Institution: London Metropolitan University (LMU)

Unit of Assessment: 11 (Computer Science and Informatics)

1. Unit context and structure, research and impact strategy

UoA-11 in the School of Computing and Digital Media (SCDM) at LMU comprises a unique combination of strategic research in cyber threat intelligence modelling; predictive analytics; intelligent security and safety planner; fraud detection using machine learning and Big data; semiconductor device modelling; and wireless communication systems. These areas are brought together to respond to emerging challenges in ICT and society, with the unit proactively engaging with industry in knowledge exchange, to promote a culture of innovation, and by identifying strategic approaches to research of scientific relevance and commercial significance. We enhance our research by bringing together external and internal experts in running seminars and brainstorming sessions, workshops, events, and exhibitions. Examples of these activities include: (i) IEEE inaugural Conference on Blockchain, 2020; (ii) 5G seminar by Mike Short CBE, DIT Chief Scientific Adviser, 2015; seminar on 'Open Banking' by William barker (Whitehall) (2019); seminar on Cyber Security by Mark Brett (Programme Director of NLAWARP), 2019; (iii) Lloyds Innovation Exhibition, 2018; (iv) International Workshop on Semiconductor Technology, 2014; Workshop on 'Big Data – Hadoop' with Hortonworks Inc., 2017; and British Council supported Workshop on 'Cyber-Defence Strategies' in collaboration with Mandi University (India), 2020. We actively create interdisciplinary synergies with other disciplines within the university, e.g. with Psychology on social science research related to online child abuse, and this was done in collaboration with the London Metropolitan Police.

The primary ethos of our research is on real-world issues, systems-orientation, and interdisciplinarity. We are motivated by solving problems involving stakeholders and data. Our research is strongly characterised by working across conventional sub-field divisions, enabling us to develop distinct areas of leadership that draw on cross-cutting and interdisciplinary expertise. The Unit's activities are consolidated by research output from our three research centres, namely: (1) *Cyber Security Research Centre* (CSRC); (2) *Intelligent Systems Research Centre* (ISRC); and (3) *Centre for Communications Technology* (CCT). Each research centre is led by a person with experience of directing major research programmes. Head of CSRC is *Vassilev*, ISRC is *Kazemian*, and CCT is *Virdee*. Although each Centre is a cohesive sub-unit, many important research areas (e.g. IoT, cryptography, computer network security, and robotics) are collaborations that cut across the groups. While the Centres provide focus, an important characteristic of the Unit is supporting a collaborative culture in research, innovation and knowledge exchange. Researchers in the Unit are proactive in exploiting the outcomes of their research through consultancy projects that involve knowledge transfer to industry. The Centres provide a supportive environment for the training postgraduate research students (PGRs), the development of their Research Assistants (RAs), the preparation of research bids and working on research and innovation projects. Researchers in the Unit actively contribute to national and international conferences, seminars and workshops. The School's Research and Knowledge Exchange Committee (RKEC), led by *Ouazzane*, sets research policy across the School, with cross-group representation comprising staff and PGRs. RKEC takes advice from the School's Industrial Liaison Group consisting of industry and public-sector advisors. The Research Students Progress Board, led by *Kazemian*, monitors the progress of the research students. Contribution to UoA-11 is put forward from members of CSRC, ISRC, and CCT.

With a new Vice Chancellor, who has transformed support for research, including appointing a designated PVC and founding a new Research and Postgraduate Office (RPO), we are well-placed to build on what has been a successful period for our Unit. We have appointed 6 new research active staff in the REF period who have consolidated the research activities of the Unit.

Over the REF assessment period, the Unit has nurtured strategic aims to enable sustained expansion, with focus on the applied research and innovation in Cyber Security, Intelligent Systems, and Communications Technology to maximize the impactful research produced by our experienced researchers and Early Career Researchers (ECR). Since 2008, the Unit has aimed

to maintain a high research profile in all its main subject areas, and in pursuance of this aim has supported applied research and innovation having clear relevance to the community and industry (especially KTPs, innovation and commercial projects harnessing our research); to fund the growth and maintenance of research centres and groups wherever they evidence excellence; to encourage and mentor promising new areas of research and researchers; to actively pursue sources of external research funding; to contribute essential underpinning for the undergraduate and postgraduate learning experience by demonstrating the relationship between research and learning; to support the professional and academic development of its staff by establishing a research environment conducive to the pursuit of excellence. In the REF period 2014-2020 the Unit's generated external income of £1,551,718 of which £1,038,000 is recorded as research income. The rest of the income is from research-based consultancies.

Our vision is to carry out rigorous world-leading applied research that focuses on high-quality research that makes a difference. We have a strong PhD programme and invest heavily in the training of research students and the provision of facilities for these students. Since REF 2014 our research strategy for high quality and impactful research and building a strong and interdisciplinary research community has been achieved by (i) reorganizing research groups for improved critical mass and better alignment with major challenges in computer science and informatics; (ii) investing in the best possible new academic appointments financed by expanding student numbers, KTP, research and innovation grants and consultancy contracts; and (iii) encouraging, rewarding and promoting subject leadership through a strong staffing strategy. Since 2014 research in the Unit has continued to thrive, with achievement of excellence in all areas, as evidenced by significant improvement in key performance indicators:

- PhDs awarded has risen by 70%.
- Research income and consultancy led research income has increased 36%.
- Research culture has enhanced with the appointment of 6 new academics and contributions by 3 existing academic staff not entered in the last REF.
- Sustained increase of journal outputs (112) in high impact factor outlets.
- Publication of 90 papers at major international conferences.
- External examination of 55 PhD students.
- Peer-review of 72 journal and conference papers.
- £229,766 in funding from prestigious EU collaborations (+£91K will be included in the next REF).
- Establishment of new research facility (Cyber Security Research Centre), with state-of-the-art infrastructural investment of £500,000.
- Investment of £100,000 in the establishment of new Computer Networking Centre housing state-of-the-art Cisco Systems and Palo Alto equipment worth over £1M.
- Engagement on 6 Innovate UK KTP projects.
- Undertaken 13 research-based consultancies.
- Delivered 11 public lectures and 6 keynote/plenary talks.
- Organization of 20 external major research events.
- Presentation at 37 international conferences.
- Editorial work in 8 major journals.
- FTEs submitted up by 67% from 2014.

