Institution: University of East London

Unit of Assessment: 11

a. Overview

The *School of Architecture, Computing and Engineering* (ACE), was established in October 2011 bringing together the subject areas of Computer Science and Informatics (CSI), to provide an organisational foundation that better supports our research plans, recognising research as a mainstream activity and strengthening our academic core to support our research strategy. Our new submission to UOA11 represents the work of a core of 4 staff (4.0FTE) from the **Software Systems Engineering research group**. The group's research is focused on two main clusters: *Software Systems Security* and *Service Oriented Computing*. The group have current funding of around £2 million from EU FP7, EPSRC and TSB. The development of the unit contributes further to our strengths in the UEL research theme of *Creative, Digital and Information Technology.* The unit has a long tradition of consultancy and knowledge transfer to the local community through schemes such as Innovation for Growth, Knowledge Connect, Innovation Associates, Enterprise Bureau, and Knowledge Transfer Partnership (KTP). CSI at UEL is supported by an Industrial Liaison Board to assist us in evaluating impact and to contribute to strategic decision-making.

b. Research strategy

This unit was not submitted in 2008 and our aim has been to create a new focussed academic core and to begin to build this new area of UEL research. We are pursuing 5 strategic aims to: (i) attract high quality research staff; (ii) enhance our research culture; (iii) develop high quality research clusters in Software Systems Security and Service Oriented Computing; (iv) produce high quality outputs; (v) build our academic collaborations, networks and reputation.

i) Attract high quality research staff

Enacting the key objectives of the *UEL Research Strategy* we have invested significantly in developing a strong academic research core by making a number of research-oriented appointments in the last few years, including appointing a number of lectureships and early career researchers. Three of these appointments (**Islam, Tartary, Falcarin**) are included in this submission, strengthening areas of expertise in software engineering and security engineering. This influx of new staff has contributed to the development of a new, dynamic, research culture, which is also impacting on longer-standing academic staff (see staffing strategy), who are developing and strengthening their research profiles and progress through the academic scales (e.g. promotion of **Mouratidis** to Reader).

ii) Enhance our research culture

We have made significant progress in developing a sustainable research culture that can support our vision to further develop our research activities. We have a number of research activities established on the School calendar and have hosted a number of visiting researchers and academics (e.g. Prof. Henderson Sellers from Australia and Prof. Edgar Weippl from Austria). The School also organises research seminars for external speakers (e.g. Prof. Christian Collberg, pioneer of software protection research). At least 10 seminars are organised per academic year, with speakers from academia and industry. Other activities include: Undergraduate Research Internships, a UEL-wide scheme where undergraduate students are funded to work on a 10 week research project in the summer; the School Research showcase, where staff and PhD students present their works to ACE staff and students but also external collaborators (both from industry and academia); and the UEL annual research conference. Additionally, research student seminars take place frequently (at least once per month), in which PhD students present their research works.

iii) Develop quality research clusters in Software Systems Security; and Service Oriented Computing

Software Systems Security: Our work in this area is contributing mainly to the domains of requirements engineering (Security Requirements Engineering), and code and protocol development (source code obfuscation and security protocols analysis). We have pioneered work

