

Institution: King's College London
Unit of Assessment: 11
1. Unit context and structure, research and impact strategy

1.1 Unit's context and developments in 2014-2020

UoA11 at King's College London (shortened to UoA11) is an international research centre with a wide scope of activities ranging from core areas of computer science to its intersections with other disciplines, such as engineering, mathematics, economics and finance, and biological sciences. UoA11 aims to advance the foundations of computer science, open new research directions, and achieve transformative impact on modern society.

Building on the foundations laid in REF2014 and supported by the university's strategic investment, during the REF2021 period, UoA11 has significantly strengthened and broadened its research, raising further its international status. With 22 new academic appointments since 2014, the unit has established two new research groups (Cybersecurity and Human Centred Computing), expanded the scope of the other groups with new research areas (including data science, web computing, game theory), and broadened its multidisciplinary research and engagement with external stakeholders.

To instil a collaborative culture that ensures wider engagement, impact and connection to real world challenges, UoA11 strategically organised itself according to the orthogonal structure of **research groups**, formed around major specialism areas, and **hubs**, which focus on external challenges arising from the economic and public spheres and facilitate cross-disciplinarity and impact creation. This structure, established in 2017, is illustrated in Figure 1.

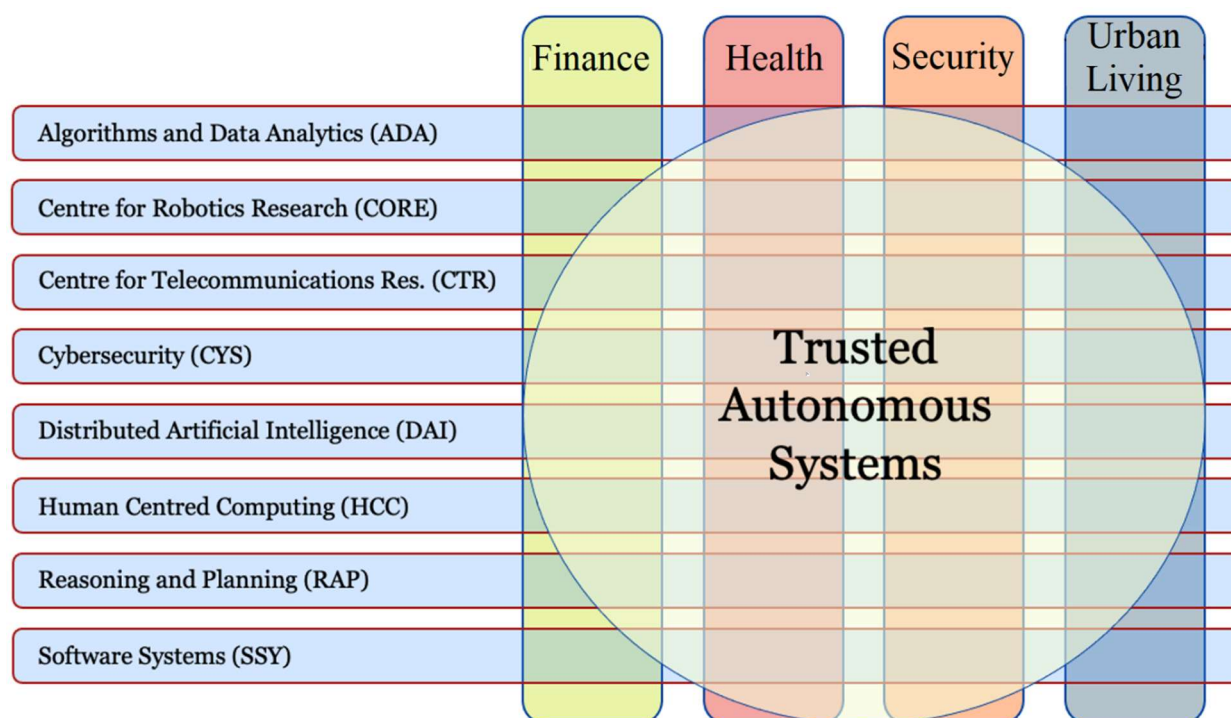


Figure 1: UoA11 research environment: **eight** research groups (horizontally) and **five** cross-cutting hubs. The Finance, Health, Security and Urban Living hubs focus on sectors of economic activity. The fifth hub has a socio-technical focus on Trusted Autonomous Systems relevant to all.

In 2014, UoA11 was fully aligned with the **Department of Informatics (DoI)**. The long-term institutional-level [King's Strategic Vision 2029](#), launched in 2016, included major investment in science and engineering to capitalise on existing research strengths within the university and to ensure the right research capacity for addressing complex 21st century technological and societal

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challenges. For UoA11, this strategy meant substantial growth of computer science, a move to the iconic Bush House building complex, which brought the whole unit into a single location, and the incubation of a new department of engineering. Supported by £52M university investment in necessary infrastructure, the new **Department of Engineering** was launched as a separate department in August 2019, initially comprising the Telecommunications (CTR) and Robotics (CORE) groups from **Dol**, together with further academic appointments. The two departments – Informatics and Engineering – maintain close collaborations facilitated by the aligned research strategies, shared hubs, and coordination and support provided by their parent **Faculty of Natural, Mathematical and Engineering Sciences (NMES)**.

Of the 46 academic staff submitted to REF2014 UoA11, 27 are submitted to REF2021 UoA11, 8 to other units (following transfers to other departments), and 11 have left King's or retired. UoA11's REF2021 submission includes 50 academic staff (all on open-ended contracts, 48.5 FTEs), 22 of whom (including 8 women) have been hired during 2014-2020. All eligible members of the six **Dol** research groups (in 2020) are included in this submission. The members of the Telecommunications and Robotics groups are submitted across UoA11 and UoA12 to highlight their contributions to the research environment of UoA11 in 2014-2019 and to outline their future plans in the context of King's developments and growth in UoA12.

As this document shows, UoA11 at King's provides a vibrant environment with the structures to support and help all its staff, with particular focus on helping new starters develop and reach their potential.

1.2 Highlights of unit's achievements in 2014-2020

The UoA11 vision set out in REF2014 was *"to be at the centre of developments in designing and realising the future intelligent computer systems and machines that will supply the physical infrastructure supporting healthcare, energy, transport safety and security, and the virtual worlds of the cloud and the connected society"*. Given King's research strategy, the evolving funding landscape, the reorganisation into two distinct departments and changes in staffing, this 2014 vision was subsequently refined and its ambition increased, resulting in overall achievements significantly exceeding the 2014 plans. The domain-based hubs have put greater emphasis on the societal impact of research and substantially expanded the range of targeted impact domains.

	REF2021	Increase from REF2014
Research income, including:	£19.8M	35%
• UK research councils, charities, govt	£13.1M	68%
• Industry, commerce, public corp.	£2.0M	106%
Best paper awards	23	64%
Women	16/50	47%

Table 1: Main UoA11 REF2021 indicators (financial increases compare annual averages).

Fundamental research on foundations of 5G telecommunication systems, including the 2018 5GUK project (King's PI: **Dohler**, UK Govt DCMS, £3M), and extensive collaborations with the telecommunication industry established King's as an international centre for advancement of 5G technologies, with a world-first 5G testbed, and surgery and art performances over 5G.

The growing breadth and quality of UoA11 research in the areas of AI and cybersecurity have received significant external recognition. In 2018, NCSC and EPSRC awarded King's the status of ACE-CSR – Academic Centre of Excellence in Cyber Security Research (Director: **Such**). Subsequently, UoA11 became a partner in REPHRAIN, the UKRI Research Centre of Excellence in Protecting Citizens Online (King's Col: **Such**, UKRI, £618K, announced in 2020).

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The unit's increased standing in AI research was crucial to the 2018 award of the UKRI Centre for Doctoral Training (CDT) in Safe and Trusted Artificial Intelligence (STAI), led by King's in partnership with Imperial College London (Director: **Luck**, UKRI, £4.9M).

The UKRI Trustworthy and Autonomous Systems Hub (UK-TAS-Hub) was awarded to a consortium consisting of the Universities of Southampton, Nottingham and King's College London. The King's side is a multidisciplinary team (lead: **Moreau**, UKRI, £2.2M) including researchers from **Dol**, Law and Business Schools, Policy Institute, Faculty of Life Sciences & Medicine and Digital Humanities. Subsequently, King's became also a partner in the UKRI TAS Node on Governance and Regulation (King's Col: **Chockler**, UKRI, £397K, announced in autumn 2020).

CUSP London – Centre for Urban Science and Progress – has won, as part of Westminster's Urban Lab Team, the 2020 Geography in Government Award for Excellence in Local Government for developing data-driven solutions which save public money and improve Londoners' lives. CUSP London is a joint King's and Warwick centre, with significant involvement of King's UoA11 staff, researching computational approaches to urban problems.

5GUK, ACE-CSR, REPHRAIN, STAI CDT, UK-TAS-Hub and Node, and CUSP London are all high-profile activities, establishing King's as a UK leader and coordinator of research in 5G Technologies, AI/Autonomous Systems, Safety & Trust, and Urban informatics.

