Institution: UCL

Unit of Assessment: 14 – Civil and Construction Engineering

a. Overview UoA14 consists of the Department of Civil, Environmental and Geomatic Engineering at UCL (CEGE). In RAE2008 we were similarly grouped as UoA27. Our research continues its broad interdisciplinary interpretation of the role of civil engineering in society reported through our *REF2014 themes*: *Civil and Environmental*; *Transport* and; *Geomatics* enacted through *13 interdisciplinary Research Hubs*. For REF2014 we include two *UCL Institute of Risk and Disaster Reduction CatA* staff who work closely with CEGE's EPICentre and one from the new *Department of Department of Science, Technology, Engineering and Public Policy* (STEaPP) collaborating with CEGE's CTS and its transport themes.

Themes	Research Hubs and Academic Leads				
Civil and Environmental[1]	**EPICentre** Global Risk Mitigation (Tiziana *Rossetto*) (& **IRDR**)	**CREE** Environmental Engineering (*Julia Stegemann*)	**AIM** Advanced Materials (*Yun Bai**)	**HIRC** Healthy Infrastructure (*Lena Ciric**)	**USAR EngD Centre** (*Helena Titheridge*) Urban Sustainability and Resilience
Transport[2]	**CRUCIBLE** Lifelong Health & Wellbeing (*Nick Tyler*)	**CTS** Transport (*Nicola Christie*)	**QASER** Finance (*Francesca Medda*)	**ARG** Accessibility (*Nick Tyler*)	
Geomatics[3]	**P3DM** Metrology for Engineering & Heritage (*Stuart Robson*)	**SGNL** Space Geodesy (*Marek Ziebart*)	**ExCiteS** Citizen Science (*Muki Haklay*)	**SpaceTimeLab** Spatio-Temporal Data Mining (*Tao Cheng*)	

Table 1. UoA14 Themes and Research Hubs

Our environment is structured to take advantage of UCL's transdisciplinary capabilities, exemplified in the Faculty of Engineering and a key feature of CEGE. This encourages researchers to think about how their work can intersect with and impact upon global issues in order to *Engineer a Better World*. To support younger staff in this approach we have developed a number of Research Hubs, which give focus and strength for cross-disciplinary research grounded in expertise, foster leadership development, are conduits for communication and have the external identity necessary to align with and take full advantage of UCL's sustained *Global University* presence.

"Engineering a Better World" means regarding research and teaching as essential partners in the education and inspiration of the next generation. Whilst maintaining capability for research with a 1:11 staff / student ratio, our academic staff, facilitated by a *new management team structure,* have transformed our undergraduate programmes, winning *praise from the Royal Academy of Engineering* and recognition as the UK's "*premier Civil Engineering Department" in the 2012 and 2013 Guardian League Tables.* In parallel our EPSRC EngD Centre has catalysed a doubling in postgraduate research students. We have invested some £7M in research facilities and increased our academic staff count by a further 30% (new academics denoted by a *) since RAE2008 to foster an academic environment within which aspirations can be achieved.

b. Research strategy *Objective:* Our post RAE2008 *objective* was to build on our pre-2008 staff investment to strengthen research activity and capitalise on our inter-disciplinary portfolio focussed on the art, science and technology of engineering. This fits into a long term *strategic aim,* mirrored at both Faculty and Institutional level, to understand, develop and apply science to the practical progress of humankind, in order to secure an enhanced quality of life for all.

Aspirations have been achieved beyond expectations and are encapsulated and *driven* by our philosophy of "*Engineering a Better World*". The philosophy encompasses *activities* from city

design, managing an ageing population and transport infrastructure, developing low-carbon concretes, through energy, water and materials resource management, to the capture, understanding and communication of spatial data. Our *practical focus* seeks to identify and define the nature of world-challenging problems that give rise to world-changing research questions. These are tackled through engagement with colleagues in the disciplines necessary to investigate these questions and enable the implementation of solutions. Such team building is supported, for example, through strategic seed funding.

Achievements capitalise on our staff profile with its *major strength in the brightest and best early career visionary researchers* built through a strategic focus in our investments in people and resources over the last 10 years coupled with a *proactive collaboration strategy* based on our view of the challenges posed by the 21st century and how responsible research should respond. Key evidence is in our *EPSRC PI portfolio which at £17.67M is significantly greater than any comparable department in the UK* (July 2013 EPSRC GoW). A new UCL finance structure driven by significant and supportive collaboration between CEGE, Faculty and Vice Provost for Research support teams has empowered strategic investment evidenced by an *increase in academic staff numbers from 36 to 47* and *£7M of internal investment* in equipment, laboratories and workshops during the review period. The result is *unprecedented growth and a transformation from our RAE2008 situation*. The success of this approach is evidenced by the department moving up 156 places in the QS World Rankings (QS World Rankings 2013) since 2011, driven by a transformative change in the academic and employer reputation criteria, placing it 48th in the world and 4th in the UK in the subject area in the 2013 tables. The trajectory will continue as careers mature and publications and citations increase.

