

Institution: University of Portsmouth (UoP)
Unit of Assessment: 11 – Computer Science and Informatics
1 Unit context and structure, research and impact strategy 1.1 Unit context Established in 2005, the School of Computing (SoC) focuses on research that solves key societal challenges in three interdisciplinary areas: health, cybersecurity, and applied computational intelligence. Our future strategy (Section 1.4) outlines our ambitious plans to further enhance our interdisciplinary research and innovation to benefit individuals and society. The school took part in RAE2008 (headcount: 16 staff) and REF2014 (14 staff). This submission includes 33 staff, a 136% increase on REF2014, reflecting a significant expansion in research volume in accordance with our strategic priorities (Section 1.3). We have also achieved income over triple that at the previous REF assessment and our research has had international impact. Most staff submitted to UoA11 are from the School of Computing (SoC), with a small number from other departments, notably the School of Creative Technologies (SCT). The submitted staff are 20% female and 42% BAME. 1.2 Unit structure Historically, most computer science research at Portsmouth has been applied rather than pure, with a strong interdisciplinary flavour. In the 1990s, research was solely in applications of artificial intelligence technologies. This broadened in 1998 to include health informatics. By the 2000s it encompassed networking and security applications. These have since evolved into the current structure where research is organised into three groups. These reflect the school's strengths and we regularly review group names and composition to maintain alignment with strategic goals and members' interests. The groups are: 1.2.1 Centre for Healthcare Modelling and Informatics (CHMI) CHMI (8 people, led by Briggs) has an international reputation for research on clinical outcome modelling. To give one example, NEWS is used across the NHS and is recommended internationally by the WHO (see Impact Case Study REF3 UoA11-NEWS). Much of this research is in collaboration with Portsmouth Hospitals University NHS Trust (REF5aPara16). Founded as the Healthcare Computing Group in 1998, the group became a formal university-wide research centre under its current name in 2007. It conducts multi-disciplinary research to answer pressing questions facing the health and care sectors including: how to design efficient, user-friendly and safe computer systems; how to ensure information exchange between systems is reliable and clinically assured; and how technology can enhance wellbeing.

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1.2.2 Computational Intelligence (CI)

CI (20 people, led by Liu) studies computational paradigms, with the aim of designing and developing algorithms that can be implemented with human machine systems. Examples include computational paradigms for artificial intelligence, human motion-sensing and analytics (for applications such as powered-wheelchairs – see REF3 UoA11-Wheelchairs), and human and machine/robot interaction (e.g. for robot-enhanced therapy for children with autism – see REF3 UoA11-DREAM). The focus of much of the CI group's work has moved to applications in health and wellbeing, and there is considerable overlap with the work of CHMI.

1.2.3 Cybersecurity (CS)

CS (11 people, led by Ashenden) was formerly the Networking and Security group. It combines computer science with social and behavioural science to address cybersecurity challenges holistically. Its research includes secure software development. It looks at the interaction between software developers and security practitioners, examining how people make cybersecurity risk decisions in different environments and under varying physiological conditions. Based on this, the group develops ways of understanding how to build converged security teams that bring together cyber, physical and personnel security functions. Ashenden is also Programme Manager at the UK-wide Centre for Research and Evidence on Security Threats (CREST), contributing to countering threats to national security.

*Table 1 – Composition of groups (*former staff not in post at census)*

Centre for Healthcare Modelling and Informatics (CHMI)	Computational Intelligence (CI)	Cybersecurity (CS)
BRIGGS, Bader, Good, Khusainov, Krokos, Prytherch, Scott, Yu	LIU, Arabikhan, Bader, Chlebkova, Dennis, Gegov, Haig, Hopgood, Iacob, Jordanov, Joo, Ju, Khusainov, Krokos, Mohasseb, Simeone*, Stevens, Yang, Yu, Zhou D., Zhou S.	ASHENDEN, Adda, Aziz, Haig, Li, Mohasseb, Owenson, Ossont, Shiaeles, Williams, Zhou S.

1.3 Achievement of strategic aims for research and impact 2014-2020

The structure above has ensured relevance to national and international priorities along with members' research interests and delivery of the Unit's research strategy. Within the context of the University's research and innovation strategy (see REF5a), we are active participants in three of the University's five interdisciplinary research themes (REF5aPara9) which were launched in 2018 to align with national and international priorities. These themes are *Future &*

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Emerging Technologies (involving the CI group), *Risk & Security* (involving the CS group), and *Health & Wellbeing* (involving CHMI).

The strategic aims below were presented at REF2014, and subsequently cross-referred to the University's research and innovation strategy 2015-2020 (in brackets). We provide a summary of our achievements within this REF period.

1.3.1 Funding: Increase our collaborative and interdisciplinary funding applications to sources that address key national and international strategic priorities, focusing on health, security and education (REF5aPara4-10&60-61)

Research income has grown to £3.3M (up 255% since REF2014). This was achieved through increasing research active staff numbers, development of existing staff, and strategic investment in 13 new posts – resulting in 33 staff with significant responsibility for research (up 136% from 2014) who are equipped to make funding bids.

Our ambitions for key new partnerships align with the University's 2030 strategy for partnerships growth (REF5aPara14-16) and our research prioritises key societal and economic issues that correspond to University research themes (REF5aPara9). For these reasons, we are successful in establishing new networks. The CI group draws on and shares expertise with the School of Mathematics and Physics, and the Faculty of Business and Law, under the theme *Future and Emerging Technologies* which is led by Hopgood. The CS group is developing new networks in *Security and Risk*, and the CHMI is exploring new collaborations within *Health and Wellbeing*.

Currently, 40% of our outputs are considered interdisciplinary. By the end of the REF period, at least 77% of submitted staff were undertaking interdisciplinary research with the following disciplines:

- Engineering: 62% of staff;
- Medicine and Health: 46%;
- Sciences: 43%;
- Business and Economics: 31%;
- Mathematics: 23%;
- Arts and Humanities: 15%.

External collaboration is now the norm, with 87% of staff collaborating in the UK, and international collaborations with:

- Europe: 74% of staff;
- Asia: 52%;
- USA, Australia, New Zealand, South Africa: 16%;

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- Africa: 16%;
- Central America: 7%;
- South America: 3%.