Our strategic plan (2021-2026) is aligned with the University's strategy for the delivery of excellence in research, innovation and impact. The principal elements of our strategy is to achieve the following goals: (i) Embark on larger research initiatives - Use growing critical mass and emergent leadership within groups to build on our strengths and generate larger-scale research programmes; (ii) Prioritize cross-discipline collaboration with other research centres in the University to facilitate opportunities to generate new knowledge and impactful research; (iii) Develop challenging research agendas through relationships with existing network of strategic partners such as Lloyds Banking Group, Callsign, Palo Alto and Cisco Systems. Seeking advice from the School's Industrial Liaison Group to identify strategic

priorities and create new opportunities for academic, industry, and public-sector research collaboration; (iv) Recruit more research active staff; (v) Complete the recently started EU-Horizon 2020 – SPIRIT (Scalable privacy preserving intelligence analysis for resolving identities) project (Ref. No. 786993); (vi) Publish high-impact research papers; (vii) Increase the number of research PhD research students; and (viii) Increase research studentship funding at PhD and post-doctoral levels.

Our strategic plan for the Unit is to build on developments achieved during the REF 2021 period to sustain and expand impactful research income, infrastructure and activities to 2026 and beyond. This will be achieved by greatly enhancing our research culture in the next five-year (2021-2026), which is aligned with the university's strategic plan 2019-2025, and that they will be supported as such. The plans include:

- To improve infrastructure to support high-quality, high-impact research.
- To increase research staff with workloads for research to at least 50%.
- To grow the volume of world-leading and internationally excellent research.
- To extend capacity for highly innovative and research-intensive work with industrial partners.
- To improve the visibility of our research and the impact it has on some of the biggest challenges facing society today.

Impact Strategy:

Our impact strategy brings together our blue skies research, our extensive industrial training and consultancy, and thus connecting the research and knowledge exchange agendas through a robust impact plan which will extend to all members of our team. This has been achieved by (i) supporting researchers to plan for impact alongside conception of the research project and to maximize impact as and when it occurs; (ii) promoting active engagement of academic staff and researchers with external stakeholders; (iii) developing a common understanding of different types and value of research impact that is independent of research discipline; (iv) supporting PGR students to work closely with stakeholders at the early stages of research planning to maximize the potential impact of the research; and (v) facilitating discussions between PGR students and users of research, including, e.g., representatives of our Industrial Liaison Group, Innovation and Knowledge Exchange Partners, thereby enabling a research-engaged culture. Our leading researchers have developed and sustained exceptional relationships with their external collaborators (e.g. Lloyds Banking Group, Callsign, Cisco, Palo Alto, etc.) to achieve impacts from their research. We are keen to ensure that our research impact culture extends beyond the REF and that as much of our research as possible is focused on being of value to society, as well as informing our curriculum. Our impact is underpinned by a track record of internationally excellent and world-leading research. Most of our research activity has involved external stakeholders from identifying the need for research and formulating research questions, to generate new knowledge, evaluating and communicating the research findings, following and evidencing the uptake and resultant benefits in society, and evaluating the outcomes. Beyond REF 2021 our approach to impact will be:

- Geared at strengthening the research capacity of the Unit and engage in high-quality change-making activities that enable our researchers to most effectively amplify the impact of their research in collaboration with and co-production of research with diverse stakeholders, partners and organizations beyond higher education,
- To maximize our engagement with our local enterprise partnerships, councils, and business support organizations,
- Establish and support relevant cross-disciplinary research and innovation,
- Facilitate impactful research collaborations with existing and new partners, especially where these can lead to funding opportunities and advance ambitions,
- Invest in those areas of excellence research most likely to deliver world-leading capacity, and to raise the international reputation of our institution,
- To significantly increase in winning impact-related funding by developing skills for all

> researchers to be competitive in winning grants,
> - Strengthening existing and emergent areas of research and innovation excellence through a targeted recruitment, retention and succession strategy, and
> - Support knowledge exchange activities that ensure our best innovations are readily translated for the economic, cultural and social benefit of users worldwide.

2. People

Staffing strategy and staff development:

School of Computing and Digital Media has a well-established and inclusive staffing strategy and staff development in place. With regards to staffing strategy, since REF2014 the Unit has recruited 6 new research orientated academic staff and we endeavor to recruit further research active staff in the near future to consolidate our research activities. Although some staff within the Unit have an established research track record, the unit is building the research profiles of other staff to enhance impactful research. New appointments are assigned established senior staff members with related research as mentors, quickly incorporating the new staff into the department's research culture. We have established mechanism for promoting and monitoring staff development via our annual staff appraisal system. In the REF period within UoA-11, *Vassilev* has been promoted to a Reader and *Salekzamankhani* to Associate Professor. We have also appointed the following new research staff: *Li*, *Fernando*, and *Kikot*. Heads of research centers appraise and line-manage researchers. During the appraisal, staff development is identified, and appropriate tasks are actioned as deliverable targets. Researchers are given sufficient time for staff development.