The unit's success is further highlighted by excelling in achieving the following four targets set in REF2014: increasing (i) cross-cutting project-funding, (ii) engagement with non-academic partners and (iii) collaboration with other university departments, and (iv) improving facilities.

Increasing cross-cutting research. UoA11's research income has increased by 35% compared to the REF2014 period (from £2,095K to £2,826K p.a.). This upward funding trajectory will further accelerate with future contributions from the 12 recently hired early career lecturers. Many projects cut across UoA11, also often including investigators from other units at King's and other academic institutions, e.g., the CONSULT, DADD, PLEAD, RESET and THuMP projects (see Section 3.1) as well as the above mentioned 5GUK, ACE-CSR, REPHRAIN, STAI CDT, UK-TAS-Hub and CUSP London. The development of funding bids for such initiatives is encouraged and facilitated by the unit's hubs, which bring together potential research collaborators from across the university, and is further supported by the King's Together scheme for multi-disciplinary research (see Section 4.2).

Engagement with non-academic partners. A census of non-academic partners on the unit's research projects exceeds 100 (see Section 3). Closer engagement with industry led to doubling the direct industrial funding from £138K per year (6.5% of income) in REF2014 to £284K per year (10% of income) in REF2021. The strong external relationships and the impact strategy (see Section 1.5) led to substantial impact activities, with the main success stories captured in the submitted Impact Case Studies (ICSs):

- ICS1 Research on automated planning and plan-execution helped **Schlumberger** to become the world leader in drilling automation, bringing improvements in efficiency, consistency and safety, resulting in savings estimated at \$150M p.a.
- ICS2 Research on data provenance and collaborations with **Imosphere Ltd** (a software company for the healthcare sector) and the ICO led to establishing provenance as an essential function of IT systems, which provides a trusted account of data processing.
- ICS3 Research on designing robot manipulators and control algorithms provided the basis for two companies, **Movendo** and **AiTreat**, to commercialise robotic therapy devices, now used in more than 100 clinics worldwide.
- ICS4 Fundamental research on 5G telecommunication systems, in collaboration with major companies (including **Ericsson** and **Konica Minolta**), contributed to development of 5G standards.

Further examples of UoA11 impactful research activities involving non-academic partners include: collaboration with the House of Commons Library on understanding and improving digital citizen engagement (**Sastry**); development of programming environments for pre-university computer science education, supported by £737K funding from Oracle and used by 3 million users annually (**Kölling**); and design of interventions for emotion regulation in children, with a US developer investing \$800K to commercialise the prototype (**Slovak**).

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UoA11 excelled in expanding the breadth of **collaboration with other university departments**, as highlighted in Table 2 (showing only the major projects and research initiatives). For comparison, the unit's collaborations within King's during the REF2014 period were confined to Digital Humanities, War Studies and Medical Schools.

	Business School	Digital Humanities	Geography	IOPPN	Law	FOLSM	Policy Institute	War Studies
ACE-CSR		x						x
CONSULT		x				x		x
CUSP L.			x	x			x	
DADD		x						
REPHRAIN		x			x		x	
RESET			x					
THUMP	x				x			
UK-TAS-Hub	x	x			x	x	x	x

Table 2. Key collaborations between UoA11 and other units at King's (IOPPN: Institute of Psychiatry, Psychology & Neuroscience; FOLSM: Faculty of Life Sciences and Medicine).



The target of **improving facilities** was exceeded due to two major developments.

(i) In 2017, the whole **Dol** moved to Bush House, a historic building complex, pictured on left, acquired by King's in 2015 and modernised to state-of-the-art academic accommodation at a cost of £8M for the space occupied by Informatics. The move created a strong sense of community within the unit and facilitated closer links with other university units relocated there.

(ii) With investment of £7M, new hardware and software labs were opened in 2019 for the CTR and CORE groups. The university invested a further £45M for larger engineering teaching and research labs (construction commenced in summer 2019), which will facilitate further research collaboration between engineering and informatics around and beyond telecommunications and robotics.

1.3 Unit's research structure and management

UoA11 has structured its committees to coordinate research and impact activities, seek inputs from and provide information to its membership, oversee its PhD programme and link with the faculty and university management and support structures. Research activities are conducted within the framework of groups and hubs (Figure 1). Groups, based around common scientific areas, are core components of the formal management structure of the unit. Hubs provide a less formal, thematic virtual clustering of researchers from all parts of the unit and are open to researchers from other departments. Coordinated by Hub Champions, hubs focus on societal challenges, which often require expertise and ideas from multiple sub-disciplines. Hubs encourage and support exploration of new collaborations between research groups, across the university, and with external partners, with a view to developing a strong impact culture.

Each group is allocated a budget (UoA11 total £74K in 2019-20) to support research activities outside funded projects, e.g. research networking or organisation of thematic workshops. Each hub has a budget for networking activities (total £20K in 2019-20).

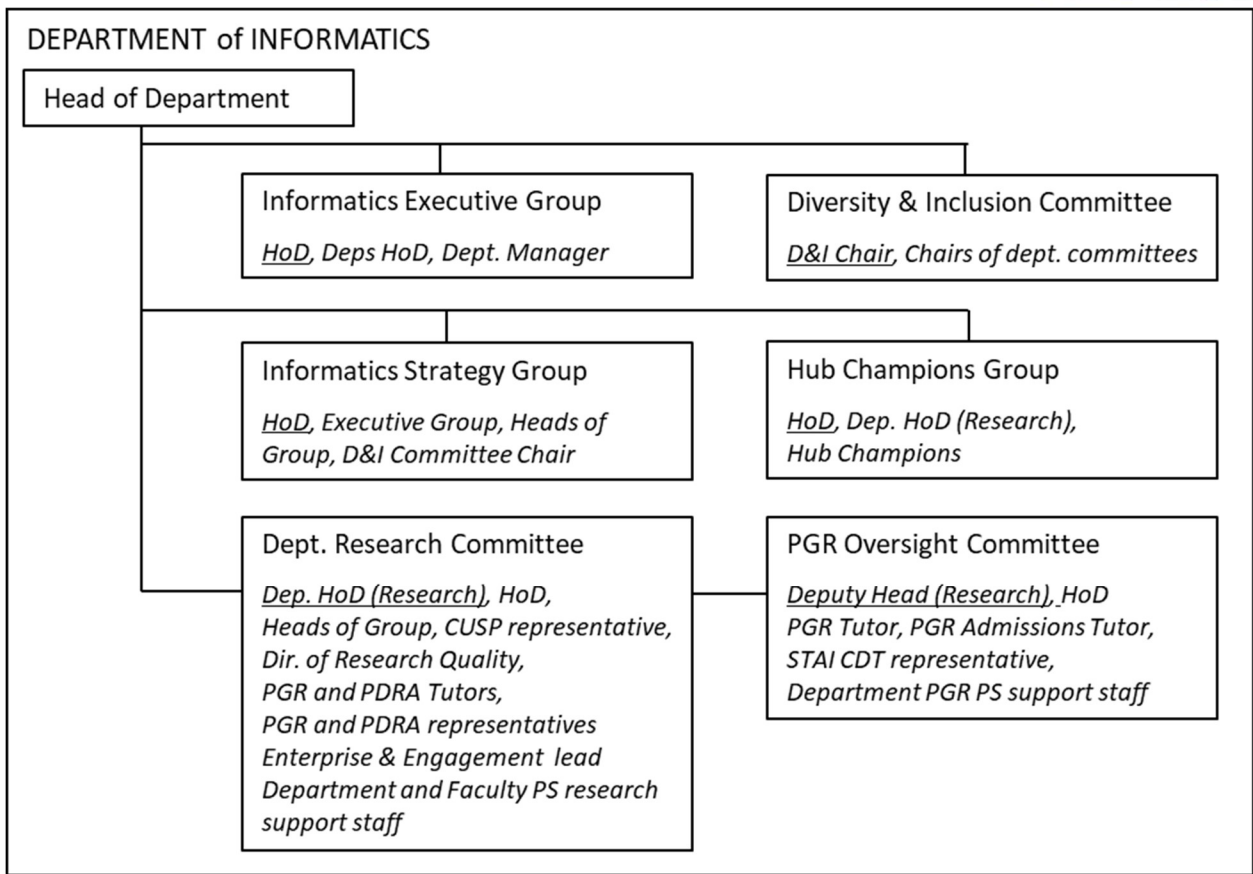


Figure 2: **DoI** Research management and support structure.

Figure 2 illustrates the structure of **DoI** research management and support. The Head of Department (**Moreau**) is assisted by deputies for Education and Research. The *Informatics Strategy Group* considers key departmental plans, such as directions for academic recruitment. The *Departmental Research Committee* coordinates support for, and monitoring of, research activities. The *Hub Champions Group* focusses on mapping out new initiatives and coordination between hubs. All matters related to PGR programmes and students are coordinated by the *Departmental PGR Oversight Committee*. The remit of the *Departmental Diversity and Inclusion Committee* includes coordination and oversight of the D&I agenda of the Research and PGR committees.

1.4 Research groups

UoA11 comprises 8 research groups, led by Heads of Groups, half of whom are women.

