

Institution: Anglia Ruskin University
Unit of Assessment: 12 Engineering
<p>1. Unit context and structure, research and impact strategy</p> <p>Context and Structure</p> <p>The unit conducts influential research that advances healthcare, prosperity, and infrastructure design and resilience. Our research has evolved and developed significantly since the last assessment exercise, with alignment to university, UK and international strategic priorities, strengthening our focus on providing technological solutions. We have built the reputational foundation of an applied industry-relevant research unit, with a focus on sustainable and efficient engineering design and solutions, and responsibility for transferring knowledge and best practice to address societal challenges.</p> <p>The 15.6 FTE staff in the submitting unit are based in the Faculty of Science and Engineering across two schools - the School of Engineering and the Built Environment (EBE) and the School of Computing and Information Science (CIS), and manifests in two research clusters, Engineering Analysis and Computing Applications. The cross-cutting and permeable nature of our structure supports research performed across the following main areas: engineering analysis, simulation and tribology; medical engineering; electronics and telecommunications; applied computing, artificial intelligence and cybersecurity.</p> <p>The Engineering Analysis Cluster, led by Prof. Shirvani, focusses on the use of nonlinear finite element analysis to simulate and address a wide range of engineering phenomena and problems. Areas of work from this cluster include blast simulation and heat transfer, computational fluid dynamics, tribological simulation using genetic algorithms, non-contact surface temperature measurement and intelligent sensor protection against explosion, digital manufacturing, digital twins and product re-engineering (Shirvani, Butt, Mebrahtu, Asadi, Ramezanpour). Other prominent topics include state-of-the-art research in musculoskeletal, vascular diseases and medical devices (Martay, Hillstrom), rehabilitation support using gaming technology (Sadeghi) and electronic systems design for telecommunications (Yousef).</p> <p>The Computing Applications Cluster, led by Prof. Cirstea M., has a particular focus on how computational modelling, artificial intelligence (AI) methods and smart technologies can be used to improve people's lives and increase productivity. Particular themes within this cluster include: digital systems modelling and design methods (Cirstea M., Cirstea S., Zhang), applications of computing methods to vision and hearing science (van der Linde, Cirstea S, Maktab), assistive technologies, auditory displays and non-linear dynamics (Vicinanza, Cirstea S), semantic web and knowledge representation, distributed computing, cyber and information security, data platforms, deep learning, data analytics and optimization (Luca, Zarrin, Maktab, Vicinanza).</p> <p>The clusters are inter-related and reflect a collegiate research community of shared interests and goals, as shown in Figure 1.</p>

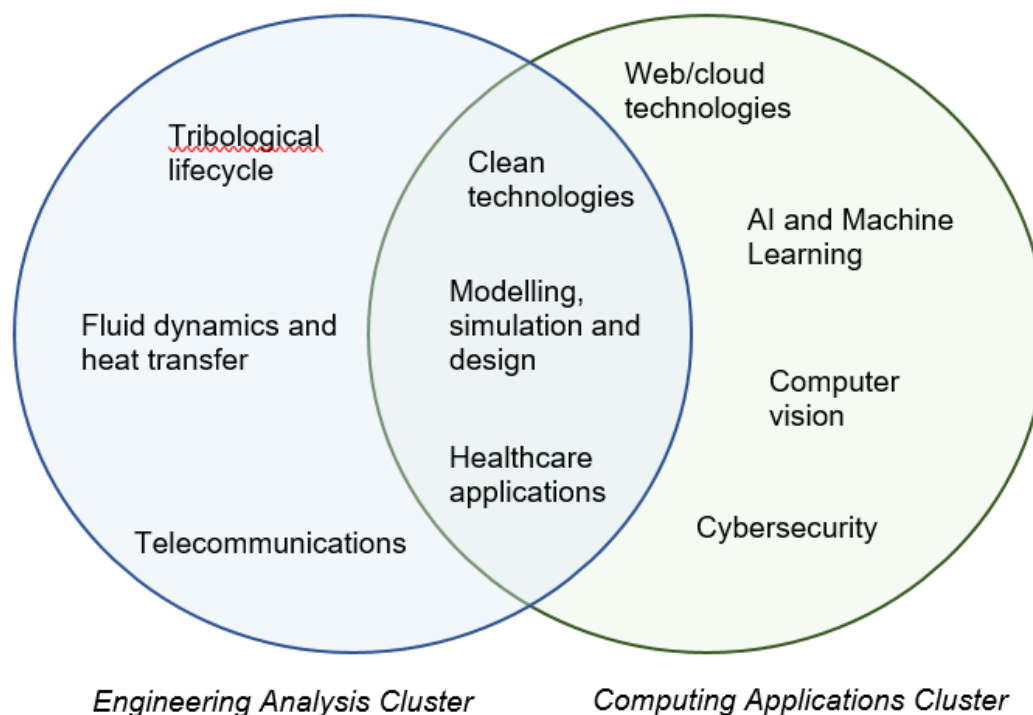


Figure 1. Research areas and inter-relationship of research clusters

Development of the Research and Impact Strategy 2014-2021

The unit has seen a substantial growth in research activity over the current REF period which has occurred as a direct result of decisions made following REF2014 where the feedback encouraged us to develop a more focussed research strategy which connected well to the university strategy. We have successfully achieved the main strategic aims for this period as described at the time of REF2014.

Aim 1. Sustain overall growth of the unit in research outputs, research income, proportion of staff applying for funding and registered number of PGR students.

