Institution: King's College London

Unit of Assessment: 12 Engineering

1. Unit Context and Structure, Research and Impact Strategy

Context: This submission represents Unit of Assessment (***UoA***) 12, King's Engineering, comprising the School of Biomedical Engineering & Imaging Sciences (***BMEIS***) and the new Department of Engineering (***DoEng***); see Figure 1 for organisational overview. King's Engineering focuses on interdisciplinary research, innovation, entrepreneurship and impact which is recognised by the award of a Queen's Anniversary Prize (2019) for excellence, innovation and public benefit from research outcomes. While BMEIS and DoEng are distinct organisational units, we work closely together in delivering a shared and mutually supportive University strategy, ***King's Vision 2029,*** to make the world a better place through the delivery of engineering innovation (REF5a).

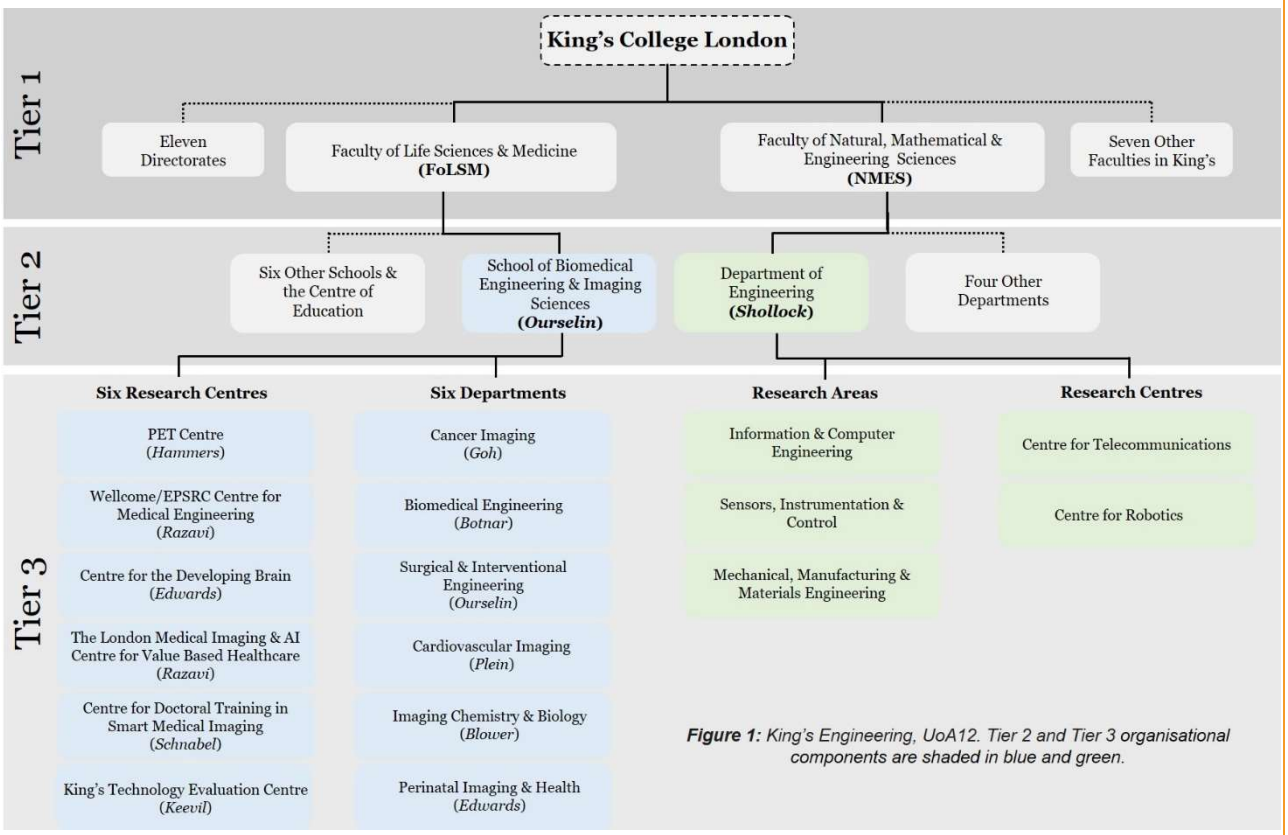

Figure 1: *King's Engineering, UoA12. Tier 2 and Tier 3 organisational components are shaded in blue and green.*

The Faculty of Life Sciences and Medicine (***FoLSM***) underwent reconfiguration in 2017 to better support the delivery of King's Vision 2029. This created seven new Schools, (including BMEIS) and a Centre for Education. BMEIS is directly embedded within Guy's and St Thomas' NHS Foundation Trust (***GSTT***) at St Thomas' campus, drawing expertise from associate hospitals which are part of our Academic Health Sciences Centre, King's Health Partners (***KHP***). This includes King's College Hospital and South London and Maudsley NHS Foundation Trusts (***SLaM***). The environment greatly facilitates BMEIS's mission to bring engineering research and innovation into medical practice. BMEIS also benefits from major infrastructure awards to support translational research from the National Institute for Health Research (***NIHR***) for two Biomedical Research Centres (***BRC***) at GSTT & SLaM. BMEIS is organised into six formal Departments and six strategic Centres (Figure 1, blue boxes) to support a critical mass of staff working within similar disciplines. Many Centres integrate research and clinical activity, e.g. the Positron Emission Tomography (***PET***) Centre performs over 11,000 patient scans annually. For the REF2014 assessment, BMEIS consisted of 350 staff (including academics, researchers, professional services) and Post Graduate Research (***PGR***) students and solely represented the General Engineering submission

for King's. It has continued to grow with the recruitment of Ourselin from UCL as Head of School (***HoS***) in 2018, and now comprises 558 staff and PGR students.

As part of King's Vision 2029, significant institutional investment is being made in science and technology. At the heart of this, we are actively growing King's Engineering (supported by institutional investment of c£50m) to build on existing strengths and expand into new areas that complement these strengths. Alongside BMEIS and a core base of engineering research and education within the Department of Informatics, DoEng was officially launched in 2019, with Shollock recruited from Warwick as Head of Department (***HoD***). The telecommunications and robotics groups (which in REF2014 were hosted within the Department of Informatics) and 10 newly appointed academics form the foundation of DoEng which comprises 138 staff and PGR students. Over the next three years DoEng intends to appoint further staff (approximately 25) including academics, technical and professional services. Within DoEng, three broad strategic research areas exist and two specialist research Centres which draw expertise from the Department of Informatics (Figure 1, green boxes). The departments of Engineering and Informatics will continue their close collaboration facilitated by their aligned research strategies, shared common research structures, co-location on the Strand Campus and belonging to the Faculty of Natural, Mathematical and Engineering Sciences (***NMES***). Specific DoEng academic staff (Aghvami, Dai, Dohler and Mahmoodi) who were previously hosted in the Department of Informatics, whose research interests cross both UoA12 and UoA11, are being returned in UoA11. DoEng is a strategically growing entity and its physical location close to Informatics, Business and Social Sciences (among others), ideally places it to work across a breath of disciplines, echoing BMEIS's ability to bring engineering research and innovation into society by co-locating expertise at a hospital campus.

King's Engineering is building a consolidated presence across both campuses to support our research vision which is aligned to national and international research priorities as outlined by key funding organisations (e.g. UKRI, Wellcome, RAEng and Royal Society) and the government's industrial strategy. ***Our vision is to foster collaborations and facilitate problem-solving research through collective insight to create solutions and an ecosystem to address some of the most pressing engineering research questions, building a better, more sustainable world to the benefit of society.*** Our research incorporates wide-ranging disciplines including physics, chemistry, imaging, computational modelling, data science, artificial intelligence (***AI***), biomedical engineering, robotics, electrical engineering, clinical research (and more). Most solutions involve contributions and components from many or all the constituent disciplines.

Research & Impact Strategy: Supporting our research vision, King's Engineering continues to build an agile multi-disciplinary field drawing on the expertise from arts and humanities, law, healthcare, as well as policy makers, cultural partners, and industry. Importantly, we work alongside other sectors to share knowledge and ensure our vital engineering research has an impact supporting global challenges and national prosperity. Our research and impact strategy is built around five key enabling pillars:

- **Recruit/retain world-class research staff** (through promotion, career development and other support mechanisms) to grow disciplinary areas and create a critical mass of expertise supported through institutional investment and/or large-scale strategic funding awards;
- **Collaborate with affiliates/partners** in support of current and new research projects. Where appropriate, attract new collaborators/partners to strengthen and promote King's Engineering research and impact;
- **Grow research income** in particular, through applying for large strategic programme/centre grants to enable an integrated approach to answer fundamental research questions and utilise key partnerships (e.g. industry, the NHS) to strengthen applications. Concurrently, ensure early career academics focus on fellowships (where appropriate) and build their grant portfolio through responsive mode funding opportunities;
- **Share knowledge across sectors and increase research impact** through publications, open research tools/software, IP & licensing, entrepreneurship and translation of technology into products and services;

- **Enhance infrastructure** and expertise required to accelerate research.

The implementation of our research and impact strategy is managed by each tier two leadership team specifically, HoS, Ourselin (BMEIS) and HoD, Shollock (DoEng). See Figure 2 for leadership and supporting roles.

Research Structure: The thematic areas and objectives set for the next five years described below are strongly aligned, both to the research interests of our academics and to our non-academic (e.g. industry) partners.

King's Engineering research is structured into three overarching thematic areas **T1: Health**, **T2: Connectivity**, and **T3: Manufacturing & Sustainability**. Each thematic area has associated sub-themes (Figure 2) incorporating the research priorities of all strategic Centres with areas of research synergy across BMEIS and DoEng.