Algorithms and Data Analysis (ADA, Head: **Iliopoulos**) has interests ranging from theoretical computational complexity to machine learning for computer vision and data-driven solutions for operational research, digital privacy and health.

Cybersecurity (CYS, Head: **Viganò**) addresses problems of security and privacy breaches and loss of trust in computing processes through: (i) systems, (ii) formal verification and testing, (iii) provenance, ethics, trust, explainability and human factors.

Distributed Artificial Intelligence (DAI, Head: **Polukarov**) explores social and technological contexts of interacting intelligent entities, including agent-based simulation, provenance, norms, trust and reputation.

Human Centred Computing (HCC, Head: **Borgo**) is concerned with design and evaluation of computing systems for complex human interaction, focussing on computer graphics, data visualisation, human-computer interaction and natural language processing.

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Reasoning and Planning (RAP, Head: **Modgil**) researches symbolic models for reasoning involving argumentation, knowledge representation and planning, and the combination of reasoning, planning and machine learning approaches.

Software Systems (SSY, Head: **Chockler**) addresses modelling, design and engineering of software systems, automated reasoning about system properties, and mathematical foundations of modelling computing systems.

Centre for Robotics Research (CORE, Coordinator: **Dai**) works on innovating robot-centric approaches to critical challenges faced by society, with high-fidelity sensing, high-dextrous manipulation, control and mechanism design.

Centre for Telecommunications Research (CTR, Head: **Mahmoodi**) is a leader in telecommunications, data & information processing, and multimedia and device technologies, recognised particularly for research and innovation in 5G and increasingly 6G.

1.5 Strategy and arrangements for enabling impact

The main principle underlying [King's research strategy](#) is to strive for the highest research quality as well as high external impact to address global challenges and meet societal needs. To enable high impact, a combination of unit, faculty and university level mechanisms are used to create an environment for discovering, developing and exploiting inter-disciplinary research opportunities.

UoA11's strategy defines a **platform of research groups and hubs** to enable development of, or connecting to, high-profile impactful activities (shown in Figure 3 as a third dimension to the unit's research environment). This is further amplified by creating a culture of impact, promoted by the Research Committee and the Hub Champions Group through discussions of potential impact of possible major funding bids. Since its launch in 2017, this strategy has already led to four substantial activities with external national recognition (STAI CDT, UK-TAS-Hub, REPHRAIN and Cybersecurity ACE-CSR) and to effective integration with CUSP London.

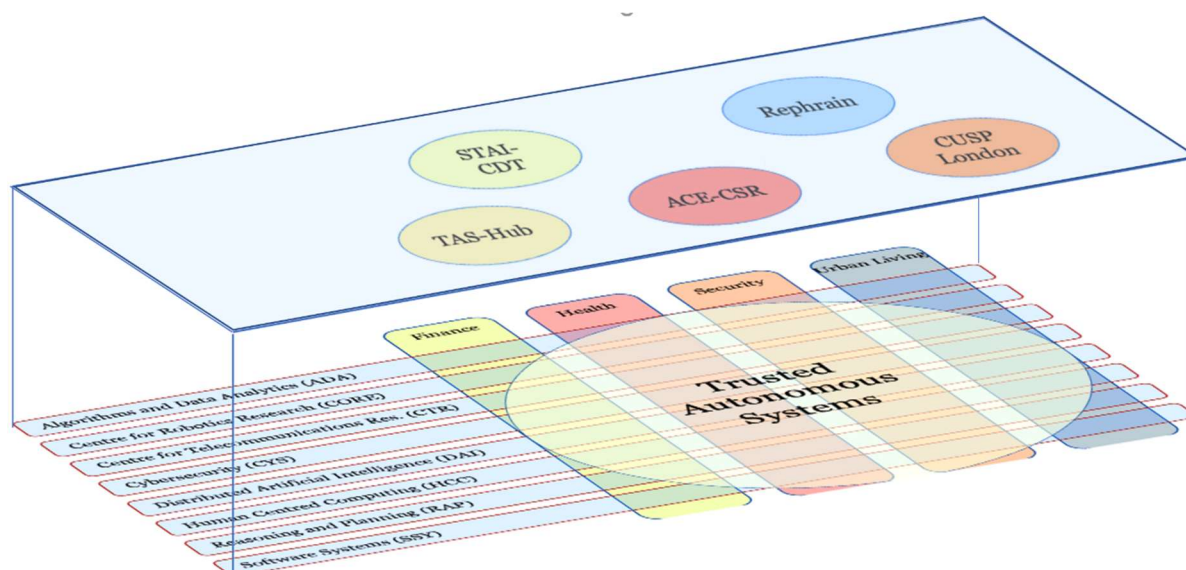


Figure 3: Impactful activities facilitated by the hubs.

Part time appointments are used by UoA11 to strengthen links with industry and explore impact opportunities. CUSP London Deputy Director (**Quercia**, Nokia-Bell-Labs, part-time in UoA11) manages the centre's relations with partners. RAEng Visiting Professor (**Lees**, IT consultant) links UoA11 with the software-development sector and also brings to the unit his expertise on software performance engineering.

Faculty and university support for enabling impact. The **EPSRC Impact Acceleration Account (IAA)**, managed by NMES (see Section 2.5) and the **King's Together** scheme (see Section 4.2) provide internal competitive funding for impact generation activities. The NMES Research Impact Lead – a full-time administrative post within the Faculty Research Development

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Team – provides support for impact activities, including recording, evaluating and reporting impact and assisting in preparation of impact-generation proposals.

1.6 Research integrity and open research

King's has enhanced its approach to Research Integrity during the REF2021 period, updating, improving and clarifying procedures. A Research Integrity Champion within NMES and Research Integrity Advisors (RIAs) embedded in units promote research integrity values, provide a point of contact for researchers with queries or concerns and coordinate with the university Research Governance Office the preparation of information and training.

The university, committed to high ethical standards in research, requires that its researchers consider and address issues such as management of risk, protection of confidentiality and the process of informed consent. Ethical clearance is required for all projects with primary data collection involving human participants (55 projects in UoA11 over the period), e.g. user studies in HCC and experimental evaluations of privacy protocols in CYS. The best practice on research ethics is spread by the RIAs and by UoA11 academics who sit on a university Research Ethics Subcommittee.

UoA11 puts emphasis on making research outcomes accessible to other researchers. In addition to the REF accessibility requirements, managed through the institutional PURE repository, research data is managed through the Library, according to data management plans defined by the researchers. King's is an institutional member of the [UK Reproducibility Network](#).

UoA11 participates in promoting open science, for example, through the coordination of the EC-funded [ACTION](#) project ([Simperl](#)), which develops digital infrastructure for helping citizen scientists set up and manage projects, share data openly and comply with Responsible Research and Innovation practices.

1.7 Strategic aims and goals for research and impact for the next 5 years

UoA11 aims to further raise its status as a leading international centre for *research in computational systems that symbiotically integrate with society and are fit for purpose by design*, influencing the advancement of the Informatics discipline nationally and internationally. As UoA11 has developed a strong reputation in safe and trustworthy AI, it now seeks to broaden its expertise and recognition in complementary areas to support its ambitious multi-disciplinary agenda on human-centred and data-driven systems requiring contribution from all sub-disciplines of Informatics and beyond. Concrete targets have been identified.

1. *Developing critical mass in strategic and complementary areas*

While ensuring a balanced growth across sub-disciplines, particular areas of expansion include vision, natural language processing, systems fundamentals, and human-system interaction. The unit's co-developed research and education strategies will shape expansion and recruitment in a financially sustainable way, with the ambition of substantially growing headcount (up to 50%) over the period.

2. *Institution-wide coordination of AI research*

UoA11 will contribute leadership and expertise to a new King's-wide AI institute (to be launched in 2021), aiming to coordinate AI research, enterprise and impact across the whole institution. This includes developing synergies between the King's £16M medical AI centre and King's CDTs in AI-related topics (EPSRC-funded Smart Medical Imaging, UKRI-funded STAI and King's-funded DRIVE-Health), and leveraging facilities such as the new Cambridge-1 supercomputer based at Guy's and St-Thomas' Hospitals.

3. *Development of research leaders*

Building on recent fellowship successes (2019 EPSRC Fellowship renewal for Tratt, 2020 UKRI Future Leader Fellowship for Slovak) and the NMES network of fellows, UoA11's ambition is to support 5-10 fellows. Likewise, the ambition is to develop research leaders able to front significant national activities and to be in a position to lead 1-2 programme grants (or equivalent).

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4. Promoting research with strong impact

UoA11 will increase the scope, reach and significance of the impact of its research, targeting various types of impact, including impact on policy. A culture of “Informatics Stories” publicising the unit’s research successes will be developed, with the appropriate resourcing (both staff and processes) to support the tracking of evidence. The pedestrianisation of the Strand, beginning in 2021, places Bush House at the centre of [A Global Creative and Cultural Quarter](#), which UoA11 will exploit to showcase its research.

5. Increasing engagement with industry

Building on its experience of working with industry gained in the STAI CDT, UK-TAS-Hub and REPHRAIN, strengthening its links with the Informatics Industry Advisory Board, and leveraging the new role of NMES Vice Dean for Enterprise and Engagement and the corresponding departmental role, UoA11 will seek to develop strategic relationships with 1 or 2 partners over the period.

