work on GNSS (EP/H004637, 1.27M) resulted in a new mitigation method reducing the 3D GNSS positioning error by 71% and the first model for the effect of rising plasma bubbles.
- **ETM:** had two prestigious platform grants: Underpinning Silicon Carbide (EP/D068827) and Strained Si technology (EP/D036682), along with more industrially focussed projects. The £7M Neptune Centre supports hostile environment electronics. Modelling has been supported by several EU FP6/7 projects (PULLNANO, ATOMICS, ATEMOX) involving large consortia with international companies (e.g. STMicrolectronics) and research laboratories (e.g. IMEC, LETI).
- **µSYS:** have a strong grant portfolio with funding mainly from RCUK and EU, but also from medical charities (e.g. Macular Degeneration, Motor Neurone Disease, Wellcome). These awards also incorporate industry sponsored components or form part of a partnership with industry, platform grants (EP/J008133) and a new programme grant (EP/K034448).
- **PEDM:** has a large volume of industry sponsored research, appropriate for research at a high technology readiness level. In addition, there are several EU and TSB funded projects and a healthy portfolio from EPSRC including: platform grant (EP/F067895); two Grand Challenges projects (EP/I031650, EP/K002252); and £1.6M from the Capital Grants programme for energy storage (EP/J021199).

A number of our current grants extend beyond 2013. In particular the £13.8M Wellcome/EPSRC Innovative Engineering for Health award (CANDO) and the £18M EPSRC Underpinning Power Electronics Initiative extend up to 7 years. Going forward, success in new research initiatives already gives us secured funding of more than £20M over the next 7 years. Additionally, our research income is anticipated to grow in the coming years as new academic staff and early career researchers become more established in their fields. This will be encouraged through training and support by experienced staff. Senior academics will also be encouraged to lead longer, larger research projects and develop new research collaborations. We actively encourage networking nationally within academia (e.g. eFutures), industry (e.g. NMI) and with international partners (e.g. SiNANO Institute), where new consortia can be built and lead to new funding opportunities.

Income from industrial funding has been boosted by consultancy projects with Dyson (**Mecrow**), Emerson (**Pickert**), Siemens (**Mecrow**, **Atkinson**), Goodrich (**Mecrow**, **Neasham**), Rolls Royce (**Wright**), Alstom (**Wright**), BAE (**Horsfall**, **Neasham**, **Sharif**), Raytheon (**Horsfall**), Samsung (**Cowern**), Elastix (**Yakovlev**), Northern PowerGrid (**Taylor**) and Enercon (**Taylor**). Academics have also provided consultancy services to public sector organisations including Northumbrian Water (**Zahawi**), South Tyneside College (**Gadoue**), South East England Development Agency (**Pickert**, **Tsimenidis**), Advantage West Midlands (**Tsimenidis**) and Gateshead Council (**Taylor**).

e. Collaboration or contribution to the discipline or research base

Research collaborations are supported by our leadership and membership of national/international networks, embedding companies within EEE, our Industrial Advisory Group, encouraging visiting professorial exchanges, and participation in the N8 research partnership. The School has collaborations which led to new funding / joint publications with over 90 academic institutions worldwide (e.g. MIT, Princeton, Cambridge). Support for interdisciplinary research comes from the University's Research Institutes (e.g. NIReS), Research Centres (e.g. nanoLAB) and the future Science Central initiative. Individual research teams have reached out to other collaborators within the university and further afield. Exemplars of high impact collaborative projects include:

- *Highly Compact Power DC/DC Converters for Low Carbon Vehicles:* A TSB funded project

(1202_CRD_LCV_IDP7_135347, £1.2M) that includes: Turbo Power Systems, Lotus, Dynex, International Transfomers, Hiflux, Industrial Capacitors Wrexham, and Hyperdrive. (**PEDM**)