Professors in the Unit mentor ECRs to become quality researchers. Training is given to ECRs on how to peer review research outputs and grant applications, apply for external research grants, supervise PhD students, etc. ECR are given opportunity to build networks with industry and academia experts through presentation at international conferences, and are given opportunity for research leave in year 1, ahead of more experienced researchers so that ECRs can travel to major research institutes at home or abroad to build their research skills and expertise as well as partners for collaboration on impactful research. The School's Industrial Liaison Group is where industrial research and secondment to industry is identified and brought to the attention of line managers and Heads of research centres for approval. Members of staff with no PhD are encouraged to engage in research. One member of academic staff has successfully completed her PhD in the current REF period (*Dr Patel*) and three members of staff (*Fernando*, *Onadim* and *Breen*) are currently pursuing their PhD research and expected to complete in 2020/2021. We fund some of our PhD students from partnership with industry. We actively encourage ECRs to be part of the PhD supervisory team. Participation at research conferences and seminars are funded by the School.

The Unit is supportive of the family and personal obligations of all members of staff, such as parents of young children. We allow people with caring responsibilities flexible working conditions, protecting them from teaching and other duties that require University attendance in especially pressured times. This is partly enabled by a culture that supports and encourages staff members to share work collaboratively with colleagues. Members of the three centers in the Unit proactively collaborate with each other on research bids and on research papers. Teams, typically made up of researchers at every stage of their careers, interact energetically throughout the processes of planning, applying for, and undertaking projects. All research bids and papers are read and critiqued by other research staff before submission, allowing researchers to learn about each other's research.

Support, training and supervision of PGR students:

The University's Research and Postgraduate Office (RPO) provides support and training to both research active staff and students. RPO is instrumental in bringing together PGR students, academic staff, and others, across the University to make academic life as a postgraduate research student as smooth as possible. This includes academic support for

students at every stage, including advising prospective applicants, and giving PGR students a platform to give feedback and contribute to the student journey. Research staff in the Unit and across the university proactively contribute towards the delivery of training sessions to PGR students on a periodic basis throughout the academic year which is organized by the RPO. The training sessions are designed to help research students negotiate the different phases of their study and the varying challenges each phase presents. In addition, the RPO plays a key part in supporting PGR students and research staff in a variety of ways including induction, drop-in sessions, training on research philosophy, critical review of the literature, supervisory training, sessions on chairing a PhD viva, workshops on writing a successful research bids, research ethics and research project management.

In the current REF period, the RPO has formed postgraduate research society whose general aim is to build a research community thereby enabling research students from different Schools/disciplines to work together. This promotes and facilitates research students to: (i) Connect with like-minded people for mutual support and peer-support; (ii) Socialize with others through social events, academic seminars and meet-ups outside University; (iii) Promote and develop a research community from all backgrounds and studies; (iv) Meet to develop research ideas among peers; (v) Create network opportunities; (vi) Get support from their whole research journey; and (vii) Attend activities aiming at developing research skills. All research active members of staff, whether experienced researchers or ECR are also given opportunities for a sabbatical period on a regular basis. Furthermore, research members of staff are encouraged to attend short courses to enhance their research knowledge and skills.

PhD students are an integral part of our research strategy, playing an active part in research activities from writing papers to presenting at our bi-monthly research seminars, as well presenting papers at international conferences and symposia. The Unit's researchers play an active part in the annual London Met Student and Staff Research Conference. In addition, some research students contribute to teaching undergraduate students and supervise final-year projects. All students have 2 supervisors. Our investment in training and supporting PhDs can be seen in the large number of PhD completions, i.e. 23 in the current REF period as compared to just 11 in REF2014, which constitutes a growth of 109%.

As part of a strategy for transferable skills training, the Unit provides students with opportunities to learn new skills that promote personal and career development goals. Research students are expected to discuss their training needs with their supervisory team and identify which activities are appropriate/necessary for their research and personal and career development.

The University wide Researcher Development Programme provides a range of training and development opportunities for PGR students delivered by experts and experienced researchers on a regular basis throughout the academic year. These courses are designed to support researchers in developing a full range of transferable, professional, personal, research, and career skills. The Programme offers a range of courses in four areas: Knowledge and Intellectual Abilities – the knowledge, intellectual abilities and techniques needed to carry out research; Personal Effectiveness – the personal qualities, and career and self-management skills needed to take ownership of and engage in professional development; Research Governance and Organization – the knowledge of the standards, requirements and professional conduct needed for the effective management of research; and, Engagement, Influence and Impact – the knowledge, understanding and skills needed to engage with, influence and impact on the academic, social, cultural, economic and broader context.

Because the Unit receives numerous internship requests especially from overseas it gives some of these PGR students opportunities for research training. In 2020 alone, several students from France were given an opportunity to engage on research projects in the Cyber Security Centre.

Information on research students' progress monitoring:

All research projects must be ethically approved. First year research students receive an induction programme including general and specific taught courses available to PhD students, and targeted Health and Safety training. Students are required to complete a post-registration progress review form twice annually. This includes description of the progress they have made on their research project since the last report to the Research Student Progress Group (RSPG); identify any challenges or problems encountered for which additional support, training or guidance might be required; and, an updated outline of their anticipated timetable for completing the research.

SCDM operates a rigorous research student progress monitoring mechanism, involving detailed 6-monthly progress reports and an annual review at the RSPG meetings in which a panel consisting of Research Supervisors and Directors of Research Centres and Research Groups assess the progress of the research and advise on the subsequent progression. As part of this process the student supervisors are required to comment on their student's progress in respect of their programme of research. An independent reader appointed by the RSPG also comments on the student's progress as well and the progress needs to be approved by the RSPG. The university employs two-phase research progression scheme in which the first phase leads to the intermediate degree of MPhil. On approval of MPhil to PhD transfer report the student is only then allowed to progress with their research leading to PhD degree.