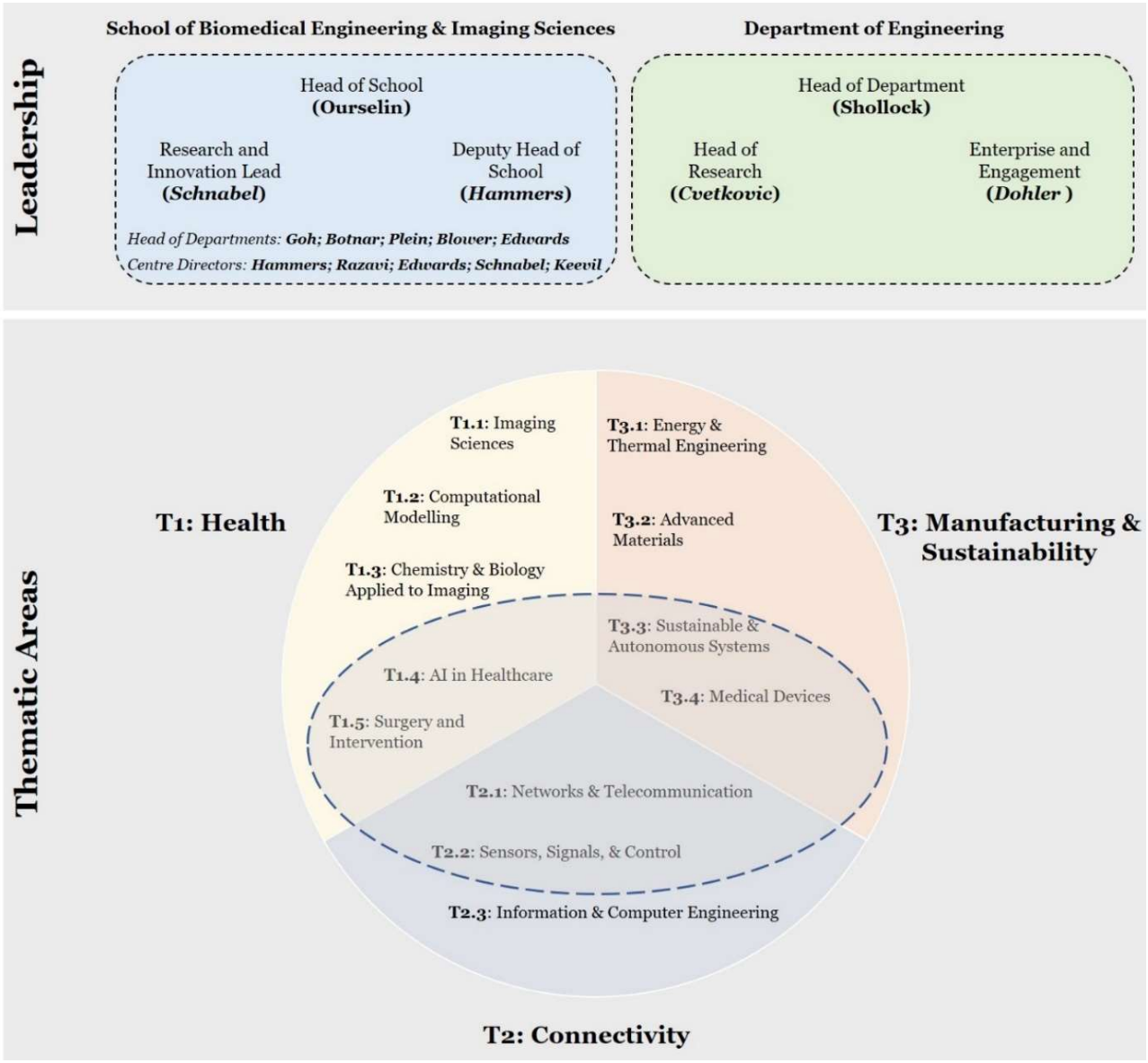

Figure 2: *Core thematic areas and associated sub-themes. The dotted blue line presents areas of current and growing research synergy within King's Engineering.*

T1: The largest area of growth over the assessment period. T1 aims to improve the delivery of healthcare through advanced engineering to treat and diagnose patients across many disease areas including cancer, neurological, and cardiovascular conditions. Research is patient-centric, highlighted through 22 clinical academics embedded within King's Engineering, many of whom

hold joint appointments with the NHS. T1 is segmented into five sub-themes, covering fundamental research areas in:

- **T1.1, Imaging Sciences:** Built around three fundamental and inter-related areas: **Imaging physics**, **computational & clinical imaging** to improve image acquisition, reconstruction, processing and analysis;
- **T1.2, Computational Modelling:** Focuses on mechanistic understanding of pathologies, precision diagnostics, and personalised therapy delivery via patient specific model-based outcome predictions;
- **T1.3, Chemistry & Biology Applied to Imaging:** Designs, develops and assesses new platform chemical technologies i.e. molecular imaging probes/tracers to help improve the detection and understanding of disease including enhance access to treatments in low-middle-income countries (***LMICs***);
- **T1.4, AI in Healthcare:** Creates AI-driven tools for higher quality images, computer-aided diagnosis/guidance software and decision-making support tools for all points of patient contact across many clinical pathways;
- **T1.5, Surgery & Intervention:** Combines diagnostic-quality imaging and sensing with ergonomic smart instruments (e.g. flexible robotic systems) to deliver pathological, anatomical and physiological optimal surgeries.

T2: This thematic area brings together the telecommunications and aspects of the robotics research alongside activities in information and computer engineering into three sub-themes covering fundamental research in:

- **T2.1, Networks & Telecommunications:** Builds on existing expertise in wireless communications and networks research with innovation in 5G and increasingly 6G, and development of resource-efficient networks as well as economic and policy implications of these technologies;
- **T2.2, Sensors, Signals, & Control:** Brings together the synergies between sensing, signal processing and intelligent control to develop Internet of Things (***IoT***) systems across numerous applications in communications, robotics and healthcare;
- **T2.3, Information & Computer Engineering:** Captures emerging areas in energy-efficient computing and bio-inspired systems in neuromorphic computing and molecular communications.

T3: A new strategic growth area, this thematic area has four sub-themes to address sustainability across a range of topics:

- **T3.1, Energy & Thermal Engineering**: A new area, focused on engineering to improve the environment ranging from energy storage and recovery to research on wildfires and their emissions;
- **T3.2, Advanced Materials:** Brings together the development, manufacturing and performance of engineering alloys, energy materials and nanoparticles;
- **T3.3, Sustainable & Autonomous Systems:** Enhances existing robotics research in high-dexterous manipulation and mechanisms with new activities in sustainable manufacturing systems including machine learning and intelligent control. New research includes continuous flow processes for vaccine manufacture and use of sustainable sources for food and fuel manufacture;
- **T3.4, Medical Devices:** Creates new devices for healthcare, with emphasis on advanced microwave and non-invasive diagnostics and haptics for prosthetics.

The three thematic areas (**T1**, **T2** and **T3**) provide a comprehensive framework, allowing all academics and research focused staff the freedom to work across other disciplines, develop additional expertise and increase collaborative activity. Figure 3 provides further details of each sub-theme and illustrates our critical mass of staff and where most of their research contribution resides.

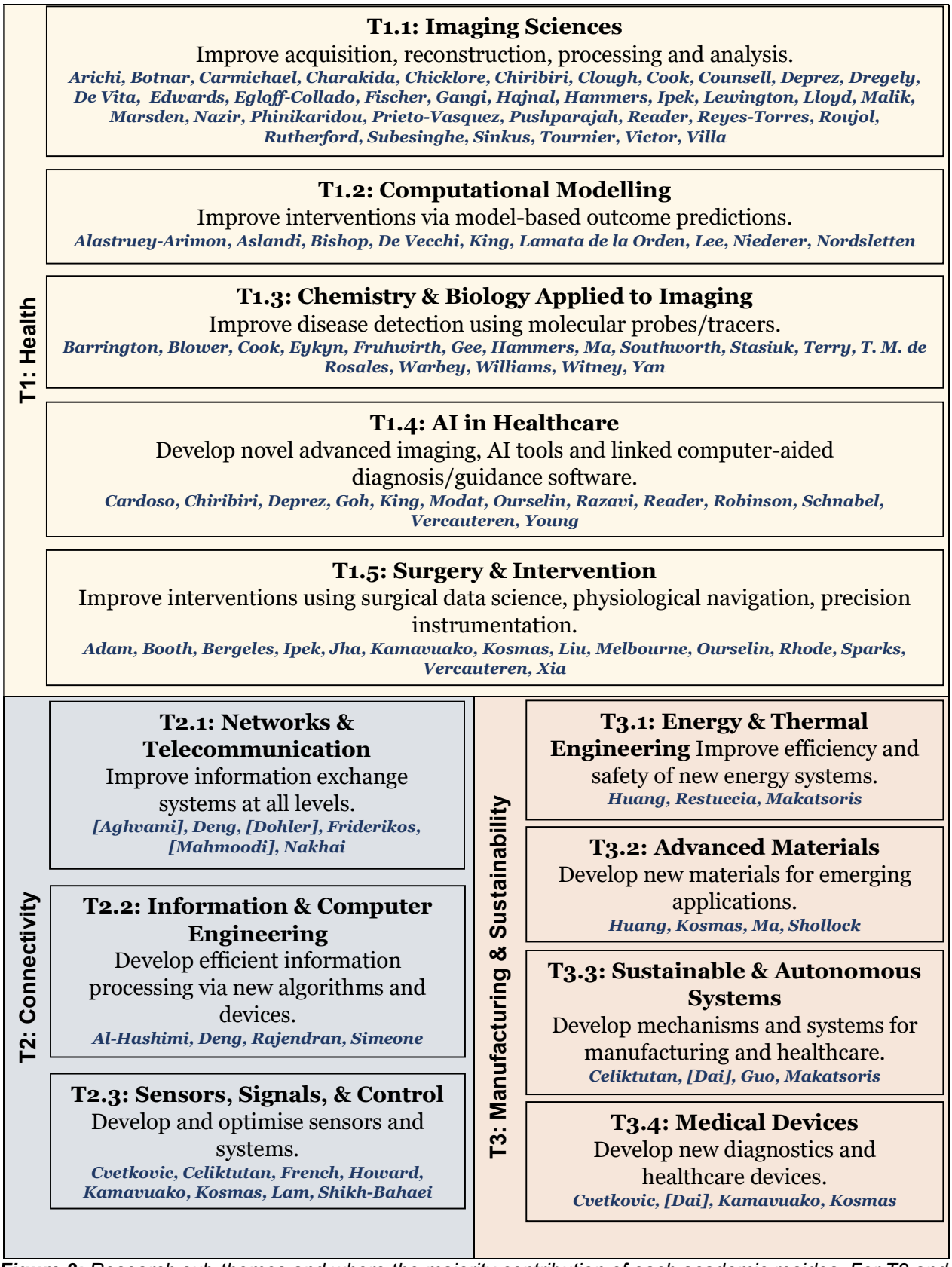

Figure 3: *Research sub-themes and where the majority contribution of each academic resides. For T2 and T3, names contained in brackets form part of DoEng however, are being submitted as part of UoA11.*

Meeting REF2014 Objectives: Staff returned to General Engineering in REF2014 were solely from BMEIS which is reflected in the objectives set and key outcomes described below.

During the assessment period a total of 3784 research articles/papers across the four objectives were published. In addition, when incorporating other outputs (including reviews, book chapters, conference proceedings) a total of 4353 outputs were published. Supporting these outputs, 51 patents were filed, some in collaboration with industry partners (Siemens Healthineers, Philips Healthcare, GE Healthcare and Theragnostics) in areas including; improved magnetic resonance imaging (***MRI***) performance and methods for synthesising radiotracer compounds (examples include PCT/GB2020/050876, WO2012063028A1, WO2017076879A1). A summary of key scientific outcomes is provided below with original objectives in italics.

1) *move to an adaptive framework for image acquisition and reconstruction, to transform how imaging modalities are used, consider new ways of combining their capabilities, and integrate acquisition, reconstruction, analysis and modelling.*

Key outcomes: Demonstration of edge-preserving noise-reduction PET reconstruction capabilities; synergistic multi-contrast MR and synergistic PET-MR reconstruction strategies allowing shorter scan times; new imaging tools for the non-invasive and radiation-free assessment; novel multi-contrast imaging sequences allowing simultaneous visualisation of heart anatomy (implemented as pre-product software with Siemens Healthineers).