- *Strained Silicon Heterojunction Bipolar Transistor*: funded by EPSRC (GR/T18950) and involved the growth of strained Si/SiGe material at Warwick University, device fabrication at KTH, Sweden and some aspects of material characterisation at Sematech, USA. (**ETM**)
- *Asynchronous design automation and design* advanced collaboration with the Universities of Manchester (SEDATE, VERDAD, GAELS), Southampton, Bristol, Imperial College (Holistic), and internationally, with Polytechnic University of Catalonia, Polytechnic of Turin, IHP (GAELS), Univ. of Utah, USC, Intel, Oracle, leading to a CASE studentship from ARM and Imagination Technologies in low power interconnect design. (**µSYS**)
- *Process models for semiconductor technology computer-aided design (TCAD)* funded by the EU under the IST projects ATOMICS, PULLNANO and ATEMOX. Experimental work was carried out at ST Microelectronics, CEA-Leti, Probion Analysis, LAAS-CNRS, France, IHP, Germany, and CNR Matis, Italy; Newcastle developed the theory which has been developed into commercial code by Synopsys, Germany and Switzerland. (**ETM**)
- *Optoelectronic neural stimulators*: has been the focus of the OptoNeuro FP7 project (249867) which has been coordinated at Newcastle in collaboration with Imperial College, the Tyndall Institute, Ireland, FMI institute, Switzerland, the Max Planck Institute, Frankfurt, and Scientifica Ltd., and has resulted in the spin out of OptoNeuro (Newcastle) and Gensight (FMI). (**µSYS**)

Exemplars of collaborative research with industry (which helps inform our research direction, along with our Industry Advisory Board):

- The Centre for Advanced Electrical Drives (CAED): an industry facing facility for research collaboration managed by a Principal RA (**Widmer**), and staffed by senior RAs. The CAED is fully-funded by collaborative research with Tata, JLR, Goodrich, Rolls Royce, Renault, Zytek, Högänas AB, Dyson Ltd with three industrialists permanently based within the School, 8 research staff and 7 fully funded PhD students (**PEDM**).
- Micro/nanofabrication: ETM have teamed with Intel and CPI to share clean room facilities and equipment to research thin films by ALD (EP/H023666, EP/J010944, CPI funding) (**ETM**)
- The Sensor Systems and Non Destructive Evaluation lab: Created in collaboration with the Research Centre of Non-Destructive Evaluation (RCNDE) has enabled us to test and evaluate samples for Rolls Royce, BAE, QinetiQ, TWI, Alstom, Airbus, International Paint and others. An eddy current pulsed thermograph, funded by EPSRC (EP/F023324, EP/J012343) in collaboration with Bath Univ, has been installed in the UK, China, India, Malaysia (**CSSP**).
- Metastability: Active collaboration with Intel, Oracle, and Sun Microsystems, on the fundamental understanding of deep metastability. Resultant collaborations with the University of British Columbia, Technion, T.U. Vienna, and Columbia University have led to asynchronous networks on chip solutions through companies such as Blendics (**µSYS)**.

Other exemplars of industrial engagement are: **O'Neill** is the sole academic Board Member of NMI, a trade organisation representing over 200 companies in electronic systems, and served on the CPI Printable Electronics Advisory Group. **Wright** served on the CPI Technical Advisory Board. **Mecrow** is the principal academic electrical advisor to Dyson, and a member of Protean Electric's Technical Advisory Board.

Examples of Academic leadership and contribution:

- UK Academic Community: **O'Neill** leads the EPSRC funded eFutures Network (EP/H048634) which has over 300 current members. eFutures, along with its predecessor, Si Futures (GR/T07879) and aims to maximise the impact of UK electronics research and initiatives over the REF period have led to the EPSRC grant application success rates in electronics doubling. O'Neill is also PI on the award to host the EPSRC national XPS facility. **Pickert** was part of the NMI Power Electronics Strategy Group, which contributed to the government White Paper on Power Electronics and the EPSRC Underpinning Power Electronics initiative. **Mecrow** was invited to contribute to the Foresight Sustainable Energy Management and the Built Environment Project by the UK Government Office for Science. The subsequent paper on 'electricity trends in electric machines and drives' was published in Energy Policy in Dec 2008.

Taylor is the Director of the newly formed £14.3m EPSRC Grid Scale Energy Storage Centre.

