

<p><b>Institution: Plymouth University</b></p>
<p><b>Unit of Assessment: 15 General Engineering</b></p>
<p><b>a. Overview</b></p> <p>Research activities in civil and mechanical engineering at Plymouth University (PU) are primarily focused on marine systems and interactions and on energy generation. There are strong interrelationships between these foci and the research is supported by an inter-disciplinary and collaborative environment, with major strategic initiatives having strengthened engineering research activity since RAE 2008. An overarching intention has been to exploit interdisciplinary expertise across the breadth of the marine arena at Plymouth. One strand of this has been the establishment of a new University approved Research Centre in Advanced Engineering Systems and Interactions (CAESI). The burgeoning research links within this grouping naturally lead to a combined REF 2014 return to General Engineering rather than the separate civil and mechanical engineering submissions that were made in RAE 2008. CAESI is organised into five research groups: Coastal Ocean and Sediment Transport, Materials and Structures, Composites and Manufacture, Analysis and Dynamics, and Engineering and Society. The recognition of CAESI has encouraged additional staff to become research active, with the total value of grants awarded in the REF period equal to £6.158m, has stimulated collaboration between civil and mechanical engineering, and provided a powerful base for the mentoring of early career researchers.</p> <p>Formation of a School of Marine Science and Engineering was an outcome of a strategic review following RAE 2008. It was intended as a springboard to enhance excellence in marine science and engineering through targeted team building focused on established academic leaders. It is a powerful academic grouping in the Faculty of Science and Environment, which includes the Schools of Computing &amp; Mathematics, Geography, Earth and Environmental Sciences, and Biological Sciences, and works with Biomedical Sciences and Psychology in the Health Faculty and Medical School. The PU Research and Innovation Strategy highlighted areas for growth and investment to be organised through strong Institutes and Research Centres. This led to the formation of CAESI, working alongside the Centre for research in Coastal and Ocean Science and Engineering (CCOSE) under the umbrella of a Marine Institute. Focused appointments have been made to align research excellence more closely with the marine sector, particularly marine renewable energy. Further driving this has been the realisation on the Plymouth campus of the £1.9M suite of nationally-leading Coastal and Ocean Sediment Transport experimental facilities (COAST Laboratory) in the new <b>£19M Marine Building</b>, completed in June 2012. This strengthening of the research expertise in coastal and ocean engineering, allied with marine physics, marine and coastal policy and marine biology (all of which form part of the School of Marine Science &amp; Engineering) has led to significant research success in European and RCUK funding as well as bringing advanced research in materials and structures to bear on the marine sector.</p> <p><b>b. Research strategy</b></p> <p>'Marine' in virtually all its aspects has been a focus of work at PU since the founding of the School of Navigation in 1862. It is a key strategic area in the University's Strategy 2020 and in its Research and Innovation Strategy. Thus there is extensive and broad expertise across the marine and maritime arena, ranging across marine-related undergraduate and postgraduate programmes, through a focus on marine-related research to the enhancement of strategic partnerships with marine education providers in the Plymouth area (e.g., Britannia Royal Naval College, BRNC, and the new marine University Technical College, UTC) and with external marine-focused research activities in and around Plymouth (Marine Biological Association, Plymouth Marine Laboratory, Sir Alister Hardy Foundation for Ocean Science, National Marine Aquarium and the Diving Disease Centre). Within the University, the Marine Institute provides an umbrella organisation crossing Schools and Faculties to support and facilitate research collaboration both within and outwith the University. The history and excellence of PU in marine and maritime endeavours was recognised in 2012 through the award of the Queen's Anniversary Prize for our education and research solutions for the global marine sector.</p> <p>The mission of CAESI is to conduct creative and high-impact research focusing on the complex interactions in marine systems and energy-generation technology, to strengthen links between fundamental research and development of new devices and services to support local and national</p>

**Environment template (REF5)**

industry, and to provide effective and directed multidisciplinary mentoring for early-career researchers. Specific objectives are:

- to extend the vibrant and supportive multidisciplinary culture that underpins engineering research at Plymouth and to provide opportunities for individual development and career progression;
- to deliver high quality engineering research solutions relevant to marine and energy systems, and advanced materials;
- to strengthen links between research, teaching, learning and consultancy;
- to create a thriving postgraduate research student community that is supported by external funding and fully integrated into the work of the Centre
- to develop proactively regional, national and international research partnerships and collaborations with other universities, external research bodies, business and industry;
- to enhance public engagement in, and understanding of, research and innovation through a range of channels and media.