2) *develop computational and statistical techniques that allow automatic analysis of images, accurate fusion of images to guide interventions, and building atlases from large image datasets.*

Key outcomes: Fetal and neonatal imaging solutions using 2D/3D ultrasound and structural MRI analysed with deep learning-based online biometric measurements; motion correction for structural and functional fetal and neonatal brain MRI; interventional, minimally invasive hybrid X-ray/MRI with commercial translation (Siemens Healthineers); unique database of over 1,000 high-quality fetal and neonatal structural, diffusion and resting-state functional MRI datasets together with genetic and developmental data; project Medical Open Network for AI (***MONAI***), an open-source community-supported, deep learning framework for healthcare imaging.

3) *achieve insight into mechanisms of disease by creating a mathematical and computational framework of electro-mechanical and computational fluid dynamic models.*

Key outcomes: Novel pipeline for the quantification at pixel level of myocardial blood supply from cardiovascular magnetic resonance perfusion; creation of several tools for the validation of quantitative perfusion measurements, including a device called perfusion phantom; new image processing and numerical workflows for rapid and robust computational models at scale from large clinical databases for guiding therapies in prospective clinical studies.

4) *address major chemical challenges of imaging: synthesising innovative molecular probes and new platform chemical technologies.*

Key outcomes: New platform chemical technologies including (i) tris(hydroxypyridonine), ***THP*** chelators for gallium-68 which have underpinned easy, accessible synthesis of a range of radiotracers including PET ^{68}Ga-THP-PSMA (which is now commercialised as a simple kit, and in phase III trials for prostate cancer); (ii) “inorganic” (non-carbon-bound) fluorine chemistry for incorporating ^{18}F into new tracers (^{18}F-tetrafluoroborate has been clinically validated in a phase I PET study in thyroid cancer patients); (iii) platforms for radiolabelling of a range of nanoparticulate materials for multimodality imaging; (iv) methods for simple, efficient cell radiolabelling to support PET cell tracking in cell based therapy; (vi) novel methods to incorporate ^{11}C and ^{13}N into biomolecules and drugs for PET imaging.

Objectives for the next five years: We will continue to develop King's Engineering as a central pillar of King’s Vision 2029, consolidate world-class strengths in science and technology alongside

health, social sciences and humanities, grow our research base targeting specific thematic areas and embed a culture of innovation and impact. Key objectives include:

- Build on the success of T1, exploit cross thematic interactions to harness the potential of total body PET (developing multiplexed imaging of multiple molecular targets) and low-field magnet technology to democratise MRI;
- Lead and build strength in AI research (T1.4) across all areas of engineering, harnessing the capabilities available e.g. Project MONAI and the UKs most powerful supercomputer (Cambridge-1, operational in 2021 through Nvidia), to solve pressing medical challenges including those presented by COVID-19;
- Explore further collaborative potential between BMEIS and DoEng. There is currently synergy between six sub-themes (Figure 2), including 5G capabilities (T2.1) and surgery (T1.5).
- Build on the success of T2 by harnessing nature inspired methods for computing and communications and develop T3 as we grow DoEng, though critical mass in research on energy storage (T3.1) and advanced materials and their performance (T3.2). T3.3 will broaden its reach to other manufacturing sectors, with focus on net zero emission for a sustainable future. T3.4 will continue to develop medical devices in parallel to exploiting advanced radiofrequency for other applications;
- Accelerate clinical translation of medical devices, (currently takes over 10 years) through leveraging the MedTech Hub (see sustainability section) and support at least 15 new technologies to reach first-in-patient trials;
- Generate (at least five) new King's spin-out companies supporting commercialisation of engineering technology;
- Provide long-term financial sustainability – i) secure industrial funding including in-kind support ii) generate income via pre-series A companies linked to the MedTech Hub iii) increase overall research income by (at least) 20%.

Enabling Impact: King's Engineering research has led to health, economic and social impact. Our approach to enable impact with examples are highlighted below.

Support formation of strategic partnerships*:** Research projects with over 40 companies (e.g. Nvidia, Nissan and Ericsson) exist and provide opportunities to take part/full-time secondments. The Smart Medical Imaging (EP/S022104/1, a renewal of EP/L015226/1) and Surgical & Interventional Engineering, ***SIE (King's funded) Centre for Doctoral Training (***CDT***) programmes have provided 10 industry internships at companies such as Google, NASA and Samsung. DoEng collaborates with the Centre for Urban Science and Progress London (CUSP London), a joint initiative which aims to bring together researchers, businesses, government agencies (e.g. Transport for London) to apply urban science to improve health and wellbeing. CUSP London follows the highly successful establishment of CUSP New York, both initiatives work in partnership.

***Co-locate staff with partners onsite*:** Key stakeholders are hosted onsite allowing close collaboration, leading to further interactions, e.g. onsite collaborations with Nvidia led to further company investment of c£40m towards the Cambridge-1 supercomputer where we are the sole academic partner. This partnership will allow King's Engineering to take a national leadership role in health data-related AI research.

Provide support for IP, licensing & commercialisation: Access to expertise for ownership, protection and commercial exploitation of IP and creation of spin-out companies is available to all staff and students. Through utilising these expertise, 51 patents were filed supporting collaborative work with industry and a new King's spin-out, Hypervision Surgical was launched with academic involvement from Ourselin and Vercauteren. Financial contribution through the King's Commercialisation Institute supported commercialisation of research outcomes (e.g. £150k was provided for the Soft and Self Propelling Endoscope project, PI Liu). Investment for new staff to steer these activities, manage industry partnerships and support the Enterprise and Engagement and Research & Innovation Leads (Figure 2) has been committed.

Invest in infrastructure: Institutional investment, both at the Strand and St Thomas' Hospital Campus has led to expansion of research space and new/upgraded research facilities. Examples include the expansion of St Thomas' PET Centre (c£17m King's investment) and the new engineering and computer laboratories for DoEng (c£8.1m King's investment). Specialist staff are employed to support scholarly activities, see section 3.

Relationship to Impact Case Studies: Our eight impact case studies (ICSs), summarised in Table 1, illustrate the breadth of impact achieved utilising the features described above.

1	Cydar, an AI driven image guidance system for minimally invasive surgery.
2	3D coronary MR angiography (***CMRA***), a non-invasive radiation-free assessment method.
3	Galliprost, democratisation of PET imaging technology through smart radiochemistry.
4	IXICO, a King's spin-out leveraging medical image data curation and analysis.
5	Adoption of stereotactic ablative radiotherapy technology in the NHS.
6	Automated quantitative myocardial perfusion, improving access, effectiveness, and quality of cardiovascular magnetic resonance.
7	Improved diagnosis and treatment of patients with lymphoma using PET.
8	COVID Symptom Study App, monitoring the spread of COVID-19 across the UK.

Table 1*: Description of Impact Case Studies Submitted for UoA12, King's Engineering*

By enabling strategic partnerships and locating over 10 Siemens Healthineer scientists on-site, EPSRC and BHF funded research led to key technologies that have been adopted by Siemens including the 3D CMRA (ICS 2) and myocardial perfusion (ICS 6) technologies. Both have been disseminated as pre-product software to centres worldwide for clinical validation in advance of commercialisation. EPSRC, CRUK, Wellcome and BRC funded research led to a PET tracer named Galliprost (ICS 3) which has benefited over 1200 patients internationally since 2017 and provided cost savings of £600-£1500 per patient. In partnership with Theragnostics Ltd, the Galliprost kit is now successfully commercialised.

ICSs 1 & 4 build on ongoing research reported in the previous REF period and showcase continued impact of King's spin-out companies IXICO and Cydar Medical leading to further patient benefit, company growth and revenue.

ICS 8 describes rapid response engineering solutions utilising citizen science and AI which led to the COVID Symptom Study App in partnership with Zoe Global. The App has supported significant policy decisions during the current pandemic. ICSs 5 & 7 have influenced/changed practice for the treatment of patients with extra-cranial oligometastatic cancer and lymphoma respectively.

Sustainability: We will continue to recruit and host staff from relevant sectors to grow our critical mass, specifically for T2 and T3. We will provide further infrastructure (institutional investment of c£75m allocated) to support our research and impact strategy. By March 2021 we will open our core experimental facility for SIE research, supporting T1. In 2021 we will complete the Manufacture of Active Implant and Surgical Instruments facility and implement a fully certified quality management system to support the translation of medical devices sustaining T1 and T3. DoEng will open new engineering laboratories by summer 2022 supporting T3. To sustain impact, we are also developing St Thomas' MedTech Hub, a purpose-built ecosystem to support the development, translation and commercialisation of innovative healthcare technologies at a single geographical location. The Hub will exploit ***core collaborative partnerships*** (academia, NHS Trusts and industry), ***enabling infrastructure*** and ***large-scale research projects*** to drive innovation. The development is supported by successful funding bids, including a £16m capital bid from Research England (led by BMEIS) alongside institutional investment of £15m, to build the ***London Institute for Healthcare Engineering*** (section 3).

Interdisciplinarity: Research conducted across King's Engineering is interdisciplinary by nature encompassing researchers with training in engineering, chemistry, physics, computer science, mathematics, biology and medicine working alongside one another. The physical location of BMEIS within St Thomas' Hospital, and the partnerships across KHP, ensures close collaboration with both clinical researchers and practitioners. Similarly, for DoEng, interdisciplinarity is reflected with collaborations across the Stand Campus and social and biomedical sciences. In particular, the strong synergies with the Department of Informatics, ensures continuing vibrancy at the important interface between computer science and engineering. Other examples include, DoEng working with King's Institute of Psychiatry, Psychology & Neuroscience (***IoPPN***) in computer vision to understand human interaction and BMEIS working with the King's Department of Twin Research & Genetic Epidemiology helping shape national policy in relation to the current COVID-19 pandemic (section 4).

Research Integrity and Open Research: As part of the University community, we commit to ensuring research conducted by staff and students is consistently of the highest quality and conforms to rigorous standards. We support honesty and transparency in all aspects of research, adherence to any relevant disciplinary standards, always ensuring that the wellbeing, dignity, and safety of research participants and our researchers are protected, alongside the reputation of the University. We encourage all staff to attend the "*fundamentals of research excellence*" at King's, a short workshop designed to raise and strengthen awareness of research integrity and provide information on relevant policies, both locally and nationally. King's has enhanced and formalised its approach to Research Integrity during the current REF cycle. Therefore, new Research Integrity Advisors, Aghvami (DoEng) and Schnabel and Fischer (BMEIS) have now been appointed to play a high-level advocacy role to visibly promote the values of research integrity and serve as a point of contact for staff queries regarding research conduct.