A new Department: UCL's new Department of Science, Technology, Engineering and Public Policy (UCL STEaPP) has recently been created to enhance our ability and expand our capacity to mobilise UCL's world class scientific (natural and social), technological and engineering expertise within public decision making environments. Over the next three years, UCL STEaPP is projected to grow to over twenty academic staff and forty research staff and students, all providing expertise, networks, policy exposure and professional training that will support and strengthen the policy impact of our research programmes.

Institutional research strategy: Our activity spans UCL's "Grand Challenges" maintaining research depth whilst accessing concentrations of specialist expertise across UCL and beyond to address aspects of the world's key problems: Global Health, Sustainable Cities, Intercultural Interaction and Human Wellbeing (the Head of CEGE is the Director of GC Human Wellbeing). As examples, elements in our portfolio include: three CIs within the UCL Energy Institute-led £5.7M *"RCUK Centre for Energy Epidemiology"* (Francesca Medda[2], Helena Titheridge[2], Ben Heydecker[2], Peter Jones[2] K011839); two CIs (Nick Tyler[2] & Francesca Medda[2]) on the University of Birmingham £6.3M *"Transforming the Engineering of Cities"* (J017698); the award of one of the Royal Academy of Engineering's four Centres of Excellence in Sustainable Building Design, led by Chris Wise[1], CEGE's Professor of Civil Engineering Design with CI membership from both CEGE and the Bartlett School of Architecture and the success of Nick Tyler's[2] £3.4M RCUK's Lifelong Health and Wellbeing Centre "CRUCIBLE" (G0700729) part of a 2008 to 2014 cross-research council initiative to strengthen multidisciplinary and collaborative research targeted at our ageing population. CEGE has been one of the most successful departments in applying for small grants from sustainable cities challenges and will lead a new UCL Transport Institute (Nicola Christie[*2]) fostering wider research collaboration and impact on societal policy.

Agile research: CEGE research structures benefit from being part of an exciting multi-faculty institution with strength across the range. Our *interdisciplinary research hubs* are formed by visionary individuals on a case by case basis considering the best focus for the funding and research domain. These are designed to accelerate the progression of early career academics who are aiming to create new multidisciplinary research areas – a task which is very difficult to achieve for any researcher, but even more so for those who are still early in their career. The hubs

provide an identifiable entity which can help to channel internal and external resources to support the endeavour. They are reviewed and adjusted where necessary to ensure that the focus is kept sharp and appropriate. The success of these can be seen in the high profiles obtained in the case of **EPICentre** (Tiziana Rossetto[1]) and **QASER** (Francesca Medda[2]). Both academics joined the department in 2004 as early career lecturers and have recently been promoted to Professor having achieved significant funding and recognition through their respective hubs. Our approach is flexible for both short and long term research activity and is able to quickly and proactively adapt to change, resulting in impressive outcomes in terms of research income. To illustrate, the CRUCIBLE Centre (Nick Tyler[2]) was set up on this model to facilitate highly speculative transdisciplinary research by supporting small seed corn projects allowing researchers across UCL to try out innovative ideas, undertake exploratory experiments or conduct literature reviews in unusual areas so that the evidence thus created can support applications for funding from more conventional resources. This has generated £15M of additional Research Council and industry funding most of which is actually realised across the whole of UCL and will appear in the relevant submissions for other UoAs. Our collegial environment encourages the breaking of traditional boundaries to expose novel lines of enquiry and inspire collaboration, thus it is no surprise that in financial terms *our CI activity is double our already substantial PI activity*.

Communication: Whilst each Hub is led by a dedicated individual, staff are encouraged to interact between Hubs in order to promote a *Research Continuum*. The continuum enhances bottom up communication between Research Hubs, complementing top down communication from University and Faculty, through our Departmental Senior Management Team and its Research Director. Intercommunication is emphasised through events such as *Open House Day* and *September Festival of Research* building from our RAE2008 “ideas room” concept.

Capacity building: Sustained funding requires *strongly focused and high quality proposals* submitted to a wide range of funders, including multiple funders for a single proposal. CEGE Research Committee (CEGE RC) strategy aims to increase the department’s funding portfolio by engaging with new sources of funding and by developing researchers’ proposal writing abilities. Higher success rates, particularly with EPSRC, enhance faculty driven strategic investment as well as the support of the research activity itself. To illustrate: **ARG** (Nick Tyler[2]) obtained some £8M of funding to CEGE in 19 grants (9 as PI) worth a total of £16M in the review period, which has been complemented by a further £11M from industrial contributions. As a result, **ARG** has grown from 1 PI and 2 PDRAs in 2003 to a team of 4 academics and 23 researchers and PhD students, completing 11 PhDs (4 in the review period).