Specifically, 84% of staff collaborate with either industry, the public sector or charities. Of collaborations, 85% are with industry, 62% with the public sector and 23% with charity.

1.3.2 Establish a cross-institutional network in Computational Intelligence (REF5aPara9)

Having planned to convert the CI group into a University-wide Centre, the creation of the University Research Themes in 2018 meant that our ambitions for the CI network were best achieved by working collaboratively cross-university to establish research links and ensure alignment of all research to themes. Activity is now undertaken through Hopgood's leadership and the CI group's participation in a newly formed cluster, AIPA (Artificial Intelligence and its Practical Applications), which sits under the *Future & Emerging Technologies* Theme.

1.3.3 Maintain and extend our focus on deploying technologies (REF5aPara17-19)

Our deployment of technologies to solve public sector and industry-related problems has increased mainly through Knowledge Transfer Partnerships (KTPs) (see Section 4), as has the number of staff involved. For example, CHMI's KTP with Xim Ltd was based on CHMI's clinical outcome modelling experience. This represents an important addition to our public sector work, as most of our KTP companies sell to the public sector.

1.3.4 Continue to increase our PGR recruitment (REF5aPara21)

Our PGR (Postgraduate Research student) recruitment has increased through a combination of institution-funded scholarships, international fee-paying students, and industry-sponsored studentships. Completions over the REF period have increased to 63 (up 103%) resulting from our increased capacity to support PGRs (see Section 2.2).

1.3.5 Support staff to establish and maintain internal and external collaborations (REF5aPara2,9&20)

Collaboration is now central to the Unit's research culture (as shown under aim 1). We achieved this through continuous focus on training and support in this area (see Section 2). For example, in this REF period, 10 staff were supported to access University "pump-priming" funds (REF5aPara12). These are awarded competitively based on strong plans to seek external funding and are expected to deliver impact at the next REF.

1.3.6 Increase research leadership (REF5aPara1-3&29)

Our research leadership was strengthened through the appointment/promotion of 2 professors and 3 readers during this REF period (see Section 2).

1.4 Achievement of strategic aims by individual research groups

The REF2014 environment statement included specific strategic objectives for each of the 3 research groups, all of which were met, and are discussed here.

All research staff actively participate in at least one research group. Groups provide support to researchers at all career stages, facilitate internal and external collaboration, provide a sense of shared research identity and foster our research culture. This is achieved through encouraging cross-fertilization between groups, with some staff belonging to two groups, a programme of regular activities providing opportunities to work collaboratively, develop research questions, present and receive feedback on research, foster partnerships, develop new methodologies and techniques, share expertise, provide mentorship and support, and train and develop our postgraduates.

Senior researchers in each group focus on staff development, ensure coherence of activities with Faculty and University strategies, ensure we attract and develop a thriving cohort of postgraduate students, and provide access to external academic partners.

1.4.1 CI group: achievement of strategic objectives

The objective was to *strengthen the research excellence* in this group. This was achieved through: supporting key researchers to progress their careers, reflected in promotions – Yu was promoted to professor, and Jordanov and Ju to reader; encouraging interdisciplinary research by strengthening collaboration – including Liu and Ju’s relocations to SoC (from Creative Technologies); addressing gaps in research expertise and building critical mass in key areas through strategic appointments (Hopgood, Iacob, Dennis, Zhou D. and Mohasseb).

As a result, the group grew from 12 (2 female, 10 male) in 2014 to 20 in 2020 (5f, 15m) and saw significant increases in research funding (including major projects such as DREAM, see REF3 UoA11-DREAM) and research publications (see Section 4).

1.4.2 CS group: achievement of strategic objectives

The objective was to *establish research to address important national and international priorities, in particular meeting global security challenges through working with 1) government agencies and public services, 2) cybersecurity education, and 3) commercialisation of our expertise to help businesses*. The strategic appointment of Ashenden was key and brought significant experience of securing and managing interdisciplinary research grant funded projects plus industry knowledge. Her direction and leadership became a catalyst for skills development within the group resulting in an attractive research environment allowing other key appointments (Williams, Li, Ossont and Shiaeles). As a result, the group established itself as a key player in this niche area in cyber-security.

This is evidenced by group members developing collaborations with key organisations (e.g. Thales, Airbus Cybersecurity, MINDS&SPARKS GmbH, Siemens, HMRC), producing commissioned reports to inform policy, Ashenden’s leadership role in the UK-wide UKRI-funded CREST and her association with the University of Adelaide (see Section 4). CREST outputs have been viewed ~181,000 times by users in ~180 countries and the CREST App has been

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downloaded by 530 devices. An independent review found "strong evidence that CREST research is having an impact for end-users... there is instrumental impact, through demonstrable changes to practice."

1.4.3 CHMI group: achievement of strategic objectives.

The objective was *to focus on applied research with maximum impact and benefit to society*. To achieve this, the group built on its growing reputation to position itself to secure additional research funding by developing stronger links with other universities and key organisations. The group now has **sustained partnerships** with the universities of Oxford and Southampton and an increasingly close and productive partnership with NHS bodies, particularly Portsmouth Hospitals University NHS Trust (REF5aPara16).

We also made strategic investments in clinical outcome modelling and developing an ongoing academic/clinician partnership. This led to hospital staff appointments into the research group (Prytherch) and secondments out to the NHS (Scott) which built additional links.

Stronger links led to an increase in publications and a five-fold increase in funding, including major projects such as Missed Care (the association between missed observations and nurse staffing levels in hospital wards), HAVEN (Hospital Alerting Via Electronic Noticeboard) and FOBS (safer and more efficient vital signs monitoring to identify the deteriorating patient), which led to life-saving impact (see REF3 UoA11-NEWS).

1.5 Strategic Review 2016-17

Responding to university-level changes, in 2016 the UoA undertook a strategic review. In 2017 it adopted these strategic aims for research and innovation:

1. Further develop and enhance research strengths aligned with our research priorities (REF5aPara4-10);
2. Increase our standing and visibility within the [university's] thematic areas through high impact publications, significant collaborative research projects and enhanced engagement with user communities (REF5aPara9-10&14-19).