We adhere to institutional rules with regards to open research as King's is a formal member of the UK Reproducibility Network who provide activities led by the King's Open Research Group Initiative (KORGI) (REF5a). As part of our research and impact strategy, staff are expected to share knowledge widely through complying with King's Open Access policy. Publications are required to be uploaded in full text in King's CRIS and repository system 'Pure' and utilise King's Open Access block grants (from organisations such as the Wellcome and UKRI) to allow fully open access outputs. Research tools such as software/code where appropriate, are shared through GitHub and GitLab webpages, where individual research staff regularly update their software/code. Where appropriate, we share imaging data (e.g. through the Global Society for Cardiovascular Magnetic Resonance registry). We are supported by King's Libraries and Collection team, who provide regular training and seminars for all staff across King's Engineering, particularly with changes in open access requirements from funding bodies. Seminars are organised by BMEIS and DoEng research administrative teams to regularly communicate information regarding open access requirements and disseminate information through internal newsletters and emails. All staff understand the importance of open access and are encouraged to be transparent to ensure the highest standards of research are upheld.

2. People

King's Engineering adopts a targeted but flexible recruitment strategy, a comprehensive support mechanism that promotes equality and diversity and addresses the needs of early career academics and research staff.

Recruitment: All academic appointments are steered by our research and impact strategy. Over the assessment period BMEIS increased critical mass and capabilities in AI (Cardoso, Modat, Ourselin, Schnabel, Vercauteren and Young) and SIE (Bergeles, Melbourne, Jha, Ourselin, Sparks, Vercauteren and Xia) research. Investment in physical infrastructure was also correlated to our staffing strategy as the new SIE research facility was directly linked to the strategic recruitment of Ourselin along with six additional academics and transfer of their research groups from UCL in 2018. For DoEng, focus was placed on strengthening existing areas e.g.

telecommunications (Al-Hashimi, Deng, Rajendran and Simeone) and broadening the research base in new areas across disciplines (Mark, Makatsoris, Guo, Huang, Shollock and Restuccia).

Processes to ensure recruitment of all new academic staff remains fair and promotes diversity are adhered to. This includes having appointment panels that are gender balanced and includes an external panel member. Further, all panel members are required to complete the "Diversity Matters" training workshop. We also encourage under-represented groups to apply through our advertisements and use appropriate networks to disseminate all vacancies. During the assessment period, 45 new academic appointments were made across King's Engineering, 35 in BMEIS, 10 in DoEng (14 Lecturers, 13 Clinical Academics, six Senior Lecturers, three Readers and nine Professorial positions). The overall academic staff profile of King's Engineering includes 73 non-clinical and 24 clinical academics. Examples of Professorial appointments include:

Al-Hashimi CBE FREng (DoEng), expertise in energy-efficient computing and systems engineering (T2). Recruited in 2020 as Executive Dean of the Faculty of NMES, formally an ARM Professor of Computer Engineering from Southampton.

Makatsoris (DoEng), expertise in Sustainable Systems Manufacturing (T3) with focus on automated continuous flow processing of novel materials and vaccines and is involved in establishing a spin-out in continuous flow manufacturing, Centillion Manufacturing Technology. Appointed in 2019 from Cranfield.

Ourselin (BMEIS), expertise in medical imaging, computational modelling, AI and medical devices. Recruited in 2018 from UCL as HoS (BMEIS) to build T1 and promote innovation and impact drawing from his expertise with many large medtech companies as he is associated with a number of spin-out companies (BrainMiner, Innersight Labs, Thames Mammography).

Schnabel (BMEIS), expertise in computational and medical imaging, machine/deep learning, supporting T1. Recruited in 2015 from Oxford as Director of the CDT in Medical Imaging.

Shollock (DoEng), expertise in advanced materials and characterisation (T3). Recruited in 2019 from Warwick Manufacturing Group as HoD for Engineering, supporting the development of engineering activity aligned to in education, research and innovation.

Vercauteren (BMEIS), expertise in machine learning for computer-assisted surgery. Recruited in 2018 from UCL, supporting T1 and innovation and translation of medical devices drawing from his 10 years of experience within industry.

Young (BMEIS, international recruitment), expertise in Analytics and AI. Recruited in 2018 from Auckland, supporting T1, specifically cardiovascular data analytics and AI.

Other new appointments that complement and diversify existing strengths and broaden capabilities beyond healthcare research:

Cardoso (BMEIS), expertise in AI capabilities in healthcare and development of medical data analytics platforms. Recruited in 2018 from UCL as Senior Lecturer in support of T1.

Stasiuk (BMEIS), expertise in design and synthesis of novel multimodal imaging agents for MRI and PET. Recruited in 2019 from Hull as Senior Lecturer supporting T1.

Guo (DoEng), expertise in biomanufacturing and bio-renewable processes. Appointed in 2019, from Imperial College London (***ICL***) as Lecturer (former EPSRC Postdoctoral Fellow), supporting T3.

Huang (DoEng), expertise in advanced materials and manufacturing for energy storage. Appointed in 2019 from Oxford as Lecturer (EPSRC Innovation Fellow), supporting T3.

Overall, 32% of academics within King's Engineering are female while, approximately 72% of academic staff are under 49, demonstrating our commitment to the development of early career

academics, providing a strong pool of talent to develop future leaders to ensure the continued vitality.

Academic Development: Both BMEIS and DoEng implement an Academic Performance Framework for all academic staff (unique to each Faculty) which offers a transparent structure articulating key areas for growth, expectations and recognises wide-ranging contributions. For early career academics, it also offers a method to strengthen career trajectories of individuals enabling greater opportunities. Broadly, the Framework includes mechanisms for formal mentorship, advice on maximising impact, raising international visibility, funding application support and post-award management.

All new academic staff are appointed with an initial probationary period (typically three years). Clear objectives/expectations/targets for this period are agreed, and staff are assigned a mentor to provide guidance and support towards building skills and strengthening research profiles, helping a smooth transition into a permanent position following probation. Successful completion of probation requires staff to demonstrate their ability to develop a sustainable high-quality programme of research.

New academic staff are provided with start-up funding to ensure they have the resources required to develop a successful programme of research and enable them to secure competitive research funding to deliver their research vision. The level of individual start-up support is dependent on specific requirements such as equipment procurement (if not available through existing infrastructure) and, for more senior appointments, funding to support the transition to King's and establishment of new strategic activities. Institutional investment in equipment/facilities for newly recruited academics during the assessment period exceeded £13.5m. For new academics, start-up packages include a £3k - £10k discretionary fund for research expenses and a four-year PhD studentship. For Senior Lecturers and above, support for a postdoctoral researcher may also be provided. All Professorial packages offered are more substantial and negotiated before formal appointment.

All academic staff participate in an annual performance development review (***PDR***) and (following successful probation) are annually offered the opportunity to apply for promotion through Faculty-led processes involving external assessment. One-to-one guidance discussions with the HoS (BMEIS) or HoD (DoEng) is available to all staff who wish to apply for promotion. For the current assessment period, a total of 40 academic promotions were awarded, including six female staff and six Black and Minority Ethnic (***BME***) staff. In line with our strategy to retain academic talent, seven academic staff were successful in more than one round of promotion (Chiribiri, Martin, King, Malik, Niederer, Nordsletten and Prieto-Vasquez) and in two cases progressed from early career Lecturer to Professor (Niederer and Prieto-Vasquez) during the assessment period.

Opportunities for sabbatical leave at other academic institutions or industry companies are offered to staff to drive impact, new funding applications, raise international staff profiles, explore new research fields and build new collaborations (e.g. three-month sabbatical to Stanford University led to a successful $2m NIH R01 award (Niederer)). To enrich the experience of staff and provide opportunities to build their international and industrial research platforms, we have hosted international leaders and visiting Professors including: Peters (Robarts Research Institute); Wells (Harvard Medical School and Brigham and Women's Hospital); Dawant (Vanderbilt School of Engineering); Shah (Arcadis RAEng visiting Professor); Bonfield MBE (Royal Society Entrepreneur in Residence); Kradjian (Chief Engineer (Research) JLR) and Mallikarjum (CEO Ericsson Silicon Valley).

Research Staff Development: Professional development supporting our community of 170 research staff (postdoctoral scientists, research assistants) is influenced by the three guiding Concordat principles with strong institutional commitment (REF5a) to delivery.

Environment and Culture: We communicate King's provisions for mentoring and training to all staff offered by the King's Centre for Research Staff Development (***CRSD***) who provide professional development support for research staff, before, during and after their time at King's. Our respective Faculty Research Staff Committees bring together research staff with academic representatives, to

formulate and monitor development and ensure that the views of all research staff are sought and represented. Activities include quarterly new starter lunches hosted by the Dean/Vice-Deans and regular symposia for research staff. Representatives for all research staff also sit on key Faculty/School/Department decision-making committees.

Employment: In line with our research and impact strategy, we are committed to support the transfer of all talented research staff on fixed-term contracts to long-term opportunities. This is achieved through mentorship and support for fellowship applications. Staff who are approaching the end of their contract are provided direct support from HR to discuss forthcoming opportunities and directed to the Internal Talent Database which advertises short-term bridging employment opportunities. Research staff are allocated 10 days pro rata per annum to focus on professional development and can attend workshops where an increased emphasis on career mapping within/or beyond academia alongside development of research identity and leadership skill are provided. Bespoke annual PDRs with specific sections on mentoring, career progression and future planning, with line-managers are compulsory ensuring these subjects are discussed in advance of contract renewal.

Professional & Career Development: Research staff can access specific courses offered through the King's CRSD on grant writing, leadership, navigating change and uncertainty, career planning (among others) offered centrally. King's Engineering has hosted many (including virtual) workshops (12 in the last 24 months) to steer fellowship applications in collaboration with major funders (e.g. EPSRC, MRC, NIHR) and King's Research Management & Innovation Directorate (***RMID***) staff. Research staff may apply for transition funding through schemes such as King's prize fellowships, which is a competitive process (REF5a). All applicants are closely mentored through this process. Four King's prize fellowships have been awarded (Arthurs; Lloyd; O'Muircheartaigh; Williams) within Engineering. The Wellcome/EPSRC Centre for Medical Engineering has also supported researchers by providing fellowship awards to talented individuals to start pursuing their own research programmes and have an opportunity to apply for further independent funding. 16 internal applications were awarded (worth c£1.3m). Approximately 55% percent of our successful applicants were female, which supports part of our strategy to promote/retain talented women in science. To bring together current and recent holders of independent research fellowships, NMES and BMEIS have established a Network of Fellows. The Network provides a community to inspire and support colleagues to develop activities to further the advancement of network members, and act as a source of advice and share good practice, creating a stronger, more vibrant research community.