The unit has doubled in size from 8 to 15.6 FTE in the REF cycle, through targeted strategic investment in new staff over the last 5 years. Of the 8 FTE submitted to REF 2014, all but two are also submitted to REF2021, evidencing the sustainability and cohesion of the submitting unit. Additional staff are at the early to mid-part of their careers, demonstrating our commitment to grow a new generation of researchers. Butt and Luca have been promoted to Reader and Principal Lecturer respectively (both retitled Associate Professor) and have gradually expanded their portfolio and leadership. The number of research outputs has grown from 100 in 2013 to approximately 200 in 2020. The research income has more than doubled from £1.4 million in the REF2014 period to £3.2 million in the REF2021 period and the proportion of staff applying for funding has increased from 70% to 100%. The number of PGR students has increased from 28 in 2013 to 37 in 2020, with the number of completions growing from 24 to 34.

Aim 2. Establish or further develop key relationships with stakeholders regionally, nationally and internationally, and focus our research towards providing innovative solutions that stakeholders could not achieve alone.

The unit has developed strong relationships with stakeholders and has provided solutions to market focussed problems, evidenced by a number of major research projects. For example, in the FP7 project REVIVAL, Shirvani and Ramezanzpour worked with international industry partners and other universities to validate a novel autonomous and reversible inflow control valve which prevented unwanted water and gas entering the oil production pipe, thereby

increasing significantly oil production efficiency and benefitting the oil industry. In a disaster management H2020 project, RECONASS, Shirvani collaborated in the development of a building health monitoring device to determine building safety and rehabilitation after an explosion, earthquake or fire. Propelair was an H2020 project in which Shirvani and Ramezanpour, working with a local SME, developed parts of a close-coupled toilet flush system capable of saving billions of litres of water. Cirstea S collaborated in the EU FP7 ECHO2ECO project which developed novel low-cost acoustic absorbers for public spaces and Hillstrom and Martay developed computational methods for surgical corrections of arthritic knees with Arthritis UK funding. Zhang has worked with partners at Cardiff University, UCL and the European Space Research and Technology Centre (ESTEC) to develop novel metamaterial components in the mm wavelength range for astronomical applications and THz communications, expected to lead to the production of many successful devices for on ground-based telescopes and for future satellite instruments. The research in the FPGA case study facilitated the commercialisation by Siemens AG of novel controllers for railway signalling through “system-on-chip” solutions, the commercial value to Siemens totals millions of pounds annually.

A new direction of research initiated by Vicinanza applies data science and programming techniques to areas such as non-linear dynamics and biomechanics, in collaboration with University of Exeter, Auckland University of Technology and Cardiff Metropolitan University. Initial outcomes included a high impact paper in Scientific Reports. The clinical use of these new metrics led to another international collaboration with University Hospital Geneva.

Auditory display and sonification research, led by Vicinanza in collaboration with NASA since 2015, aims to create auditory displays based on space science for the general public, for example, a series of ringtones based on Mars weather simulation downloadable from the Pleiades Supercomputer.

The unit has also collaborated on the UK-India Education and Research Initiative project (Yousef) and two Erasmus Mundus partnerships, SMARTLINK and FUSION (Cirstea S), which all aim to foster international cooperation between European HEIs and those in emerging Asian countries through the promotion of mobility at all levels of study.

Aim 3. Enhance knowledge exchange, including increased use of Knowledge Transfer Partnership (KTP) and Knowledge Exchange Embed Partnership (KEEP) mechanisms.

The unit has won a large number of knowledge exchange projects over the reporting period. The Faculty has employed a commercial manager and has been instrumental in the development of University’s central knowledge transfer team which now supports this activity and helps units to grow the knowledge transfer portfolio. The unit has engaged in 12 research projects and 41 (36 KEEPs, 5 KTPs) knowledge exchange programmes with over 70 companies, almost trebling the income resulted from UK-, EU- and non-EU industry, commerce and public corporations from £298k to £777k. These projects enhance the business performance of collaborators and provide demonstrable impact. For example, a range of healthcare focussed knowledge transfer projects led by Luca, in partnership with Lane Data Solutions and AT Technology Services Ltd, transformed business systems through the enablement of secure mobile data access.

The unit has engaged widely with initiatives that engender sustainability of the discipline and enhance international cooperation by facilitating transfer of knowledge and best practice in training the next generation of researchers. Shirvani, Mebrahtu and Butt have collaborated with partners from five EU countries in the Erasmus+ GIENHAS project which focusses on bringing HEIs and SMEs together by employing innovative methodologies for research and development that include industrial PhDs and setting up observatories for research. Butt and Mebrahtu collaborate with the Business School in the ERDF Growin-4.0 project which, working alongside SMEs, aims to improve skills and competencies to raise innovation levels through extensive networks that combine knowledge and new approaches.

Aim 4. Increase our bidding for international research funds, especially for Horizon 2020 calls, enabling collaboration with non-academic partners who will directly benefit through their participation.

We have actively engaged in conversations with businesses and SMEs across EU and have worked with Ixion – a company providing bidding support to develop proposals for EU-funded calls. These efforts have resulted in eight large EU-funded projects, increasing more than six times the amount of income from European government bodies (Horizon2020, European Space Agency, ERDF) from £230k in the REF2014 period to £1,446,535.

Aim 5. Promote and disseminate our research accomplishments by organizing research conferences and through media appearances.

Members of the unit have chaired and hosted major conferences on industrial electronics and informatics and cyber-security (OWASP AppSec 2014, INDIN2015, ISIE2017) and have contributed to organising many other international conferences (IECON2018/19/20, ISIE2018/19, OPTIM2014/15/17/19/21). Our academics have made numerous media appearances on high profile outlets including BBC News/Radio 4, Naked Scientist, Discovery Channel, CNN. Vicinanza has a regular presence at NASA events and the Supercomputer fair in the USA, where he gave a guest plenary talk on converting Voyager data to music. He presented at the European Consortium for Supercomputing section on remote sensing in space research, Moon exploration and space weather, and organised and delivered four distributed concerts by pioneering the fastest audio-video link technology in the world, streaming a 4K video at 800 Mb/s, across the USA. For the last few years Vicinanza has been regularly invited to CERN, where he organised a hackathon, performed live music based on data generated by the *Large Hadron Collider* and was a speaker at the CERN Open Days in 2019, event attended by more than 70,000 people.

