Institution: University of Strathclyde

Unit of Assessment: UoA13 Electrical and Electronic Engineering, Metallurgy and Materials

a. Context

The successful transfer of research knowledge from the University to industry and other societal beneficiaries is a fundamental objective of the University of Strathclyde's strategic plan. In 2012, Strathclyde was awarded the *Times Higher Education* (*THE*) *UK University of the Year* award and in their citation the judges praised the close links with business and industry, and its commitment to making an impact on the global economy. UoA13's approach to generating impact from its research, successfully executed over 20 years, is fully aligned with the University's strategy, and the unit's success has been a major factor in securing the *THE* accolade.

UoA13 comprises 60 academic staff (59.2 FTE), 95 research staff and 186 PhD students. 51 of the academic staff are from the Dept of Electronic and Electrical Engineering (under 5 themed academic research groupings on *Signal Processing*, *Communications*, *Energy and Environment*, *Ultrasonics*, and *Microsystems and Photonics)* and 9 are from the *Institute of Photonics* (IoP).

The **main types of impact** arising from UoA13's research are:

- **Economic impact and job creation:** Evidenced by spin-out company formation, company growth, innovative products and devices, intellectual property licensing and new services;
- **Societal impact:** Arising from implementation of research in renewable energy, improvements to health, safety and wellbeing, and influences on policy, standards and regulations.

The **main non-academic beneficiaries** of our research are:

- **Industry (national and international):** Products arising from or influenced by our research are manufactured and sold by companies ranging from multi-national organisations to SMEs;
- **Public sector organisations and communities:** Impact from UoA13's research has benefited the NHS, Government departments, and local, rural and international communities.

UoA13 creates ***Industry Engagement Research Centres*** (IERCs) to offer a strategic and focused approach to the delivery of impact, with each themed IERC supported by a number of industry partners and technology sectors, and managed within the main research groupings. UoA13 has 21 IERCs, many developed during REF. Further details are in the UoA13 Environment Template.

b. Approach to impact

UoA13 research aims to deliver impact in a number of identifiable sectors:

Commerce and Industry: One of the main impacts relates to growth of business and economic activity via a multi-faceted programme of knowledge transfer with industry. Over the REF2014 period, industrial impact has been generated by 5 spin-out companies, 6 KTP programmes, 14 companies engaged with our EPSRC Knowledge Transfer and Impact Accounts; £2.6M of direct R&D consultancy, > 40% of studentships having an industry/CASE partner, 4 industry managed and collaborative TSB projects, in-kind industry support of more than £2M, and the 21 IERCs.

Natural Environment: Research on renewable energy has resulted in direct environmental and economic benefits to society through outcomes in low carbon energy generation derived from the *Centre for Doctoral Training in Wind Energy* (2009-13 and 2014-17) and the £4.5M *Low Carbon Power and Energy Programme* (2013-17) on offshore wind within the University's *Technology and Innovation Centre* (*TIC*). Digital communications research delivers enhanced management of the environment and natural assets, including livestock asset management, and canal-bank monitoring. Renewable energy wireless base-stations provide low intrusion broadband connectivity on the Isles of Tiree and Bute. Partners in these projects include *ScottishPower, SSE, Scottish Canals, British Telecom, BBC, Scottish Water, Wood Group,* and *Harbro Ltd* (livestock products).

***Informing Practice and Policy; Standards and Regulatory Bodies*:** UoA13 academics chair and contribute to the *UKTI Energy Excellence Board* [*J McDonald*] and also lead the UK activities in the *European Energy Research Alliance* for both Smart Grids [*Burt*] and Wind Energy [*Leithead*]. Research outputs have been incorporated in national and international standards and research-informed technical input has been provided to the UK electricity and gas regulator, *Ofgem*, through projects *LENS* (2007-09) [*Ault*] and *TransmiT* (2010-12), led by UoA13 researchers [*Bell*]. UoA13 IERCs directly engage with *Ofcom* on UK white space radio pilots and trials [*Stewart, Weiss*]. Sensors research has informed UK Government agricultural policy and generated formal recommendations through the ICT Forum [*Andonovic*]. The public body, *Quality Meat Scotland*, has also benefited from UoA13's hyperspectral imaging research [*Marshall, Ren*].