As part of their training, research students are expected to present their research at conferences and symposia. SCDM employs the policy to provide funds to enable all full-time PGR students to attend national and international conferences during their studies on the condition they have published an output at the event. Student are expected to present a poster on their work at the annual Enterprise and Network Day of the School. Effective interaction between PGR students and staff in the School is promoted through regular bi-monthly seminars and social events. External speakers participate in the School's Research Seminar Series, which raises awareness of key research developments as well as facilitating collaboration. PhD students are required to present their research at one of the research seminars organized by the School to gain experience and confidence in public speaking.

Supporting Equality, Diversity and Inclusion:

The Unit operates within University policies and procedures for equality, diversity and inclusion.

The Unit, and indeed the University, is committed to ensuring all students, staff and visitors have a positive experience of the learning, teaching, research and work environment. Majority of researchers (staff and students) in the Unit are from the BAME (Black, Asian and Minority Ethnic) community. In fact, 66% of staff submitted in UoA-11 are BAME, which means we profile similarly to our overall student community. The Unit recognizes that BAME students may have different experiences, and therefore needs. Hence, Professors and research staff in the Unit regularly make aware to such students of their availability to provide appropriate support and mentoring should they need it. The University disseminates policy and good practice in relation to both staff and students. We provide training and advice on interpretation and implementation of policies and codes of practice. The University's Equality, Diversity and Inclusion addresses gender, marital status, age, race, religious belief, political belief, disability, sexual orientation, and responsibility for dependents. The University is preparing application for bronze status of the Athena Swan Charter to promote equality for women in STEM subjects. The University has entered the Stonewall Diversity Champion programme and joined Stonewall's Workplace Equality Index process, to assist us in implementing LGBT+ inclusive policies and practices across the University. The University is taking part in the government's Disability Confident scheme as a Disability Confident Committed employer and have published information to help and support our staff. We support equality of opportunity through open communications to staff about strategic

initiatives, funding opportunities and training.

Contributions to the Discipline
Cyber Security Research Centre *(Lead: Vassilev)*

This is a new Centre created in September 2018. The Centre's research is critical in addressing cyber security issues, in particular (i) responding to unanticipated cyberthreats; (ii) ensuring the resilience of networked systems; (iii) coping with the fluid nature of identity; and (iv) instilling a cyber-security culture across organizations. To achieve these goals the Centre closely works with researchers in the other two Centers having expertise in computing, intelligent systems, computer networks and electronics and communications. This and the other Centers in the Unit are heavily involved in developing the research skills of members including ECRs not entered in REF. These people are vital part of our research community and it's important they become world-class researchers through mentoring and participating in workshops, seminars, and conferences. Research profile of some of the Centre's members is outlined below.

Ouazzane is full professor of computing and knowledge exchange. He is the research lead at SCDM, the founder of the Cyber Security Research Centre (2018) and has acted as the University's KTP Director for the period 2014-2018. Since 2014, he has published 22 refereed research papers and 11 of which are journal papers (publications in IEEE Transaction on Neural Network and Learning System, International Journal of Situation Awareness, and IEEE Transaction Engineering Management). He has presented papers at various international conferences (e.g. Conference on Applications and Systems of Visual Paradigms 2016, IEEE Cyber Security 2019 Conference, Oxford June 3-4th 2019). He is a peer reviewer for numerous conferences and journals (e.g. IEEE Geoscience and Remote Sensing journal, and IEEE Transactions on Neural Networks and Learning system). *Ouazzane* has examined over 21 PhD thesis and was a keynote speaker at four international conferences including IEEE Cyber Security 2019 Conference, Oxford June 3-4th 2019, and The Eighth International Conference on Business Intelligence and Technology in 2018.

Since 2014, *Ouazzane* has worked and acted as a consultant for several companies and charities such as Lloyds Banking Group, Barclay cards, Callsign, LifelineIT, Ask outlets, Disability Essex. He has played a major part in bringing businesses and policy makers into the Unit, which has significantly contributed to enhancing the Unit's infrastructure, embedding the culture of innovation, and developing world-leading research and translating its key aspects into areas of societal importance. *Ouazzane* was a recipient of two KTP projects 2016-2018 whose outcomes were rated outstanding by InnovateUK. He has organized a number of seminars, workshops and events inviting external speakers from businesses and government bodies to enhance knowledge exchange within the School/University; he organizes the Summer School Enterprise and Networking Day (SEND) inviting businesses, academics and students; organized seminars such as Open Banking delivered by a speaker from the Whitehall-2018; co-organized workshops such as 'Hadoop big data platform' delivered by Hortonworks from the US-2017; co-organized the launch of IEEE blockchain in the UK and Ireland hosted by London Metropolitan University in February 2020, the first one of its kind in the UK; co-organized and participated at the inaugural of Lloyds Innovation Community exhibition, held on 20th November 2018 at the Royal Horticultural Society, Westminster.

Ouazzane is a Fellow of British Computer Society, Senior Member of IEEE and a Senior Member of American Society of Mechanical Engineering. He was appointed as non-executive Director at LifelineIT Ltd. (2014-2017) overseeing the development of the company Security policy framework. *Ouazzane* is currently the Chair of the European Cyber Security Council at Brussels; overseeing discussion about the increasing range of vulnerabilities created by the introduction of new technologies and business model like BYOD. He is also working on EU Network and Information Security Directive and the reforms to EU data protection legislation. Since 2015 he has been a guest member of InnovateUK sitting on grants 'panels such as proof of concept and proof of prototype. Since 2018, *Ouazzane* has been a member of Parliament Internet Communication Forum at Westminster debating strategic topics such as 'Impact of AI on the UK economy', 5G network technology

in the UK and cyber threat on the UK grid energy.

Since 2014, *Vassilev* has published 16 peer-reviewed papers, 5 of which are journal articles published in refereed international journals. *Vassilev* is a member of British Computer Society, Bulgarian Association of Artificial Intelligence and European Big Data Value Association. Since 2014 he has peer reviewed articles for several IGI international journals and examined 7 PhD students.