(**Mouratidis**) which has resulted in the development of Secure Tropos methodology (see impact case study titled "The impact of Secure Software Systems Engineering to business processes and information systems". Our research has shown that the use of the methodology leads to the identification of security requirements that might otherwise have not been recognised. In today's systems, where security is of critical importance, the lack of identifying all the relevant security requirements might lead to the development of systems that are vulnerable to security threats. Work in that area has been enhanced (**Mouratidis, Islam**) with the development of a framework to support the consideration of laws and regulations during the development of secure software systems. In particular, the novelty of the framework is that it enables software developers to: (i) correctly elicit security requirements from the appropriate laws and regulations; and (ii) trace these requirements throughout the development stages in order to ensure that the design indeed supports the required laws and regulations. We have furthermore developed (**Islam**) heuristic assistant tools to support reuse of existing experiences that are relevant for security. In particular, they include Bayesian classifiers that issue a warning automatically when new requirements seem to be security-relevant, which improve the ability to identify security-relevant requirements. We have made also important research contributions to the domain of Source code obfuscation. Source code obfuscation is a protection mechanism widely used to limit the possibility of malicious reverse engineering or attack activities on a software system. Although several code obfuscation techniques and tools are available, little knowledge is available about the capability of obfuscation to reduce attackers' efficiency, and the contexts in which such efficiency may vary. For example, **Falcarin** has developed research that quantifies to what extent code obfuscation is able to make attacks more difficult to be performed, and reveal that obfuscation can mitigate the effect of factors that can alter the likelihood of a successful attack, such as the attackers' skill and experience, or the intrinsic characteristics of the system under attack. On the other hand, **Tartary** has made important contributions to the construction and analysis of protocols for secure distributed computing. A major axis of this research is data authentication. Recently, **Tartary** has developed a black box construction based on list recoverable codes for authenticating streaming. In addition, he has shown how to tune internal parameters to satisfy several efficiency trade-offs such as computational power and throughput. This work has applications in a large set of areas including videoconferences, software update, air traffic control and stock quotes. **Tartary** has also made contributions to securing multiparty computation. This covers areas such as electronic auctions and database interactions. He has targeted the problem of designing protocols for generic function evaluations. A key point in this work is that the communication complexity of our protocols is independent on the size of the Boolean circuit used to represent the functionality. This is a major improvement with respect to existing generic protocols in the area of multiparty computation and thus it opens new research directions to investigate the design of efficient protocols in this discipline.

Service Oriented Computing: **Falcarin**'s work has supported the development of the StarSLEE platform, which extends JAIN-SLEE (JAIN Service Logic Execution Environment) in order to compose JAIN-SLEE services with Web services and the StarSCE service creation environment, which allows exporting value added services as communication web services. In a Telecom world, JAIN-SLEE (JAIN Service Logic Execution Environment) is an emerging standard specification for Java service platforms targeted to host value added services, composed of telecom and IT services. Our work has led to the development of optimization for OAuth 2.0 adoption in the Enterprise. This optimization is achieved by introducing provisioning steps to pre-establish trust amongst enterprise applications' Resource Servers, its associated Authorization Server and the clients interested in access to protected resources. This is done with the introduction of referral tokens to enable Marketplace applications federation across organizations. In the proposed architecture, trust is provisioned and synchronized as a pre-requisite step to authentication amongst all communicating entities in the OAuth protocol, and referral tokens are used to establish trust federation for Marketplace applications across organizations. Moreover, we have contributed to the field of Capacity Planning at the deployment stage of cloud services as a way to eliminate the problem of overprovisioning of resources in Datacentres, which is currently a key industrial problem (leading to substantial waste in energy). By breaking the application into isolated modalities (a modality is a scenario in which an application is used) and measuring resource cost per modality, the research has managed to reduce overprovisioning from as much as 300% to just over 30%. On the other hand, **Falcarin**'s research has contributed

to the development of an effective architectural framework for context data management. The main novelties of such work include: the architecture with a generic context broker and pluggable context providers; the definition of a ContextML language for context data representation, and a Context Query Language (CQL) to access context information based on subscription and high-level data filtering. Asynchronous context requests to devices are supported using the XMPP protocol and context providers and application integration is simplified offering REST interfaces. **Mouratidis** and **Islam** have applied their works on security requirements engineering to the cloud domain, with the aim to develop modelling languages and methods to support the selection of cloud providers and cloud models based on security requirements. Recent research has shown that security is a major concern for the adaption of cloud computing. In particular, the lack of a clear and well-defined framework to assist cloud adopters to evaluate different providers and deployment models based on security requirements deters many organisations from moving to a cloud based infrastructure. The work produced by Mouratidis and Islam has introduced a novel solution to this gap, by the realisation of a method that relates cloud providers selection with security requirements.