2. People

2.1 Staffing strategy and academic recruitment

King’s decision in 2016 to invest strategically in science and technology allowed UoA11 to draw up expansion plans and intensify recruitment of new academic staff. The principles of UoA11’s recruitment strategy are: (i) to appoint a diverse set of researchers with an excellent research record for the stage of their career and clear promise for further development; (ii) to support the growth of the unit in the identified research directions; and (iii) to ensure a balance between junior academics starting their career as independent researchers, and senior academics who can provide research leadership and mentor other staff.

In 2014–2020, UoA11 made 22 appointments (including 8 women) to academic posts with teaching and research responsibilities: **13 lecturers**, **4 senior lecturers/readers**, and **5 professors**. Three were recruited internationally (2 USA, 1 France) and 60% have had past research positions in international institutions. The appointments were in the areas of AI (**Cocarascu[◊]**, **Criado[◊]**, **Malizia[◊]**, **Moreau**), web computing (**Simperl**), cybersecurity and data security (**Cavallaro**, **Pierazzi[◊]**, **Suarez[◊]**, **Such**), data science (**Letsios[◊]**, **Loukides**, **Mallmann-Trenn[◊]**, **Shi[◊]**), human centred computing (**Abdul-Rahman[◊]**, **Borgo**, **Slovak[◊]**, **Yannakoudakis[◊]**), game theory (**de Keizer[◊]**, **Polukarov**, **Ventre**), computational biology (**Bentley**) and software systems (**Kölling**). Symbol ◊ indicates Early Career Lecturers at the time of appointment (less than 4 years as independent researchers).

2.2 Support for Early Career Lecturers (ECL)

UoA11 aims to develop ECLs into successful academics. This begins with their appointment with appropriate start-up packages, a rigorous, fair and encouraging probation process, adjusted workloads and a supportive environment.

Start-up. ECLs receive a start-up fund to support their research endeavours until external research funding is secured. Such funds are normally used for additional research equipment, attending conferences, visiting research collaborators, or setting up small exploratory research projects. The total of £364K start-up funds in UoA11 during the REF2021 period included £154K for ECLs. In addition to this, 18 PhD studentships were committed to new starters since 2017, including 9 studentships for ECLs.

Workload reduction. To help new starters bootstrap their research over their 3-year probation, their initial teaching and administrative loads are reduced to 50% of a normal load, gradually increasing to 100% by the end of probation. This creates extra time to build up independent research, prepare publications and develop initial research proposals.

Mentoring and training. The unit and the university provide mentoring and training support for new lecturers. The mentoring scheme includes advice and assistance on developing publications and proposals, while the unit also offers internal review of draft proposals. The training includes grant-development sessions, normally taken within the first year of probation. The probation

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process also offers a mechanism to periodically discuss, set and review objectives with a probation mentor, to ensure ECLs develop into successful academics.

Support Network. ECLs in **DoI** form a support network with informal monthly meetings to share best practice, to learn from each other and to identify common issues for departmental consideration. This network, initially established by the Department, is now run by the ECLs themselves, who set the agenda and format of meetings.

2.3 Workload

DoI staff are typically involved in research, education and administration. To address both educational and research aspirations, the Department also employs staff on the Academic Education Pathway (AEP), reaching 8 AEP lecturers in post on 31/7/2020 with teaching and related administration as their main responsibilities.

Transparent Workload. A workload allocation model capturing assigned duties is published in the Department and informs all discussions and decisions about load and duties. Explicit documentation sets load expectations for staff.

Reduced Workload. Load is reduced not only for ECLs but also for staff returning from extended leave (e.g. parental leave or sickness). Load can also be reduced to support staff who have secured fellowships or are PIs of substantial grants.

2.4 Staff development

Whilst annual processes for performance development review (PDR), pay recognition, promotion and study leave are set by the university, UoA11 strives to encourage all staff to develop to their full potential and supports them through training, mentoring, reviews and promotion advice.

PDR Process. UoA11 assigns each staff member a PDR reviewer who helps identify individual training needs, feeds into the recognition-pay process, and offers discussions of longer-term career plans and aspirations, including promotions. The PDR process includes setting annual research objectives, in terms of publications and grant submissions, and further feedback and encouragement from the Head of Department, who reviews all PDR documents.

Promotions. As part of its Athena Swan Bronze award, UoA11 introduced an Informatics Promotions Panel to provide informal feedback on draft promotion applications, to assign a senior academic to each applicant to help prepare the final application, and to identify staff on the cusp of potential promotion. A particular strength of this process is to identify and support potential women and minority applicants, or other staff, who might lack confidence to apply. Internal promotions in UoA11 in the REF2021 period included 9 to Senior Lecturer (2 women), 6 to Reader (2 women) and 1 to Professor.

Mentoring. UoA11 runs its own mentoring scheme through which staff can elect to be paired with an informal mentor. The nature of the mentoring process is determined by the individuals and can vary from casual discussions to career progression advice. An incentive scheme for mentors and mentees is provided and elements of training are available to mentors.

Training. UoA11 supports staff by recommending them for university training programmes. The *Emerging Leaders Programme* provides PIs and team leaders with core leadership skills (participants: Miles 2016/17, Black 2017/18, Zschaler 2019/20). The *Leading Researcher Programme* provides professorial-level participants with targeted development, enabling accelerated career progression (participants: Cavallaro 2018/19, Such 2019/20). The recent *Emerging Research Programme* targets earlier stage researchers (participants: Abdul-Rahman 2020/21). The *Strategic Leadership Programme* focuses on the development of staff in senior roles (participants: Vigano 2016/17, Kölling and Moreau 2017/18).

NMES Network of Fellows (current and recent holders of advanced fellowships and major single investigator awards) develops activities to further the advance of network members as well as to inspire, support and advise other colleagues, creating a stronger, more vibrant research community within the Faculty, benefitting the UoA11 staff.

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Study Leave. Every member of academic staff is entitled to apply for study leave after 6 years in post. UoA11 prioritises applications with strong research plans, includes considerations of equality and diversity and undertakes a post-leave review. In the REF2021 period, 18 academics, including 5 women, were granted one-year study leave (6 professors, 4 readers, 7 senior lecturers, 1 lecturer).

2.5 Support for obtaining external research funding and developing impact

UoA11 and NMES offer personalised support to prospective PIs in their grant proposal development endeavours.

Internal peer review. UoA11's Director of Research Quality leads internal peer-reviews of grant proposals for competitive external funding. A review panel of 3-5 academics and a member of research development staff provide the proposers with constructive feedback. Earlier versions of proposals, starting with 1-page outlines, are also reviewed, in particular to support ECLs. Proposers are also offered help with preparing rebuttals to reviewer comments, and mock interviews when interviews are part of the application process.

Training programme. NMES has launched a 12-week training programme for developing grant proposals. By the end of the programme, each participant should have a completed proposal ready for submission. Eight UoA11 staff participate in this programme in 2020/21.

Faculty support. Investing significantly over the past few years in professional services, NMES now provides a team of 8 full-time staff focussed on supporting research. New appointments include a Faculty Research Manager, Faculty Research Coordinator, Research Development Manager and a dedicated Departmental Research Officer in each NMES department. Further expansion of the faculty research support team is planned for 2020/21, with an additional full-time Senior Research Officer and a second Research Development Manager.

The **IAA scheme** at King's provides longer-term support for achieving research impact. Managed by NMES, IAA funding is awarded as 'Advancing Impact' grants (up to £60K) for supporting proof-of-concept work and knowledge transfer, or 'Rapid Access' grants (up to £10K) for shorter-term activities promising immediate impact. IAA funding has been used strategically to support the ICSs, but also to nurture impact broadly across NMES. UoA11 received £304K IAA funding in 2015-2020, including funding for projects: "Deployment of Expressive Continuous Numeric Planners in Large Scale Applications" (**Amanda Coles**) in collaboration with Schlumberger, which contributed to ICS1; and "Provenance based explanations" (**Moreau**) in collaboration with the ICO, which contributed to ICS2. The unit's IAA grants supporting broader impact included "KCL planning technologies on board the international space station" (**Magazzeni**) in collaboration with NASA, and "Blockchains and nuclear non-proliferation" (**McBurney**), which involved confidential discussions with nuclear verification experts and led to McBurney's invited seminar on the topic to the Directorate of Safeguards at the IAEA (Vienna, 4/2018).

King's Undergraduate Research Fellowships (6-9 each year in UoA11) provide funding for summer internships with the dual aim of integrating research and teaching, and helping academics explore new ideas for future proposals.

Incentivisation. An important aspect of the promotion process is to recognise and reward staff for high quality research and achieving impact. Both aspects are closely reviewed at all stages of the process. UoA11 provides project investigators with funding (£47K in 2019-20) in proportion to overheads generated to enable exploration of new research possibilities beyond currently funded projects for subsequent grant proposals.

2.6 Career development support for post-doctoral researchers

UoA11 brings together its community of post-doctoral research assistants (PDRAs) – 30 to 40 researchers at any given time during the REF period – by establishing a departmental PDRA Tutor to assist them in their ambition to become independent researchers. PDRAs are integrated within research groups and are represented on the departmental Research Committee.