Impacting Health, Safety & Wellbeing: UoA13 research has provided outcomes that limit crime within major cities via intelligent video surveillance [*Marshall*] and information encryption and security. "Facial palsy" recognition research [*Soraghan*] has resulted in healthcare benefits from an internationally adopted scoring scale. High intensity narrow spectrum light technologies for sterilisation have been deployed for hospital infection management [*MacGregor*, jointly with *Anderson (*UoA3)]. Research has also led to benefits via bionic hand projects with *Touch Bionics Ltd* [*Soraghan*], as well as devices and methods used by the *NHS Institute of Hearing Research*, and imaging methods used at the *Beatson Cancer Unit*. For safety and mission critical systems, notable examples include: software for nuclear industry monitoring [*McArthur*]; ultrasonic sonar for mine detection [*Gachagan*]; and tuneable laser based systems for gas detection [*Johnstone*].

Impacting UK Unserved Regions and Developing Countries: Research has seeded a substantial programme of renewable energy mini-grid installations to support lighting, IT and mobile communications in Malawi (e.g. Scottish Government MREAP programme - £1.7M). The Isle of Bute White Space test-bed has led to development of micro-generation solar/wind powered base-stations for off-grid broadband provision on the Isle of Tiree. Demonstrators were set up with *Microsoft* in Kenya to bring broadband data connectivity to off-grid communities, schools and clinics. As part of the 8 partner EU FP7 ORIGIN project (2013-15) intelligent ICT systems for management of energy in communities are being developed and installed in three isolated locations.

b.1 Stakeholders, Funding and Support Mechanisms to Generate Impact

A key principle adopted by UoA13 is that research should be accessible and presented pragmatically and with clarity, in order to be shared with non-academic users for societal benefit. Such sharing is more than just academic "publication": it requires us to make the first external contact, to actively disseminate research via our IERCs, and to bring research to the readiness level required for impact. The University also has a pragmatic approach to generating and managing intellectual property (IP) and IP agreement is rarely a barrier to engagement. The main mechanisms to achieving impact, and the associated stakeholders, are summarised as follows:

***Industrial and Commercial Partnerships*:** Focused knowledge exchange and joint research programmes have facilitated impact within a number of industry areas. For example, successful research outputs from UoA13 delivered and sustained over a period of 10 years or more through a range of multi-lateral industrial partnerships have led to two new flagship industry engagement research centres (IERCs). These centres are the £9.4M *Power Network Demonstration Centre (*2013) (*SSE, Scottish Power, S&C Electric, Alstom, Omicron*) and the *Scottish Sensor Systems Centre* (jointly with Glasgow and Aberdeen Universities) which has engagement from over 20 companies (including *Freescale, British Canals, Poseidon Ltd, Traceall Ltd*). The University's flagship *Technology and Innovation Centre* (*TIC*) includes research themes and programmes in sensors systems, power and energy, and intelligent lighting and will stimulate expansion of our partnerships with industry. In addition, long term (> 5 years, with some partnerships > 15 years) bilateral research partnerships have been established with *Scottish Power, SSE, Rolls-Royce, National Grid, EDF Energy, and Xilinx Inc*.

Spin-out Companies and Licensing: Spin-outs created directly from UoA13 research include: *Embedded Technology Solutions (ETS) Ltd* (2009, impact case study) on wireless methods for animal health monitoring; *Smarter Grid Solutions Ltd* (2008, impact case study), on smart grid control; *MLED Ltd* on solid-state optical micro-projection systems; and *Bellrock Technology Ltd* (2012) on condition monitoring decision support software for electrical utility companies. UoA13 also has successes with projects where technology IP and know-how are "imported" and then managed with UoA13 staff and facilities. An example is the company *TreeGreen Ltd* (2010) where support from a *Royal Society of Edinburgh Industry Fellowship* and available IP led to the spin-out company producing home/business energy efficiency tools now sold in high street stores. Where appropriate, UoA13 will also licence technologies to companies, e.g. an agreement was set up by IoP with *Element Six Ltd* in the photonics area (impact case study).