These will continue to provide the framework for our strategy in the next REF period.

1.6 Future research strategy 2021-2026

Many of our key partnerships are with local organisations and bring local benefits. This contributes to the UoP's commitment to being a 'civic' university (REF5aPara16). As part of this, we will continue to work collaboratively to promote inclusion and positively enrich economic, social and cultural life in the city and our region. We will strengthen our local partnerships while ensuring that outputs continue to have international reach and growing international impact. We remain committed to the areas of health, security and applied computational intelligence but will explore emerging areas that address key societal challenges (REF5aPara9&11).

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The Unit's future strategic objectives will continue to receive strong institutional-level support through the UoP research themes (each group with pump-priming and impact-building funding allocated to it, see REF5aPara12). The activities that will take us towards meeting the future strategic aims outlined below include developing our research leadership, training, capacity to generate income, research coherence for our interdisciplinary work, and developing our PGR community.

1.6.1 How research culture underpins our future strategy

A strong research culture includes integrity, ethical and legal standards (REF5aPara22-24), a vibrant research culture characterised by collaborative and interdisciplinary research (REF5aPara4,9,25,60,61,66), strong support for individual initiative (REF5aPara53-55), evidencing of impact (REF5aPara11-12&14-19), and dissemination of research to students and the general public (REF5aPara25-28). We continue to foster this by providing staff "refresher" development in **integrity**, and ethical and professional standards (REF5aPara22-23).

We are increasing our commitment to **open access, open data and open science** – making them the norm to maximise research visibility (REF5aPara24). Building upon previous training, we will now embed this more strongly in our everyday activities.

We will increase opportunities to present and be exposed to colleagues' research (internal, external or industry) through group, school/department, faculty and theme seminars. We will encourage more national and international presentations and networking visits (academic and industry-related) through our internal travel budget/policy that was revised following COVID-19 and will be monitored/adjusted to maximise benefits.

To grow our postgraduate community, we will support and incentivise staff to access UKRI PGR funding via Doctoral Training Partnerships and Centres for Doctoral Training.

Our staff engage in school and media outreach, and we will build on this with more training, increasing end user engagement. We will strongly support individual initiatives aligned with our strategy. Our staff conduct a wide range of activity contributing to the research base, economy and society (see section 4) which will continue to receive strong support.

1.6.2 Strategic aims 2021-2026

Aim 1: Funding: To continue to grow and diversify external research and knowledge transfer income (REF5aPara18-20)

We will achieve this by:

Focusing on staff support and development. To win more high-quality funding, we must develop everyone's capability and commitment to excellent research. We will provide resources to enable staff to become more highly research-active within the school and across disciplines. For example, we will accelerate the interdisciplinary careers of promising ECRs (early career researchers) by encouraging and supporting them to gain fellowships (REF5aPara32) that fund them to visit/embed with non-academic partners.

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Supporting collaborative and interdisciplinary research aligned with our priority areas.

We will build on recent success to maximize links between computer science and other disciplines internally, nationally and internationally. To achieve this, we will boost staff confidence in working with external organisations through training and maximise the number of staff eligible for “pump-priming” funding (at university, faculty and department levels) (REF5aPara12) for interdisciplinary research.

Encouraging knowledge exchange activity. Our expertise in knowledge exchange has grown since 2014 (Section 4 describes some of our KTPs during the last assessment period) and we aim to grow this area further. Our next steps are to identify priority areas in each research group and to up-skill staff through training, coaching and mentoring (REF5aPara33-37). We will target industry partnerships that enhance our public sector work, increase participation in relevant fora and host events.

Capitalising on opportunities to increase PGR recruitment. Additional PGRs require generation of additional funding. We will exploit our academic collaborations to jointly develop new Centres for Doctoral Training. This will be coupled with a drive to engage our undergraduate and masters students in research, building an internal pipeline of potential students. We have a track record of developing PGRs into high-quality candidates for internal and external positions (see Section 2).

Aim 2: Research Coherence: To continue to build a coherent research portfolio through collaborative and sustainable interdisciplinary groups (REF5aPara4&9)

We will achieve this by:

Ensuring sustainable, coherent research groups. Each group’s focus area is determined strategically, based on emerging research and staff specialisms. To ensure longevity, each group is developing and implementing a leadership succession plan. We will ensure senior researchers are upskilled in various ways, including a new training program for Readers to progress to Professor (REF5aPara34). Groups provide subject-specific support and development opportunities, and will expand their leadership teams. Where expertise is lacking, we will appoint externally, bringing in research leadership (as done successfully for CS). Within existing areas of expertise, we will develop current staff in their leadership capability and appoint new staff (typically at lecturer level) to reinforce established strengths and build synergies within groups.

Increasing focus on key priorities. We will prioritise applied work in health, security and education that is relevant to the public sector rather than purely commercial. We will identify research challenges relevant to the local community, in line with our commitment to the Civic University Agreement (REF5aPara16). We will track new outputs and partnerships against priority areas at unit and group level.

We developed the following action plans for each group as part of ongoing work developed following the 2016 review (see 1.3.2) overseen by the SoC Research and Innovation Committee (RIC). The aims are:

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CI group

Grow the volume, coherence and quality of research activity and establish a sustainable research environment that will endure beyond current personnel.

The group saw significant growth during the REF period and is positioned to further increase research-active staff through support including workload policies, mentoring, access to internal funding and promotion opportunities. Specifically, we will:

- Grow and diversify funding by supporting staff to identify sources, with training/feedback on writing, coaching staff on networking skills and providing more bid development time in workloads.
- Provide mentoring, sharing of established networks and inclusion of junior- and mid-career staff as co-investigators on bids.
- Develop specialised training for its PGRs.

CS group

Narrow down the direction and scope of research to ensure all research addresses at least one of our three priorities (see 1.3.1), to maximise impact.

We have secured research leadership during this REF period by prioritising significant research expertise over the subject fit of new staff. The group is now poised to capitalise on this in the priority research areas (public sector, education and commercialisation). Ashenden's research leadership, including her role at CREST and work with the University of Adelaide (and the connections being made there), will provide focused research opportunities for the group. Early successes in education, including funding from IBM, and strong links with companies with vendor certification, will also be exploited (see Section 4).