iv) Produce high quality outputs

Members have published more than 150 peer-reviewed publications with a significant number in world-leading journals in their respective fields, such as *IEEE Transactions on Software Engineering* (e.g. **Mouratidis**), *Requirements Engineering Journal* (e.g. **Islam**, **Mouratidis**), *Journal of Systems and Software* (e.g. **Islam**, **Mouratidis**), *Journal of Cryptology* (e.g. **Tartary**), *The Computer Journal* (**Mouratidis**) and the *Empirical Software Engineering journal* (**Falcarin**). Such works have produced in excess of 2500 citations from the academic community. They have also contributed as guest editors in special issues in high quality journals and magazines (e.g. *Requirements Engineering* - **Mouratidis**, and *IEEE Software* - **Falcarin**) and they have contributed to books and conference proceedings related to their areas of research. Moreover, our findings have been cited and widely presented at high quality conferences such as *International Conference on Software Engineering* – ICSE, *International Conference on Requirements Engineering* – RE, *Advanced Information Systems Engineering* –CAiSE and *International Conference on Practice and Theory of Public-Key Cryptography* - PKC.

v) Build our academic collaborations, networks and reputation

We have been successfully building our reputation, academic collaborations and networks through publications of our work (see above section), and by investing in developing, at an international level, our working relationships with existing collaborators and developing new links. We have been successful in doing so as demonstrated by our contribution to EU projects (see section income, infrastructure and facilities) and our contribution to international working groups and activities as well as our leadership in events related to our research fields (see section e).

Future Strategy

Our future research strategy is focused on consolidating our existing success and expanding our research base in order to be recognised internationally for the quality and impact of our research. Our strategic vision is to be one of the leading national and international sources of expertise on the development of techniques and their supporting tools for the design and analysis of secure software systems and to play a key role in enabling the University to develop an international reputation for secure software systems engineering. We have five (5) main aims:

i) Support our early-career and mid-career research active staff

We have made several appointments of early career research staff (e.g. Bashroush, Naeem, Tawil). These appointees have already produced high quality outputs and made significant contributions to their areas of research but they need support to further build the quantity of their research outputs and expand their contribution to their research areas. We have a number of university and school wide initiatives (see Staff section) to support these early career researchers to achieve that aim and progress in making an important contribution to our research group. Moreover, in line with our research strategy to develop each generation of researchers, we plan to introduce opportunities and support for mid-career research active staff as we have done for early career staff. In particular, we plan to support our staff to improve their grant writing skills as well as provide UEL funding schemes especially for mid-career research active staff.

ii) Further expand our expertise

We aim to further develop our research group into a fully operational research centre, and explore and identify opportunities for cross-disciplinary collaboration within and outside UEL. We will strengthen our existing areas of expertise and develop new strengths in areas related to these, such as Software Protection, Software Architecture, Security Requirements for the Cloud, and Trust and Privacy Engineering. We will also explore new interdisciplinary areas such as Bioinformatics for computer modelling, simulation and analysis of models of micro-organisms in order to create effective drugs.

iii) Increase the generation of external research and knowledge exchange income

We will effectively utilise the existing UEL system to receive support for research bids to funding bodies by strengthening our relations and collaboration with the ReDS team and other relevant teams at UEL. We will support the development of the skills of our staff to increase success rates for external grant writing. We will support best practice and we will build a repository of successful grant applications that will be available to our staff. We aim to gain an average of £250k+ per researcher in the next assessment period.

iv) Establish a critical and healthy mass of postgraduate research students

We plan to develop clear routes from BSc to PhD in research areas where we have demonstrated strength, to provide opportunities for our top BSc/MSc graduates to engage in research degrees. We aim to develop our research culture to improve the inclusion of BSc and MSc students through internships and research-based projects, whilst simultaneously broadening the base of our PhD supervisory teams.

v) Further develop strong links with external academic and non-academic stakeholders

We will support the development of sustainable links with external academic and non-academic stakeholders, through a series of activities, such as an Annual Distinguish Seminar Series, specialised knowledge transfer workshops, and the Annual Master Class, where one or more distinguished researchers can be invited to work on a specific research subject. We are also planning to support active participation and contribution to relevant national and international conferences and gatherings. We will also strengthen our collaboration with the Industrial Liaison Board, which we are planning to extend, if necessary, to support the development of our research culture.