During the last 5 years *Vassilev* contributed in the organization of the Second and the Third International Conference on Recent Trends and Challenges in Computational Models (ICRTCCM) and has been keynote speaker at 3 international conferences: International Conference on Recent Trends and Challenges in Computational Models (ICRTCCM2017, Tindivanam, India; Keynote title "Programming vs. Component Development: Evolution of Enterprise Computing and its Challenges to University Education"), IEEE Conference on Cloud Computing, Data Science and Engineering (CONFLUENCE2020, Noida, India; Keynote title "From Pages on the Fly to Workflows in the Cloud: Evolution of Web Computing"), International Conference on Artificial Intelligence and Applications (ICAIA2020), Janakpuri, India; Keynote title "AI on Demand through Hybridization and Containerization"), International Summer School on Big Data Technologies (GATE Summer School 2018, Sofia, Bulgaria; Keynote title "Introduction to Big Data Management using Hadoop") and UK Data Mining Society (Annual Meeting 2015, London, UK; Keynote title "Enhancing online analytics tools with dynamic user profiling using intelligent methods for classification").

In the REF period, *Vassilev* has given 4 keynote talks and presented papers to the World Congress in Computer Science in Las Vegas, USA (2016), 21st International Conference on Metadata, Semantics and Ontologies in London, UK (2019), 10th IEEE Conference on Cloud Computing, Data Science and Engineering in Noida, India (2020) and 2nd International Conference on Artificial Intelligence and Applications in Janakpuri, India (2020). Over the last five years *Vassilev* has been also a regular presenter of invited talks at the Royal Institute in London (2017, Model-based Individual and Group Dynamic Behaviour Analysis; 2018, How to Authenticate Yourself Online; 2019, How to make intelligent programs). He has led 4 projects under Knowledge Transfer Partnership and Cyber ASAP programmes of InnovateUK, funded by UK DCMS, and 6 consultancy projects, funded by Lloyds banking Group. *Vassilev* is also an external consultant for the biggest Horizon 2020 project for establishing of a Centre of Excellence in Big Data Technologies in Sofia, Bulgaria. He is the recipient of outstanding award for contribution to the National Programme of InnovateUK, 2014.

Intelligent Systems Research Centre *(Lead: Kazemian)*

The Centre's research is on application of artificial intelligence and machine learning to improve a wide variety of IT-based systems, devices, and software in domestic, medical, and industrial products. Research activities include data mining and data warehousing, virtual learning environments (VLE), pattern recognition, natural language processing, cognitive science, biometrics and GIS database performance, parallel distributed systems, and agent-based approach for building data warehousing. Profile of a couple of the Centre's members is given below.

Kazemian leads Intelligent Systems Research Centre. Since 2014, he has published 11 refereed journal papers and 7 refereed international conference papers predominately in the applications of Artificial Intelligence and Machine Learning to membrane protein, IT security, identity resolution, steganography, cryptography, Neuro Linguistic Programming, watermarking, remote sensing, WiFi and ZigBee. He is a member of the Editorial Board of ICTACT Journal of Soft Computing and since 2014 he contributed to three international conferences as program committee member, technical advisory committee and session chair. He has obtained three grants and one KTP as principal investigator: (i) EU-Horizon 2020 – SPIRIT (Scalable privacy preserving intelligence analysis for resolving identities) project in 2018. This EU funded research project has 17 European partners. The outcome of the research project will be used by six police forces across Europe, Thames Valley Police, West Midlands Police, European Centre of Psychology Investigation and

Criminology, Antwerp Belgium Police, Hellenic Police Borders Unit in Greece, Polish Police Academy and Ministry of internal affairs of the Republic of Serbia adding to the impact of this research work; (ii) EPSRC on two occasion as a peer review college member activities; (iii) KTP in 2015 with eConnect Cars and EV Technology. He is peer review college member for EPSRC. *Kazemian* has eight PhD completions since 2014. He has supervised three postdoctoral research fellow/assistants: *Michael Phillips* from Sept.2015-Sept.2017 for KTP eConnect Cars, *Amirhosseini* for the EU-Horizon 2020 Spirit project from Nov.2018-March2020, and *M. Phillips* for the EU-Horizon 2020 Spirit project from Dec.2019. He has examined 12 MPhil/PhDs during this period. He is a Chartered Engineer (CEng), Fellow British Computer Society (FBCS) and Fellow of Institute of Engineering and Technology (FIET).

Kikot specializes in Artificial Intelligence. Previously he was a postdoctoral researcher at the University of Oxford, where he worked on query planning in databases. Prior to this he was a researcher at Birkbeck College included ontology-based data access. He has contributed to the development of the Russian search engine Yandex, where he applied his expertise on automated reasoning, natural language processing, web navigation and information retrieval. *Kikot* has published eight research papers since 2014.

Centre for Communications Technology *(Lead: Virdee)*

Research in Communication Technology has a long tradition at London Met and is now integrated in UoA-11. This is a natural development as the field has moved from roots in electrical engineering to embrace computer networking, software modelling, IoT and robotics. People in this Centre contribute to the research activities and consultancy projects of the other two Centres in the Unit. Profile of some of the Centre's members is given below.

Since 2014, **Virdee** has published over 200 research papers, 87 of them in journals including Scientific Reports which is an open access journal from the publishers of Nature and the 11th most cited journal in the world; IEEE Transactions on Antennas and Propagation; IEEE Access; IEEE Antennas and Wireless Propagation Letters; IET Microwaves, Antennas and Propagation; International Journal of Electronics and Communications; Journal of RF and Microwave Computer-Aided Engineering; Microwave and Optical Technology Letters; Journal of Electromagnetic Waves and Applications; IETE Journal of Research; International Journal of Microwave and Wireless Technologies; Electromagnetics; Optik; Electromagnetic Waves and Applications; Radio Science; International Journal of Microelectronics and Computer Science; Electronics; Progress in Electromagnetics Research Letters; Journal on Wireless Communications and Networking; Wireless Personal Communications; and ICT Express. In addition, he has co-authored one book and 6 book chapters.