The impact of the first strategic objective is evidenced in the increasing multidisciplinary capability across civil, coastal, mechanical and manufacturing engineering, in a dynamic network of external collaborations with industry and academia across the UK, Europe, and internationally, and in a strong linkage between fundamental and applied research. Cross-disciplinary innovation has been facilitated through members of the Coastal, Ocean and Sediment Transport (COAST) research group within CAESI also forming part of the University recognised Centre CCOSE. Both CCOSE and CAESI are included within the multidisciplinary Marine Institute. Since 2008, major investment in support of this has occurred in a new Marine Building and COAST Laboratory, in excellent new academic appointments at both senior and junior levels, and in advanced facilities for materials characterisation and analysis. This has unlocked substantial success in new research funding, both from RCUK and EU sources, along with increased opportunities for industrial collaboration, commercial work and associated societal impact.

The strategic aims are closely aligned with the wider University strategy and specific examples of how the strategy has been implemented and realised, with the support of University, Faculty and School structures, in each of our five research groups are given in the relevant sections below.

**Coastal, Ocean and Sediment Transport (COAST) Research Group** (Borthwick, Chadwick, Fox, Greaves, Iglesias, Littlewood, Magar, Miles, Raby, Simmonds, Stripling, Toffoli).

COAST's strategic objective is to respond to issues of national importance, and it is focused firmly on the major problems facing society from rising sea levels, flood risk, coastal erosion and in the exploitation of marine renewable energy that have been highlighted repeatedly by Government reviews and by the Government's 2009 Renewable Energy Directive, which set a target of 15% of electricity supply being generated from renewable energy by 2020. The Renewable Energy Roadmap sets out the proposal for achieving these targets and the Marine Energy Action Plan (2010) was developed by DECC as a route to implementation of the targets. Greaves was a member of the review committee contributing to this plan.

The new COAST laboratory together with the targeted research strategy has greatly enhanced research collaborations, both nationally and internationally, and has led to COAST Research Group being recognised as a key UK player in the marine renewable energy sector. For example, members of the group are leading a €2 million EU project SOWFIA on the streamlining of offshore wave farms impact assessment, leading EPSRC Research Grant EP/J012866/1 (FROTH), leading EPSRC EP/K012177/1 (The hydrodynamics of deformable flexible fabric structures for wave energy conversion), and partner on EP/J010235/1 (X-MED), on EU FP7 Project Marinnet, on Interreg Project MERIFIC, on Interreg ARC Project Atlantic Power Cluster, on EPSRC EP/K038303/1 (Virtual Wave Structure Interaction, WSI, Simulation Environment), on EPSRC UKCMER SuperGen Marine III, and Associate Partner on the proposed EPSRC SuperGen Wind Hub. The 2012 UKCMER SuperGen Marine Assembly was held in Plymouth University to coincide with the Official Opening of the new Marine Building and COAST Laboratory by the Duke of Edinburgh on the following day. A notable aspect of the Official Opening of COAST was the presentation of SoundWave: a novel interdisciplinary musical collaboration between the COAST research group and the MI composer in residence, Alexis Kirke. Raby has taken part in post-tsunami visits to Samoa and Japan through EPSRC grant EP/I01778X/1 EEFIT Earthquake Mission Grant: Funding for Improved Response and Dissemination.