Knowledge Transfer Partnerships: Companies engaging with UoA13 researchers via KTPs include several SMEs: *D-TACQ Ltd* on FPGAs for physical measurement (jointly with UoA12); *Alba Ultrasound Ltd* on next generation of ultrasonic transducers for application in sonar and non-destructive testing; *Smarter Grid Solutions Ltd* on smart grid control test environments; *M Squared Lasers Ltd* on the next generation of lasers for environmental sensing applications; *Community Energy Scotland* on smart grid and demand response solutions; *Macom Technologies Ltd* on

condition monitoring for wind turbine gear box oil; and *eCOM Scotland Ltd* on artificial intelligence prototypes for test setting and marking structure. Strathclyde is in the UK top 5 universities for hosting of KTP projects and UoA 13 makes a significant contribution to the portfolio.

Engineering Doctorate (EngD) Programmes and Industrial CASE/PhD Studentships: Centres for Doctoral Training (CDT) provide a platform for companies to directly engage with UoA13 research via sponsorship of industrial PhDs and Engineering Doctorates (EngD). UoA13 engages in a number EPSRC funded doctoral training centres including (i) *Wind Energy*, (ii) *Medical Devices*, (iii) *Nuclear Engineering*, (iv) *Optics and Photonics Technologies*, (v) *Systems Engineering*, (vi) *Offshore Renewable Energy*, (vii) *Advanced Forming and Manufacture*. In 2013 UoA13 secured a new CDT in Power Networks (2014-21) and an extension of the CDT in Wind Energy (2014-21). Examples of companies who engaged in our CDTs and other managed doctoral programmes over the REF2014 period include *Thales, Powerlase, EDF Energy, Rolls-Royce, Motorola, Wolfson Micro*, *Sgurr Energy, SSE, ScottishPower* as well as SMEs such as *A2E*, *Linn Audio* and UoA13 spin-outs (set up pre-2008) such as *Steepest Ascent*, *OptoSci*, *Alba Ultrasound*.

EPSRC Knowledge Transfer Grants: Strathclyde's £2.6M "*Knowledge Transfer Account*" grant [EP/H50009X/1, 2009-12] was to enable, accelerate and enhance links with industry through collaborative R&D, two-way secondments, industry studentships, pre-proof of concepts projects, and support of research in SMEs. This KTA enabled follow-on UoA13 projects with nine industry partners that seeded further longer-term engagement, e.g.: *British Telecom* and *BBC* engaged in rural white space wireless broadband trials; *David Brown Gear Systems Ltd* and *Sgurr Energy* co-funded an IERC on Condition Monitoring; and *ETS Ltd* developed decision support services for the farming sector. As a follow-on to the KTA, the £1.8M "*Impact Acceleration Account*" [EP/K503861/1, 2012-15] promotes a cross-disiplinary approach across the University and to date UoA13 has established activities with *Silverwing, Spirit Aerospace*, and *Microsoft*.

***Technology Strategy Board (TSB)*:** We have participated in industry-led TSB projects including: (i) "Extending GigaBit Ethernet Access using TV White Space", (2010-2012) with *British Telecom*, *BBC* and three local SMEs; (ii) "Agricultural Innovation through Technology (ALERTS)" (2011-2013), with *ETS Ltd*, *Scottish Rural College*, *NMR* plc, *The Harbro Group* Ltd, *Well Cow Ltd*, and *Wm Morrisons Supermarkets plc*; (iii) "Brain Machine Interface (BMI) enabling multi articulating prosthetic (MAP) hand", with *Touch Bionics Ltd*; and (v) "Laser Design", with *Coherent Scotland Ltd* and *M-Squared Lasers*. Furthermore, UoA13 is a partner in the TSB "Catapult Centre" in *Offshore Renewable Energy*, and the *Glasgow Observatory within the Future Cities Catapult*.