The unit focusses strongly on translational research and knowledge exchange projects with over 50 projects in total conducted with more than 70 companies/SMEs. For example, as part of the Government's National Cyber Security Strategy, funding from Innovation to Commercialisation of University Research (ICURe), promoted our BotProbe, designed to extract from big data the data that matters in threat intelligence. The recently secured Cyber-Protect project sponsored by the Home Office, evaluates the most effective and impactful ways to motivate the long-term adoption of cyber-security measures amongst key stakeholders at risk of cyber-attack.

The unit disseminates its research to end users and potential beneficiaries through presentation and publication with organisations such as IEEE (Cirstea, M.) and I MechE (Hillstrom). Beneficiaries of the research include the Sankara Nethralaya Eye Hospital and the Faculty of Low Vision Care, Elite School of Optometry, Chennai, India (Cirstea, S) and the Hospital for Special Surgery, New York (Hillstrom).

Interdisciplinarity

The essence of our work is application, particularly the application of engineering and computing, to a wide range of disciplines. It is therefore vital that we conduct interdisciplinary research in collaboration with colleagues from other faculties, institutions and industry. Much research is carried out in the ARU priority area of Medical Technology and Devices, including collaboration with the Medical Technology Research Group (MTRG, UoA3) and the Vision and Eye Research Institute (VERI, UoA3). This is exemplified by: the work of Martay and Hillstrom on medical devices for musculoskeletal and vascular applications; Hillstrom also led interdisciplinary research on biomechanics applied to orthopaedic surgery in collaboration with Essex hospitals and the New York Special Surgery Hospital; Hoque-Tania and Oghaz's development of hand-held diagnostic devices, Cirstea, S. and van der Linde's work on the psychophysics of visual impairment and its interplay with hearing; Sadeghi-Esfahlani's use of virtual gaming for rehabilitation of patients.

Van der Linde, in collaboration with colleagues from Psychology (UoA4) and VERI, developed computer models to study the human visual system and neuropsychological testing, and Vicinanza collaborated with Sports Science (UoA24) on sonification in the training and rehabilitation of athletes. The Unit worked with the Policing Institute, Eastern Region (PIER, UoA21) and the Metropolitan Police High Tech Crime Unit on protection methods against cyber-attacks through increased data/internet security.

Knowledge exchange activities exemplify some of our best interdisciplinary work. The Digital Health Care KTP carried out with AT Technology Services applied machine learning and data fusion algorithms to a business intelligence platform enhancing efficiency and productivity in patient health management. A KEEP+ project was conducted with Lane Data Solutions to develop an IT solution providing an instant messaging service for UK healthcare professionals. On other KTPs we worked with MG Electric to develop an AI-aided pump for laryngectomy patients and with Bertrand Ltd and the Business School to develop an innovative Virtual/Augmented Reality capability to enable the company to widen its core expertise and create new services. The KEEP+ with Prime Accounting developed accounting software for the trading of perishable goods.

As a result of these strong links through cross-faculty research projects, many interdisciplinary projects for doctoral candidates have emerged and are co-supervised across a variety of disciplines, including Medicine, Vision, Psychology, Built Environment, English Language and Literature.

An Open Research Environment

The unit satisfies REF open access requirements and has engaged with the university's open access fund to publish over a third of our papers via the Gold Route and in online-only journals. Colleagues in the unit are expected to have an ORCID account, and an open research workshop was organised by van der Linde to enable colleagues to create ORCID, Research Gate and Publons accounts. Individually, 94% have LinkedIn and ResearchGate accounts and use university and personal media streams including Facebook, WhatsApp and Instagram to promote their research. Code is shared on the public repository Open Science Framework. European Union funded projects are promoted through project web sites including [REVIVAL](#), [RECONASS](#), [GIENAHS](#) and [Propelair](#). Unit members engage with Open Access requirements through ARU's repository - ARRO - and with the Library Research Services Manager around issues of copyright.

All members of the submitting unit of assessment subscribe to the Concordat to Support Research Integrity and have successfully completed the Epigeum Research Integrity (Concise) course. The unit's research projects, including PGR projects, are reviewed at the appropriate level within the university ethics processes. Analysis of research results is peer-reviewed or duplicated by collaborators, and methods and findings are shared and debated internally in regular research seminars. Support for less experienced unit members is provided by the established members, and a peer review process (Cirstea, S., Cirstea, M., van der Linde,) critically appraises grant proposals prior to submission.

Data protection is also a pre-requisite and all staff have received GDPR training and implement it in all of their research activities.

Priorities over the next REF cycle

Now that the Unit has established itself as a centre of excellence for applied engineering research, our focus over the next few years will be on achieving critical mass in areas where we can add most value in responding to societal and economic need. Reflecting on our development over the last five years, the key theme to emerge is AI and Engineering for Sustainability. This aligns well with the Four Grand Challenges identified by the UK Government and with regional industrial strengths in advanced engineering (Essex) and data science

(Cambridgeshire). We will focus on growing our existing teams and regional and international collaborations and seeking the highest-impact industry partnerships.

Strategic Objectives

To establish an international reputation in interdisciplinary research in AI and Engineering for Sustainability through strategic investment and growing critical mass.

The extraordinary challenges of the climate emergency and ecological breakdown must become central to engineering, and sustainability will be the focus of engineering research at ARU. We will prioritise and pursue research projects which will investigate the environmental efficiency and sustainability of processes and products and their impact in space and time. We will use our expertise in engineering analysis, AI and big data to develop sustainable design, life cycle analysis, pollution prevention, energy efficiency and materials management. Sustainable engineering requires an interdisciplinary approach, which the structure of our unit exemplifies, and we will focus on adding value, working with businesses and designing products with societal benefits.

We will continue to invest in medical engineering and, through collaboration with the Medical Technology Research Centre (MTRC), we will develop novel biomedical technology solutions and AI systems for healthcare.