The PDRA Tutor provides advice and coordination for PDRAs, communicates the development opportunities available at faculty and university levels and considers any issues which may hinder

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their work. The PDRA Tutor also reviews the PDRA's PDR documents to identify emerging themes and agrees appropriate actions with the Informatics Strategy Group; an example of action is provision of teaching opportunities, in response to a desire by PDRA's to develop wider academic experience.

Research Staff Development. The Centre for Research Staff Development (CRSD), launched in April 2016, is a crucial element of King's commitment to delivering the principles of the *Concordat to Support the Career Development of Researchers*. CRSD provides university-level professional development support for research staff to achieve their potential before, during and after their time at King's, with active support from the most senior staff in the university. The support includes career advice, relevant courses and workshops (e.g. leadership training workshops for research staff) and providing information about opportunities and general developments in the Higher Education sector. The Centre's overarching objective is to facilitate and support an active and engaged research staff community where researchers can provide input into policies and initiatives at King's and nationally.

2.7 PGR students

UoA11 complements the institutional regulatory setup with processes to (i) ensure that students are admitted with the right qualifications and experience, and matched to supervisors with similar expertise and enthusiasm; (ii) monitor student progress and ensure that remedial actions and adequate support are provided promptly to both students and supervisors, if necessary; (iii) oversee the departmental PhD programme in a way that is consistent, accountable, transparent and fair to all; (iv) provide personal support via a PGR Tutor; and (v) offer a thriving research environment for development of student skills and career plans.

In 2019/20, **DoI** had 160 PGR students, of whom 30% were women. During the REF2021 period, 125 doctoral degrees were awarded in UoA11.

Supervision team. Each PGR student has at least two academic supervisors. All supervisors are required to complete supervisory training and take refresher training at least every five years to ensure that they provide high quality support.

Progression. All students have their study progress and training needs reviewed every six months. Two major progress assessments are the UoA11-specific 9-month assessment and the university-wide 18-month (MPhil-to-PhD upgrade) assessments, both based on a technical report and viva with a panel including the supervisory team and an independent assessor.

PGR Tutoring and SSLC. Research students are supported by the departmental PGR Tutor, who provides pastoral advice and helps resolve any challenges that may affect students' work. Issues wider than individual concerns are discussed within the departmental Staff-Student Liaison Committee for PGR students, held once per term and chaired by the PGR Tutor.

Oversight. UoA11 introduced the PGR Oversight Committee (PGR-OC) which coordinates all activities (admissions, progressions, funding) related to PGR students. The committee meets monthly to provide prompt feedback on students' progress, consider offers for entry to the PhD programme and for studentships, and monitor departmental PGR processes.

Environment. Each PGR student participates in research activities of the group of their main supervisor, including seminars and discussions with visitors. Research groups form the immediate communities for PGR students, where they learn from others and are encouraged to discuss and present their own work. PGR students in the same research group are normally co-located in the same open-plan office space to facilitate collaboration and peer support.

Training. At the university level, the Centre for Doctoral Studies supports PGR students by offering training courses for developing transferable academic skills, providing networking opportunities and creating a community environment for all research students.

Entrepreneurship. Innovative training, designed by King's Entrepreneurship Institute, such as *Entrepreneurial Mindset*, is open to PGR students and research staff across King's. The programme helps participants develop their skills as innovators, critical thinkers and collaborators, enhancing their future career prospects. The programme is compulsory for students from the STAI

Unit-level environment template (REF5b)

CDT and open to other UKRI funded students. The first cohort (2019-20) consisted of 12 UoA11 students.

RTSG funding. UoA11 PGR students are strongly encouraged to write research papers for presentation at external workshops and conferences. RTSG funding (Research Training Support Grant) is available for all students (irrespective of the source of their funding) to cover and support conference attendance and other research activities.

Admissions. The departmental PhD admissions tutor coordinates the evaluation of applications and ensures that the admissions process is conducted according to university regulations, departmental guidelines and EDI best practice. Applicants considered for entry are interviewed by two academic staff (or three, if a studentship is considered). PGR-OC makes final decisions on admission and studentship offers.

Funding. The main sources of funding for PGR students in UoA11 are departmental PhD studentships, funded by EPSRC DTP and NMES (8-12 studentships each year), and the STAI CDT. Other available PhD funding schemes include King's-China Scholarship Council studentships, with 6 to 9 offers in UoA11 each year.

2.8 STAI CDT

Led by King's College London (**Luck** – Director, **Black, Criado, Rodrigues**) in collaboration with Imperial College London, the UKRI Centre for Doctoral Training in Safe and Trusted AI focusses on the use of symbolic AI techniques for ensuring the safety and trustworthiness of AI systems. This CDT offers 8 studentships per year at King's and the first cohort started in October 2019. A key aspect of the CDT is engagement with 20 non-academic partners offering a range of problems and data sets to drive the research and opportunities of placements for students.

2.9 Equality, Diversity, Inclusion (EDI)

Both King's College London and **DoI** have Athena Swan (AS) Bronze Awards, with the departmental award obtained in 2017 (following a faculty-level award in 2014) and reconfirmed in 2020 (after the creation of the new Department of Engineering). **DoI** is implementing its Athena Swan action plan and is now working towards an application for the silver award. The unit's EDI agenda is embedded within the wider university framework of EDI policies and practices, as described in the REF5a document.

UoA11 follows university staffing policies on equality, diversity, age, sexual orientation and disability, which aim to maintain an inclusive environment where all individuals are valued and able to succeed. These policies include EDI requirements and recommendations for the appointment processes, e.g. for the composition of interview panels. All UoA11 recruitment panels for academic positions during the REF period have included at least one woman, and panel members must first take unconscious bias training. Similar arrangements are required for interview panels for postdoctoral research positions and for applicants to PhD programmes.

In accordance with its AS action plan, UoA11 has introduced a number of practices to promote a more inclusive and diverse research environment. Key examples are:

- The departmental D&I committee, chaired by two D&I Champions, plays a central role in **DoI** with membership including the Head of Department and the chairs of all main departmental committees.
- D&I Champions are recognised as major departmental roles and *ex officio* members of the Informatics Strategy Group (ISG). EDI is a standing agenda item on the monthly meetings of ISG.
- The departmental Workload Allocation Model is based on equality, fairness and transparency principles. During the REF period, 3 members of staff who were on maternity leaves benefitted from workload reduction (see Section 2.3).
- Equality, diversity and inclusion are considered in the process of allocating shared offices. The unit also provides customised office furniture (e.g. specialty adjustable desks) for those who require them for medical reasons.

Unit-level environment template (REF5b)

- In consideration of staff well-being, the department discouraged sending work emails out-of-hours and organising meetings on Fridays during the pandemic.

The following table shows progress achieved during the REF2021 period in improving gender balance in UoA11.

	Women (All)	%
REF2014	10 (46)	21.7%
Academic recruitment in 2014-2020	8 (22)	36.4%
REF2021	16 (50)	32.0%
Heads of Group and Hub Champions	5 (14)	35.7%
Sector national average (2019/20)		23.1%

Table 3. Gender balance in UoA11.

UoA11 staff engage in national and international EDI initiatives. **Criado** gave a talk about gender discrimination in AI at the 2018 EU Gender Summit and was a panellist at a meeting of the BCS Women in Technology network. **Borgo** has been involved in 'Women in HPC', which aims to improve equality, diversity and inclusion in High Performance Computing. **Simperl** gave a talk at a UK's ACM-W professional chapter.

NMES organises the annual *Women in Science Week* to celebrate women working in science, highlight the issues surrounding under-representation of women in STEM subjects and promote gender equality as a relevant and important topic for all. *Ada Lovelace Day* is the flagship event of the week and consists of inspirational talks from a wide variety of speakers. NMES also operates a system of flexible working arrangements for staff with caring commitments. In 2019/20, 7 UoA11 staff (including 2 women) had formal flexible working arrangements.

Various university-wide EDI initiatives are presented in the institutional-level environment statement. These include the Race Equality at King's hub, 'Proudly King's' LGBTQ+ staff network, the NEST network supporting staff with parental or caring responsibilities, 'Access King's' disability inclusion network, and King's Parents and Carers Fund.

While preparing the REF submission, UoA11 followed the university's REF2021 Code of Practice, further enhancing some of the EDI provisions. For example, all UoA11 staff were involved in reviewing potential REF outputs and their feedback was considered by the unit's REF Output Selection Group. This 11-member group was selected to represent all research groups, various seniority levels and the UoA11 gender balance. At all phases of the output selection process, the outputs of those with 1 or 4-5 selected papers were particularly closely scrutinised to avoid under- or over-representation. A particular focus was also placed on the gender balance of the selection. Where decisions were needed between outputs evaluated as being of similar quality, the unit followed the principle of improving the gender balance of the overall selection. All UoA11 staff were regularly informed about REF processes and the outcomes of various phases of output selection.