**Environment template (REF5)**

**Materials and Structures** (Abraham, Basu, Christopher, Cree, Ellis, James, Kim, Le, Li, Rafiq, Rizvi):

The expertise in materials and structural integrity demonstrated in RAE 2008 has been strategically expanded through recruitment of new staff into nanomaterials, as well as giving a greater focus to offshore structures. Research into the optimisation of welding and bonding processes seeks to minimise residual stresses and maximise performance and reliability of advanced structural materials in marine structures, offshore energy devices, and thermal power plant, as in James's work on nuclear pressure vessels and steam turbine components. The work in this area firmly links fundamental research with a strong application focus, as evidenced by our strong links with the South African Energy Utility, Eskom, which has attracted some 40 days of peer reviewed synchrotron or neutron beam time at STFC-supported facilities since 2008.

Other agenda-changing research has focussed on the initiation and development of defects and damage to develop new models of the crack tip stresses that drive crack growth. This is a long term multidisciplinary collaboration of James, Christopher, and Le with mathematics and with experimental mechanics at Liverpool. This has led to a better incorporation of the effects of plastic deformation in crack growth models. Multidisciplinary research areas include work by Li and Le on the development of novel electrochemical processes using nanoparticles to protect reinforcing steel from corrosion in reinforced concrete structures and the multi-phase modelling of biomaterials to investigate the interaction behaviour between the material and its surrounding environments (such as cornea and cartilage). This is an area of strategic importance for the UK because of the emerging focus on lifelong health and wellbeing and links are growing with the strong nanotechnology/ecotoxicology research group in the School of Biomedical and Biological Sciences (Handy) and Peninsular Schools of Medicine and Dentistry (Tredwin). Le has recently received two full PhD studentships (worth £124k) to investigate the biocompatibility and biotoxicology of carbon nanotube reinforced ceramic bone replacement material and self-assembled titania nanotube coating on medical implants and this research has attracted significant interest from a number of new staff (Abraham, Basu, Rizvi). Li led MRC/G0902218 (£68k) on Multi-scale and multi-phase modelling of mechanical and physiochemical interaction in human corneas.

**Composites and Manufacture** (ACMC), (Graham-Jones, Grove, James, Le, Summerscales).

Plymouth has a longstanding and successful track record in innovation and industrial impact in both the design and the manufacture of polymer composite components and batch manufacturing processes with SME partners. There is a strong track record and an extensive portfolio of Knowledge Transfer Partnerships that have given a high impact on commercial competitive developments. The group provides a regional and national lead in developing sustainable composites using natural fibre reinforcements, in commercialising a novel patented in-Mould Gel casting process (e.g., Summerscales's EU-funded £1.4M InGeCT grant), and the work of James, Summerscales, and Le in further developing research on marine composite structures for the renewable energy domain.

**Analysis and Dynamics** (Marine and Industrial Dynamic Analysis - MIDAS) (Dai, Hatton, Sharma, Sutton).

MIDAS has a focus on the application of Artificial Intelligence (AI) techniques to the navigation, guidance and control of autonomous marine robotic vehicles, and has extended this expertise into wave energy devices and marine propulsion systems. These activities have been supported by Sutton's EPSRC award (EP/I012923/1, £354k) and PhD studentships under the supervision of Sharma from TSB and ESF (£107k). Core expertise covers AI, optimization techniques, advanced control systems theory, multi-sensor data fusion, dynamics in application to marine power plant, marine vehicle performance prediction, integrated navigation systems and marine renewable energy devices.

**Engineering and Society** (Fox, Hodgkinson, Littlewood, Rafiq)

This is a new interdisciplinary initiative intended to interface engineering solutions with socio-economic issues, and hence has strong links with the School of Psychology (joint EPSRC research project, EP/K002465/1) and the School of Social Science and Social Work. It is focussed on UK strategic needs that would benefit from the cross-over between socio-economics and engineering, and hence both on the impact of engineering solutions on society and the impact of society on the success of engineering solutions, recognising that close integration between the two is necessary

for a sustainable future.