To act as a catalyst between regional industry strengths in data science and advanced Engineering to significantly increase knowledge exchange.

Research activities will continue to be informed by and engaged with businesses, collaborators and stakeholders identified by the unit supported by the Research and Innovation Development Office (RIDO). Key stakeholders include AT Medics, CERN, NASA, Home Office, Teledyne E2v, ARM and Samsung. Growing such collaborations, and recruitment through targeted appointments will maximise the social, economic and cultural impact of our research. Aligned with the UK Government Industrial Strategy, research areas to be developed include sustainability, AI and Cybersecurity. Growth in relationships with key stakeholders will be achieved in a number of ways: continued engagement with repeat business derived through established relationships with collaborators; via engagement with umbrella networks such as Cambridge Cleantech, a network of over 300 organisations interested in clean technologies, and the Oxford-Cambridge ARC, supporting economic growth in the East of England; development of a new commercialisation pipeline working with our Partnership Development Manager.

Leverage institutional and external investment for a new Advanced Engineering and AI for Sustainability Research and Development facility.

The greatest value of our unit will be in fully realizing the synergies between engineering and computing, for example enabling interconnectivity between technologies in smart cities (e.g. vehicles and smart appliances). The unit is committed to additional strategic investment for staff and infrastructure supported by QR, institutional funds and investment from industry, to develop this area over the next REF period.

In part, this aim will be achieved through involvement of the unit in the recently funded £16.47m Manufacturing and Materials Research and Development Centre which will be housed on our new Peterborough campus. The centre - a partnership with Cambridge and Peterborough Combined Authority and Photocentric - will drive the manufacture of materials that will help achieve a Net Zero economy. In parallel, we will seek further external investment to develop an Advanced Engineering and AI Research and Development Centre on our Chelmsford campus over the next five years. Collectively, the two centres will serve to provide materials, technological, and software solutions to support the green recovery, create jobs and train the next generation of engineers.

Work towards achieving gender balance within the unit by 2027.

Through initiatives such as the Women in Engineering programme, we aim to achieve gender balance by 2027 at all academic levels, from technicians to professors.

Double our research income and activity over the next REF period by building upon existing strategic partnerships (e.g. CERN, NASA, AT Medics, ARM) to realise regular staff and student exchange programmes and research opportunities.

New research business will also be sought through existing relationships which have been developed by other areas of university activity, for example Degrees at Work and Degree Apprenticeships and external speakers at seminar series. The number of staff members in the unit is expected to grow by 50% over this period, alongside a significant increase in affiliated and visiting staff.

2. People

Staffing strategy and staff development

The unit's staffing strategy, aligned with the university strategy 'Designing our future 2017-2026', stimulates research activity that enhances our profile, professional visibility and overall esteem in engineering analysis and applied computing.

The research staffing strategy aims to attract, retain and reward staff who undertake competitive research and knowledge transfer activities aligned to the unit's research themes. Implementing this staffing strategy has led to the unit's doubling in size, from 8 FTE in 2014 to 15.6 FTE in 2020. This growth has been achieved by investing strategically in the development of existing staff and in new permanent academic positions to support existing areas of strength (engineering modelling) and to develop others (AI, data science, cybersecurity). The SRR staff complement includes 2 research active professors, 7 readers/principal lecturers, 5 senior lecturers and 2 lecturers. Three of these are early career researchers (ECRs). Non-research lecturer practitioners (5.7 FTE) have been employed over this period to ensure that research time in the unit is protected. QR funding has also been invested strategically in 3 post-doctoral positions and in 7 PhD studentships.

We have sought to develop a nurturing research culture where new staff are mentored and work with more experienced colleagues on larger research projects with external exposure. We also facilitate exchanges with academic, business and industry partners through various routes including honorary fellowships and academic visits. The research culture is enriched by 4 visiting Professors, including one sponsored by the Royal Academy of Engineering (S Kear), 3 Emeritus Professors and 4 honorary visiting research fellows. In the REF census period, the unit has hosted 4 visiting academics: Prof. Sergiu Dascalu, University of Nevada (November 2017), Dr. J. Zhou and Dr. L. Zong, both from Shaoyang University (August 2017), and Y. Zhan, Hubei University of Technology, China (March 2018).

Starting with probation, and then at the yearly appraisal, every member of the unit reviews and defines their research plans in the strategic context for the upcoming year and the resources required. Research and external income generation are key criteria of the promotion scheme and approximately 50% of the unit's academic staff have been promoted during the REF period. Research activities are also rewarded through faculty and university awards, such as: Dean's Award for External Income Generation (Shirvani, 2014), ARU Innovation and Knowledge Exchange Award (Shirvani, 2015), Dean's Award for External Profile Raising (Vicinanza, 2020).

Research activities are allocated time resources formally through the Academic Work Balance Model. Established academics have a stepped research time allocation in their AWBM, which

increases in proportion with external income from research grants and may be up to 100% of their time in a given trimester.

The recruitment and support of high calibre ECRs is a very important thread of our research staffing strategy. ECR time allocation is aligned to the ARU ECR Charter and amounts to a minimum of one day per week every trimester to develop research ideas, outputs and funding bids. They are supported by a research mentor either from the unit or the wider institutional community. Guaranteed funds (£2,000 over 5 years) are allocated to each ECR to support any aspect their research, including networking and community building, conference participation or equipment purchase. Additional support is provided for ECRs in output preparation and submission and bid writing.

All members of the unit engage with the ARU Researcher Development Programme through their Individual Research Plan and Personal Development Plan revisited at appraisal. This programme includes face-to-face, online and external development opportunities. All academics have a mentor allocated on appointment and development support is available to all and includes funding for conference attendance and travel to enable collaborations and networking. All academic staff can apply for the university sabbatical scheme and 4 sabbaticals have been awarded through a competitive process, resulting in 1 PhD and 3 journal papers. Over the period, 5 academics benefitted from significantly reduced teaching load in one trimester so they could focus their research. The university organises writing retreats, with 5 unit staff attending in the REF period, resulting in a number of papers and funding bids. RIDO offers regular training and networking activities.