Virdee is Fellow of the Institution of Engineers and Technology (IET), Senior Member of IEEE and Senior Fellow of HEA. Virdee is Chair of IET Technical Professional Network on RF and Microwave (since 2018) and Executive Member of the IET Technical Professional Network (since 2011). He serves as Chair in the Technical Programme Committee of EuCAP since 2018, and International Program Committees of (i) OPTICS (since 2015); and (ii) ELECO (since 2011). He is Journal Editor for Cogent Engineering, Taylor and Francis Group (since 2017), Editorial Boards of RFMiCAE, Wiley (2016-2018), Far East Journal of Electronics and Communications (since 2012), Guest Editor Int. Journal of Antennas and Propagation, Hindawi Publishing Corporation (2014), and Int. Journal of Antennas (since 2015).

Virdee is a peer reviewer for EPSRC research bids and has been a member of the judging panel of IET's Innovation Awards since 2014. Since 2014 Virdee has examined over 30 PhD thesis internationally and has organized and participated in the following research-based events: IET International conference on "Towards 5G Mobile Technology – Vision to Reality", The Royal Society, London (19 Nov 2015); MOS-AK/GSA Workshop on "Semiconductor Technology and Device Modelling" at London Met 28-29 March, 2014; The 2nd Annual Active and Passive RF Devices Seminar, IET Birmingham, 29 October 2014; IET Conference on "5G Technology – The Future of Mobile and Wireless Communications Technology" Savoy Place London, 30 Oct 2014; IET Conference on "The 5G revolution – Movers and Shakers" Savoy Place London, 25 Jan 2017; IET Conference on "5G - State of

Play", Savoy Place London, 24 Jan 2018; IET Conference on "5G - The Advent", Savoy Place London, 30 Jan 2019; and IET Conference on "5G - Unleashed", Savoy Place London, 29 Jan 2020.

Virdee has been involved in the professorial promotion panels at Australian College of Kuwait, 28 June 2018 and Leeds Metropolitan University, 12 March 2019.

He has presented research papers at various international conferences including IEEE MTT-S International Microwave Symposium, San Francisco, USA, 22-27 May 2016; IEEE MTT-S Int. Microwave Symposium, USA, 4-9 June 2017; IEEE Int. Conference on Advanced Information and Communication Technologies, Lviv, Ukraine 2-6 July 2019; and IEEE Asia Pacific Microwave Conference, Singapore, 10-13 December 2019. He has been a peer reviewer for various journals and conferences including EuCAP, Applied Sciences, ELECO, IETE Journal of Research, Frequenz, PIER Journal, IEEE Transactions on Antennas and Propagation, IEEE Access, Int. Journal of Electronics and Communications, IEEE Transactions on Antennas and Propagation, Royal Society Open Science, Sensors, Electronics, Journal of Electromagnetic Waves and Applications, Int. Journal of Engineering Science and Technology, Chinese Optics Letters, Int. Journal of Engineering Science and Technology, Int. Journal of RF and Microwave Computer-Aided Engineering, IEEE Microwave and Wireless Components Letters, EMERGING, Analog Integrated Circuits and Signal Processing, Electronics Letters, Radio Science, and Results in Physics.

Since 1988, **Brinson** is a Fellow of The Institution of Electrical Engineers (FIET). He was instrumental in organizing MOS-AK/GSA Workshop on "Semiconductor Technology and Device Modelling" at London Met 28-29 March 2014. Since 2014, *Brinson* has given numerous public lectures on his research activities including (i) IEEE EDS mini-colloquium, 24 June 2015, Torun Poland; (ii) IEEE EDS Distinguished Lecturer mini-Colloquium on GaN HEMT Technology, 22 June 2016, Lodz, Poland; (iii) IEEE EDS Distinguished Lecturer Mini-Colloquium, 21 June 2017, Bygoszcz, Poland; (iv) IEEE EDS Distinguished Lecturer Mini-Colloquium, 21 June 2017, Bygoszcz, Poland; (v) IEEE EDS Distinguished Lecturer Mini-Colloquium, 20 June 2018, Gdynia, Poland; (vi) IEEE EDS Distinguished Lecturer Mini-Colloquium, 26 June 2019, Rzeszow, Poland; (vii) IEEE EDS Distinguished Lecturer Mini-Colloquium, 25 June 2020, Wroclaw, Poland. Mike was chaired at several international conference sessions including: (i) MIXDES 2015, Special session III (Part 1): Open Source Compact/SPICE Modeling, 25 June 2015, Toruń, Poland; and (ii) MIXDES 2019, Special session II (Part 2): Compact Modeling for Nanoelectronics, 27 June 2019, Rzeszów, Poland.