c. People

i. Staffing strategy and staff development

As is consistent with the *UK Concordat to support the career development of researchers*, we have focussed on recruiting, selecting and retaining researchers with the highest potential to achieve excellence in research; in the unit and the University, researchers are valued as essential to its human resources and the development of researcher's careers at all stages of the career cycle is recognised and promoted. Research ability, fit to existing groupings, and an existing research record, and/or potential, are important factors for our recruitment process. Since 2008, and in order to support our goal of enhancing our research culture, all new appointees must demonstrate they are research active. As part of our staff retention and development strategy, once appointed, research-active members of staff are given significantly lighter teaching and administrative duties than non research-active staff, with research activities explicitly included in the school's workload model. New academics are assigned a research mentor, advising on publication, the development of a funding portfolio, and general research career progression. Our strategy is to ensure that every research active member of staff is able to organise their time and commitments so they have around two days per week free from teaching in each semester. Further adjustments are made in cases of promotion or grant awards to enable staff to fulfil their research objectives. The majority of staff members have their own offices and their own networked computers, with relevant software for their research and teaching needs. In addition, the staff member in this unit have been supplied with specialist hardware and software for specific research project work.

To develop UEL researchers across their careers the *UEL Researcher Development Programme* offers a wide range of skills development workshops and on-line resources designed to meet the needs of research-active staff and postgraduate research students. This training curriculum uses the *Vitae* framework and is designed to help UEL meet the UK Concordats for researcher

development and integrity. UEL has recently been awarded the *HR Excellence in Research Award*. Staff from Computing have attended training courses in: securing grant funding, writing research papers, effective supervision and consultancy and knowledge exchange training. All research student supervisors receive regular update training. New research colleagues can improve their research skills by attending the School based M- or D-level, advanced research methods modules. In-house forums for research presentations within Research Groups provide constructive feedback to colleagues new to research. There is also a School based seminars series.

The Research and Development Support (ReDS) team provides UEL with a one-stop-shop service for supporting all aspects of academic research and knowledge exchange funding including consultancy and tenders. Appropriate grant application opportunities are brought to ECRs' attention by the Research Group leaders, mentors and the REDS unit.

Early Career Researchers (ECRs) are eligible to apply for the ReDS supported *UEL Early Career Researcher Accelerator F*und, awards up to £10K for each proposal, and a number of colleagues from CS&I that fit the eligibility criteria have been successful in obtaining funding for their research through that route (e.g. **Falcarin**, **Islam**). Internal School and University funding opportunities, including the Research Development Fund, the Alumni Start-up research grants, and the Undergraduate Research Internships scheme, are available to support all research active staff. Assistance may include funding attendance at conferences or engagement in external research activities or in preparing research proposals. Such funds have been focussed on achieving research outputs that can be submitted to the REF. CS&I researchers have been proactive in applying for such research funding and have successfully obtained Research Development Fund Awards (Islam, Tawil), UEL Alumni Start-up research grants (Naeem) and several undergraduate research internships since the UEL programme was initiated in 2011 (e.g. Tawil, Al-Nemrat, Naeem, Baravalle, **Mouratidis**, **Islam**, **Falcarin**).

In 2011 UEL initiated a staff sabbatical scheme to support development opportunities for individuals across the University by advancing their pursuit of research activity. Three full sabbaticals were awarded to CS&I staff in Semester B 2011/2 (e.g. **Mouratidis** and **Falcarin**) and a further two (**Islam**, Tawil) were granted in the 2012/13 academic year. Such sabbaticals have provided opportunities for staff to improve their publications portfolio (total of 12 publications, 8 journal and 4 conferences have been produced by relevant staff), to apply for external research funding (3 EU proposals and 1 EPSRC proposal), and to engage in knowledge exchange activities. Staff are encouraged and supported to apply for opportunities to progress their careers. Staff on fixed term research contracts are supported to apply for full time academic posts while staff on full time posts are eligible to progress their research career through the University's annual promotion round for Reader and Professor. We have retained quality researchers, who were initially on fixed contract appointments and are now on full time academic contracts (Lee from Research Assistant to Lecturer/Senior Lecturer) and we have provided development routes for colleagues who started their academic career with us (Mouratidis, Lecturer/Senior Lecturer to Reader).