Looking beyond 2020, UoA11 will continue expanding its EDI agenda and activities. In particular, while the gender balance in UoA11 is now significantly better than the national average, the unit will continue with the actions set out in the 2017 Athena Swan application to achieve further improvements. In particular, through its promotions panel, the unit will aim to improve gender balance at more senior academic grades, where women remain more under-represented.

2.10 Supporting staff, researchers and PGR students during COVID-19 pandemic

UoA11 has shown resilience and resolve when facing the challenges of the COVID-19 pandemic. Most research projects continued with only minor adjustments of schedules, but some user evaluation studies had to be postponed or re-designed.

The unit was very effective in switching all communication online. Regular staff meetings, research group meetings, and various interest group meetings provided support and a sense of community,

Unit-level environment template (REF5b)

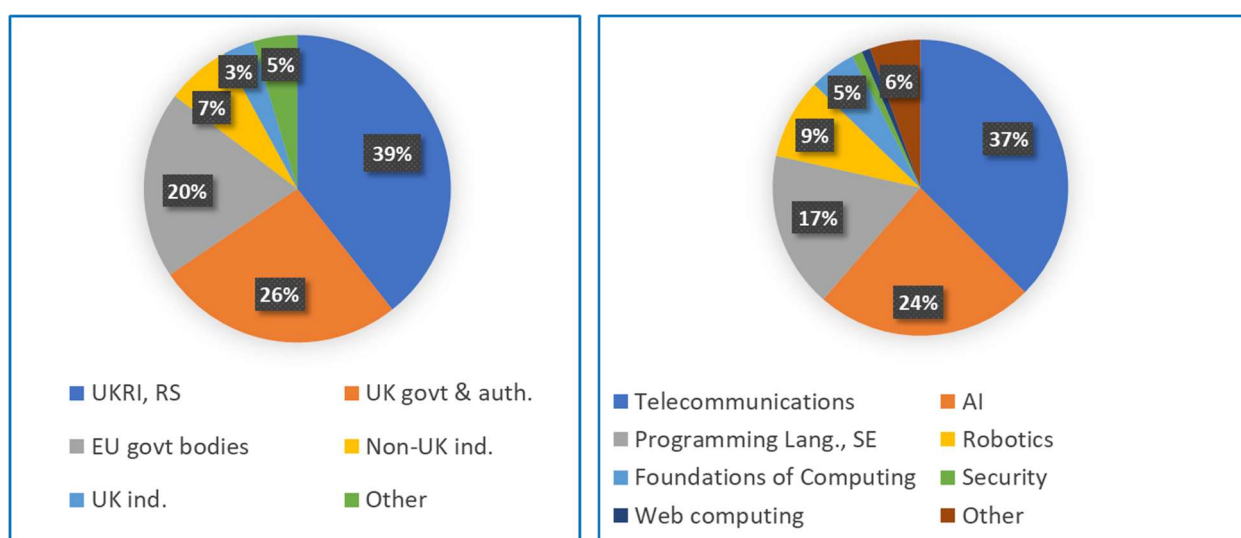
often surpassing the pre-COVID experience. PGR students were offered laptops on loan if needed, the university extended some PGR assessment deadlines, and the faculty funded extensions to studentships, if research progress was affected by lockdowns. The university also put in place special arrangements for online PhD vivas, and examiners were asked to consider the student's *Covid19 impact statement* (if submitted with the thesis) whilst always upholding the academic requirements for a research degree award.

The university has implemented detailed processes for returning to work on campus, which consider individual staff circumstances.

3. Income, infrastructure and facilities

3.1 Income

For the REF2021 period, the unit's research income was £19.8M in total (for 48.5 FTE), a yearly increase of 35% compared to REF2014, or a yearly increase of 28% per FTE. This total included industrial funding of £2.0M, which doubled, p.a., compared to REF2014. This performance should be understood in light of the high number (12) of ECLs appointed during the period.



The charts above illustrate the distribution of research spend during the REF period according to funder and area of research. The highlights below (and throughout the document) refer to all funding secured during the REF2021 period, including new projects (where spend does not yet show in the charts) to indicate the upward trajectory and shift of the UoA11 research focus. Each quoted value (here and in Section 1) is the amount committed to King's by the main funder.

In Artificial Intelligence, funded projects have focused on three principal areas: fundamentals of AI, AI for business performance, and explainability discrimination and trust in AI. [CONSULT \(Modgil, EPSRC, £1,381K\)](#) won the best demo award at the Human Agent Interaction 2018 conference for its argumentation techniques to help patients suffering from chronic diseases self-manage their treatment. [ERGO](#) and [ADE \(Coles, EU, £487K\)](#) contributed, with GMV Aerospace and Defence, AI planning technologies for space robotics towards European capabilities for orbital maintenance and planetary exploration. [DADD \(Such, EPSRC, £654K\)](#) researches digital discrimination in collaboration with Google, while [THuMP](#) and [PLEAD \(Moreau, EPSRC, £1,361K\)](#) advance the state-of-the-art in explainable AI and provenance-based explainability with Schlumberger, Save the Children, Experian, Roke Manor and Southampton City Council. The STAI CDT and the UK-TAS-Hub (see Section 1.2) also contribute to this area.

Funded projects in Programming Languages and Software Engineering have focused on language runtimes, software engineering methodologies and programming environments. A fellowship on tooling to support programming language compositions ([LECTURE – Tratt, EPSRC, £953K](#)) led to talks at Facebook and Oracle, which in turn were instrumental in supporting a follow-up fellowship extension on performance of virtual machines with Intel and Mozilla Foundation ([HAMLET – Tratt, EPSRC, £923K](#)). UoA11 leads a network to improve the state of the art in model-driven software engineering with the Institute of Coding ([MDE-Net – Zschaler, EPSRC, £463K](#)). Oracle funding

Unit-level environment template (REF5b)

supports the development of Greenfoot and BlueJ object-oriented programming environments used by millions of learners (**Kölling**, Oracle, £737K).

In the area of Security, funded projects have focused on system security, secure AI and online threats to individuals. Under the ACE-CSR umbrella, illustrative projects include: an investigation of the modularity of virtual machines to improve security, with ARM and Shopify (**CapableVMs** – **Tratt**, EPSRC, £837K); the use of machine learning to detect malware on mobile devices with McAfee Labs (**MobSec** – **Cavallaro**, EPSRC, £243K); and a study of attacks and protection of AI assistants with Microsoft, Humley, Hospify and Mycroft (new project **SAIS** – **Such**, EPSRC, £1,155K). Finally, **REPHRAIN** (**Such**, EPSRC, £618K) addresses tensions and imbalances between benefits of the digital economy and the potential for harm through loss of privacy, insecurity, and disinformation, with over 20 private and public partners.

Projects in Foundations of Computing have focused on algorithmic foundations, distributed ledgers and computational models, and include development of algorithmic techniques for distributed graph processes (**EP/M005038/1** – **Cooper**, EPSRC, £312K), design of trusted and transparent voting systems using ledger technologies (**VOLT** – **McBurney**, EPSRC, £374K), and design of novel algorithms for sequencing of molecular data and other big-data challenges (**Iliopoulos**, Royal Society, £198K).

In the area of Web computing, funded projects have focused on citizen science and data-driven innovation. **ACTION** (**Simperl**, EU, £420K) led by King's with 10 partners develops a participatory science toolkit against pollution. **MediaFutures** (**Simperl**, EU, £249K) builds on a long-established collaboration with the Open Data Institute's "Data-as-Culture" programme and addresses the responsible and innovative use of the Web, while **EUhubs4data** (**Simperl**, EU, £170K) investigates techniques to federate the data services of 12 hubs and 60 SMEs in Europe.

Funded Telecommunications projects have focused on fundamentals and applications of 5G. Besides the world-first 5G testbed discussed in Section 1.2 (**5GUK** – **Dohler**, DCMS, £3M), other projects focus on designing advanced physical and upper layer techniques (**SOLDER** – **Aghvami**, EU, £320K), 5G applications to the automotive sector (**5GCAR** – **Mahmoodi**, EU, £392K), sustainable energy (**VirtuWind** – **Mahmoodi**, EU, £432K) and immersive video services for mobile objects (**PriMO-5G** – **Mahmoodi**, EU, £278K).

In the area of Robotics, funded research has focused on manipulation, mechanism, control and planning, and included projects on control strategies for manufacturing processes (**Q-PreMan** – **Dai**, EPSRC, £312K), robotic mechanisms for innovative rehabilitation methods with AiTreat and DIH Technologies (**REST** – **Dai**, EPSRC, £413K), and integration of machine learning and automated planning for robot navigation (**SQUIRREL** – **Dai**, EU, £1,079K).

Funding and collaboration from industry. UoA11 has secured research funding directly from industry, totalling £2.0M, and provided by: BT, Nominet UK, Ericsson, Bosch, Oracle, Vodafone, Cisco and BAE Systems. The unit has also secured two InnovateUK projects with industry (£83K). Further support from industry has come via collaborations within projects funded by UKRI, UK government bodies or the EU, with over 100 industry and public sector partners.