Facilitating research: CEGE RC meets quarterly to support and promote our thriving and vibrant research culture: *weekly research seminars* with national and international speakers from industry, government and academia; *red teaming of all large RCUK grant proposals* with input from those who have been successful or act on panels to critique and provide positive feedback; A *SharePoint* repository giving *examples of successful grant proposals* along with responses to panel feedback; A close relationship with *Faculty research staff* who are well connected to RCUK programme managers to both understand and influence funding policies. Centrally held information in the *UCL IRIS research and RPS digital publication portals* provide automated information for CEGE’s content management system underpinning our website and REF2014 submission.

Engineering a better world for the 21st and 22nd centuries means developing deeper insights in the core civil and environmental engineering disciplines, taking into account not just the consolidation of knowledge gained in the last two centuries, but embracing and taking forward new knowledge developed in the most recent advances. This means *fundamentally innovative work in materials*, for example: Yun Bai*[1] has won a £1M TSB award to develop a microwave-based technique for manufacturing low-carbon concretes; Nick Tyler’s[2] EPSRC Wearable Assistive Materials project (K020323) is a new approach to improving locomotion for disabled people by means of an invisible exoskeleton, the developed material having obtained the interest of Airbus as a potential method for introducing shape-changing wings and seats. More broadly Luiza Campos[1]

is researching water treatment using UV and nanotechnology; Lena Ciric*[1] is working on airborne and haptic transmission of infections in constructed environments; Tao Cheng's[3] research seeks to model spatio-temporal complexity in society, economics and engineering; whilst Gert van der Heijden[1] has an internationally leading profile on the mechanics of braided and ribbon structures.

As exemplars: our Hub strategy has enabled and supported Tiziana Rossetto[1], to build up **EpiCentre**, a unique earthquake and tsunami engineering hub, bringing social psychology, anthropology, economics and engineering together to tackle the complexity of the needs of civilisations living in zones at risk. Work with HR Wallingford, funded by a Euro1.9M ERC Starting Grant, is developing the world's largest tsunami generator in order to reproduce the complete complex characteristics of tsunamis and thereby better understand the phenomenon and to take this understanding to areas badly affected by tsunamis. Similarly **QASER** has enabled Francesca Medda[2] to build a unique capability in financial modelling resulting in several £4M RCUK projects including: Explaining, Modelling and Forecasting Global Dynamics (H02185X); the International Centre for Infrastructure Futures (K012347) and the RCUK Centre for Energy Epidemiology and its study of energy demand in a population (K011839). It has also supported Nick Tyler[2] and **ARG** to exercise his approach to engineering, for example in the EPSRC Programme Grant "Transforming the Engineering of Cities" (J017698) in changing the entire vision, methods and use of engineering to meet future needs, developing new engineering techniques to drive the development of policy (in Colombia and Peru with FCO), the consideration of healthy ageing and infrastructure (in Japan with FCO and the British Council). One example brings together of UCL Chemistry, Chemical, Biochemical, Mechanical and CEGE to develop a new biofuel based on the extraction of hydrogen from rice, which has led the major Chinese bioenergy company to construct a £1.4M laboratory in their manufacturing plant in China for UCL Biochemical Engineering as part of a new-fuel-to-vehicle-design-to-city planning project in China which has a budget of approximately £2bn to reconstruct a city to support low carbon living In recognition of this innovative insight into technology for which Nick Tyler[2] was awarded the CBE in 2011. The same flexibility has supported Marek Ziebart[3] (**SGNL**) to develop a deep approach to space geodesy and navigation, resulting in a research group with multi-million pound funding that has led to NASA's adoption of its models as operational standards for missions contributing to IPCC policy. Stuart Robson's[3] **P3DM** has grown from a single academic to a 24 strong team: solving in-flight parachute and rotor craft wind tunnel tracking challenges at NASA Langley; validating next generation non-contact optical metrology tools with Airbus and NPL (EPSRC Light Controlled Factory K018124); developing novel large volume metrology instrumentation (EURO-MET IND53 Luminar); optimising 3D digital colour capture to exhibit 3D digital surrogate models across the International Museum sector and; developing new dimensional monitoring understanding for Network Rail's Thameslink Project through an EPSRC EngD.

Two future research goals will stimulate change in the real world to meet the complex challenges being thrown up by contextual variation (e.g. climate, political complexity, globalisation) in a variety of ways. First we will develop the core disciplines to become more transdisciplinary (learning from and being applied to different disciplines in depth), and more interactive with other nonconventional Civil, Environmental or Geomatic Engineering disciplines (cf **ARG** + Neuroscience, Neurology, Chemistry, Psychology; **HIRC** + Microbiology, infection control; **EPICentre** + Anthropology, Social Psychology, **ExCites** + empowering change through participatory citizen science), *The first CEGE goal is to be at the forefront of innovative reappraisal, study and implementation of new approaches to the disciplines of Civil, Environmental & Geomatic Engineering.* Secondly, we will bring about the implementation of the new knowledge through the development of strong axes of engagement with governments at local, national and supranational level to encourage and facilitate political involvement in funding the implementation of the knowledge in world-changing applications (cf **ARG** + China, Peru, Colombia), **CTS** + DfT, **CREE** + Environment Agency). *The second CEGE goal is therefore that within ten years we will see our approach being adopted in each of the major continents through our intellectual leadership in significant civil, environmental and geomatic*

projects. This development of intellectual leadership is core to the institutional vision and we would expect activities to be aligned with other departments within UCL.