In each School, research activity is monitored by the *Research and Knowledge Exchange Leader*, with close support from other professors and the Research & Knowledge Exchange Committee, a group which consists of senior researchers. These staff members also provide academic leadership in their fields and share in research management and mentoring and in leading new initiatives. For example, Computing is represented (by Mouratadis) within the ACE School Research Committee which is then represented at the senior research strategy forums in the University – the Academic Board and the Research Committee, as chaired by the Deputy-VC for Research. The latter committee meets three times yearly to bring together Research Leaders from across all UoAs. Each school has a PhD degrees leader and chair of the Research Degrees Sub-Committee (which oversees all post-graduate research students and their programmes).

The University's Staff Development and Review (SDR) scheme with its annual reviews for all staff includes personalized identification of research goals and training needs and a Personal Development Plan (PDP) agreed with the relevant line manager. Several non-returned members of staff in the Department are currently undertaking doctorates with the school supporting payment of fees. Doctoral studies are taken into account when setting staff workloads. New research active

members of staff are provided with opportunities, from early on, to participate in PhD supervision teams in conjunction with more experienced colleagues.

Equality and Diversity

We are committed to quality and diversity, from the recruitment process to the every day support we provide to our very diverse body of researchers in our unit. We have made a significant number of international appointments and our unit staff originate from 9 different countries. Members of the team have benefited from flexible hours and paternity leave and we are fully committed to the Athena Swan initiative.

ii. Research students

During the period of assessment, 13 students related to the unit have been awarded PhD degrees and 4 have been awarded Professional Doctorate degrees. There are currently 24 Doctoral students and eleven (11) Professional Doctorate associated with the CS&I unit. Sources of PhD studentships mainly include EPSRC and industry (e.g. ELC, BT, FORD) as well as overseas governmental schemes (e.g. Luxemburg Scheme). Most of the Professional Doctorate students are sponsored by the companies they are employed, such as *Reuters* and *Barclays*. Our research postgraduate students are a significant integral part of the unit's research environment.

Each student is allocated, at time of enrolment, a supervisory team, which consists of at least two members of staff with research knowledge and expertise related to the student's research project. Student progress is monitored thorough well-established events, including Annual Reviews and minuted supervisory meetings, and a list of important milestones such as Registration and Transfer. All students have access to all University facilities, including a 24/7 library, and a dedicated research student room with networked computers, printing facilities and phone links. The School also supports its PhD students to achieve an all round academic profile by providing funding for PhD students to attend internationally recognised conferences when they have an accepted paper and by providing opportunities for part-time teaching.

PhD students have to attend two taught modules related to research methods and research development. Moreover, there are various training opportunities provided by the School as well as the University's Learning and Development unit. We provide a long-standing and internationally recognised professional doctorate programme in Information Security that is undertaken predominantly by research. The Professional Doctoral students all have significant on-going working and practical experience, and as such they bring a different and complimentary dimension to our School's PhD students, creating an environment of Postgraduate research that is driven by theoretical as well as practical problems. We have supported our postgraduate research students to further their research careers either through support for external research or industrial posts or by retaining some of them to full academic posts (Al-Nemrat, Mousavi).

d. Income, infrastructure and facilities

We have been successful in securing funding from national and international funding bodies and industry. Some examples of recently funded projects include the PANDORA project (http://www.pandoraproject.eu), funded by the EU Framework Programme 7, CASE Awards with British Telecom (BT) and FORD through the EPSRC CASE Studentships scheme, Knowledge Transfer Partnership funded by Powerchex Ltd and the Technology Transfer Board. CS&I staff have also lead European Regional Development Fund supported projects on m-Commerce (m-com) and participated on two European Regional Development Fund projects on Sustainability (Eureka and Flash) assisting local SMEs in meeting the challenges in these key areas. More recently, with the advancements in developing our research culture, the unit has been more proactive and dedicated to increase our research income generation. As such, since August 2012 the CS&I unit has submitted 8 project proposals, for EPSRC, Royal Society and EU funding, of a total value of around £5.8 million. From those, 2 proposals have been accepted (EU FP7 projects of around £1.8million UEL funding). Additionally, we have secured funding under the EPSRC CASE studentship and KTP schemes. All these are not yet shown in HESA data since projects have recently started or start in early November 2013.