UoA11 has actively supported **part-time or secondment work in industry** as a mechanism to forge deeper collaborative links and potentially strong research impact. In 2016, **Fox** and **Long** joined Schlumberger to oversee deployment of automated planning technology developed at King's, which resulted in ICS1. **McBurney** was Head of Technology Consulting at the Norton Rose Fulbright law firm in 2018-2020, advising on AI technologies for the legal sector. **Magazzeni**, on leave of absence during 2020-2021, is Executive Director at J.P. Morgan (JPM) AI Research, exploring opportunities for impact in finance from his research on automated planning and strengthening the partnership between JPM and the unit, including JPM staff delivering talks to the unit's PhD students, and one PhD student selected as a 2021 JPM PhD Fellow.

While academics individually maintain portfolios of external collaborators, UoA11 is also supported by NMES roles of Vice-Dean for Enterprise and Engagement, programme manager for industry partnerships and manager for industry internships.

Unit-level environment template (REF5b)

3.2 Infrastructure and facilities

Institutional Provision. Since 2013, NMES has contributed to core research computing infrastructure – **Rosalind** – provided by King’s IT. This comprehensive research platform includes: a High Performance Computing (HPC) cluster, a private cloud for flexible, scalable development environments, and very large, highly resilient storage for long term curation of research data.

To expand, modernise and increase flexibility of this platform, King’s has recently created a new university-wide **e-Research** function, underpinned by an investment of £800K for a research data storage platform and £1M for hardware refresh of Rosalind, and two new leadership roles, with more engineering and support posts to follow in 2021. UoA11 plays an important role in advising King’s IT on various aspects such as security (**Such**) and HPC (**Rodrigues**).

King’s library services have been evolving to focus on providing comprehensive and easy online access to varied resources. All researchers have access to a broad range of journals and bibliographic services, including electronic access to all major resources particularly relevant for UoA11 (ACM, LNCS, IEEE, Science Direct). This access has been crucial during the pandemic.

Local provision. UoA11 benefits from the Rosalind HPC cluster for research on image processing, systems security, NLP and AI technologies, allowing convenient integration of dedicated computing hardware within a larger infrastructure. The facilities are advertised to new starters through their offer letter, and routinely accessed by UoA11 researchers and PhD students. New starters with specialised computing needs but without their own research funding yet, are supported by further investment in a UoA11-dedicated facility with a mix of CPUs and GPUs, also complemented by Cloud access for peak usage.

Resource sharing. The NMES Computing Support Team consists of 12 staff supporting research 50% of their time. Placing the core computing infrastructure and IT support at the faculty level provides efficiency and flexibility. NMES increasingly operates multi-purpose laboratories wherever possible, for instance in the £45M Strand investment for Engineering, and encourages the sharing of resources as it promotes collaboration. This is routine for robotic-related research and 3-D printing. Likewise, the recent £40M Nvidia Cambridge-1 supercomputer is being used as a further mechanism for collaboration with the health faculties. Beyond King’s, examples of resource sharing include STAI CDT students having access to HPC facilities at King’s and Imperial, the UK-TAS-Hub deploying a cloud-based infrastructure to manage its research programmes across the UK, and system security researchers sharing computing resources between King’s and Royal Holloway.

Bush House. As mentioned in Section 1, **DoI** moved in 2017 to Bush House (BH) – a complex of three Grade-II-listed buildings at Aldwych, London, which was acquired by King’s in 2015, substantially enlarging the historic Strand campus. Researchers and PhD students occupy large open-plan areas, typically co-located by research group. Dedicated social spaces were a key factor in bringing the department together, facilitating interactions between staff and students. Sharing the central BH building with the Business School and Entrepreneurship Institute helped with starting new multidisciplinary collaborations.

To reflect the changing nature of its research with a large influx of new staff, UoA11 is setting up experimental spaces, allowing HCC researchers to conduct user studies, CYS researchers to safely experiment with malware detection and RAP researchers to investigate robot planning. With an investment of £100K, two rooms have been designed as multi-purpose facilities (to encourage cross-fertilisation between groups) including workstations to program robots such as the HSR Robot donated by Toyota, sensors to detect movement of users and devices, and visualisation equipment. (Work on the conversion of this space was postponed as premises were not accessible during the pandemic.) CUSP London space in BH was equipped with a visualisation suite which has been used to visualise data in collaboration with London partners.

Specialised facilities. To support the *Systems Security Research Lab*, an investment of £200K, in the form of start-up grants, provided high-specification hardware (3 nodes x 2 CPUs x 26 cores, >100Tb storage) for program analysis using machine learning. To allow CTR to demonstrate *5G technology* capabilities, an integrated system-level testbed platform was supported by institutional investment of £250K. Dedicated server room space was upgraded with installation of 5G and 4G

Unit-level environment template (REF5b)

Core networks servers, with a new cabling network in the Strand campus for an indoor testbed comprising Ericsson Radio Dots, and installation of outdoor antennas mounted using a new mast on the roof.

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

4.1 Collaboration through Research hubs

UoA11 comprises 5 research hubs, led by Hub Champions, two of whom are women. Hubs are intended to be agile, being terminated as activities dwindle, or spawned as new themes arise. Hubs were set up to promote thematic collaborations, and the Hub Champion Group provides lightweight coordination and oversight. Hubs' actual organisation is left to their members, in order to encourage bottom-up initiatives and a sense of belonging. Thus, hubs have evolved in distinct ways, seizing opportunities in their respective area, as shown next.

The **Finance hub** (Champion: **Ventre**) is at the intersection of finance and computation, a sector colloquially known as FinTech. The hub has established collaborations with the Department of Mathematics and King's Business School, and also with key financial institutions, including the Financial Conduct Authority. It has a strong presence in the UK-TAS-Hub.

The **Health hub** (Champions: **Curcin, Tsoka**) bridges UoA11 activities with those in King's health faculties (Curcin is in the King's School of Population Health and co-author of ICS2), as well the Francis Crick Institute and Health Data Research UK London. Of note, the King's DRIVE-Health CDT (Co-Director: **Curcin**) was launched in 2020 with a first student supervised in UoA11 (**Miles, Zschaler**).

The **Security hub** (Champion: **Such**) co-ordinates researchers from across the unit around security, with a focus on information and cybersecurity. In collaboration with King's War Studies and Defence Studies departments, the hub led the successful EPSRC and NCSC ACE-CSR accreditation which facilitates engagement with external stakeholders, including government organisations, research funding agencies, and industry.

The **Urban Living hub** (Champion: **Borgo**) is strategically aligned with CUSP London (see Section 4.3) and has developed partnerships with public and private stakeholders in London, including the Greater London Authority, London Ambulance Service, Transport for London and Westminster City Council.

The **Trusted Autonomous Systems hub** (Champions: **Andrew Coles, Magazzeni**) has actively pursued major funding opportunities in this area, securing the UKRI STAI CDT and involvement in UK-TAS-Hub and the TAS Governance node. These bring together a pool of researchers, PhD students and many governmental and industry partners sharing interests in systems with autonomous behaviour.

4.2 Multi-disciplinary Collaboration

In addition to hub-driven collaborations, UoA11 takes advantage of King's status as a partner in the **Francis Crick Institute** for Biomedical Research to create new opportunities for impactful research. **Bentley**, placed at the Crick for 2018-2022, leads research on computational biology (Crick investment of £2M) and builds collaborative bridges between UoA11 and the Crick. The first success here is a collaboration with **Zschaler** on domain-specific formal languages for cellular modelling, which contributed to the MDE-net (see Section 3) with the Crick as a network partner. Two UoA11 staff spent year-long study leave at the Crick to expand their multidisciplinary research (**Steinhöfel, Tsoka**).

The university-wide **King's Together** (KT) scheme supports the development of innovative multi-disciplinary collaborations. This key component of the King's Research Strategy provides 'seed awards' (up to £20K) for adventurous initiatives, and 'substantial awards' (up to £100K) for innovative research in strategic areas with clear impact potential.

Since the KT launch in 2016, UoA11 staff have been Co-PIs in 12 KT projects (approximately £300K: 11 seed awards, and 1 substantial award as junior partner). The unit's Co-PIs included 4 women and 2 ECLs. A KT project "Remote sensing and machine learning to detect global dams

Unit-level environment template (REF5b)

and associated reservoirs” (**Shi**) is a collaboration with the Department of Geography, which led to subsequent external funding (**RESET**, Col: **Shi**, EU, £670K). “Establishing an interdisciplinary computing education research institute” (**Kölling**) helped initiate such an institute, promoting the unit’s research on pre-university computing education, funded by Oracle. “Improving hospital patient flow through performance modelling and agent-based simulation” (**Zschaler, Miles**), a collaboration with St-Thomas Hospital, has led to a studentship award. “Towards a King’s institute for artificial intelligence” (**Luck**) surveys King’s AI landscape, precursor of a planned AI Institute (see Section 1.7).