We will Engineer this better world by activating *five headline objectives* geared to placing sustainable Research Hub activity in a global context so that at the end of the ten year horizon: (1) Each *Research Hub has tuned its research portfolio* to contribute directly to the achievement of the department's aims to address the world's desired outcomes; (2) *All Research Hubs have undertaken some blue-skies research*, especially by initiating, becoming involved in and developing multidisciplinary approaches and techniques across CEGE, UCL and the international research community as a whole; (3) *All Research Hubs will have undertaken some applied research*, including collaborations with the profession, industry, Government, the public and/or other bodies as appropriate; (4) We have *supported each member of academic, research and support staff* – and each doctoral student – to contribute fully to the overall research programme and to maximise their own potential; (5) We have *invested in the most relevant and up-to-date facilities* to advance leading-edge research.

New facilities to support our goals include: expansion of the **ARG** PAMELA facility to include multiple laboratories, climate capability and enhanced instrumentation; replication of the PAMELA laboratory model with new facilities in: Large Volume Robotics and Tele-operation (**P3DM**); an Environmental / Gravity Loading Walk-In Chamber (**EpiCentre**); radical improvement of our **AIM** materials laboratory by establishing advanced microwave systems and cement and concrete testing/analytical facilities and stronger interface with the Institute of Making. Through our **EpiCentre** collaborations with HR Wallingford, a joint Laboratory for Innovative Fluids Research is envisaged, building upon and expanding our unique tsunami generation capabilities that will become a hub for worldwide research on extremely long waves. We will instigate *new broad collaborations*: for example **ARG**'s laboratory facilities are already linked to the Royal National Orthopaedic Hospital, the UCL Institutes of Orthopaedics and Musculoskeletal Science, Ophthalmology, Neurology/Cognitive Neuroscience and the Ear Institute, the Department of Mechanical Engineering and the Bartlett for unique transformative research in sustainable human / built environment interaction, but these facilities will be incorporated more closely with the UCL Faculty of Population Health Sciences and the UCL Medical School to enhance research and medical practitioner education in community health. The resulting facility will then incorporate *a new model of community health provision, education and research*, in which the environment and its use as part of the therapeutic regime is included and research is instigated on the Citizen Science model of **ExCiteS** to ensure that future medical thinking includes civil and environmental engineering (and other) disciplines in order to become more effective in coping with the needs and challenges of a population challenged by the impacts of climate change and ageing. This is putting the outcomes of the CRUCIBLE Centre **(ARG)** into practice in a real and exciting way and placing innovative civil and environmental engineering research at the core of a multidisciplinary development of society for the future. The **ARG** PAMELA facility in its enlarged form will be at the core of this new concept.

c. People, including:

i. Staffing strategy and staff development

Strategic recruitment: CEGE has consolidated strengths and increased capacity in core areas in order to target growth through an ambitious equal opportunities policy of recruiting young staff and industry orientated staff. As a result we have increased our academic staff numbers, including teaching fellows from 36 to 47 whilst maintaining our 50/50 male/female staff ratio. Recruitment includes a new professorial appointment (Christopher Wise*[1]) to strengthen our design capability and industry links, two new readers (Ilan Kelman*[1] and Dina D'Ayala*[1]), senior lecturers Nicola Christie*[2] and Yun Bai*[1], and 10 lecturers: Jan Boehm*[3], Lena Ciric*[1]; Claire Ellul*[3]; Raul Fuentes*[1]; Taku Fujiyama*[2]; Stuart Grey*[3]; Paul Groves*[3]; Catherine Holloway*[2]; Rodolfo Lorenzo*[1] and; Shepley Orr*[2]. Our team also comprises 33 research staff, 26 technical and professional staff and four teaching fellows, targeted to reduce the teaching duties of research

active staff, particularly new academics.

Promotion: Six professors have been promoted since RAE2008 following their attainment of UCL's world class seeking criteria (Tao Cheng[3], Francesca Medda[2], Muki Haklay[3], Stuart Robson[3], Tiziana Rossetto[1] and Marek Ziebart[3]), and four senior lecturers (Sarah Bell[1], Luiza Campos[1], Helena Titheridge[1] and Jan Boehm[*3]). All promotions followed the UCL Excellence document embodied through staff appraisal often accelerated following recognition of research success (RAE208 strategic aim).