Brinson has presented research papers at international conferences and workshops including (i) MOS-AK/GSA Workshop on "Semiconductor Technology and Device Modelling," 28-29 March, 2014; (ii) 7th International MOS-AK Workshop, Berkeley, USA, December 12, 2014; (iii) 12th MOS-AK ESSDERC/ESSCIRC Workshop, September 26, Venice, 2014; (iv) MOS-AK Workshop at DATE Conference, March 12, 2015, Grenoble, France; (iv) 22nd International Conference Mixed Design of Integrated Circuits and Systems (MIXDES). 25-27 June, Torun, Poland, pp. 192-197; (v) 8th International MOS-AK Workshop, Washington DC, 9 December 2015; (vi) 13th MOS-AK ESSDERC/ESSCIRC Workshop, 18 September 2015, Graz; (vii) 23rd International Conference Mixed Design of Integrated Circuits and Systems (MIXDES), 23-25 June 2015, Lodz, Poland; (viii) International Siberian Conference on Control and Communications (SIBCON), May 12-14, 2016, Moscow, Russia; (ix) 23rd International Conference on mixed design of integrated circuits (MIXDES), ISBN: 978-83-63578-09-1; (x) 14th MOS-AK ESSDERC/ESSCIRC Workshop, September 12, 2016, Lausanne; (xi) 24th International Conference Mixed Design of Integrated Circuits and Systems, 22-24 June 2017, Bydgoszcz, Poland; (xii) MOS-AK Workshop, 31 March 2017, Lausanne, Switzerland; (xiii) 25th International Conference-MIXDES, 21-23 June 2018, Gdynia, Poland; (xiv) 26th International Conference Mixed Design of Integrated Circuits and Systems (MIXDES), 27-29 June 2019, Rzeszow, Poland; (xv) 49th European Solid-State Device Research Conference, 23-26 September 2019; (xvi) 12th International MOS-AK Workshop Silicon Valley, Santa Clara, California US, December 11, 2019; and (xvii) MOS-AK Workshop THM Giessen, Germany, March 17-18, 2020.

Since 2014, *Brinson* has peer-reviewed numerous journal and international conference papers including (i) International Journal of Electronics; (ii) Journal of Numerical Modelling:

Electronic Networks, Devices and Fields; (iii) IET Circuits, Devices and Systems; (iv) IEEE International Conference on Modeling of Systems Circuits and Devices; and (v) Special Issue of Solid-State Electronics covering MOS-AK compact modelling of devices from 2018 to 2020. Mike was a keynote speaker at the 27th International Conference Mixed Design of Integrated Circuits and Systems, 25-27 June 2020, Wroclaw, Poland.

3. Income, infrastructure and facilities

Research income:

The Unit encourages and supports research investigators to exploit a diversity of funding sources to avoid overdependence on a small number of income sources. Sources of public and private funding have included: EU-Horizon 2020, InnovateUK knowledge transfer and innovation projects, UK and overseas industry consultancy projects. During the REF 2021 period up to 2019-20 as per HESA record the income generated by the Unit under various research funding schemes is **£1,038,000**. The total income in the REF period from both research and consultancy-led research projects is **£1,551,718**. Research and consultancy-led research projects undertaken include:

- **£103,000:** Lloyds Banking Group (User-centric testing of an authentication service for voice-controlled devices)
- **£98,000:** Lloyds Banking Group (Cross-channel security policy in digital banking)
- **£36,600:** Lloyds Banking Group (Technological proof of concept for fraud analysis in digital banking using big data tools and technologies)
- **£46,214:** Lloyds Banking Group (Behavioural biometrics for customer authentication in online banking)
- **£78,000:** Lloyds Banking Group (Next generation fraud analytics on big data platform)
- **£108,000:** Lloyds Banking Group (Building threat intelligence model for logical vulnerabilities in cross channel transactional monitoring using machine learning techniques)
- **£95,000:** Callsign (Cross channel fraud detection framework in financial services using recurrent networks)
- **£107,000:** InnovateUK KTP (Development of a forecasting solution which will help identify trends and facilitate optimum stock management)
- **£108,000:** InnovateUK KTP (To build a knowledge management system to support the transformation of the traditional reactive production business into a modern productive and profitable knowledge intensive and proactive business, including the company's culture)
- **£103,000:** InnovateUK KTP (Beacon–based authentication)
- **£8,000:** Consultancy (Logical vulnerability analysis and security risk assessment)
- **£38,600:** InnovateUK KTP (Strengthening the marketing and CRM capability of the company)
- **£13,040:** InnovateUK ASAP (Institutional trust, secure and scalable sharing of clinical data in healthcare systems)
- **£11,1111:** InnovateUK ASAP (Enhancing network intrusion protection systems with predictive capability for stopping unknown malicious attacks)
- **£118,684:** InnovateUK KTP (Bespoke software development for large scale use of electric vehicles)
- **£185,000:** EU Horizon 2020 project 'SPIRIT' No. 786993. (the remaining **£91,000** will be included in the next REF period)
- **£59,703:** Research consultancies for LD Didactic GmbH, Agilent Technologies, EDA Solutions.
- **£44,766:** EU Horizon 2020 (Fricke und Mallah Microwave Technology GmbH)
- **£190,000** – Charities

Infrastructure and facilities:

The University provides truly world-class library facilities, comprehensive information system and computing services. In the REF 2021 period the School invested **£500,000** to expand and establish a new Cyber Security Research Centre, within which provides space for our external industry partners Lloyds Bank, Cisco Systems and Callsign. During the first year of operation the Centre established the first private cloud of the University, based on the industry leading Kubernetes system and operated entirely by the staff of the Centre. The Cyber Security Research Centre has an innovation hub where businesses, academics and research students work together for embedding a culture of innovative. It is a well-equipped facility that includes a dedicated laboratory for cyber security, digital forensics and data analytics. Facilities in the centre includes: 53x I7 Desktops; Collaboration desk; Audio-visual facilities; BT lease line (100MGB); 3 physical powerful servers for Big Data and cyber security; a relished 4G Access point; Eduroam Access point; Access point for virtual network; private cloud environment (Kubernetes); FTK toolkits and Cellebrite for mobile forensics; 30 Raspberry pi and Arduino kits and 2 dedicated technicians for the lab maintenance. The University also invested **£100,000** in the establishment of a specialist Computer Networking Lab housing state-of-the-art Cisco Systems and Palo Alto equipment worth over **£1M** for research requiring set-up and dynamic automation of realistic network user scenarios. This investment has substantially expanded the existing facilities and added dedicated environment for research/development activities in computer networking. All our research students have a dedicated office room. The Unit has a range of specialist computing facilities, e.g. mobile platform development environments and personal computing devices. A large suite of software products is available for doing research using state-of-art tools, including Labview, MATLAB, 3ds Max and Adobe CS5, Opnet, Hadoop, Kubernetes, etc. and instrumentation equipment (e.g. Vector Network Analyser, Spectrum Analyzer, Anechoic Chamber etc.) necessary to conduct research in the Unit. We have dedicated labs that accommodate research in computer science and informatics, cyber security, computer networking, wireless communications (5G, RFID, IoT), Robotics, digital signal processing, games, and microprocessor systems. We have a PCB production lab that enables research students to design and build electronic circuits and devices. Specialist technicians based in the labs provide software and hardware support for all research projects while university central services provide dedicated staff to support the general-purpose computer science labs, networks and standard software builds for computers. Our researchers have online access to top journal including IEEE Explore, IET, Wiley, Cambridge University Press, etc. The Research Office and a Finance Officer provide administrative support for the School in terms of preparing, costing and submitting bids.