CHMI group

Grow research capacity and capability to exploit our excellent partnerships to ensure our work addresses real-world problems and produces impact.

Since 2014, the number of CHMI staff winning external funding has grown from 1 to 6. Early seed-corn funding allowed us to appoint new staff (at research fellow level) who were able to support the writing of good quality bids. We also encouraged existing staff to become more research active through mentoring and support. We are poised to capitalise on this performance and turn our success at winning small/medium funding into success at winning larger amounts. During this REF period, ~£1.5M in grants was won through seven awards (over 5 times more than during the previous assessment period). Most work is already done in collaboration with NHS organisations and/or companies. We need to nurture existing partnerships and establish new relationships. We will also work within the University to help other disciplines replicate our relationship with relevant departments of Portsmouth Hospitals University NHS Trust (REF5aPara16).

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Aim 3: Impact: Ensure that all our research promotes impact (REF5aPara11-19)

We will achieve this by:

Generating, documenting and disseminating research with impact. So much of our research is already applied and interdisciplinary, and aims to make a difference to individuals, society and the economy. Routes to impact, therefore, tend to be direct. This is the case with our REF3 Impact Case Studies on clinical outcome modelling (UoA11-NEWS), autism (UoA11-DREAM) and powered wheelchairs (UoA11-Wheelchairs). Future impact will be generated through two broad approaches, used together where possible:

- technology as a tool to benefit individuals, society and the economy; and
- user and stakeholder involvement in research.

We have identified a need for:

- internal funding allocated for staff to integrate, collect and evidence impact throughout the life of their research projects;
- identifying impact pathways in research plans through Performance and Development Review (PDR) and at group level;
- raising the importance of impact as a route to successful career development and promotion;
- nurturing existing stakeholder relationships and developing new relationships with a variety of partners (facilitated by the University research themes);
- providing training and mentoring to build expertise in: identifying relevant stakeholders; working with them effectively; articulating impact effectively; collecting evidence of impact from end users; and costing impact activities and time to deliver within budgets.

2 People

The Unit's research leadership is provided by the SoC Associate Head (Research and Innovation) (Khusainov), who is Chair of the School Research and Innovation Committee (RIC). He works closely with the previous research lead (Briggs), now Associate Dean (Research) for the Faculty. The RIC also involves the Head of School, group leaders, professors and readers, the REF Unit Coordinator, the PGR Coordinator, the ethics lead, plus ECR and student representatives. Other appointments were made to maintain equality and diversity aims. The Associate Head (Research and Innovation) collaborates with other faculty research leads via a forum led by the Associate Dean (Research), facilitating cross-departmental work and sharing best practice.

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2.1 Staffing Strategy and Staff Development

The number of research-active staff has increased by 136%, supported by strategic appointments (REF5aPara29), the systematic allocation of research time (REF5aPara2), mentoring (REF5aPara37), staff development opportunities (REF5aPara33-35) and internal funding (REF5aPara12&36).

The staffing strategy has been, and continues to be, focused on building areas of strength, as well as alignment with national and international research agendas. The recruitment strategy over the REF period combined two elements: (a) increasing research leadership by promoting from within in areas of strength (CHMI and CI) and by appointing external senior researchers in growth areas (CS); (b) new appointments, particularly at ECR stage, to increase research dynamism.

Key external appointments were three professors (Ashenden, Hopgood and Prytherch), three senior lecturers (Ossont, Shiaeles and Williams) and four lecturers (Iacob, Dennis, Owenson and Li). Our success in developing ECRs has led to the appointment of two research staff and one teaching fellow to permanent lectureships (Arabikhan, Mohasseb and Zhou D.). In recognition of research leadership, two colleagues were promoted to professor (Briggs and Yu), three to reader (Jordanov, Ju and Scott), and four to senior lecturer (Iacob, Dennis, Owenson and Li) within this period. We actively encourage staff in their efforts to gain research recognition; evidence of success includes our high rate of journal reviewing and editorship (Section 4).

This approach has brought substantial expertise and contacts that support others' development. For example, leadership in the CS group has developed through three strategic appointments (Ashenden, Williams and Shiaeles). Ashenden is PI on the EPSRC project Cyber Security Across the Life Span (cSaLSA) and shares this experience through mentoring junior colleagues. Her substantial national and international profile provides expertise for ECRs to draw on. Williams (appointed 2019) brought a growing research profile in partnership with industry, also acting as a role model. Aziz, Mohasseb, Owenson and others received external recognition (Section 4).

Staff support and development is delivered through internal funding, sabbaticals, PhD studentships, mentorship and targeted training for research leadership skills (e.g. networking, grant writing, generating and documenting impact, PhD supervision). We also facilitate collaborative, interdisciplinary and applied research, one-to-one, in team meetings and via annual PDRs. This complements staff participation in the central Research and Innovation Staff Development Programme (REF5aPara33), which is positively encouraged.

Our allocation of research time supports staff at all career stages. All staff with significant research responsibility receive a baseline research workload allocation of 20%. This is reviewed annually and updated periodically according to planned/completed research activities. ECRs have a reduced teaching workload in their first year to facilitate development of their research (REF5aPara41). Research and innovation plans are discussed at PDRs, including resourcing the necessary support to fulfil them (REF5aPara53).

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All staff are encouraged to participate in mentoring, as mentors or mentees. Mentors meet mentees regularly and discuss their research, priorities and career prospects. Mentoring is acknowledged in the workload and PDRs. ECRs are typically paired with mentors that can help them with research-related processes and general research skills. An institution-wide mentoring scheme (REF5aPara34-37) provides the opportunity to learn from other disciplines.

ECRs and recently appointed lecturers are encouraged to attend "Chair in 10 years" workshops developed by the UK Council of Professors and Heads of Computing (CPHC) and currently organised by our Head of School. Four sessions were attended by 50 UK academics (3 from UoP).

Ten members of staff have benefited from internal funding, totalling £160k, for pump-priming, building research consortia and documenting impact (Adda, Ashenden, Aziz, Bader, Zhou D., Gegov, Haig, Ju, Liu, Scott).