Career development: *Early career researchers* are prepared in terms of teaching experience, publication, enabling and outreach skills required to enter a full academic post, whether this is at UCL or elsewhere. The department follows the *UCL Concordat to Support the Career Development of Researchers and Teaching Fellows*. A research-specific mentoring system for new academics is provided, as part of the probationary process, by the *UCL Staff Development Training Unit* and includes training in managing research, PhD supervision and research finance. All staff have access to the in-house networking facilities including the *Open House and September Festival of Research events*. Selection for decision making posts and committee membership is made by expression of interest and evaluation against a role description. All roles are advertised, limited to three or five year periods, and include clear role descriptions to allow rotation between staff. *Our open and transparent approach ensures workload balance, promotes gender equality and addresses individual career progression.*

World Leading Careers: Our capability to foster the next generation of world class research leaders is evidenced through *three RCUK Challenging Engineering Award holders* within the review period. Each ~£1M award holder has been supported to form a Research Hub able to act as a focus and building block for their activity: **EPICentre** was formed by Tiziana Rossetto[1] (F012179); **HIRC** with its unique biological laboratory was formed by Ka-man Lai[1] (G029881) and is now led by Lena Ciric*[1]; **ExCiteS** has been grown from the RAE2008 Chorley Institute by Muki Haklay[3] (I025278). We have the capacity to further grow outstanding careers evidenced by the *2013 award of a 5 year European Research Fellowship* to Tiziana Rossetto[1] and by Nick Tyler's[2] position in the "top 50" research earners within UCL, one of only 4 in UCL Engineering. Ka-man Lai has taken up a Chair in Hong Kong Baptist University, and Julien Harou will take up a Chair with Manchester University commencing in November 2013.

***Enhancing research capacity*:** *A new two level management structure* was instigated in 2009 to accommodate growth. This comprises a *strategic level* led by Head of Department (HoD) (Nick Tyler[2]) and four Directors: Research (Nicola Christie*[3]); Education (Paul Greening[1]); Knowledge Transfer (Richard Simons[1]) &; Finance (Richard Sharp). Five Section Heads (Dina D'Ayala*[1], Julia Stegemann[1], Yun Bai*[1], Helena Titheridge[2] & Jon Iliffe[3]) constitute the facilitating level, each managing around ten staff grouped by *CEGE Theme*. Section Heads report to the HoD, manage workload and deliver formal appraisal to *ensure each academic has the capacity and freedom to develop their own research remit*. Cross linked with Research Hub ambition and resourcing, the two layers meet monthly to ensure good communication and deep understanding of the research priorities, resource needs and capacity of all academics.

Commitment to equal opportunities: CEGE was awarded an Athena Swan Silver award in 2009, extended in 2013. As a direct result of our policies *to promote women academics at all levels* and to *increase the number of women in positions of leadership*: women are being promoted at a faster rate than men in CEGE; the proportion of women at Lecturer, Senior Lecturer and Reader positions are dramatically higher than the national average and; nearly 50% of our management team are women. CEGE is enhancing its family friendly policies to apply for Athena Swan Gold in 2014. More widely CEGE takes a lead role within UCL Women in Engineering and participates in the UKRC gender culture pilot survey. CEGE has a diverse staff covering 14 different nationalities.

Investment in technical staff: Applied research necessitates well founded laboratories which can only thrive with sustained expert staff. Technical staff are employed on continuing contracts funded

from core CEGE budgets to avoid the uncertainty of ad-hoc project commitments. A full time Technical Resources Manager (Ian Seaton) balances workload and ensures that all facilities have the responsible and reliable technical cover necessary to support research. Expansion during the review period has resulted in the recruitment of 3 new technical staff, bringing our complement to 26, all of whom have entered our system of training and continuous professional development. All technical staff are required to have appropriate professional qualifications and are supported in their progression to Incorporated Engineer status where appropriate. As a result of the increasing level and inter-disciplinary complexity of our research activity some of our support staff are required to be educated to PhD level. Currently three of our technicians have PhDs.