Industry Advisory; Industry Sponsored Academics and Visiting Academics: Research advisory discussions with *Visiting Academics* enhance the exchange of knowledge into external organisations and provide direction for research with higher potential for impact. Visiting academics are appointed from a range of industry, academic and public bodies, with the current appointments including senior staff from *National Grid, QinetiQ Ltd; Motorola Mobility; Gilden Photonics; Iberdrola; Consejo; Spanish National Research Council; SgurrEnergy; Parsons Brinckerhoff; Scottish European Green Energy Centre; Innovalia Association; National Renewable Energy; Innovation Centres Scotland; Intel Inc; Agilent Ltd; Thales Optronics Ltd; Coherent Scotland Ltd; M Squared Lasers Ltd;* and *Honeywell Ltd*. Formalised industrial advisory boards and management boards are also a feature of UoA13's IERCs and are chaired and populated by industry leaders. A number of academic positions are directly supported/endowed by partners including *Xilinx*, *Texas Instruments*, *Raytheon*, *SSE* and *ScottishPower,* representing almost £1M over the REF period*)*.

Internationalisation: As already reviewed, Strathclyde has established many international industry collaborations to create impact from research. Specifically, and as part of our internationalisation strategy, UoA13 participates in a number of EU/FP7 funded industry/academic projects and initiatives delivering direct research impact, e.g.: *VERTIGO* (on mid-IR semiconductor disk lasers, completed 2009*); NATAL* (on visible semiconductor disk lasers, completed 2008); *TWENTIES* (electrical wind power transmission operation, 2010-13), and *ORIGIN* (community energy management, 2013-15). Also, UoA13 was a core part of the *RCUK Science Bridges Programme* in *Photonics* (*SU2P*) which enabled engagement with the high-tech companies affiliated to Stanford. UoA13 participated in EPSRCs joint UK-China sustainable electric power consortium, and maintained extensive UK-China industry and academic engagement on electrical power systems and designs. Other examples of impact from internationalisation include working with NASA / Rolls Royce (Indianapolis, USA) on aero-electrical architectures (RTAPs, 2013-14).

c. Strategy and Plans

The UoA13 research strategy for impact in industry, society and for UK economic benefit is summarised in Figure 1 by our "***4P outputs model***" where academic ***P****ublications*, ***P****roof* of concept, *intellectual* ***P****roperty*, and most notably trained ***P****eople* (researchers) lead to spin-out companies, licensing arrangements, societal contributions, economic and industry value and the establishment of new *Industry Engagement Research Centres* (IERC). At the census date UoA13 had 21 IERCs engaging with more than 60 industry, business and community partners. Figure 1 summarise the routes for creation and evolution of IERCs, and the linkages to the researcher base.