Academics are encouraged to apply for external funding and are supported through proposal peer reviews by experienced colleagues and costing and risk assessment through the faculty Business Development Manager and RIDO. The faculty Projects Team ensures post-award project management support.

All staff participate in regular research strategy days, where priorities, themes and milestones are discussed. Following training for new PGR supervisors, academics are included in PhD supervisory teams and in appropriate PGR monitoring processes. Staff also have competitive access to the Undergraduate Research Placement scheme, which allows them to employ an undergraduate student for up to eight weeks for research support. Members of the unit benefit from 3-4 such placements every year, some in co-supervision with other units.

Where research leave is required in support of funded projects or other work, the leave is supported through the schools in which the submitting unit resides. The school “back fills” the post using project funds if allocated, QR funds or other revenue as required. In total 4 such periods have been taken resulting in the successful completion of a research project and development of a new funding bid. Leave in support of impact is also encouraged within the unit and QR or school funds are used to support it (travel, accommodation, data gathering).

Research students

The unit’s PGR community has increased from 28 (24 completions) in REF2014 to 37 in 2020 with 34 completions during the census period. Since REF2014 the unit has awarded 10 studentships, 7 funded internally and 3 sponsored through funded research (Erasmus Mundus programmes FUSION and SMARTLINK). Most PGRs are self-funded. All join projects which support strategically identified research areas ensuring a critical mass in each subject area and an excellent doctoral experience.

Postgraduate research students are supported and monitored through a variety of mechanisms. Their primary point of contact is their supervisory team, comprising at least two supervisors. The research proposal, upgrade of candidature and annual monitoring processes are undertaken by senior researchers independent of the supervisory team and mock vivas are offered. Progression of the unit’s PGR candidates is directly monitored by the Faculty Director of

Research Students and the Deputy Dean (R&I). PGRs benefit from dedicated school and faculty PhD offices with computers, kitchen and social space to encourage interdisciplinary exchanges of ideas and debates.

There are a number of mechanisms for the support and integration of PGR students. In the census period, 4 PGR Graduate Teaching Assistants and 6 PGR Associate Lecturers have been appointed, giving the opportunity to develop teaching/communication skills and become part of a wider academic community.

Research students are fully involved in the thriving research culture of the unit and have multiple opportunities to disseminate their work and develop presentation skills at a wide range of events, such as Annual Faculty and University PGR Conferences and internal research seminars and PGR Days. Within the unit, hosting schools are committed to fully support each PGR student to attend and present at one international conference during their studies and the Faculty offers writing retreats specifically for PGR students.

We provide a rich and positive researcher development environment, where PGRs benefit from the mandatory Doctoral School training programme, as well as unit-specific development events, like the OWASP series of research talks and meetings with industry. PGRs are offered the opportunity to work with academic staff in organising conferences and running events (e.g. INDIN2015, OWASP series), and payment for administrative help is offered.

As testament to the unit's staff development during the assessment period 7 PGRs and 5 post-docs have gone on to take up academic posts at ARU and other national and international institutions, with the remainder going into a range of industry and other professional roles. Destination institutions include University of Oxford, UCL, and Royal Holloway University of London. One particular success saw a PhD graduate progress to an academic career with ARU from lecturer to reader, before continuing with a Professorship at New York University.

Equality and diversity

The unit is proudly diverse with members coming from all over the globe. 30% of the unit are women, comparing favourably with the sector-wide proportion of women in engineering occupation (12%) (Engineering UK Report, 2018). However, we continue to work to improve this and strategic objectives have been set to work towards gender balance by 2027.

To support all the women in our Schools we have developed a Women in Engineering programme with dedicated mentoring and placement opportunities for students with companies such as Leonardo, GSK and Network Rail.

In addition to the institution becoming a member of [Athena SWAN](#) in 2012, and achieving a renewed institutional Bronze Award in October 2018, members of the submitting unit contributed to the successful Bronze Award achieved by the Faculty of Science and Engineering in 2019 (Cirstea S, Luca).

The unit is actively engaged with embedding our university's Valuing Diversity and Promoting Equality Statement through staff recruitment, support and training. Advertisements for posts are written to draw in as wide an applicant pool as possible and have been amended in the light of the Athena Swan institutional Bronze Award. Amendments include removing the need for travel which may preclude those with caring responsibilities from applying.

Career progression for members of the submitting unit, whether full-time, part-time or fixed-term, is essentially identical. Roles are subject to a rigorous grading process through the Human Resources team to ensure equity and transparency. The appraisal process is compulsory for all staff and all can seek regrading through the HR processes.

To engender an inclusive environment that welcomes staff with young families or other caring responsibilities, the unit is increasingly adopting “agile” and flexible working to accommodate family routines. Internal conferences and seminars are scheduled at child friendly hours and in accessible buildings or online. Staff on maternity leave (1 in current REF period) have been supported through the Keep In Touch days and an institutional £4,000 fund to ramp up their research upon return is available.

Everyone in the submitted unit must undertake equality and diversity training and comply with our [Valuing Diversity and Promoting Equality Statement](#). We ensure that research meetings and events are not scheduled at times of spiritual relevance for colleagues (e.g. Friday lunchtime).

Staff wellbeing is a priority of the unit and the institution is a [Mindful Employer](#) meaning we offer information and support to staff experiencing stress, anxiety, depression or other mental health conditions. Members of staff (2) and PhD students (1) who experienced mental health issues have been supported through phased return to work and close support from their line manager/supervisor. The unit takes special care to ensure equal access to infrastructure to colleagues with physical (1) or mental health needs such as provision around the workstation and a buddy system.