ii. Research students

A Hub of Postgraduate Activity: CEGE postgraduate research is accomplished through a broad portfolio of studentships funded by external sponsors, including EngD, Industrial CASE, KTPs, scholarships and those funded privately. Postgraduate *student numbers have doubled to 120* in the review period. Funded until 2018, CEGE's *EngD Centre in Urban Sustainability and Resilience* **USAR** (Helena Titheridge[2], Marek Ziebart[3], John Twigg[1]) draws upon £6M of EPSRC funding supporting 50 doctorates as well as leveraging further studentships *meeting our most ambitious RAE2008 strategic goal*. It has accelerated our postgraduate research activity and enhanced our industrial and governmental connections. The centre has built creatively upon our location in the heart of London, *the investment and civil engineering construction capital of the UK* and UCL's reputation as one of the world's premier Universities. CEGE engages across UCL with additional Engineering Doctorate Schemes, including "Vision, Imaging & Virtual Environments (VIVE)" and forensically orientated "UCL Secret". Here we strike a balance between the EngD cohort and a feeling of belonging within CEGE by assigning each student into a Research Hub. For example four UCL VIVE students are assigned into **P3DM.** The CRUCIBLE Centre (Nick Tyler[2]) has 13 interdisciplinary PhD students, each being based in two faculties in UCL. CEGE provides the hub resource to bring them together and hosts the associated MRes in Lifelong Health and Wellbeing. **USAR** has also spun out a change in our PhD student education with cohort working, the ability to take formal courses in "Research Methods" and "Professional Development". Students are encouraged to attend faculty events such as inaugurals and lecture series and have access to material across UCL. CEGE supports and hosts a cohort of 10 PhD students associated to the EPSRC Programme Grant (J017698) (Nick Tyler[1]) and we are working on extending our approach for research training to the students associated with this project and based in other universities in the Consortium. CDT activity will be further supported through Stuart Robson[3], CI in the recently announced £5.4M EPSRC CDT in Science and Engineering in Arts, Heritage and Archaeology led by UCL Bartlett's Sustainable Heritage in partnership with Oxford and Brighton Universities.

Student recruitment: **USAR** *manages a highly competitive call for funded places* by bringing industry, prospective students and academics together at its *annual recruitment fair*. In addition to EngD, CASE, UCL scholarships and institutional DTC allocations, CEGE allocates finance for several studentships each year. Awards are made through a competitive process managed by Postgraduate Tutor (Taku Fujiyama[3]). All postgraduate admission is supported through the Engineering Faculty Prism administration system. The relatively high proportion of female supervisors for projects and the focus on linking our research to real world, interdisciplinary problems help attract female research students to engineering and evidence the effectiveness of our equality policy. *46% of CEGE postgraduate students are female (national average 18%).*

Student progression follows a *UCL wide Graduate School skill development programme* and is centrally administered via the UCL Electronic Research Log. This process ensures that all of our postgraduate students experience a common pathway and helps to foster CEGE cohort activity. Pivotal to progression is the secondary supervisor, who has responsibility for the *rigorous UCL MPhil / PhD transfer process allowing both student and staff to reflect on progress and make decisions on direction*. As part of our family friendly policy, the secondary supervisor is also a fall back principal supervisor in case of illness or maternity leave of the principal supervisor. Within

CEGE the cohort experience consists of a rich mix of research student seminars, networking events, EngD Centre industrial events and information on the CEGE intranet. Professional staff member Sarah Davies has recently been appointed as Postgraduate Research Administrator to further develop the cohort experience.

Bridging the gap: When nearing completion students are assisted with industrial engagement through the UCL career service. REF2014 metrics demonstrate a jump in completion rates linked to UCL's strategic studentship investment during RAE2008. EngD completion will have a significant effect in the next research cycle. EngD projects coupled with follow on funding provide a direct way of stimulating career research. For example "Integrated Production of Algal Biomass" [Varicon Aqua Ltd & Luiza Campos[1]] with inter-faculty collaboration focussed on renewable and sustainable replacement of conventional petrochemical refineries. The project has secured follow on funding through our EPSRC "Bridging the Gaps" (Sarah Bell[1]) scheme to develop a larger scale working prototype located on the CEGE roof. We also make use of the availability of UCL Graduate School Funding to carry RAs and PDRAs between projects. In addition promoting students to think of follow on funding before graduating can be highly effective, this is evidenced by the ESRC/NERC Fellowship awarded to Victoria Sword-Daniels[*1] on 1st October 2013 enabling her entry into this UoA as an independent researcher.

d. Income, infrastructure and facilities

Income: Our goal to strengthen our core EPSRC research through strategic investment in new staff and facilities, supported through a team based internal pre-review process, has *exceeded all of our RAE2008 income targets*. In addition to our UK leading PI based EPSRC funding portfolio, 21 EPSRC awards with significant CI activity highlight the success of our collaboration strategy. A third of our EPSRC successes include key input from new academic staff. *The chronology of our combined PI and CI EPSRC investment portfolio represents a ten fold increase on RAE2008*: 7 awards commenced during and will complete within REF2014 (£6.15M); 17 awards commenced during REF2014 and will complete between 2015 and 2018 (£43.12M) (EPSRC GoW). With NERC we held 7 PI grants to the total value of £1.47M including significant awards for satellite orbit modelling and dynamics (Marek Ziebart[3]), a Knowledge Exchange Fellowship (Victoria Sword-Daniels[1]) and a doctoral training grant (Nick Tyler[2]). Recent EU funding awards, for example in big-data (Jan Boehm[3]) and metrology (Stuart Robson[3]), have attracted collaborations with MIT, NASA, Fraunhoffer and Airbus. CEGE growth parallels that of our interdisciplinary Faculty of Engineering *which holds the second largest EPSRC portfolio in the UK and has increased its research income by 70% in the last 3 years*. We are seeking to increase our international research and industrial funding and to increase the proportion of funding coming from UK Research funders other than EPSRC. The aim is for these combined sources to match our core EPSRC income by 2018.