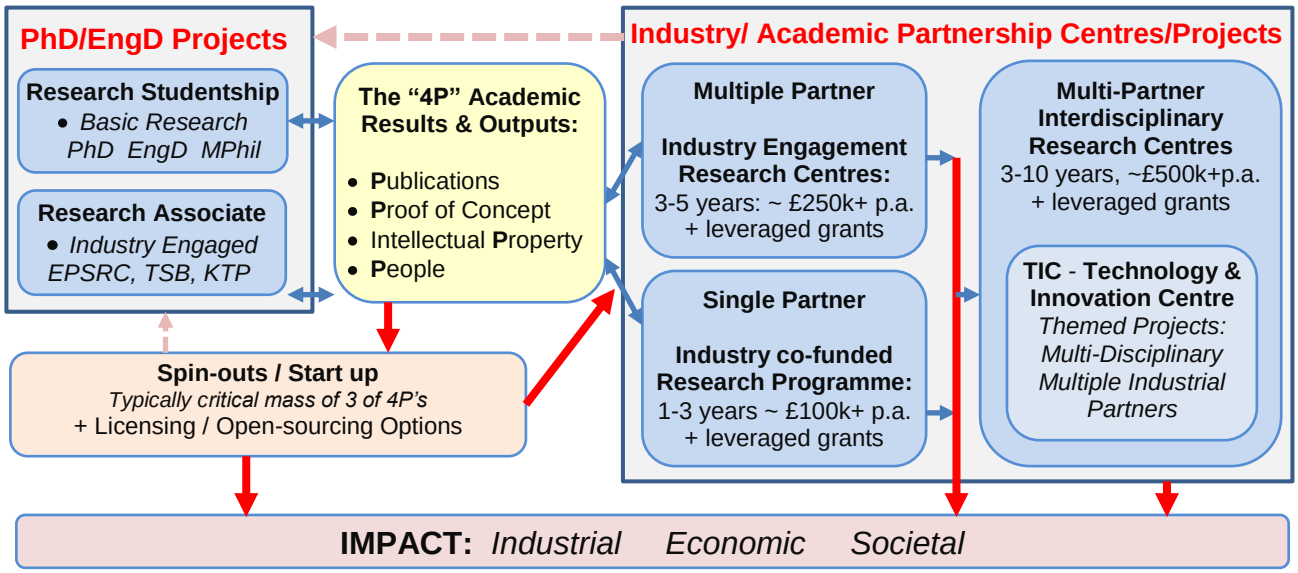

Figure 1: The Strathclyde (and UoA13) Strategic Research Routes to Impact.

The plan for further growth in impact is to both support existing initiatives that generate substantial impact and to nurture new avenues to impact. Immediate and on-going actions include:

(i) Delivering the Strathclyde *Technology and Innovation Centre* (*TIC*) model for multi-partner, multidisciplinary research and knowledge exchange programmes to accelerate impact. UoA13 is leading the establishment of centres in the areas of *asset management and condition monitoring*, *nuclear engineering,* and *low carbon power and energy.*

(ii) *Appointing new staff in relevant research areas* using the new *University Knowledge Exchange Fellow* scheme to create enhanced opportunities for impact, including the attraction and appointment of experienced industrialists.

(iii) Enhance our *Continual Professional Development programmes* based on core themes and industrial/societal needs. For example, pilot programmes have been developed and delivered for S&C Electric (smart grids) and with the United Nations (on energy for developing countries).

(iv) *Working in alignment with the University's Knowledge Exchange* agenda of events, CPD, consultancy, disbursing Faculty KE support/grants, KTPs, and innovation vouchers that provide further targeted investment in KE relevant research areas.

d. Relationship to Case Studies

Five of the seven UoA13 case studies feature spin-out and start-up companies coming from UoA13, all of which provide technological solutions leading to economic and societal benefit. Two of these companies were formed over the REF2014 period: *Smarter Grid Solutions Ltd* (in 2009), and *ETS Ltd* (in 2010), and the other three (former) start-ups: *Alba Ultrasound Ltd* (formed 2001); *DMS-Qualitrol Ltd* (formed 1994); and *OptoSci Ltd* (formed 1994) are now established companies that have maintained a strong relationship to UoA13 via KE activities such as KTPs, EngDs secondments, and support for our IERCs and strategic research projects. The other two case studies feature licensing of photonics technology to *Element Six Ltd* and the delivery of safety-critical software diagnostic systems for extending the life of nuclear power stations with *EDF*. There are many other similar examples of UoA13 derived impact over the REF period, such as spin-out *Industrial Control Systems* Ltd (formed 1994) providing embedded advanced control methods to customers including Ford and Toyota; the spin-out *MLED Ltd* (from 2011) on photonics IP to deliverable products; and *Steepest Ascent Ltd* (formed 2004, acquired by MathWorks Oct 2013) working with UoA13 to deliver wireless 4G-LTE software tools and communication systems.