Mentoring Schemes for All Staff: Mentorship is key to support skills development at all career levels. There are two institutionally supported mentoring schemes (More Than Mentoring and B-MEntor) open to all staff. B-Mentor is a specific cross-institutional mentoring scheme for BME academics and researchers. Both schemes are promoted regularly to staff. Within BMEIS, an additional mentoring programme, complementing the institutional schemes was first launched in 2013 where senior academics offer mentorship to junior academics and postdoctoral scientists to develop their research profile, teaching and leadership skills. Development of the scheme was initially guided by an external consultant. BMEIS has delivered four dedicated workshops for mentees and mentors since the scheme started. There is a strong emphasis on feedback to ensure the scheme is useful for mentees. In total, over 50 early career researchers have been supported by this scheme during this assessment period.

Career Development Support for All Staff: In addition to courses offered through the King's CRSD, other programmes available to all staff includes the King's Emerging Leaders Programme. In the last round, this attracted five staff (including Howard and Liu) and provides training in the essential skills and tools required for future leaders. The King's Entrepreneurship Institute offers an entrepreneurial training programme providing an opportunity to develop skills as innovators, critical thinkers, and enhance future career prospects. A number of colleagues have benefited from the Leading Researchers Programme (including Niederer and Vercauteren) aimed at senior academics just at or on the cusp of Professorial appointments, who are trained as part of a cohort

to think further about effective mechanisms for leadership, project management, generating and developing big grant ideas, taking risks and collaborating across disciplines.

All staff participate in an annual PDR. The streamlined process provides an opportunity to reflect on successes and difficulties with an emphasis on research and planning career development steps in the medium to long-term, all with the help of senior colleagues. This also allows line managers to systematically recognise successes and difficulties and make appropriate adjustments to workload to ensure adequate time is available for research and related activities (including grant applications, impact development and dissemination of research outcomes). Objectives for the forthcoming coming year are set and opportunities to sit on advisory committees or deputise on decision-making committees are discussed.

Research Development Support for All Staff: We ensure provisions are in place to support research grant funding, in particular for early career researchers. Staff benefit from three dedicated, PhD qualified Research Development Managers (two through RMID and one embedded directly within BMEIS) to support the development of strategic funding applications, provide academic staff training and act as a key point of expertise on applications. In addition, all applications are expected to pass through internal peer review monitored by Research Development Managers. To support the development and success of grant proposals, applications by early career academics are offered one-to-one mentorship from senior academics (e.g. all candidates selected to apply for Future Leaders Fellowships were assigned a senior mentor to provide critique and guidance throughout). Internal peer-review of pre-submission versions of grant proposals for all competitive funding schemes are based on hour-long sessions involving the proposer, 3-5 other academics and Research Development Managers. After submission, proposers are offered help with preparing answers to reviewer comments, and where the application process involves a panel interview, mock interviews are organised for the candidate.

King's Engineering has also developed structured, high-quality cohort-based support programmes e.g. NMES20, to assist early career academics in developing successful grant and fellowship applications. During the assessment period, 19 external fellowships were awarded in total: 10 **UKRI**; four **Wellcome**; two **Royal Academy of Engineering**; one **European Research Council**; one **CRUK** and one **NIHR**, details in section 3.

Supporting Impact: Impact is predominantly achieved through working closely with stakeholders across sectors (e.g. industry and NHS). Across T1, due to complex regulatory processes that need to be followed to allow first-in-patient studies, clinical trial approvals, translation and subsequent commercialisation, six members of staff (which includes a health economist, process engineer and a quality systems manager) provide expert advice to support our academic community to ensure successful navigation through the R&D process. Additional support from the King's Commercialisation Institute, and IP and Licensing Office is also available to enable commercial uptake of technology. Increased investment from Siemens Healthineers and Medtronic (c£20m, including in-kind support) has also led to new Master Research Agreements supporting a plethora of collaborative research opportunities. For DoEng, a new role of Vice Dean (Enterprise and Engagement) was established in NMES to support departments in achieving a higher degree of non-academic impact and creating potential new income streams, with similar roles at departmental level. This NMES role is complemented by a Faculty Industrial Partnerships Manager.

King's has held an EPSRC Impact Acceleration Account (***IAA***) since 2015 managed by NMES in support of the development of impact from EPSRC funded research. The IAA has both supported workshops to encourage a focus on impact by academic and research staff, and funded impact projects through competitive calls. Applicants to the scheme are provided with one-to-one support to develop their proposals to ensure the development of a pathway to impact for the underpinning research. To date, 18 projects have been funded in King's Engineering which in turn has leveraged over c£2m of additional research and innovation funding. We have also successfully secured 12 awards from the King's Together (REF5a) funding stream supporting new interdisciplinary

collaborations this includes projects entitled "*Tracking brain states in epilepsy*", PI Cvetkovic and "REBoot, Research Epidermolysis Bullosa orthotics" PI Howard.

Equality, Diversity and Inclusion (ED&I): King's is one of only 10 UK institutions to hold a Race Equality Award, receiving Bronze in 2015, we are also a Stonewall Diversity Champion member since 2016 (REF5a). King's Engineering therefore has a strong commitment to embedding the principles of ED&I respecting all protected characteristics including issues of race and racial inequality and ensuring LGBTQ+ inclusivity. To help support and communicate these principles, we have Development, Diversity & Inclusion representatives (Marsden (BMEIS) and Shollock (DoEng)). We also hold Athena SWAN Silver and Bronze Awards for BMEIS and DoEng respectively. All staff are required to attend the "*Diversity Matters*" training workshop to understand and promote an inclusive and diverse research environment where policies and practices are followed, including those related to recruitment. In 2019, over 90% of our academic staff attended the "*Diversity Matters*" workshop, where for many, this was a refresher course. All recruitment panels have at least one (usually two) senior female panel members. To further support our staff, we encourage the use of the University supported Parents and Carers Fund which provides return to work funds (c£10,000) for all staff following a period of maternity/adoption/additional paternity/caring responsibility leave (four people within King's Engineering have been awarded funding). We operate a compassionate system of flexible (and where appropriate part-time) working arrangement for staff with caring commitments, both informally and formally facilitated. We strongly encourage all colleagues to keep meetings and other communications within 'core' working hours (10am-4pm) to promote staff wellbeing. Our seminar series are run during lunchtimes and early afternoon slots to ensure those with caring duties are also able to attend. All employees have access to mental health and wellbeing support. This includes one-to-one and group counselling sessions (including out of hours support) and Disability Advisers (expert mental health advisers).

Overall, the percentage of female early career Lecturers has increased from 33% in 2014/15 to over 60% at end 2018/19. We anticipate that the percentage of female staff in higher academic grades (currently Senior Lecturers 25%, Professors 20%) will now increase reflecting the large number of junior female academic staff now potentially available for promotion. For the same period, the overall percentage of BME staff remains close to 25% (all staff) and is currently 23% for all academic staff and 20% at Professorial level. With regards to nationality 45% of King's Engineering academic staff are from the UK, 30% from the EU and 25% from non-EU countries.

To further support diversity & inclusion, we actively work to help women in STEMM (as highlighted through the increase in percentage of female lecturers appointed) to address the current imbalance of women working and studying in these areas. In 2013 the NMES Women in Science Initiative was established to assess, address and challenge the inequities women face in their academic careers; initiatives include the establishment of the Gender Equality Student Fund, open to all students in the Faculty to support innovative projects, activities or events that promote gender equality in STEMM.

REF Submission: To support the UoA12 submission, a management group led by Schnabel, including Jha, Ourselin and Shollock as senior members was formed (with support from five administrative staff). Two oversight groups to enable output and ICS selection were formed with representation from both BMEIS and DoEng. The UoA12 management group regularly reported to Panel B lead at institutional level. Training workshops were provided for all staff being returned to support the preparation of their the 100-word statement accompanying each output. Further, ICSs were prepared with the lead academic with support from Jha and the central REF submission team.

Post Graduate Research Students: We currently have 279 PGR students (201(BMEIS) and 78 (DoEng)) supervised by academics within King's Engineering. This has more than doubled since REF2014 (113 students). Our PGR programmes are supported through two CDTs (described in section 1), Doctoral Training Partnerships (DTPs), King's-China Scholarship Council programme and industry-funded studentships. Additionally, our academics supervise PGR students admitted through University-wide or cross-Institutional interdisciplinary PGR programmes, such as the MRC DTP in Biomedical Sciences, the BBSRC funded CDT London Interdisciplinary Doctoral

Programme with eight London universities, and the CRUK RadNET City of London (UCL, King's and Queen Mary University of London (***QMUL***)).

Our training courses are mostly 3.5 or four years, with recruited students from a diverse set of academic backgrounds (e.g. applied mathematics, chemistry, physics). Our four-year programmes feature a comprehensive and structured training approach with (in BMEIS) an MRes in Medical Imaging Sciences (from 2019 onwards this has been transformed into a new MRes in Healthcare Technology) in their foundation year at King's, and enhanced skills training over the subsequent PGR years. Taught courses cover the core subjects related directly to the students' programme of study and are complemented by courses that provide broader skills training. Training through the "King's Entrepreneurial Mindset", "Responsible Research and Innovation" courses and public engagement activities are firmly embedded within the CDTs and provided to other PGR students. The CDT also offers external mentorship and placements in industry and international academic laboratories for enhanced employability prospects. PGR students at King's have at least two supervisors, benefit from an academic PGR Lead/Coordinator/Tutor (pastoral care and conflict support), an assessment at 9-months, a follow-up upgrade assessment and a dedicated Thesis Progression Committee, with further support from the Centre for Doctoral Studies (***CDS***). All students will also have a formal MPhil/PhD upgrade examination to monitor their progress. Due to the nature of some of our research programmes, where appropriate, students also have a clinical supervisor (facilitating interactions with patient groups) maximising benefit from being embedded within a major research and teaching hospital.

All students have access to mental health 'first aid', which was created based on evidence from research in PGR student experiences and is supported by the CDS. King's leads the UKRI Student Mental Health Network and has a strong focus on student wellbeing, providing named support staff for students across the University, ongoing monitoring, and a "taskforce" led by IoPPN. Advice for career development is available through dedicated career advisors. Workshops for interview preparation and grant writing to aid those who wish to apply for postdoctoral positions is delivered in collaboration with the CRSD. The student alumni network is a further mechanism to support graduates in their future career. Students are also provided opportunities to gain public engagement experience, organise symposia, and contribute/present at internal seminar series.

Our current PGR population have an excellent gender balance (50% male, 42% female, 8% undisclosed), while overall percentage of BME students has remained fairly constant over the return period at 25% overall, with 35% being non-UK domicile. Our recruitment process features independent interview stations to mitigate bias. We uphold all ED&I principles and have a commitment to advancing the careers of women in STEMM for employment in higher education and research and the Race Equality charter, which aims to improve the representation, progression and success of minority ethnic staff and students within higher education.

3. Income, Infrastructure and Facilities

Research Funding: Our approach for generating new income to drive our research vision is directly linked to our research and impact strategy and the objectives set in REF2014. In addition to supporting responsive mode applications, we have focused on increasing our portfolio of programme and centre grants in areas of established research excellence (e.g. imaging sciences, including chemical tracers), and targeted areas of research (in line with funding organisations) to build a critical mass of expertise, an example for this being AI in healthcare research.