The support mechanisms above, in conjunction with promotion workshops, are intended to help staff get promoted to reader or professor roles. This support contributed to, for example, the promotions of Ju and Scott to Reader. Much of the above supports the implementation of the Concordat to Support the Career Development of Researchers (see also postdoctoral researchers in 2.2.8).

2.2 Research Students

We aim to produce fully-fledged independent researchers who exceed the expectations of the hallmarks of a UoP graduate.

2.2.1 Increase in PGR numbers

Since 2014, PGR recruitment has grown and PhD completions have more than doubled (63 vs. 31 in 2014) - an indicator of the increase in quality of support for PGRs, as well as our research reputation.

Despite rising completions, the ratio of PhD students to staff has recently gone down. This is due to staffing increases, the balancing of work allocations for ECRs, the focus on quality supervision and a rigorous student selection process. In the long term, our strategy is to further increase supervisory capacity and select high-quality applicants to facilitate a steady growth in high-quality students.

Recognising the importance of students to the research culture, the Faculty and University fund several studentships every year. We have seen a diversification of funding sources for PGR, including sponsored students (by industry or foreign government schemes), funding from UoP and self-funding. Of funded students, 12% are funded by University bursaries, 23% by Faculty bursaries, 38% by departments (SoC and SCT) and 27% externally (of which 12% by industry, 8% by external research funding and 8% by foreign government schemes). Our reputation enabled us to recruit high-quality students supported by the China Scholarship Council. Increasing externally-funded PGR is an important aim for the next strategy (Section 1.6.2 and REF5aPara21).

2.2.2 Increase in PGR supervision capacity

The development of existing staff, strategic appointments since 2014 and increased grant income enabled us to supervise and support more PGRs. Supervision teams routinely include ECRs, allowing them to participate in supervision and acquire supervisory skills.

2.2.3 Quality of PGR

As a result, the quality of the research produced by PGRs has increased, as indicated by the increase in completion rates, external recognition of the work through best paper awards, best presentation awards and other prizes (see 2.2.7 below) and career progression. Recent successes include Zhou, D. and Mohasseb, who obtained highly-competitive lectureship positions within SoC.

2.2.4 Recruitment, induction and training

We attract high-quality international and home/EU applicants across all research areas. Our PGR admissions processes rely on the expertise and experience of our staff. Applications meeting general University admissions criteria are circulated within the Unit to seek feedback from subject experts, with selection panels formed (gender balanced, where possible) to ensure rigorous evaluation of candidates based on academic abilities plus the merits of their research proposals.

As well as participating fully in University-wide common training and support (REF5aPara38), we expect all PhD students to take at least 10 days of research training per year, monitored by supervisors, and to attend their departmental seminar series (postdocs and staff, including from other schools, are also encouraged to participate). Students also attend external training sessions (e.g. those offered by the Data Intensive Science Centre in the South East Physics Network, DISCnet).

2.2.5 Major Review and Annual Appraisal

Significant effort is made to prepare PhD students for their end of first year major review. For example, students are expected to present their research at the departmental seminars for constructive feedback. Students are also encouraged to present at the annual Faculty Research Conference and SoC Student Conference.

2.2.6 PGR support

Several support systems exist for students. For example, we prepare and encourage students to participate in the University's student employment scheme, and our PGRs frequently take up posts in IT support and laboratory demonstration. Typically, at any one time, several are employed as short-term research staff on funded projects, or as teaching assistants/part-time lecturers (details in 2.2.8 on career paths).

2.2.7 Immersion in research culture and achievements

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Students are an important part of the research culture. All take active (and often organising) parts in the school and faculty research activities, such as student conferences, research seminars and research group activities, and these are generally well attended. Students access funding (via their supervisor) for presenting at international conferences, attendance at which helps them in developing external/international research networks and increases employment prospects. They are also incentivised to apply to external funding sources to gain experience and broaden their participation in a variety of academic and non-academic activities.

As a result, PGRs make a significant contribution to the School's research output: 39% of published papers within the REF period had at least one PGR co-author.

Examples of recent PGR achievements include:

- Best Paper Award, 2018 IEEE 17th International Symposium on Network Computing and Applications (a student supervised by Owenson and Haig)
- Winning external funding to attend summer schools or international conferences (two students supervised by Haig; one student supervised by Gegov)
- Selection for competitive internships/placements (e.g. Data Science Campus, UK Office for National Statistics) (a student supervised by Gegov, a student supervised by Haig, two students supervised by Jordanov)
- Winning start-up funding: Small Business Research Initiatives healthcare scheme (<https://sbrihealthcare.co.uk>) (two awards) (a student supervised by Bader and Briggs)
- Presentation prizes at conferences (e.g. Research Spotlight competition prize, London Hopper Colloquium) (a student supervised by Bader and Haig)

Our expertise with PGRs is exploited centrally to help deliver the university's Graduate School Development Programme (REF5aPara38), including sessions led by Briggs, Gegov and Good.

2.2.8 Career paths including as postdoctoral researchers

Of students who completed their PhD within the current REF period, 16% entered an academic career as postdocs, teaching fellows and/or lecturers. Four are lecturers at UoP, of which three (Arabikhan, Zhou D., Mohasseb) are included in this submission; five have academic positions elsewhere (Senior Bioinformatician, King's College London; postdoc, Shenzhen University; lecturer, Winchester University; lecturer, Central Lancashire University; and lecturer, Mustansiriyah University, Iraq) or are in industry. For example, we supported one PGR to undertake internships at Expedia and Hotels.com who is now a Senior Data Scientist at Expedia.

Several have become postdocs within the Unit. With the addition of externally recruited postdocs, postdoc numbers have more than doubled since 2014. In addition to promoting talented postdocs to permanent lectureship, we equip our postdocs to pursue leadership roles and careers at prestigious and dynamic organisations – one is Chair of the University Research

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Staff Forum; others took up roles at Oxford University, A*Star (Singapore), and as Technical Director for a tech start-up.

2.3 Equality and diversity (E&D)

In this submission, staff are (by FTE): 20% female, 0% on fixed-term contracts; 44% non-UK, 42% BAME, 5% disabled; 6% part-time and 13% ECR.