Infrastructure: Our collaborative philosophy recognises the need for new equipment and laboratories resulting in a broad *£800K Research Hub equipment investment* in 2010-11. We have also invested in a *computing server backbone* with a move to take advantage of virtual server technology and; through consultancy we have funded *equipment for* **ARG** at our off-site PAMELA laboratory, including a £100K *fibre optic link*. Larger items include: a London-spec double decker bus equipped with a wide variety of sensors for ARG (£360K) and updating equipment and a new technician for HIRC. A 2013 *£2.4M EPSRC equipment award* (Robotic Teleoperation for Multiple Scales: Enabling Exploration, Manipulation and Assembly Tasks in New Worlds Beyond Human Capabilities), backed by £600K of UCL cash, partners UCL Computing Science, **P3DM** and MIT in a new pioneering robotic tele-operation facility in bioengineering, healthcare and manufacture with **P3DM** will developing robotic large volume sensing for manufacture and reverse engineering.

Facilities: The review period has seen an *acceleration of investment and refurbishment* into the Grade 1 listed Chadwick Building in order to improve research infrastructure and particularly to strengthen our core Civil Engineering facilities. Highlights include: recently constructed facilities for **ARG** with its *internationally leading Pamela laboratory* located in leased premises investigating

people movement in full size tube trains for example (£2.8M); **EPICentre** with the arrival of Dina D'Ayala*[1] and *a test facility for historic buildings (£50K)* and with *completely refurbished geotechnical laboratories* (£440K); an EPSRC Challenging Engineering award into **HIRC** £1.22M (£250K from CEGE) for a *unique laboratory to investigate pathogen interaction* with the engineered environment; **USAR** with a *new EngD dedicated space* (£170K); **P3DM** with a laboratory to make a *step change in optical metrology* for monitoring, manufacture and construction (£60K); **SpaceTimeLab**, with research space for the digital modelling and analysis of behaviours and interactions in complex systems (transport, crime, and social media); refurbished space for a *UK Transport Research Centre* with a £244K CEGE contribution; a £9K contribution to UCL Estates and Facilities *refurbishment of **AIM's** concrete lab;* A new *3D imaging and visualisation* workstation space in GM06 (£45K). All five floors of the Chadwick Building have been largely refurnished to better accommodate staff and students, for example we have updated two postgraduate research spaces with £70K of new furnishing. Research space has been increased following the £50K digitisation of our Transport and Geomatics libraries. *Faculty strategy in the next funding cycle will drive major refurbishment in our estate and alleviate space constraints on further growth.*

e. Collaboration or contribution to the discipline or research base

Engineering international change is an essential step in delivering on our future goals. **ARG** has built a successful portfolio of 'technology diplomacy' research activity, funded by the UK Foreign Office in China, Japan, Peru, Colombia and Cuba, in which the quality and rigour of the Group's research into accessibility and sustainable city design is the basis for achieving wider diplomatic and commercial benefits for the host countries and the UK and leverages a total associated project budget of ~£10bn. **AIM** is drawing upon extensive Chinese research excellence and practical experience in order to develop novel cushion layer materials for future high speed railways. Royal Society and Natural Science Foundation of China joint International Exchange Scheme (2013-2015) sponsorship has established a strong partnership with Tsinghua University and Central Research Institute of Building and Construction in China. **CREE** is working on Sustainable Water and Sanitation Systems applying hydro-economic modelling techniques have been applied in projects in collaboration with the University of California Davis, UK water regulators, the World Bank and the European Commission through the ARCC-Water project. Another direct example is **EPICentre**'s "Networking for Resilience" supported by the International Institute for Environment and Development - one of the world's most influential international development and environment policy research organisations. **SGNL** developed techniques for modelling surface forces on space vehicles adopted as operational standards by NASA Jet Propulsion Laboratory and Goddard Space Flight Centre for the principal satellite platforms used to measure global sea level change, and also developed the gravity field models used as the national standard to define height by the Ordnance Survey – hence supporting all major UK civil engineering construction projects.

International Networking: We continue our track record of hosting international workshops, for example: World Bank World-wide Water Hackathon 2011 (Julian Harou[*1]); Spatio-Temporal Data Analysis and Data Mining & ISPRS II/3 Workshop 2011 (Tao Cheng[3]); Urban Data Management Society 2013 (Claire Ellul[*3]). CEGE hosted 52 visiting researchers and academics, 182 associate staff and 38 continuing students during the review period, including RAEng funded Senior Visiting Fellowship recipients Prof. Mark Shortis, Australia and Dr Angelo Beraldin, Canada. A *recent sabbatical policy review* will further expand the opportunities for academic staff to engage in reciprocal exchange with international partners.