Application Support: Proposals are written collaboratively, coordinated by the lead academic with support of research administrative staff and all applications undergo a stringent review process before submission. Funding opportunities are highlighted to all academics through a fortnightly newsletter. For strategic bids, where application numbers are limited, RMID organise a thorough and fair internal peer reviewed selection process with diverse panel members. Central Pre-Award Teams support the submission of applications, formal acceptance/negotiation of awards and provide general advice and training sessions. The contracts team offer specialist expertise for industry funding, consultancy projects and negotiate agreements (e.g. material transfer and/or non-disclosure agreements). Since 2019, King's has deployed a new grants management system with a dedicated 'Help Desk', which has improved research support and offered a more streamlined approach for grant management.

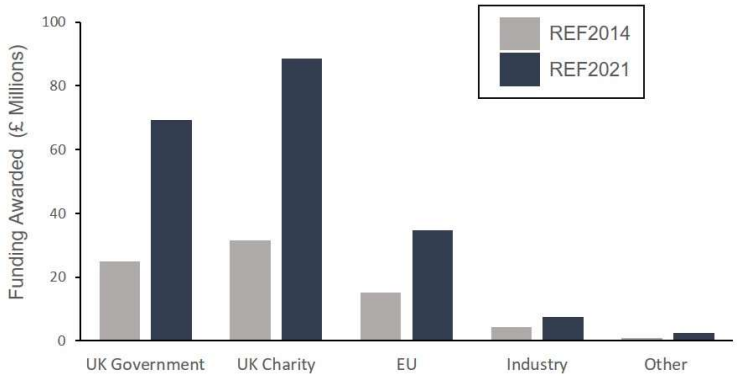

***Figure 4**: Sources of Research Awards Between August 2013 to July 2020, King's Engineering. UK Government figures include all funding awarded from UK Research Councils.*

King's Engineering has been hugely successful in forming many strategic partnerships and consortia leading to 502 awarded research funding applications or industry contracts worth over c.£202m (compared to c.£76.8m value reported in the REF2014 return period). Figure 4 highlights the increase in total funding awarded to King's during the REF2021 assessment period from different sources compared to REF2014. The greatest increase in funding secured was from UK government and charities (which includes contribution from the Wellcome Innovations, Collaboration in Science and Multi-user Equipment funding streams). The increase research funding awards is reflected in our research income for the current return period, c£111.2m in total, or c£15.8m of average research income annually, increasing from the c£6.2m annual average during REF2014. Examples of major funding awards highlighting our partnerships, national and international research influence and broad research topics are highlighted below.

- We host one of two UK Wellcome/EPSRC Centres of Excellence in Engineering. Our **£12.1m Centre for Medical Engineering** (PI Razavi, NS/A000049/1), awarded in 2017 is the only one of the previous four Medical Engineering Centres of Excellence to be renewed. The Centre brings together King's Engineering and IoPPN to focus on medical imaging to improve the understanding, diagnosis and treatment of people with cardiovascular, neurological, cancer and psychiatric conditions. The Centre drives collaborative research and provides funding for personnel (e.g. regulatory and quality management specialists) to support first-in-patient studies and the translation of technology.
- King's Engineering hosts one of four UK AI Centres of Excellence which use AI to deliver precision medicine to patients. The **London Medical Imaging and AI Centre for Value Based Healthcare (AI4VBH,** PI Razavi**)** is supported by c.£10m of Innovate UK funding and has led to the formation of a consortium with ICL, QMUL, KHP, Bart's Health, multinational industry (Siemens, NVIDIA, IBM, GSK), 11 UK-based SMEs and the Health Innovation Network. The Centre enables the formation of new partners within a framework where knowledge and know-how can be exchanged.
- EPSRC Programme Awards i) The **MITHRaS Programme** (King's, ICL and the University of Southampton), awarded in 2019 (EP/S032789/1, c.£6.4m, PI Blower). The programme aims to make molecular imaging affordable and accessible to patients globally by developing new, fast and easy-to-use chemistry for synthesis of radiopharmaceuticals in hospitals and centralised radiopharmacies. ii) **redOx⇌KCL**, an interdisciplinary programme led by Oxford University, awarded in 2019 (EP/S019901/1, c£5.3m, King's PI Blower) bringing together leading organic and inorganic chemists, molecular biologists and imaging specialists alongside GSK, Syngenta, Pfizer, Theragnostics and GE Healthcare. The project investigates the dynamics of the redox environment in complex biological systems.

- EPSRC CDT Programme in **Smart Medical Imaging** CDT programme (jointly ICL), awarded in 2018 (EP/S022104/1, c£6.0m, PI Schnabel). A core PhD training programme which leverages 40 partnerships from different sectors. The objective is to train the next generation of medical imaging researchers utilising the full potential of medical imaging for healthcare through integration of AI, targeted, responsive and safer imaging probes.
- EPSRC International Centre-to-Centre grant enabled the **Centre for Spatial Computational Learning** (EP/S030069/1, c£1.2m, King's PI Al-Hashimi). This reflects a key international partnership which has the potential to put the UK's expertise at the centre of the technology revolutionising the way high performance and low energy computation is specified and delivered, opening opportunities from ultra-low energy machine learning in IoT devices through to powering scientific discovery in high-end server farms.
- EPSRC **Prosperity Partnership** grant (EP/R004927/1, c£2.6m (c£3.2m of matched industry funding) PI Shollock), with Jaguar Land Rover Limited to explore the underlying engineering science to deliver vehicle electrification.
- EPSRC GCRF Awards i) **DeMoStroke** (EP/R013918/1, c£834k, PI Kosmas), awarded in 2018 develops affordable and practical system based on microwave technology, to provide accurate information on the evolution of stroke ii) Clear Road Ahead Developing a Combined Technological and Socio-Economic Approach to **Freeing Affected Communities from Anti-Vehicle Landmines** (EP/P02906X/1, c£1.0m, PI Kosmas) awarded in 2017 with a focus on creating a new tools for detecting landmines iii) **LoCoMoTE** (EP/R013977/1, c£1.0m, PI Liu) awarded in 2018 to solve the unmet needs of China's endoscopic gastrointestinal screening due to its large, aging population.
- European Commission Programme, **The Developing Human Connectome Project** (ID: 319456, c.€14.9m, PI Edwards) awarded in 2013. With ICL and Oxford University the project investigates how conditions such as autism and cerebral palsy arise.
- UK Department for Digital, Culture, Media and Sport (DCMS) awarded £16m in 2017 (King's PI: Dohler) to develop the **world's first end-to-end cutting-edge 5G test network**. The consortium includes King's and Universities of Bristol and Surrey.

We also secured capital awards to develop/build physical infrastructure. The four grants highlighted below will be crucial to support our research and impact strategy and support/sustain many research groups.

- A Wellcome c.£4m award to support the **Multi-User Ultra-High Field Clinical Imaging Research** Centre for London (7T Imaging system), in 2017 (PI Hajnal), partnership between UCL, ICL and the Institute of Cancer research (***ICR***). Additional institutional support of £6.4m, enabled the creation of a hospital embedded clinical 7T MRI system.
- Wolfson Foundation £1m in 2018 (institutional award, led by Ourselin) for procuring equipment for the **mock interventional suite** embedded within the SIE laboratory space.
- A Wellcome c£5.2m award to establish the **Manufacture of Active Implant and Surgical Instruments facility** in 2019 (PI Ourselin), in partnership with King's, UCL and Newcastle University. All partners were awarded the three Innovative Engineering for Health awards from the Wellcome in 2013 and this facility will enable the prototyping of Class II/III medical devices for use in first-in-patient studies. The facility will also support the MedTech Hub, specifically supporting the translation of healthcare engineering research.
- UKRI University Research Partnership Investment Fund from Research England awarded £16m in 2019 (institutional award, led by Ourselin) for building the **London Institute for Healthcare Engineering** to house a medtech accelerator and multi-national industry partners (up to 350 people). This award was facilitated by c£15m of University investment and leveraged c£32m of industry investment (direct cash and in-kind) which has driven the implementation of other infrastructure such as the High Performance Computing (***HPC***) required for the AI4VBH Centre.

Fellowships Awards: In support of our strategy to retain staff talent, knowledge and know-how, during the assessment period King's Engineering has attracted c£15m through 19 successful fellowships. This include: 10 **UKRI** (including Future Leader, Career and Skills Development

Fellowships); four **Wellcome** (including Henry Dale and Senior Research Fellowships); two **Royal Academy of Engineering** (Enterprise and Senior Research Fellowships); one **European Research Council** (Consolidator Grants); one **CRUK** (Career Establishment Award) and one **NIHR** (Research Professorship).

Industry Awards: During the assessment period, we have secured c£7.2m in funding from industry to support research projects of mutual interest, which has increased from £4.6m reported in the REF 2014 assessment period. Direct funding and in-kind support was provided by: Abbott Medical, AstraZeneca, Boston Scientific, BT Group, Celleron Therapeutics, Cisco, Cosmonio, Ericsson Ltd, GE Healthcare, GlaxoSmithKline, Gilead Sciences, Holoxica, Huawei Technologies Co, IBM, Medici Technologies, Medtronic, Monde Nissan, NanoMab, Perspectum, Pfizer, Philips Medical Systems, PMB Alcen, Siemens Healthineers, Theragnostics, Ultromics, and William Cook.

In addition to direct funding, in-kind support from industry has been beneficial to many research areas, and therefore our ability to achieve impact. Key examples include the donation of an O-Arm Surgical Imaging System (£600K) and StealthStation Surgical Navigation System (£293K) from Medtronic. This equipment will support SIE research. IBM has also provided a distributed Learning System (worth c£50K) which has supported the AI4VBH Centre. Further in-kind investment is the know-how and expertise from over 10 industry funded scientists that are embedded onsite who are directly working and influencing the outcome of R&D projects of mutual interest leading to tangible impact (examples highlighted in ICS 2, 3, and 6). Both British Telecom and Monde Nissan have provided equipment to support bioprocessing of food proteins.

Organisational Infrastructure: King's Engineering can utilise organisational infrastructure to support our research and impact. Many world-class research facilities have been outlined in REF5a. Those significant to King's Engineering research includes:

- Biological Services – support all the pre-clinical investigations, especially for novel tracers developed within T1.3;
- King's Clinical Trial Unit – a UKCRC Registered Clinical Trials Unit which offers methodological and operational support for clinical trials for all healthcare engineering research;
- e-Research – a new University-wide e-Research function to provide a highly flexible research computing infrastructure designed to fit all shapes and sizes of computational workload;
- Rosalind – a collection of research computing infrastructure hosted by King's established from the pooled contributions of hardware, staff and running costs. This platform includes a HPC cluster, a private cloud platform and a highly resilient storage area for longer term curation of research data.