SoC and SCT are both proud to have achieved the Athena Swan Bronze Award in 2016, recognising our commitment to supporting gender equality. Within the action plan that arose from this, increasing female staff participation in research is a priority and there has been an encouraging increase in the proportion of female staff submitted to this REF (22% by headcount) compared with 2014 (15%).

Our data analysis revealed a factor with significant impact on research activity and, consequently, submission to REF, this being the lack of a PhD for several female staff. Although not a requirement, it is an important milestone. To address this, female staff have been supported to undertake PhDs, with one completion within this REF assessment period. Our progress has been slower than planned; however, one of our three professorial appointments was female.

We are working towards our Athena Swan submission in autumn 2021 and are striving to improve our performance and consolidate our Bronze award (REF5aPara44). This aim does not indicate any lack of ambition but recognises the reality of the steady national decrease in women in computer science over the last 10 years.

Comparing this submission with 2014, we have fewer staff aged under 36 and fewer over 55. Although many staff joined us in this REF period, we observed an increase in the age of lecturers. This results from appointments being made for strong research leaders at professorial level for strategic reasons outlined in Section 1, reducing the number of opportunities open to ECRs. This also contributes to the relatively low number of ECRs in this submission.

All staff must take E&D and related training (REF5aPara47); managers undertake additional training and encourage consideration of E&D through team meetings, one to ones and PDRs. Diverse representation is carefully considered for interview panels (including for PhD students) and committee memberships, while ensuring that staff with protected characteristics are not overburdened. For this REF submission, all REF team members participated in bespoke E&D training (REF5aPara50).

To facilitate participation of staff and students with caring responsibilities, our weekly research seminars have moved from 3pm to 2pm. Staff can request timetabling constraints to accommodate caring responsibilities, and all staff with over 20% research allocation have one non-teaching day per week, minimum, to facilitate research.

In addition to this, staff can work flexibly, including remotely (REF5aPara46). All requests for flexible working have been granted. Female and male staff returning from maternity/paternity leave can and do so part-time.

3 Income, infrastructure and facilities

3.1 Research income

Income has more than tripled since 2014, growing from £930k to £3.3M and, in 2019/20, the university income target was exceeded in all three research groups. This funding comes from increasingly diverse sources, including research councils (EPSRC, ESRC), Innovate UK, the Royal Society, the Royal Academy of Engineering, the National Institute for Health Research, charities (e.g. Wellcome Trust), industry (see examples below) and the European Commission.

This funding has been achieved by delivering the strategic plan for this area, including to: make strategic appointments of experienced grant-funded researchers in key areas; cascade this expertise throughout the Unit via mentoring, research group activities and faculty events; use this expertise and the contacts developed to target funding sources, matched to research interests; support the promotion of staff to reader and professor; grow external partnerships; and develop ECRs through a variety of activities (as detailed in Sections 1 and 2).

Key examples of grant awards spanning all 3 research groups include (dates are year funding started):

- DREAM, 2013 (Development of Robot-Enhanced therapy for children with Autism spectrum disorders) funded by the European Commission – €6.7M consortium (£695k for UoP), Co-Investigators (Co-I) Liu, Yu and Ju; founded on Liu's previous links with the lead institution. Impacts include improved support for patients and changes to national and international practise guidance (see REF3 UoA11-DREAM).
- HAVEN, 2015 (Hospital Alerting Via Electronic Noticeboard) funded by Health Innovation Challenge Fund, a joint venture of the Wellcome Trust and Department of Health – £1.8M consortium (£298k UoP) over 4 years (including extension); Principal Investigator (PI) Briggs; founded on Briggs' and Prytherch's long-standing NHS partnerships. Its algorithm for improved prioritisation of patients for intensive care has the potential to save lives (through early detection of deteriorating patients). Initially involving NHS Trusts in Portsmouth and Oxford, three more hospitals joined the collaboration in 2020.
- FOBS, 2018 (Safer and more efficient vital signs monitoring to identify the deteriorating patient: An observational study towards deriving evidence-based protocols for patient surveillance on the general hospital ward) funded by NIHR – £867k consortium led by UoP over 2.5 years; PI Briggs, Co-I Prytherch; follow-on from HAVEN. Ongoing work leading to new strategies for prioritising nursing workload.
- CREST, 2015, funded by EPSRC – £7.5M consortium (£263k UoP), Co-I Ashenden; initially awarded 2015-2018, extended to 2020 (further £199k to UoP); extended further to 2023 (£5.3M, £237k to UoP). Founded on Ashenden's long-standing partnerships, CREST delivers world-class, interdisciplinary activity countering national security

Unit-level environment template (REF5b)

threats. This international network of excellence involves governments, industry and communication specialists.

- Real-Time 4D Facial Sensing and Modelling, 2016, funded by the EPSRC – £100k; PI Yu. Computer vision algorithms developed by UoP are an integral part of a smartphone app for facial palsy assessment, which Emteq Labs now offer across multiple continents. Internal “pump-priming” funds for Yu had consolidated the collaboration with Emteq.
- PPADSO, 2018, People Powered Algorithms for Desirable Social Outcomes funded by EPSRC – £907k consortium (£24k for UoP); Co-I Ashenden. Focusing on algorithmic interactions between individuals and the state, the project will enhance individuals’ wellbeing and security, protect state security, and increase confidence in digital services.
- cSaLSA, 2017 (Cyber-Security Across the Lifespan), funded by EPSRC (£287k to UoP); PI Ashenden. By more fully understanding diverse cyber-security experiences and behaviours, this project is leading to more effective cyber-security services and educational materials. A related PhD project to support this bid was given internal funding.

These awarding bodies and partnerships were prioritised due to synergy with school and group research aims. They result from several strategic decisions taken to support and grow existing areas of research expertise (Section 1.3). As these align closely to national and international priorities and fall within three of the University’s research themes, research facilities are also supported by UoP (see 3.2 below).

A 2018-19 faculty-level review of our internal process for external funding applications resulted in a simplification that supports staff and speeds up administration, saving staff time, shortening the proposal development timeline and improving success rates. Now, all submitted staff are actively applying for funding and approximately 55% have been successful.