Strategic agreements: In addition to UCL's development of UCL Australia in the area of Natural Resources, CEGE has collaborative research agreements across its remit including: University of Illinois at Urbana Champaign; Joint Centre of Disaster Research in Massey University, New Zealand; University of Aveiro (Portugal), Korea Institute of Technology Construction, University of Los Andes (Colombia), Pontificia Universidad Catolica del Peru, Guangzhou Research and Development Institute (China) and Henan Tianguan Group Key State Laboratory (China).

Industry collaborations include many of the key leaders in our discipline. For example EngD and CASE funded studentships span fundamental and applied research with Arup; Laing O'Rourke; Expedition Engineering; Atkins; Network Rail; Airbus; NPL; Local and UK Government; Willis RE; World Bank and; AIR. UCL owned company **UCLB** *provides institutional level assistance for industrial collaboration*, for example fostering a five year partnership with Canadian Company Arius3D in 3D Colour scanning leading to the award of "Best SME" in 2010. Similar support fostered a £1. M TSB award to **AIM** and City University, partners Microwave Systems Ltd, Macrete Ltd, Network Rail, The Concrete Society, British Precast Concrete Federation, Highways Agency, Constructing Futures Ltd and COMSOL Ltd to develop a lower energy solid-state microwave system and related concrete manufacturing techniques for manufacturing low-carbon concretes. Efficient consultancy engagement is embodied in **UCLC** which provides negotiation, legal and budget support needed to sustainably engage with the project orientated industries that typify the engineering sector. Exemplars include: DfT Boarding and Alighting times for Thameslink 2000; London Underground Analysis of platform humps; TfL Analysis of horizontal delineators for Exhibition Road and; London Underground Design analysis for the New Concept Deep Tube Train. UCL's **Research Grants and Contracts** provide a *research collaboration pathway permitting academic publication*, for example: **P3DM** guided Airbus in the metrology necessary to validate the performance of Airbus 350 composite aircraft prior to CAA first flight approval; **SpaceTimeLab** led a quantitative assessment of road works and tube strikes on London road traffic leading to a TfL Central London charging scheme and a visualisation tool enabling TfL to reliably evaluate 2012 Olympic Games journey time; whilst **CTS** has participated in numerous safety related projects, including a £1M evaluation of the Neighbourhood Road Safety Initiative.

Contributions to the discipline are diverse with the following giving a flavour of our activity: BSI where Tiziana Rossetto[1] serves on Committee BS525/8; Stuart Robson[3] advises on CPW/172 and Lena Ciric[*1] contributes to ISO 15883. Peter Jones[2] is a member of the Independent Transport Commission, the London Roads Task Force and Overseas Special Advisor to the International Association of Traffic and Safety Sciences. Francesca Medda[1] advises UNESCO, The European Investment Bank, TfL, VEOLIA and UITP through **QASER** with projects such as trade facilitation in Uganda and in the South Pacific Islands for the World Bank. Richard Simons[1] serves on the UK Coastal Monitoring and Forecasting Service Advisory Group and on the ICE Journal of Maritime Engineering Advisory Panel. Marek Ziebart[3] regularly contributes to news items and documentaries on BBC Radio 1, 4, 5Live, News 24 and World Service. Julia Stegemann[1] is a Fellow of the Institute of Materials, Minerals and Mining, European Editor of Environmental Engineering Science and on the ICE Waste Management Board. Ben Heydecker[2] is a Fellow of the Royal Statistical Society and the Transport Research Foundation; John Ilife[3] and Stuart Robson[3] are Fellows of RICS whilst Nick Tyler[2] is a Fellow of the ICE and the Royal Society of Arts and was appointed CBE in 2011 for services to technology.

***Contributions from new staff* members** are encouraged through formal appraisal and evidenced by Nicola Christie's[*2] membership of the Parliamentary Advisory Council for Transport Safety and recent invitation to be a founding member of a National Safety Commission; Raul Fuentes[*1] as a chartered engineer with ICE and a qualified Ingeniero Industrial; Dina D'Ayala[*1] edits the Bulletin of Earthquake Engineering and heads an EU COST action. IRDR's David Alexander[*1] is Editor-in-Chief of the International Journal of Disaster Risk Reduction, he also received the Distinguished Research Award from the International Society for Integrated Disaster Research. STEaPP's Professors Brian Collins (CB, FREng, FBCS, FIET, FIOP, FICE, FRSA, CEng) and Jeremy Watson (CBE, FREng, FIET, FICE, FRSA, CEng) bring a wealth of government and industrial senior management experience. This includes serving as Chief Scientific Advisor across several government departments (Collins: Transport; Business, Innovation & Skills; Watson: Communities and Local Government), and Director of Science and Technology in leading government agencies and corporations (Collins: Government Communications Head Quarters; Watson: Arup).