3. Income, infrastructure and facilities

Research funding and strategies for generating research income

Since 2014 the unit has attracted research funding from diverse sources, ranging from small grants to multi-million-pound programmes, to the value of £3.2m. This approach has helped reduce the risk of dependence on any one type of funder and has enabled all members of the unit to play their part. ECR researchers have engaged with the Faculty “escalator programme” where funding application skills are developed (Maktab, Zarrin). The unit seeks funding for a wide range of innovation voucher, knowledge transfer and exchange programmes, which facilitates the development of strategically important engagement with businesses, industry and the users of research directly leading to impact (e.g. Glazing Vision, SeeClear, Calnex Electronics, i-Dash, AT Technology Services, TR Control Solutions). The unit also actively seeks out larger grants and has been particularly successful in EU programmes where our expertise can be brought to bear. Examples include REVIVAL, an FP7 project with an EU contribution 1.158M Euro which is the subject of one of the case studies for this submission, and the Horizon 2020 projects RECONASS, EU contribution 4.26M Euro, and Propelair, EU contribution 1.3M Euro. To broaden the research base, funding for exchange programmes has been won from UK-IERI (Yousef) and the EU: Erasmus+ (GIENAHS), Erasmus Mundus (FUSION, SMARTLINK) and an Erasmus exchange programme with the National Technical University of Athens (Asadi).

Going forward, the unit will build upon this success by developing “strategic compacts” with blue chip multinational organisations to grow the significance, reach and impact of its research. We will strengthen our links with CERN using their summer placement programme as a vehicle for developing research partnership opportunities. More broadly, we will continue to diversify income streams via an increasing emphasis on the application of AI and Engineering approaches to areas such as the developing world (e.g. GCRF), prosperity (e.g. Innovate UK) and healthcare (e.g. NIHR), seeking partnerships with major players such as Samsung AI, Nvidia.

Organisational infrastructure supporting research and impact

In the second half of the current REF cycle (2018), the unit took possession of new laboratories within the ARU Science Centre on the central Cambridge Campus. This £45M facility, developed with strategic input from the unit, allows academic and research staff and students to come together in one central location, facilitating cohesion and further critical mass. State of the art accommodation includes an electronics laboratory, an internet of things laboratory and a cybersecurity laboratory. These latter enable, for the first time, dedicated attention to areas of

development which will be central to the growth of the unit going forward. The Electronics laboratory includes a range of Electronic Design Automation packages, FPGA/DSP/Microprocessor boards, embedded system boards, simulation software, an optical 3D scanner, electrical machines and drives test bed, solar panels, renewable energy converters and a small wind turbine. These facilities allowed, for the first time, collaboration with companies such as the leading IP technology provider ARM. Additionally, a psychophysics and electrophysiology laboratory (including eye tracking and EEG equipment) allows unit members to conduct interdisciplinary research on brain computer interfaces and usability testing with ARU's Vision and Eye Research Institute and School of Psychology and Sports Science.

On the Chelmsford campus, a wide range of equipment relevant to medical engineering is available, including mechanical testing equipment (Instron 8874, Bose ElectroForce Biodynamic), force and pressure measurement devices (AMTI, emed-x, Pedar) and a movement analysis system (Vicon). The simulation and testing facilities enable the evaluation and improvement of different surgical practices, implant designs and rehabilitation and treatment methods for different pathologies (joint disease, venous ulcers, gait abnormalities). The engineering analysis team benefits from laboratories supporting mechanical and electronic engineering with industry-standard software for design, finite element analysis and computational fluid dynamics, low flow rate atomizers, a tensile testing machine, a scanning electron microscope and rapid prototyping facilities. Modelling is central to the projects of the unit - facilities available include computational modelling and simulation packages (Abaqus, ANSYS, MIMICS, CATIA, OPNET, HYPERWORKS, LS-DYNA, PAMCRASH) used for research related to vehicle structure and impact barriers during crash tests.

Infrastructure, facilities and expertise are utilised in relation to impact in a number of ways. Research expertise is used to support translational research and knowledge exchange. Companies assisted through such knowledge transfer projects include Lane Data Solutions Ltd (Luca), whose business systems were transformed through secure mobile data access, increasing operational efficiency and sustainability, or Eclipse Veterinary Ltd. (Luca) who achieved similar mobile and web-based solutions applied to the veterinary domain, demonstrating the cross-discipline nature of such applications.

Two KEEP projects with Glazing Vision (Luca) led to a real-time web-based software platform, replacing company's carbon-heavy sales and costing system. The result was an environmentally friendly, digital platform that can be utilised by sales staff away from office to generate quotations using a portable device. The company has recently expanded internationally, and the software supports all their product pricing and configuration requirements, removing the need to contact UK offices. The integrated real-time nature of the application has reduced its carbon footprint by saving on multiple commutes to the office and on printing.

A current project with AT Technology Services Ltd. (Luca) applies AI, particularly machine learning, fusion and optimisation algorithms, to existing business intelligence data to enhance efficiency and productivity in patient health management and to detect critical health trends.

The impact for the beneficiaries is often of such significance that they return for further research support: i-Dash (data centre solutions), Calx Electronics (smart sensor based embedded control solutions), Glazing Vision (business systems), SeeClear.

Collaborative and cross HEI use of infrastructure is core to the research of the unit and has been enabled by international programmes. For example, Yousef, working with the Indian Institute of Information Technology and Management (IIITM) in Gwalior, India, led a UK-IERI funded project on development of Mobile Ad-Hoc networks (MANET) where hardware and software facilities were shared, while academics and PGRs undertook exchanges of up to three months. Further, Yousef co-supervised a Newton-Babha funded student with IIITM on usability of smartphone touchscreens for blind users.