Operational Infrastructure: King's Engineering is split across two sites, St Thomas' Hospital campus and the Strand campus. In line with our research strategy, we provide state-of-the-art facilities which support novel engineering research. These include:

- 1903m^2 of state-of-the-art chemistry and biology (including confocal microscopy, flow cytometry, and HPLC) laboratories, new engineering workshops, pre-clinical PET-CT, SPECT-CT, PET-MR scanners, ultrasound and a 9.4T NMR for spectroscopy and imaging with an additional hyperpolariser.
- 1035m^2 of space dedicated to the Imaging Clinical Research Facility (ICRF) with seven clinical grade MRI scanners including a hospital-embedded 7T MRI Ultra High Field Scanner. The scanners also provide on average, 12,000 patient scans per year, allowing staff within BMEIS direct engagement with patients for research studies. We also have a radiofrequency laboratory supporting MRI hardware prototyping activities for clinical MRI scanners including cardiac imaging coils and 3T parallel-transmit head coils.
- 644m2 of space dedicated to the PET Centre supporting research and providing a clinical service. Following major investment from the University (£17m, total project costs c£28m) in partnership with GSTT, we have created a world-class facility with the Centre being among the largest in Europe. Further, in 2019 BMEIS and GSTT launched the Positron Emitting Radiopharmaceutical Laboratory (PERL). The PERL laboratory houses eight research hotcells, two GMP cleanroom laboratories housing 12 manufacturing hotcells and two isolators.

- HPC & Storage: All HPC capabilities supports all research. BMEIS purchased (2019) a new enterprise HPC cluster, that consists of 2816 compute cores dedicated to data processing. Each compute node includes 256GB DDR4-2666 RAM, with 64 cores per node this equates to 4GB per core. BMEIS also purchased 6 DGXs, high performance graphical card clusters dedicated to AI research. The DGXs, have been setup as a GPU research cluster totalling over 60 cards able to concurrently efficiently train many large AI based models. Finally, a large enterprise storage solution, totalling 320 TB of resilient and back-up disk was purchased in 2018. DoEng also provides a HPC cluster to support large parallel workloads with high core count nodes, Infiniband networking and Lustre filesystem. In 2019 this cluster was expanded with additional CPU and GPU capacity for large parallel workloads with OmniPath networking.
- 5G Network Testbed: To demonstrate 5G technology capabilities we have created an integrated system-level 'hub' testbed platform (supported by institutional investment of £250k). Development of the King's UK5G testbed was performed in close collaboration with Ericsson, including integration of prototype equipment. This is part of the 5G Tactile Internet laboratory established between the Centre of Telecommunications (King's) and Ericsson in 2016 and the UK Programmable Fixed and Mobile Internet Infrastructure (INITIATE, EPSRC EP/P003974/1). Dedicated server room space in the King's Strand Campus was upgraded with installation of 5G and 4G Core networks servers, with a new cabling network in the Strand Campus Buildings for an indoor test-bed comprising Ericsson Radio Dots, and installation of outdoor antennas mounted using a new mast on the roof. Connectivity for external users is facilitated by a dedicated 10 Gbps JANET connection.
- Health Technology Assessment (***HTA***) Centre: King's Technology Evaluation Centre (***KiTEC***) is a well-established HTA Centre, providing expert support evaluation and policy assessment across a wide range of healthcare technologies and interventions. KiTEC functions as an external assessment centre for NICE and NHS England programmes.

Scholarly Infrastructure: Our academic and research staff are supported by a core team of 121 professional service staff. This includes strategic research programme and Centre managers, administrators (to cover estates and other general issues), research and development support staff (team of 3 supporting grant submissions), specialist technical laboratory managers (team of five) and medical device regulatory experts who also support ethics applications working across all departments. We also have quality system experts, clinical trial coordinators, health economists and process engineers (supported through Wellcome awards). To promote research outcomes and help increase research impact, BMEIS has a core Public and Patient Engagement team (Wellcome and EPSRC funded) and a Communications and Marketing team (centrally funded). We have a team of four full-time IT support staff who manage all HPC infrastructure described above and general IT issues. A team of 40 staff, including radiographers, nurses, technicians and chemists, support clinical research facilities including the ICRF and PET Centre.

Access to Infrastructure: All King's Engineering experimental research facilities and scholarly infrastructure are shared and can be utilised by many research groups for research purposes. All specialist infrastructure (e.g. PET scanners) are run through a booking system, all users are charged to support general maintenance and technical staff costs. Within BMEIS, significant facilities are managed within the School and therefore planning usage and upgrading of systems is managed by the Head of School, School Manager and appropriate technical personnel.

Cross-HEI Shared and Collaborative Use of Research Infrastructure: Due to the nature of our research, many of our funding applications are collaborative and some are joint submissions with other HEIs. A key example being a Wellcome Award (c£4.1m) alongside direct capital investment from King's (c.£6.8m) which led to the London Collaborative Ultra-high Field MR System (***LoCUS***) and a fully integrated 7T clinical imaging research facility. LoCUS catalyses a vision of collaborative research across London, to ensure that large scale, capital infrastructure is intensively and efficiently used to maximise output and impact. To this end, a joint management group exists across all partner Universities (King's, UCL, ICL) and ICR. Together these institutions have contributed £327,264 (in 2020) towards running the facility.

Two new Wellcome Multi-user Equipment Awards (worth c£1.9m) also support cross HEI collaborations. Facilities include equipment for the SIE laboratories (PI Ourselin) and the London Metallomics Facility (PI Blower) for molecular imaging and radionuclide therapy. External HEI collaborators for these activities includes: ICL, Kent, Leeds, UCL, Vanderbilt and Warwick.

The Physics & Engineering Research Facility at the Strand Campus, and the Centre Ultrastructural Imaging at Guy's Campus, both part of a network of facilities across the London Centre for Nanotechnology, ***LCN*** (REF5a) service the increasing need within DoEng for the characterisation of materials across length scales from nanometre to micron. Likewise, King's partnership in the LCN provides researchers in King's Engineering with access to LCN facilities, such as cleanroom nanofabrication, at ICL and UCL.

4. Collaboration and Contribution to the Research Base, Economy and Society

National and international partnerships across King's Engineering spans many sectors including: academic institutions, learned societies, healthcare providers, funding bodies, advisory groups, industry and government organisations. We form collaborative partnerships where it promotes and supports the delivery of our research and drives impact.

Effective Collaborations: We currently host 116 visiting appointments (including 26 non-UK residents) and 39 honorary appointments enabling academics from other organisations to become fully embedded in research projects of mutual interest. Honorary appointments support clinical partnerships which continue to grow across KHP and other NHS Trusts (e.g. Imperial Healthcare) with many honorary clinical collaborators having adjunct positions (Ashkan, Arora, Connor, Lumsden, Mah, O'Neill and Rinaldi) equivalent in stature to University employed clinical academics. A key enabler for collaborative research is physical co-location with end-users allowing the exchange of knowledge. For T1, many healthcare technologies are developed jointly with clinicians and industry scientists onsite at St Thomas' Hospital. DoEng is located at the Strand Campus which enables frequent interactions with expert academics from other disciplines. A key mechanism to form/support collaborative projects with academic and non-academic partners usually occurs within the remit of a grant or industry funded project. Proof-of-concept collaborations also exist to gain data supporting larger funding applications. Many large programme grants usually have a duration of five-years and have developed and/or reinforced collaborations supported by formal arrangements/contracts. To encourage networking seminars, research meetings, conferences and workshops (to report project updates or provide a forum to discuss new innovative ideas) are organised between partners regularly and are hosted at King's, or at national and international conferences, and more recently, via virtual platforms.

Industry Collaborations: Through our unique positioning, extensive expertise and infrastructure available, we have built strong relationships with over 40 industry companies. This includes the large multi-national companies, as well as small and medium-sized enterprises (***SMEs***), start-up and spin-out companies. For example, the AI4VBH consortium includes four multinational industry partners (Siemens, Nvidia, IBM, GSK) and 11 UK-based SMEs (Ainostics, Biotronics 3D, Brainminer, CyDAR, Innersight, Ixico, Kheiron Medical, Mirada, Owkin, Perspectum and Thames Mammography). Our CDT programmes benefit from industry studentships and where appropriate students are co-supervised by industry scientists and/or undertake internships. Example collaborations with SMEs includes the work led by DoEng (Kosmas) in partnership (since 2013) with MediWise. Research focuses on disruptive medical diagnostic solutions based on microwave sensing and imaging to tackle diagnostic challenges in cancer and stroke. This collaboration has impacted both MediWise and King's Engineering leading to six collaborative grants from Innovate UK (raising c£2.8m), a platform to promote our research (articles in The Scientist and interviews on labiotech.eu), company revenue, growth and acquisition by Metamaterials Technologies Inc. The Ericsson collaboration provides £100k per annum to support 5G research spanning many fields including medicine, education, gaming and culture. Projects within the Ericsson 5G Tactile Internet Laboratory include the potential for remote superior precision medical interventions and the world's first 5G connected theatre performance in June 2018. Musicians from the Guildhall School of Music and Drama performed in tandem with pianist and Professor of Wireless Technology (Dohler) who was physically located in Berlin. Work conducted has led to significant press and media

coverage which Ericsson have evaluated as the equivalent marketing spend in the order of c£122m.

Interdisciplinary Partnerships: To reflect the scope of our healthcare engineering research we draw expertise from many NHS Trusts. A recent collaborative award (to the AI4VBH centre and GSTT) funded by DHSC for £16m has facilitated significant expansion of the AI4VBH Centre consortium from four to 11 NHS Trusts enabling the Centre's AI research to reach a further seven NHS Trusts and provide more innovative and accessible healthcare solutions to the public. Vital infrastructure leveraged by research groups includes support from 13 BRC funded posts (including database managers, radiographers etc.) within BMEIS to support research. BMEIS hosts two of the three awarded Innovative Engineering for Health Awards provided by the Wellcome and EPSRC including the Intelligent Fetal Imaging and Diagnosis (iFIND) project (PI Razavi, c£9.9m) started in 2014 and is in collaboration with ICL, Philips and GSTT. Key innovations include improved 3D visualisation of major vascular abnormalities using fetal cardiovascular MRI providing clarification on fetal heart defects before birth so doctors can plan the best care for these families, this project had national exposure on ITV and BBC news channels. In response to global priorities to control the spread of the COVID-19 virus, interdisciplinary research groups within BMEIS (Ourselin, Cardoso, Modat), the Department of Twin Research & Genetic Epidemiology and Zoe Global, created the COVID Symptom Study App (ICS 8). Using the unique data collected, we significantly contributed to the understanding of and response to the pandemic, publishing 17 research outputs. Highlights include information gathered on geographical "COVID-19 hotspots", symptom prediction models, identification of a much wider range of symptoms associated with COVID-19 including anosmia. In early 2020, in response to the UK government's call for the development of low-cost mechanical ventilators for potential use in ICUs across the country, multidisciplinary teams within BMEIS (Ourselin, Bergeles, Jha), King's Human Physiology, Sport and Exercise Science Department, Oxford University and Smith+Nephew designed and prototyped the OxVent ventilator. In late 2020 the OxVent invention led to an IET Award as one of best innovations of the year. A unique partnership with the National Gallery and DoEng has jointly launched (2019) National Gallery X, a collaborative R&D programme exploring how technological developments can be applied to cultural institutions in the future. This ambitious project will put DoEng at the forefront of digital innovation.