4.3 Contribution to Economy and Society

CUSP London is a research centre (Director: **Miles**) formed in 2015 in alignment with King’s London strategy as a joint initiative from King’s College London and the University of Warwick under franchise from CUSP at New York University. CUSP London at King’s consists of 16 members from Informatics, Geography, Environmental Sciences and IOPPN (8 of whom are submitted in UoA11). It has developed a collaborative network with businesses, local authorities and government agencies to apply urban informatics and improve public health and wellbeing. Building on CUSP-led training, high profile hackathons (e.g., with the London Ambulance Service), MSc and PhD students projects, and tackling real city problems, CUSP has established itself as an authoritative source of advice and policy guidance, as illustrated by advice provided by UoA11 staff to the Greater London Authority’s City Data Analytics Board (**Miles**), Westminster City Council Parenting Strategy (**Slovak**), the Police and Crime Plan of the London Mayor’s Office Advisory Group (**Miles**), and Westminster and Kensington & Chelsea Councils’ data sharing (**Simperl**).

Collaboration with Ericsson aims to improve quality of life and work in society. Ericsson has provided £100K p.a. to support UoA11 5G research spanning many fields including medicine, education, gaming and culture. Projects within the Tactile Internet Laboratory include the potential for remote superior-precision medical interventions. With the City of London, the world’s first 5G connected theatre performance was hosted in June 2018. Musicians from the Guildhall School of Music and Drama performed in the old Roman Amphitheatre in tandem with pianist and UoA11 professor (**Dohler**) who was physically located in Berlin. The collaboration led to significant media coverage, which Ericsson estimated as equivalent to marketing spend of approximately £120M (see ICS4).

UoA11 contributed to articles and global-media programmes for a general audience, explaining topical science and research issues. **Abdul-Rahman, Cavallaro, Dai** and **Yannakoudakis** contributed to articles in *Guardian*, *Daily Mail* and *New Scientist*, while **Dai, Dohler, Mahmoodi, Miles** and **Sastry** were interviewed for BBC programmes. **Modgil** contributed to a *Guardian* podcast panel discussion on AI ethics and **McBurney** authored a series of articles on blockchain and cryptocurrencies for *Accounting and Business Magazine*.

Opened in 2018, Science Gallery London connects art, science and health. **Black** advised for the 2020 season on AI, ethics and health, while **Such** collaborated on AI gender bias. Likewise, **Borgo** sits on the advisory board for National Gallery X, a National Gallery organisation set out to create new technology-based museum experiences.

UoA11 has contributed to the Royal Society scheme, Rapid Assistance in Modelling the Pandemic (RAMP), part of the national COVID-19 response. As part of the Scottish COVID-19 Response Consortium (SCRC), **Borgo** and **Abdul-Rahman** worked on a generic visualisation toolbox for addressing the need for rapid observation of huge amounts of data.

Contributions from UoA11 staff to economy and society include the following engagements in advisory groups for public and private institutions.

Aghvami: Expert Advisory Group for EU NetWorld-2020, Advisory Board of Advanced Wireless Technology Group. **Borgo**: roundtables for the All-Party Parliamentary Groups on AI and Data Analytics. **Dohler**: Cambridge Wireless Advisory Board 2018-2019, Ofcom Advisory Board. **Kölling**: Board of Computing in Schools, BCS Academy of Computing. **Luck**: Scientific Advisory Board at ContactEngine, scientific advisor to the Board of Aerogility Ltd. **McBurney**: Academic Advisory Council of Financial Conduct Authority. **Miles**: City Data Analytics Board, Greater London

Unit-level environment template (REF5b)

Authority. **Simperl**: scientific advisor for the European Data Spaces initiative and European Data Portal.

International Partnerships

The unit is involved in a significant number of EU projects, and in particular is leading [ACTION](#), a consortium of 10 partners concerned with crowdsourcing techniques (**Simperl**). The unit is also active in the [PLuS Alliance](#), a strategic partnership of King's, Arizona State University and the University of New South Wales to tackle global challenges. One example of funded PLuS Alliance collaboration is a project on risk management for natural disasters such bush fires and flooding (**Steinhöfel, Vigano**). UoA11 has further strengthened international connections by hosting in 2014-2020 almost 200 visitors, 70% of whom were international.

4.4 Contribution to and recognition by the research base

UoA11 academics actively contribute to the wider scientific community by reviewing grant proposals submitted to various funding organisations, holding editorial roles for many scientific journals, organising conferences and other major scientific meetings, and playing leading roles in international scientific associations and frameworks. Such leading roles include membership of the EPSRC Strategic Advisory Team (**Dohler**) and membership of the REF2021 Sub-panel 11 (**Fernandez**). The table below summarises contributions to key activities.

Journal editorial boards	> 30
Chairing conferences	> 40
Conference committees/organisation	> 600
Best paper awards	> 23
Keynotes at conferences	> 100

Table 4. UoA11 indicators of wider influence and recognition.

Journal editorship

UoA11 staff are on the Editorial Boards of more than 30 international journals, including the following leading editorial roles.

Chockler: Editor-in-Chief, *IET Software Journal*. **Dohler**: Editor-in-Chief, *Transactions on Emerging Telecommunications Technologies*; Editor-in-Chief, *EAI Transactions on Internet of Things*. **Luck**: Co-Editor-in-Chief, *Journal of Autonomous Agents and Multi-Agent Systems*.

Mahmoodi: Executive Editor, *Transactions on Emerging Telecommunications Technologies*.

McBurney: Co-Editor-in-Chief, *Knowledge Engineering Review*. **Rodrigues**: Executive Editor, *Journal of Logic and Computation*. **Simperl**: Co-Editor-in-Chief, *Human Computation Journal*; Managing Editor, *International Journal on Semantic Web and Information Systems*. **Tratt**: Editor-in-Chief, *Journal of Object Technology* (until 2016).

Leading roles at major international conferences

UoA11 staff have been involved in more than 600 programme, organising or steering committees of international conferences and workshops, including chairing the following conferences.

Borgo: CGVC 2014, 2015. **Cavallaro**: ACM EuroSec 2020. **Chockler**: CAV 2018. **Coles**: ICAPS 2016. **Criado**: EUMAS 2016. **Dohler**: IEEE WCNC 2018 and WiMob 2015 **Fernandez**: CSL 2020. **Kurucz**: AiML 2014. **Mahmoodi**: Network of the Future 2017. **Modgil**: COMMA 2018. **Simperl**: ODBASE 2018, ISWC 2016. **Tratt**: DLS 2014. **Urban**: ITP 2015. **Vigano**: POST 2016.

UoA11 staff delivered more than 100 invited talks at international conferences and workshops, including the following major conferences.

Aghvami: IEEE ISCC 2015, ICETE 2016. **Dohler**: IEEE IPCCC 2019, ICASSP 2019, PIMRC 2018. **Fernandez**: CiE 2014. **Kölling**: Koli Calling 2018, ISSEP 2014. **Kurucz**: TALC 2019. **Long**: ICAPS 2019. **Luck**: AAMAS 2014, ICAIL 2015. **Moreau**: WEBIST 2020. **Simperl**: ODBASE 2019; EC 2015 Innovate, Connect, Transform. **Ventre**: ADT 2017.

Unit-level environment template (REF5b)

Leading roles in international scientific associations

Black: Secretary of Board of Directors European Association for Multi-Agent Systems (EURAMAS). **Criado, Modgil:** Chair of Board of Directors EURAMAS (at different times). **Fernandez:** Executive Board member of the European Association for Computer Science Logic, General Secretary of the Board of the European Association for Programming Languages and Systems. **Dohler:** IEEE Communications Society's 'Strategic Planning' and 'Emerging Technologies' Committees. **Kölling:** Committee on European Computing Education. **Simperl:** IEEE Special Technical Community on Human Computation. **Yannakoudakis:** Association for Computational Linguistics SIG on Building Educational Applications.

Major honours and research distinction

UoA11 staff have been recognised for their world-leading research contributions. Prominent examples include:

Dai: 2015 ASME Mechanisms and Robotics Award (for lifelong contribution); 2020 ASME award in Machine Design. **Fernandez:** 2020 IEEE BigDataSecurity Award (for outstanding and sustained research contributions for over 10 years). **Kölling:** inaugural ACM-SIGCSE 'Test of Time' award. **Simperl:** in 2020 AMiner top 100 most influential scholars in knowledge engineering and in the 2020 AMiner 'Women in AI' list.

The unit includes fellows of major professional organisations and learned societies. RAEng:

Aghvami, Dohler; IEEE: **Aghvami, Dai, Dohler,** IET: **Aghvami, Dohler, Moreau;** BCS: **Kölling, Luck, Moreau, Simperl;** IMechE: **Dai;** ASME: **Dai;** RSA: **Dai, Dohler, McBurney;** ATI: **Simperl (2018-20); EurAI: Luck.**

Best paper awards

UoA11 staff were awarded at least 23 best paper awards, including the following. **Abdul-Rahman:** Vannevar Bush award JCDL 2017. **Dai:** IEEE ICAR 2018; Mechanism and Machine Theory 2018 Crossley Award. **Dohler:** IEEE Globecom 2014. **Iliopoulos:** SPIRE 2018. **Modgil:** AIJ 2014 Prominent Paper Award. **Slovak:** CHI 2017; CSCW 2018. **Such:** 2016 ACM Annual Best of Computing. **Suarez:** ACM Internet Measurement Conference 2018. **Urban:** Thoralf Skolem (ten-year test-of-time) award at CADE 2015. **Zschaler:** ICGT 2020.