Our strategy is to continue to increase this number while focusing on sources that best align to research strategy, plus emerging ones. We will do this by: supporting staff; continuing to encourage strong participation, particularly from female, part-time, fixed-term and ECR colleagues; and continuing to remove unnecessary bureaucracy from internal processes.

3.2 Infrastructure and facilities

We have four specialist labs that facilitate our research:

1. CS group utilises the **networking and cloud computing** lab (e.g. for CREST and cSaLSA projects). This houses over 200 Cisco networking devices and a private cloud with circa 300 cores, 700 TiB of RAM and 60TiB of attached storage. In 2018, SoC secured an official partnership with Cisco Systems to further support research facilities in networks and cyber-security. In 2019, the University invested £200k to upgrade the laboratory’s networking equipment, match-funded by Cisco.

Unit-level environment template (REF5b)

2. CI group utilises the **robotics lab**, containing: a robot-assisted Autism spectrum disorder (ASD) Intervention platform, with a diagnosis and intervention system (funded by the DREAM EU FP7 project); a computer vision-based sensing platform with eye tracker system by Elonxi (funded by UoP as an investment in the DREAM project); an Industrial Robotics Platform with a Sawyer robot by Rethink Robotics (funded by UoP); and a Motor Function Rehabilitation Platform with i-limb by Touch Bionics (funded by EPSRC).
3. Within CHMI, the Clinical Outcomes Group (COG) operates a **virtual server** for secure storage of healthcare data. Currently it does not hold patient-identifiable data, but we expect it (and its management) to be certified in 2021 as meeting NHS Digital standards. This will facilitate collaboration with NHS and academic partners. In addition, COG staff all have high-spec laptops to facilitate health-related data science research where specific enhanced data security policies exist.
4. The **data science** lab was established in 2018 for all groups. The most significant investment (£42k from UoP) was an IBM AC922 server (with four Tesla V100s) with IBM Power AI Vision. As an illustration of its power, a single PhD student working on improving recommender systems at scale (those with billions of users e.g. at Facebook, Netflix) achieved results with a 10 billion point dataset comparable to that achieved in industry by larger teams.

In addition to the School's computing labs and specialist software, staff and students (particularly the CI group) use the University's 3702-core SCIAMA supercomputer (REF5aPara64) for extra memory and/or processing power for data mining/machine learning; for example, a current student is using it to process textual data with large dimensionality for detecting social media behaviours including hate speech, misogyny and suicide ideation. A dedicated technician manages the supercomputer's use and supports staff.

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

Ensuring that our extensive network contributes to the quality, breadth and impact of our mainly collaborative research has been and continues to be part of our strategy (see Section 1). These collaborations are internal (e.g. Department of Psychology, the Engineering schools and the Institute of Criminal Justice Studies), national (e.g. Portsmouth Hospitals University NHS Trust, universities of Southampton, Oxford and Cardiff) and international (most notably, organisations in Sweden, Belgium, France, China, Romania and South Korea). Our partners enrich, inform and fund our research.

4.1 CHMI collaborations

CHMI has a long-term relationship with the Portsmouth Hospitals University NHS Trust (PHUT) (since 2001), with new UoP/PHUT agreements signed in 2018 (establishing a Technology Trials Unit) and 2019 (formalising the strategic partnership). CHMI also has links with the Wessex Academic Health Science Network and the South East Health Technologies Alliance. In 2019, Scott took a 0.5FTE position as Digital Healthcare Architect with PHUT, a major role in their digital transformation, following internal support for Scott's research through "pump-priming"

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internal funding. These partnerships have produced impact through, for example, a patient early warning system (now NEWS2), which was the only one recommended in the May 2020 guidance issued by the World Health Organisation (WHO) for the clinical management of suspected or confirmed COVID-19 patients (see REF3 UoA11-NEWS).

Instead of running a small internal seminar series, CHMI builds external engagement through event organisation. From 1998 to 2016, it organised the Southern Institute for Health Informatics series of conferences, typically attracting 50-100 participants. More recently it has sought to engage with communities who share our technical skills and areas of interest through online workshops.

4.2 CS group collaborations

In the Cybersecurity group, an area of strength is Ashenden's interest in a socio-technical vision of cybersecurity that bridges computer science and social science and sees people as solutions. This led to CREST, 2015, and includes the universities of Lancaster and Bath. An outcome is her appointment as DST Group-University of Adelaide Joint Chair in Cybersecurity, where she is building connections with Australia's Defence Science and Technology Group.

The group's work on The Onion Routing (TOR) network arose through Owenson's interest in dark networks. This achieved world-wide media coverage, invited papers to Chatham House and CIGI, a reference to his work in a speech by the US Deputy Attorney General and an invited talk to the US Department of Homeland Security. The work led to the establishment of Searchlight Security Ltd, a world leader in darknet intelligence. A former student in the group established an internationally renowned company (TryHackMe), with over 300,000 registered users.

4.3 CI group collaborations

The CI group, notably through Gegov and Khusainov, has provided research input into powered wheelchair research, funded from a range of sources. This was instrumental in securing the recent award from EPSRC (2018, £466k, attributed to UoA12 in this REF). Its impact is documented in REF3 UoA11-Wheelchairs. Another group member, Hopgood, is Director of the South Coast Centre of Excellence in Satellite Applications hosted at UoP.

4.4 Industry collaborations – all groups

This is exemplified by the seven KTPs completed in the REF period (contributing 21% of all UoP KTPs – REF5aPara18), providing impact through export and import of expertise, unification of the global agenda on cybersecurity and influence at a global level. Two of these were:

- Smart-E Ltd, which developed and embedded the capability to engineer audio-visual switching products for network-efficient adaptive digital media streaming over existing computer networks. This benefits clients including banks, hotels, and airports and potential exists in education and hospital settings.
- Xim Ltd, which supported NHS partners to prevent hospital admission using standard smartphones to measure vital signs and provide early warning, potentially saving the

Unit-level environment template (REF5b)

NHS £2.4bn pa in the future (Healthwatch England). Xim Ltd approached Briggs due to his long standing relationship with the NHS/health organisations above.