Work on the Erasmus+ project GIENAHS (Grasping Innovation in Europe through a closer iNterAction between HEIs and SMEs), brings together HEIs and SMEs, who share facilities and boost research through innovative methods such as industrial PhDs and observatories for research. An Erasmus agreement with the National Technical University of Athens (NTUA), 2018, facilitated three staff mobilities and two PhD co-supervisions. Asadi used NTUA's crash test facilities for experiments, which generated joint publications.

Future development of strategic compacts will facilitate growth in collaborative use of infrastructure. We are developing a strategic compact with TWI Ltd, a world leading research and technology organisation, also involving the Faculty of Business and Law. Working with TWI will enable access for TWI to our research specialists, and our access to TWI's National Structural Integrity Research Centre, and further global facilities through TWI member organisations.

Arrangements around **benefits in kind** are fully supported by the unit. For example, the unit supported the relationship between Hillstrom and the Hospital for Special Surgery (HSS) in New York – a leading USA hospital for orthopaedic surgery. HSS provided data sets for medical engineering modelling and hosted Hillstrom to model surgeries on cadavers. Vicinanza uses NASA space exploration data and supercomputing facilities at NASA and CERN for sonification research.

4. Collaboration and contribution to the research base, economy and society

Research collaborations, networks and partnerships, and engagement with stakeholders

As set out in the REF2014 objectives, the unit has strategically established 'key relationships with stakeholders regionally, nationally and internationally' in order to 'focus our research towards providing innovative solutions that stakeholders could not achieve alone' and has further developed 'existing partnerships, to ensure maximum benefit for all parties'.

Much of the research undertaken includes external partners as co-authors/collaborators from universities, public institutions and businesses worldwide. These strategic collaborations help maximize our research outputs from our relatively small research base, through involvement in more projects and reaching extended equipment, facilities and information. Such collaborations were supported through hosting visiting academics (Prof S Dascalu, Prof E Monmasson, Dr Y Zhan) and PhD students (R Etz, T Patarau) or joint PhD supervisions with other universities (Imperial College, Urmia University (Iran), University of Sheffield) or companies (Jaguar Landrover, LMK Thermosafe).

The unit engages with and contributes to relevant professional organisations: international (IEEE, IET, Audio Engineering Society, OWASP, European Simulation Society - EUROSIS), national (BCS, IMechE, IISP, (ISC)²) and local (Cambridge Wireless, Cambridge Network), for disseminating research outputs, forging collaboration and raising profile. Thus, we maintain currency with technological developments, reach relevant funding opportunities, and develop aspirational industrial or academic collaborations at the highest level of relevance, visibility and impact. Our staff coordinated 3 major conferences: IEEE International Conference on Industrial Informatics INDIN2015 (260 delegates from 45 countries, co-chaired by Cirstea M); IEEE International Symposium on Industrial Electronics ISIE2017 (Cirstea M general co-chair); OWASP AppSec Europe (2014) (ARU host/organiser).

The unit organises monthly OWASP cybersecurity events (Cambridge campus) attracting 100-200 participants, including contributions from industry, BCS Special Interest Group on Cybercrime Forensics, IISP and (ISC)². We also hosted British Computer Society seminars (Cambridge, Chelmsford). Cirstea S. organised periodic IET talks in Cambridge, and Campbell served as Chapter head for Audio Engineering Society, Cambridge Section, organising regular events. Mebrahtu organised regular events as a member of the IET Essex Committee.

Ramezanpour organised engineering seminars as vice-chairman of the South Essex IMechE committee.

Research collaboration within the framework of large EU/international projects (RECONASS, REVIVAL, Echo2eco, FUSION, SMARTLINK) led to over 10 publications and 4 exchanges of research students. These projects also produced a US patent and an EU patent application, both developed by S Cirstea; Shirvani had two UK patents approved and seven design rights.

Staff have engaged actively with industrial partners in over 40 knowledge exchange projects, delivering the innovation agenda of businesses and of funding bodies such as ERDF, Innovate UK and local authorities. The projects have enhanced the unit's research culture through internal research talks and engagement of postgraduates. Several projects generated repeat business (i-Dash, Glazing Vision, Calex Electronics, LMK Thermosafe, Propelair/Phoenix, SeeClear), consolidating benefit and widening impact.

Contribution to the economy

Our contributions to the economy and society are demonstrated through multiple industrial and interdisciplinary collaborations under three themes: medical and healthcare applications, sustainability technologies, and cybersecurity.

In healthcare, we have conducted projects to develop technological platforms for health and disease self-managing using mobile technology, with a focus on cardiovascular disease and hypertension. As part of a KEEP+ project we developed a secure social networking app for health professionals and through a KTP we developed a data analytics framework for preventative medicine in GP practices.

Innovate UK has funded sustainable technology projects where members of the unit have designed a low-cost modular solar power system using Total Internal Photonic Absorption (TIPA). Other Innovate UK projects focussed on the development of an adaptive learning framework to enable reduction of defects in buildings and developed a real-time weather prediction app to enable cycling and walking trips around Peterborough. Other sustainability projects include a KEEP which developed low-energy domestic power systems whilst a further KEEP addressed the optimisation of maps for smartphones.

In cybersecurity, a collaborative project with the Department for Work and Pensions for the detection of botnets contributed to eCentre (Cybercrime Centre for Excellence Network for Training Research and Education) and in the development of cybercrime guidance for the Metropolitan police. The Botprobe project has developed a new technique that significantly reduces the volume of traffic to be analysed in botnet threat detection systems and the Innovate UK Risk2click project developed a plugin to reduce risk and empower internet users.