- Software hosting: We host 6 open source software tools. The AIMPRO code has been developed, maintained and supported in Newcastle by **Briddon**. It has been used to address problems in materials science, physics, chemistry, biology, engineering and bio-medical applications. This has led to 125 publications in leading journals; 93 with interdisciplinary and 77 with international co-authorship.
- EPSRC College members: **Atkinson, Boussakta, Briddon, Dlay, Mecrow, Olsen, O'Neill, Sharif, Tian, Wright, Yakovlev, Taylor**.
- Other Panel memberships: Commonwealth Scholarship Commission (**Dlay**); Royal Academy of Engineering Fellowships (**Olsen**); Swedish Science Council Grants (**Olsen**); Chinese NDT (**Tian**); One NorthEast Regional Development Forum (**Pickert**); Chinese ChangJiang Scholar (**Tian**) and Thousand Talent Programme (**Tian**).
- Journal Editorial: 30 Roles including Editorial Board: IET Computers & Digital Techniques (**Yakovlev**); IET Circuits, Devices & Systems (Dlay); IET Signal Processing (**Woo**); Electronics (**Boussakta, Cowern**). Guest Editor IET J Drives for Aerospace Applications (**Mecrow**); American Journal of Electrical & Electronic Engineering (**Cao**); Journal of Sensors (**Tian**); Journal of Wireless Communications and Mobile Computing, IEEE Comms Lett and Wireless Comms Lett (**Ding**); Associate Editor IEEE TNSRE (**Nazarpour**).
- Conference organisation: 120 roles including IEEE ICC SPS Chair (**Boussakta**), IEEE ICC TPC (**Boussakta, Tsimenidis**); IEEE Globecom TPC (**Boussakta, Tsimenidis**); IEEE WCNC TPC (**Tsimenidis**); Far East NDT co-Chair (**Tian**); IEEE WiMob TPC (**Tsimenidis**); ASYNC & NOCS 2008 General Chair, ASYNC 2010 TPC Chair (**Yakovlev**); ACSD Steering Committee Chair (**Yakovle**v); EMC TPC (**Olsen**); ESSDERC TPC and 2008 tutorial chair (**O'Neill**); IET PEMD 2010 co-chair (**Pickert**) Bioengineering 08 Steering Committee (**Degenaar**); IEEE ISBME 2009 Workshops Chair (**Nazarpour**); IEEE MLSP 2013 TPC (**Nazarpour)**
- Keynote: 13 including [2008] Gordon Conference, USA (**Goss**)] [2011] International Workshop on Energy Efficient Systems, Barcelona (**O'Neill**); IEEE WOSPA (**Boussakta**); JEMI (**O'Neill**);
- Invited Lectures: 170 including: [2008] FMI Institute, Switzerland, (**Degenaar**) [2009] AStar Institute, Singapore, Nanjing SE University (**Degenaar**) [2010] Texas Tech University, Universidad Iberoamericanca, Mexico (**Degenaar**) [2011] Suzhou University (**Degenaar**), ETH, Zurich (**Degenaar**); IHP Frankfurt, Univ of Bristol (**Yakovlev**) [2012] Scuola Superiore Sant'Anna, Italy (**Nazarpour**); Univ of Oxford, Univ of Manchester (**Yakovlev**) [2013] Imperial College (**Yakovlev**); [2012] ECS Spring, USA (**Olsen**); ECS Fall, USA (**O'Neill**);
- Medical/patient group disseminations: (**Degenaar**): [2008] Western Eye Hospital; [2010] Royal Victoria Infirmary [2011] North East Eye day, Newcastle; Amsler Club, London; North East Optical Society, Newcastle [2012] Top Doctors, Newcastle [2013] Macular Disease Society meetings, York, London (600 patients at each meeting). (**Nazarpour**): [2012] National Spinal Cord Injuries Unit, Glasgow Southern General Hospital.
- Best paper awards: International Electric Machines and Drives Conference, USA 2012 (**Mecrow**); IEEE PEDM 2012 (**Horsfall**); IEEE ICMTS (**Yakovlev**), IEEE Sensors, chemical and gas sensors track (**Horsfall**); LDIA'13 (**Cao**); AICT 2009 (**Sharif, Tsimenidis**); IoP Dielectric 2013 (**Goss**); IEEE DDECS (**Yakovlev**); (DATE (**Yakovlev**))
- Other Prizes/Awards: Denny Medal by Institute of Marine Engineering 2012 (**Pickert, Zahawi**); Grimwade Medal 2010, 2012 (**Tian**); IMechE Water Arbitration Prize 2010 (**Neasham**); IEEE Comsoc. SPCE award (**Boussakta**), IET Innovation award 2010 (**Taylor**).
- Fellowships: EPSRC Dream Fellow (**Yakovlev** EP/J005177); RCUK Fellow (**Degenaar** EP/C509463); IET Fellow (**Boussakta, O'Neill, Sharif, Tian, Taylor**). EPSRC Advanced Fellowship (**Wright** GR/S52216), Marie Curie Fellowship at Princeton (**Ding**), Faculty Research Fellowships (**Vasilevskiy, Mokhov**)
- Secondments: **Horsfall**, RAE secondment to BAE Systems; **Tian**, RAE Glob. Res. Award.