Other companies that approached us which led to KTPs were Lane Telecommunications Ltd, the Purple Group Ltd and Fresh Relevance Ltd, to develop specialised software, a commercial wireless sensor network location system and an intelligent, adaptive and scalable digital marketing tool, respectively. Additionally, the KTPs with Emteq Ltd resulted in wearable technology to monitor people with Parkinson's disease and the one with Doye MosSE Productions Ltd investigated visitors' experiences in museums.

4.5 Wider activities resulting from our collaborations

During this REF period, four staff – three of whom were appointed/promoted this REF period (Hopgood, Ashenden, Yu) – served as advisors to government, public bodies, and/or industry in the UK and three outside the UK. Six staff engaged with the media in an expert capacity. One served as an expert in a court case, and two have/had prominent roles in professional, statutory and regulatory bodies.

Four female colleagues participate in the national R Ladies Group monthly meeting in London. Moreover, Kovacs, a senior research associate in CHMI, established the Portsmouth R User Group, with over 170 members and 20-30 attendees at quarterly meetings. This enhances our status and industry connections with, for example, the Office of National Statistics (ONS), Ministry of Defence (MOD), Defence Science and Technology Laboratory (DSTL), local SMEs, academics and independent researchers. During the COVID era, it has attracted attendance internationally.

Below are selected examples illustrating the wealth and diversity of activities, achievements and influence resulting from our collaborations:

- Hopgood advises BCS on future professional training in AI; he is a committee member for SGAI, the BCS specialist group for AI since 2000.
- Ashenden sits on the UK MoD's Defence Science Expert Committee; she is also Co-I and Programme Manager for Protective Security at CREST (www.crestresearch.ac.uk), funded via ESRC and an academic fellow at the UK's National Cyber Security Centre (www.ncsc.gov.uk).
- Williams's research related to passenger engagement for rail safety, including passengers with restricted mobility, involved live trackside trials of technology with Chiltern Railways and stakeholder engagement with Rail Delivery Group and Train Operating Companies, including Chiltern, Virgin and Govia Thameslink Railway.
- Williams's collaboration with Visa, Natural History Museum, Goodbox and Streeva, and, in consultation with HMRC, on the Swiftaid pilot, a platform to automate Gift Aid processing.

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- Aziz and Williams’ involvement in the EPSRC CryptoForma network (until 1 November 2015), to increase security and confidence of cryptographic protocols and their applications.
- Yu won an Industrial Fellowship from the Royal Academy of Engineering working with Emteq Ltd on Dynamic Facial Expression Reconstruction from Upper Half-Face Data; he is also a member of Connected Everything: Industrial Systems in the Digital Age Network Plus (EPSRC).
- Eight researchers, some ECRs, have been awarded prizes or other recognition. For example, alongside training, mentoring and internal funding for conferences, Mohasseb progressed from PhD student to research assistant to lecturer. She received (with Aziz) the Bronze Prize in the Korean Industrial Technology Security Hub annual international competition for best project in cybersecurity. This research had been supported by Aziz’s “pump-priming” funding.
- Good engaged with the media about fake news and social media during the pandemic, managing screen time during social isolation, and technology and mental health.
- Briggs and Chlebkova have Research Visiting Fellowships at the universities of Oxford and Dauphine, Paris, respectively.
- Haig is Technical and Academic Advisor for Deary, a UK tech company using AI.

4.6 Wider activities providing connections and expertise, and leading to funding

4.6.1 Journals

100% of submitted staff are involved with academic service activities such as journal reviewing and conference programme committees. 55% are involved in editorial activities, of which, in this REF period, 71% are/were on the Advisory Board of at least one journal and 59% serve/served as a Guest Editor for at least one journal. Examples include Gegov (editorial board of *IEEE Transactions on Fuzzy Systems*), Liu (Co Editor in Chief for *International Journal of Intelligent Robotics and Applications*; Associate Editor for *IEEE Transactions Industrial Electronics*, *IEEE Transactions Cybernetics*, *IEEE Transactions Industrial Information*) and Yu (Associate Editor for *IEEE Transactions on Human-Machine Systems*, *IEEE Transactions on Computational Social Systems*).

4.6.2 Reviewing grants

45% of staff review funding bids (both UK and worldwide). The UoA makes a substantial contribution to the EPSRC review process, with 4 members of the EPSRC full peer-review college (Briggs, Haig, Hopgood and Yu) and 3 members of the EPSRC associate peer-review college (Ashenden, Ju and Liu). Two (Liu and Haig) received letters of recognition from EPSRC for their high level of contribution (top 6%) to reviewing during the 2017-2018 academic year. Although not part of the peer-review college, other staff have peer-reviewed for EPSRC (Aziz,

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Chlebikova, Gegov, Jordanov, Krokos, Shiaeles). Briggs is a member of the NIHR Artificial Intelligence Health and Care Award Panel and regularly reviews for other NIHR programmes.

Staff served as reviewers for other funding bodies including the American Mathematical Society (Chlebikova), the Australian Research Council (Gegov), the Austrian Research Council (Gegov), the British Council (Aziz), Cyprus Research Promotion Foundation (Briggs), EU-Horizon2020 (Haig, Shiaeles), National Natural Science Foundation of China (Ju), National Science Centre Poland (Chlebikova, Haig, Ju, Yu), the Newton Fund (Yu), The Royal Society (Jordanov), Science Foundation Ireland (Briggs), South Africa National Research Foundation (Shiaeles) and Swiss National Science Foundation (Ju).

4.6.3 Conference organisation

Involvement in conference organisation is also high, with 81% of staff involved, of which 32% served as a General Chair, 48% as a Programme Chair, 36% as a Track Chair, 88% as a workshop/tutorial/special session organiser/chair and 30% as a keynote/plenary speaker. The SoC has hosted six national and international conferences since 2014, the most significant being the major European Conference on Information Systems (ECIS), the leading conference in Europe of its type, in 2018.

4.6.4 Student development

We also contribute to sustainability of the discipline through PhD supervision and examination. Within the REF period, 67% of staff served as external examiners for PhD students at other institutions. All but one staff member was involved in PhD supervision. Specifically, 80% served as a 1st PhD supervisor, 83% as 2nd PhD supervisor and 80% as 3rd PhD supervisor, with 60% supervising at least one student to completion as 1st supervisor.