Public engagement

Public engagement supports our mission to 'apply our collective and individual creativity to conceive and develop new ideas, implementing them for the benefit of the communities we serve'. Members of the unit strive to bring the results of our work closer to the community and demonstrate the wider benefits and societal relevance. Our staff have engaged with the Science Festival (Chelmsford and Cambridge) and Science Week (Cambridge), offering talks and demonstrations on subjects such as applications of sonification to space exploration data, smart devices, testing AI algorithms and games for safe cycling training. These bring science and engineering closer to the local community aiming to inspire youngsters towards STEM careers. Hillstrom gave a TEDx talk (Aachen University, 2018) on the application of engineering principles to resolve medical problems, primarily in osteoarthritis. RECONASS project outcomes (on post-disaster construction recovery planning) were widely disseminated via social media and three end-user group workshops (more than 100 organisations). Butt's research featured in

Metal Working World Magazine (2016). Martay published biomechanical resources on forums including Biomech-L and <http://www.articlesbyaphysicist.com>.

Vicinanza presents regularly at NASA and CERN Open Days (2019 audience reached 70,000) and conferences with his work on sonification, including of Voyager spacecraft magnetometer and plasma detector, Earth CO2 monitoring, Mars surface sonification. As National Coordinator for the UK for the 'Scientists for a Day' programme, Vicinanza organises and delivers activities at NASA and CERN annually (<https://cds.cern.ch/record/2286501>). He organised talks and demonstrations at Supercomputing2019 and PRACE (Consortium for Supercomputing in Europe), where he talked about remote sensing in space research, Moon exploration and space weather. Vicinanza also leads an interdisciplinary project, "Yellowstone's Geyser Music" which joins technology and art to create music from scientific measurements, to explore and communicate to a wide audience the unique Yellowstone's geothermal features (eventually to become public exhibition at the Natural History Museum in London). Another public engagement of Vicinanza showcases the digital reconstruction of the epigonion (antique harp) he realised using mathematical modelling - exhibition on Science in Ancient Greece hosted by the London Science Museum. This digital reconstruction has already been used by musicians of the Conservatories of Music of Salerno and Parma in concerts and featured in classical music CDs.

The unit has benefitted from press attention and has engaged with the public through topical interviews with: BBC News/Look East, CNN, Discovery Channel, BBC Radio 4, BBC Radio Cambridgeshire, national daily papers and international magazines. The EU-funded project RECONASS featured on the breaking evening news of TV4 channel in Sweden after the successful pilot test.

Contribution to sustainability of the discipline

Our staff make significant contributions to discipline sustainability, supported by the schools through co-funding, project management and time allocation. Unit members gave plenary tutorials to IEEE conferences (M Cirstea – IECON2019) and keynote presentations (Butt - International Conference on Open Source Systems and Technologies 2019, Essex 3D Printing week organised by the Knowledge Transfer Network) and published a high number of journal and conference papers, responding to national and international priorities.

We have contributed to the development of researchers through two large Erasmus Mundus projects (FUSION, SMARTLINK) and an international programme funded by UK IERI and Newton Fund that allowed academic exchanges with Asian institutions. We have engaged with the UK and EU agenda on reducing the carbon footprint of businesses through our contribution to over 30 Low Carbon KEEP projects, while supporting small and medium size enterprises to become sustainable through digital innovation (major UK/EU priority). The Erasmus+ project GIENAHs and ERDF's Growin-4 both contribute significantly to the discipline.

Zhang is part of a collaboration with Cardiff University, UCL, Mullard Space Laboratory and Stockholm University, responding to the European Space Agency (ESA) priorities on the next generation of instrumentation for space exploration. ESA awarded 600k Euro to the project to demonstrate the performance of large low-loss anti-reflection-coated lenses for refractive telescope optics at cryogenic temperatures.

Staff have disseminated their work in high calibre journals such as: Frontiers, Scientific Reports, IEEE Transactions in Industrial Informatics/Electronics, IEEE Transactions in Antennas and Propagation, Expert Systems and Applications, Optics Express. Two papers featured on the issue front covers (Hillstrom, Journal of Orthopaedic Research, 2019; Butt, Journal of Designs, 2020) and one book chapter was selected in Top 10 Contributions on Bioinformatics & Systems Biology (2018). A third of our papers are published via "Gold route" open access making use of over £15k of the University's open access fund.

Staff are active members of Editorial Boards for leading journals. Cirstea M is Associate Editor of the IEEE Transactions on Industrial Informatics and was Associate Editor of IEEE Transactions on Industrial Electronics. Van der Linde is on the Associate Editor Board of Quantitative Psychology and Measurement (specialty sections: Frontiers in Applied Mathematics and Statistics, Frontiers in Psychology), and on the Editorial Board for Paladyn: Journal of Behavioral Robotics. Shirvani is member of the Journal of Bioengineering & Biomedical Science's editorial board. Butt was Guest Editor for Applied Sciences for the Special Issue "Current Topics in Process Systems Engineering". Hillstrom was invited Guest Editor for "Journal of Functional Biomaterials". Yousef is associate member of the Editorial Board of the International Journal of Systems Assurance Engineering and Management. All unit members are active reviewers for many journals (Scientific Reports, Neurocomputing, IEEE Transactions on Industrial Informatics/Electronics, Proceedings of IMechE, Optics Express, IEEE Access). Butt received the 'Top Reviewer Award' for being the third most prolific peer reviewer on Publons for the Journal of Materials (2017).

Our significant contribution to the research base is also demonstrated through our staff membership of grant review panels and pools of reviewers, such as: Italian Ministry of University Education and Research programme PRIN2017 (Cirstea S); The Croatian Science Foundation (HRZZ) (Cirstea S); Netherland's Organisation for Scientific Research NWO VIDI funding programme (Cirstea S); Technology Agency of the Czech Republic (Butt); Newton Fund (Luca, Ramezanpour). Cirstea M was a referee in the engineering assessment panel for Aalto University Research Art and Impact Assessment RAI2018 (Finland). Shirvani is member of the advisory boards of the Engineering Department at Urmia University (Iran) and at Nottingham Trent University Business School.

Staff have received recognition for their professional standing. Cirstea M became Doctor Honoris Causa and Zhang and Sadeghi both achieved Chartered Engineer status. Most staff are fellows or senior fellows of the Higher Education Academy.