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

Our research culture is to provide opportunities to industry and commerce with new ideas, techniques and methods for the betterment of the economy and wider society. This enables us to transfer computing know-how and rigor into other traditions thus expanding our research base across a wide range of disciplines. Our research is highly collaborative, frequently involving partner disciplines that are more public facing than computer science tends to be, giving us an opportunity to strengthen the discipline of UoA-11 through engagement with a wider society.

Research collaboration and mechanisms to promote collaborative research:

The success of the Unit is because of our long-established culture of strategic collaboration with our external partners. Over the REF period our staff have engaged in collaboration with numerous national and international companies and institutions. We collaborate with companies through KTPs, through consultancy, EU Framework grants, and through direct commercially funded contract research. Collaborating companies and institutions include Lloyds Banking Group; Callsign; Fricke und Mallah Microwave Technology GmbH; LD Didactic GmbH; Agilent Technologies; EDA Solutions; Nydor Syskus Technologies Anonymosetairia, Greece; A E Solutions (Bi) Limited; Fraunhofer Gesellschaft Zur Foerderung Der Angewandten Forschung E.V., Germany; Universidad Autonoma De Barcelona, Spain; Singularlogic Anonymi Etaireia Pliroforiakon Systimaton Kai Efarmogon Pliroforikis, Greece; Linkopings Universitet, Sweden; Centro Europeo Di Psicologia Investigazione E Criminologia, Italy; Stad Antwerpen, Germany;

Wyzsza Szkola Policji W Szczytnie, Poland; West Midlands Police Authority; Police And Crime Commissioner For Thames Valley; Ministarstvo Unutrasnjih Poslova Republike Srbije, Serbia; Hellenic Police,Greece; Live Srl, Italy, Swiss Federal Laboratories for Materials Testing and Research; Leibniz Institute for Solid State and Materials Research Dresden, Germany; Research Institute for Solid State Physics and Optics, Budapest, Hungary; Corrosion and Metals Research Institute, Stockholm, Sweden; Imperial College London; Univ. of Antwerp, Belgium; Univ. of Oviedo, Spain; St. Petersburg State Univ., Russia; Univ. of Belgrade, Serbia; Indiana Univ., USA; AQura GmbH, Germany; LECO Instrumente Plzeň, spol., Czech Republic; Thyssen Krupp Steel AG, Germany; Shiva Europe EAG, France; and TOFWERK AG, Switzerland. Our research activities and strengths have been heavily informed and shaped by our collaborations.

Collaborating with users is a natural part of our research and impact strategies. Much of our work is widely disseminated and the anticipation of that dissemination is fundamental to the thinking in the research. For example, *Kazemian* is part of a **€5 million EU-funded Horizon 2020 project** which is helping law enforcement agencies stop cybercriminals. Based across 17 organization in Europe, the EU-funded 'Scalable privacy-preserving intelligence analysis for resolving identities' (SPIRIT 786993) project will help law enforcement agencies identify cybercriminals by developing sophisticated artificial intelligence-based (AI) tools that can analyze millions of pieces of data from a wide range of sources, including the so-called Dark Web. London Met is the only university from the UK involved in this ground-breaking EU-Horizon 2020 project.

In terms of professional leadership activities, as is evident in Section 2, our research active staff collectively hold editorships and editorial board memberships. In addition, some members are Fellows of IET, senior members of IEEE, and the BCS; 2 have served as members of the EPSRC Peer Review College during the period; 1 is Chair and Executive Member of IET Technical Professional Network; 1 has served in judging panel of IET's Innovation Awards since 2014. As is evident in Section 2, during the REF period members of the School have given invited keynote addresses at international conferences, workshops, research seminar and have organized or co-organized conferences or workshops, examined PhD thesis nationally and internationally.

We also work with our specialist business incubator, Accelerator, in Shoreditch, the heart of London's ICT and digital media community (https://accelerator-london.com/), with our researchers in the Unit providing expert help, advice and support. In 2019, the Accelerator generated revenue of £24.3M, created 94 jobs and raised £10M of investments.

The Unit has several mechanisms to facilitate research collaboration with other institutions and industry. To aid this, the Unit hosts bi-monthly research seminars where external guest speakers are invited from other HEIs, industry and commerce. This informal forum allows research active staff to network and seek opportunities for collaboration. We have Industry Liaison Group comprising of industry members some of whom collaborate on research projects. Students and staff exhibit their work through posters, demonstrations and talks at our annual Research and Enterprise Day. We invite external guests to the event from industry and commerce. This is a show case event that provides our staff to discuss with external people ideas for research, funding opportunities, KTP ventures and consultancies. The external guests help us understand professional practice and help us bring those ideas to computing as well as bringing computing ideas to these practices. Research staff regularly attend conferences and external academic institutions and industry to network for collaboration partners.