The unit has developed an infrastructure and a set of facilities to support its day-to-day operation.

In particular, we have control of a specialised Software Engineering laboratory where a series of powerful MACs and PCs are available alongside specialised software, and a dedicated security laboratory, which operates outside the university's backbone and supports computer security related activities. The School has research lab space for PhD researchers and research visitors. There are also computer laboratories for both teaching and research. A room has also been dedicated for "Research lunches", where research active staff, irrespective of the research group or research areas, can meet and discuss research over lunch. Recently CS&I researchers have been focusing their research in the domain of Cloud Computing, and a significant financial investment has taken place, through UEL capital equipment funds, for hosting our own cloud infrastructure consisting of 10 Dell PowerEdge rack servers. We are constantly making an effort to improve our facilities and an assessment of our current facilities is currently being compiled. From this information it is intended to produce a resource strategic plan that will enable CS&I to provide a platform to drive its research toward a healthier and stronger future.

e. Collaboration and contribution to the discipline or research base

Research links demonstrate our international reputation, which enjoys active research collaboration with some of the world leading academic and industrial groups in the UK and abroad. We collaborate on a EU FP7 project (ASPIRE) with teams, amongst others, from Ghent University, Politecnico di Torino, Gemalto Ltd. and NAGRA Ltd. In addition, we lead on a EU FP7 project (PEDCA) with collaborators such as Leeds University, TU Delft, DCA and CERIOS. We participate as external collaborators on a project funded by the Spanish Government and led by Prof. Medina – Paton at the UCLM Spain on security governance for the cloud. **Mouratidis** leads an Open Models Initiative (www.openmodels.at) project on developing automated tools to enhance security analysis and design of software systems, collaborating with researchers from the Vienna University (Austria), the University of the Aegean (Greece) and the University of Castilla La Mancha (Spain). **Mouratidis** is collaborating as a visiting professor with the University of Aegean in Greece and has hold visiting posts at the National Institute of Informatics (NII, Japan), University College London Computer Science Department, and British Telecom.

Falcarin collaborates with Prof. Mark Harman at UCL on software diversity for security and with Profs Basile and Morisio at Poletecnico di Torino (Italy) and Profs Ceccato and Tonella at Fondazione Bruno Kessler (Italy) on software protection. **Mouratidis** collaborates with British Telecom (Security Unit) and BOC Ltd (Austria) on developing novel methods for Trust analysis and modelling and with the National Institute of Informatics (Japan) on software systems compliance with laws through software patterns. **Tartary** collaborates on security engineering with Aarhus University (Denmark), Macquarie University (Australia) and Tsinghua University (China); **Mouratidis** and **Islam** collaborate on security requirements engineering with Prof. Jurjens (TU Dortmund) and Prof. Schneider (Leibniz Un. Hannover); and cloud computing security with Secure Business Austria Ltd.

Across our research areas, we are internationally active and competitive. **Falcarin** has been guest editor of IEEE Software special issue on Software Protection and on the PC of various conferences. **Islam** and **Tartary** have contributed to the organisation of relevant conferences. **Mouratidis** is editor in Chief of the International Journal of Agent Oriented Software Engineering and on the editorial board of leading journals including the Requirements Engineering Journal. **Mouratidis** has been general and PC chair of well-respected international conferences, such as CAiSE (General Chair, 2014) and has initiated events related to his area of research, such as WISSE. **Mouratidis** has grant-reviewed for EPSRC, EU and HEA and has acted as expert evaluator for EU projects. **Mouratidis** is member of IFIP WG 8.1 and ERCIM Security and Trust Management Working Group. **Mouratidis** has given keynote presentations to international events (e.g. WOSIS, Global Security), academic/industrial institutions (e.g. UCL, University of Vienna, University of Trento, BT, National Institute of Informatics) and he has contributed as subject expert in events organised by the EU (e.g. Secure Software Engineering Day) and NATO (e.g. Cybersecurity Day). **Mouratidis** actively participates on the Security Engineering Forum, an international effort to establish secure software engineering as a discipline.