International Partnerships: Over the assessment period, a total of 25 EU funded grant proposals were successfully secured highlighting a strong international presence supporting all thematic areas. Linked to T2, we are capturing emerging areas in information engineering, including the FOGHORN project which aims to develop the theoretical and algorithmic foundations of fog-aided wireless networks (EC, Simeone, c.£1.7m). Beyond Europe, the demand for improving care in LMIC is rapidly increasing. BMEIS (Wellcome, Razavi, c£3.5m) in collaboration with Oxford, and funding support from the Wellcome, has built a project team of Vietnamese and international clinicians, biomedical engineers, and computational scientists to fulfil the mission of using new technology to provide low-cost solutions for monitoring critically ill patients, assist rehabilitation, and generate clinical decision support systems to improve diagnosis and treatment.

Engagement with Diverse Communities: King's Engineering academic staff contribute to the global research base through organising, hosting and chairing major conferences and scientific meetings. Staff have been invited to speak at c230 keynote/plenary lectures and have held many leadership roles for conference organisation providing further evidence of research influence. Some *highlights* include: European Association of Nuclear Medicine, Barcelona Spain, 2016 - *Plenary Lecturer (**Barrington***); Royal Society meeting on Chemistry in Imaging, 2017 - *Keynote Speaker (**Blower***); IEEE International Symposium on Biomedical Engineering, 2018 - *Keynote Speaker*, (***Counsell***); Australia and New Zealand Nuclear Medicine Society Annual Meeting, 2019 - *Keynote Speaker (**Goh**); 21st IEEE International Workshop on Signal Processing Advances in Wireless Communications, 2020 - Keynote Speaker (**Makatsoris***)*; Advanced Satellite Multimedia Systems Conference and Signal Processing for Space Communications conference, 2018 - *Keynote Speaker (**Simeone***)**;** Gordon Conference on High Temperature Corrosion, 2015, *Keynote Speaker (**Shollock**);* World Molecular Imaging Congress 2019 - *Keynote Speaker (**Witney**).*

Further, staff have participated in over 270 public engagements events to communicate, promote and teach engineering sciences and research outcomes. Regular public engagement activities are planned across all research themes and supported by a dedicated team of three public engagement officers through Wellcome and EPSRC funded programmes. Our research has been showcased at events such as the Royal Society Summer Exhibitions, Bloomsbury Festival, NewScientist Live, RAEng Festivals and Science Gallery exhibitions. Significant research outcomes have also been promoted through the national media including BBCs Horizon '10 things you need to know about the future' 2017 (Edwards) illustrating work from the **Developing Human Connectome Project** and Trust Me I'm a Doctor (Ourselin) highlighting research outcomes from the multidisciplinary **EpiNav™** (epilepsy navigation) project between University College Hospital and King's (Ourselin, Sparks). The technology has been used in over 150 epilepsy surgeries and commercialised by Medtronic.

Consultancy*:* Our academic staff provide expertise to other organisations including: Apple UK and US, Phillips, HTC and Asus (***Shikh-Bahaei***); Centillion Technology Limited (***Makatsoris***); PCC Aerostructures *(**Makatsoris***); Pfizer (***Niederer***); Theragnostics (***Blower***); Ultromics (***Lamata***).

Contribution to Research Base: All academic Staff continue to develop their international research reputation evident through the research collaborations. Many have been recognised for their contribution through the Engineering discipline by being included as fellows of major professional organisations and learned societies or awarded distinguished prizes.

Distinguished Fellows: Fellow of Institute of Materials, Mining and Minerals (***Shollock***); Fellow of Institute of Electrical and Electronics Engineers (***Aghvami, Dai, Dohler, Lam, Schnabel, Simeone***); Fellow of Institution of Engineering and Technology (***Aghvami, Dohler***, ***Shikh-Bahaei, Simeone***); Fellow of International Society for Magnetic Resonance in Medicine (***Botnar, Hajnal, junior Fellow Hutter***); Fellow of Society for Cardiovascular Magnetic Resonance (***Botnar, Chiribiri, Ismail, Roujol***); Fellow of the Academy of Medical Sciences, (***Edwards***); Fellow of the Royal Academy of Engineering, (***Al-Hashimi, Aghvami, Dohler, Hajnal***); Fellow of the Royal Society of Chemistry, (***Blower***); President Society of Radiopharmaceutical Sciences (***Gee***); Senior Member of US National Academy of Inventors (***Rajendran***); Fellow of Medical Image Computing and Computer-Assisted Interventions (***Ourselin, Schnabel***); Fellow of the Institution of Mechanical Engineers (***Dai***).

The quality of our research outcomes and leadership can be demonstrated through recent successes especially in response to the global pandemic. Other achievements and prizes which showcase the calibre of our academics and their contribution to engineering and society during the assessment period includes:

Al-Hashimi was awarded *Commander of the Most Excellent Order of the British Empire*, CBE in 2018 for his services to engineering and industry. Further he has also been awarded the *Faraday Medal from the Institution of Engineering and Technology* in 2020 for his notable scientific/industrial achievement, for services rendered to the advancement of engineering.

Barrington was awarded a *British Nuclear Medicine Society Roll of Honour* in 2019, an award for highly distinguished members who have contributed to the history of nuclear medicine.

Blower was awarded a *British Nuclear Medicine Society Norman Veall Medal* in 2020 for outstanding contribution to UK science/practice of nuclear medicine.

Makatsoris was awarded a *Royal Academy of Engineering President's Award for Pandemic Service* in 2020 for advancing the manufacture and deployment of cost-effective vaccines with his 'factory-in-a-box', a novel process intensification technology for vaccine production. This project was in collaboration with ICL.

Razavi was awarded a prestigious *Joint Royal College's Medal and Honorary Fellowship of Royal Photographic Society* in 2019 for outstanding contribution to medical imaging and its application in the service of medicine and surgery.

King's Engineering academics actively contribute to the globally scientific community. Table 2 summarises key activities staff have or are contributing to. Staff are involved in peer reviewing grant proposals submitted to various funding organisations and contribute to their research disciplines through holding editorial roles for many scientific journals. Table 3 highlights a *subset* of grant panel schemes, editorial and advisory roles held by academic staff. Staff also contribute to 14 international grant funding panels, further highlighting the expertise and research reputation of our staff on an international platform. Further, staff were invited as guest editors for over 33 journals.

King's Engineering Contribution to Research Base				
Peer Reviewing		**Advisory Roles**	**Engagement**	
Academic staff serve on 95 national and international grant funding panels.	Academic staff hold 127 scientific journal editorial roles.	Academic staff have served on 70 national & international committees & advisory Boards.	Academic staff have participated in, organised and/or chaired 230 scientific conferences.	Academic staff have participated in and/or organised 270 public engagement events.

Table 2: *King's Engineering, Contribution to Research Base Overview*

rant Panels	UKRI Engineering and Physical Sciences Research Council	DTP Statement of Intent and DTP Doctoral Mobility Pilot Chair: **Al-Hashimi**; Grant Panel Members: **Blower, Cvetkovic, Lam, Simeone, Huang, King, Liu, Malik, Niederer, Razavi, Schnabel, Xia, Makatsoris**; Platform Grant Panel Chair: **Shollock**; Programme Grant Panel Chair: **Ourselin**; EPSRC Fellowships Panel Chair: **Ourselin, Shollock**; Manufacturing Fellowships Panel Member: **Makatsoris**
	UKRI Medical Research Council	DPFS Grant Scheme Members: **Hajnal, Ourselin**; Funding Panel Member: **Razavi**
	CANCER RESEARCH UK	City of London Grant Review Panel Member: **Cook**; Clinical Expert Review Panel Member: **Barrington**; Multidisciplinary Award Panel Member (CRUK/EPSRC): **Goh, Schnabel**; Transatlantic Fellowship Grant Panel Member: **Witney**
	wellcome	Clinical Interview Committee: **Edwards**; Sir Henry Dale Fellowships Panel Member: **Botnar**; Programme Advisory Group: **Razavi** (Chair); **Ourselin** (Member); Wellcome Innovations Flagship Programme Chair: **Ourselin**

Advisory Roles

Electron Devices Society Nanotechnology Committee (Member**: Rajendran**); Engineering in Medicine and Biology Society Administrative Committee (Elected Technical Representative: **Schnabel**); Nuclear and Plasma Sciences Society Administrative Committee (Member: **Marsden**); Nuclear Medical and Instrumentation Sciences Council (Member: **Marsden**)

British Society of Cardiovascular Magnetic Resonance (President: **Razavi**)

European School of Radiology (Steering Committee: **Goh**)

Technical Network on Robotics and Mechatronics: (Steering Committee Member: **Bergeles**)

Wellcome Open Science Early Career Advisory Committee (Member: **Hutter**)

Gold Medal Committee of Society for Cardiovascular Magnetic Resonance (Chair: **Botnar**)

Engineering Strategic Advisory Team (Members: **Al-Hashimi, Shollock, Schnabel**)

Funding Programme Review Panel (Invited Member**: Fruhwirth**); Quinquennial Assessment Review (Member: **Ourselin**)

Young Investigator Award Committee of ISMRM: (Member: **Botnar**)

Editorial Roles

Editors: IEE Transactions on Wireless Communications (**Nakhai**) **Deputy Editors**; Magnetic ResonanceE in Medicine (**Prieto**); Radiology (**Goh**); **Editorial Board Members:** Cancer Imaging and Diagnosis, Frontiers in Oncology (**Eykyn**); European Heart Journal Cardiovascular Imaging (**Botnar**); Eur J Nucl Med Mol Imaging (**Cook**); Journal of Intelligent Learning Systems and Applications (**Lam**);Journal of Clinical Oncology (**Barrington**); Medical Image Analysis (**Ourselin, Schnabel, Vercauteren**) **Associate Editors:** IEEE Transactions on Communications (**Yansha**); IEEE Transactions on Molecular, Biological and Multi-scale Communications (**Yansha**); European Heart Journal (**Charakida**); European Radiology (**Goh**); IEEE Journal of Antennas and Propagation (**Kosmas**); (**Yansha**); IEEE Trans Information Theory (**Bergeles**); IEEE Transactions on Biomedical Engineering (**Schnabel**); IEEE Transactions on Circuits and Systems II: Express Briefs (**Lam**); IEEE Transactions on Fuzzy Systems (**Lam**); IEEE Transactions on Medical Imaging (**Ourselin**, **Schnabel**); IEEE Transactions on Neural Systems and Rehabilitation Engineering (**Kamavuako**); IET Control Theory & Applications (**Lam**); Radiology Imaging Cancer (**Goh**); Scientific Reports (**Ourselin, Young**)

***Table 3**: King's Engineering, Staff Contribution to Research Base*