### The Future

CAESI reports regularly on its activities to the Faculty Research Committee and is monitored annually through the University Research and Innovation Committee. Research activities are monitored against key performance indicators and the outcomes of this monitoring inform the development of our strategy and shape our plans for the future. Research in mechanical and civil engineering is on a strong upward trajectory, building from the powerful base established in RAE 2008. The critical mass achieved in key research areas, coupled with increasing interdisciplinary collaboration and the overarching strategic vision evidenced through the COAST laboratory and the CAESI Research Centre give Plymouth a powerful springboard into a greater national and international presence in the chosen areas of marine systems and energy generation technology, both of which are of high national and societal importance. The very significant investment into infrastructure and equipment over the last 4 years and the focussed re-missioning of the waterside Marine Station will continue to unlock new research and networking opportunities across all areas of the School, but with particular benefit for the engineering grouping. Marine renewable device manufacturers will have access to an increasingly sophisticated and complete suite of resources, expertise and equipment that will shorten time-to-market and reduce prototyping costs. Over the next few years, the opportunities unlocked by research into novel applications of friction processing and optimisation of structural performance will lead to even stronger collaboration with industrial partners who wish to exploit the opportunities offered by solid-state joining. This will lead to cost benefits and improved plant monitoring in thermal power plant.

### c. People, including:

#### i. Staffing strategy and staff development

The recruitment, development, and promotion of staff are geared towards leadership succession in the delivery of our research strategy. CAESI aims to support the growth and development of research leadership and to build critical mass across key academic partnerships. It aims to:

- build on current strengths and, through key strategic appointments, link with other areas of potential strategic fit to provide a breadth and depth of expertise supporting all staff to become research active;
- provide leadership training for PGR students and early-career researchers;
- embed research into the student experience through research-informed teaching

These staffing aims are integral elements within our research strategy and operate through a new University Performance Development Review (PDR) framework, aimed at identifying, nurturing and developing leadership potential, and the Concordat to Support the Career Development of Researchers, under which the university was awarded the EU HR Excellence in Research Award in 2011. The key principles of the Concordat are embedded within all areas of our work, with all new early career researchers being assigned a mentor to guide their career development. Mentoring aims to develop future research leaders, increase the breadth of research activities and deepen the research culture within the engineering group. This is enabled through the staff mentoring system, the PDR, and leadership training (e.g. with the Barefoot partnership <http://www.barefoot-thinking.com>) and focussed research away days.

Succession planning since 2008 has led to **new appointments** that extend the expertise in key areas at both senior and early career level. Mechanical and marine engineering appointments include Abraham, Cree, Gingele, Graham-Jones, Kyte, Le and Li, who are making significant contributions to offshore structures, marine composite structures, surface coating technology and nanotechnology for biomedical devices and ecotoxicology. Civil and Coastal engineering has been strengthened with Buller, Chadwick, Ellis, Fox, Littlewood. In addition, the coastal, offshore and marine renewable leadership has been strengthened by the appointment of a new professor of Coastal Engineering (Iglesias), and an additional Reader (Toffoli). Alongside these, appointments have been made of a scientific manager (Stripling) for the COAST laboratory, a Marine Commercial Director (Corney) and the technical support has also been extended (Reynolds, Arber). University funding has been used to appoint two PDRAs in numerical modelling working across the structural integrity and marine renewable energy areas. In addition, a Research Officer has been appointed to support the High Performance Computing activities within the group.

These new appointments reflect the deliberate and strategic policy of enhancing academic leadership and of ensuring succession planning across the broader arena opened up by the

strategic restructuring of the University, and the acquisition since 2008 of new facilities in coastal and ocean engineering, and in materials analysis and characterisation. The international recruitment of Toffoli and Iglesias in particular has brought fresh perspectives and contributed to further development of international collaborations with Spain, Italy, Brazil, France, Norway and Australia. A clear path for **leadership support** and internal career progression has led to tangible outcomes, and since RAE 2008 Greaves has been promoted to Professor, and Raby to Reader. The School is committed to Equality and Diversity and to the advancement of women in science and engineering. Civil/Coastal and Mechanical/Marine engineering were awarded Athena SWAN Silver in 2009 within the Faculty award. The School is currently working towards a new SWAN Silver submission in the light of re-structuring, which has significantly changed the composition of disciplines within the School. Women currently comprise 26% of the academic staff in the Civil/Coastal Subject Group. Our gender-equality initiatives include the Women in Technology Network for female students and many events aimed at increasing schoolgirls' aspirations, skills and confidence in engineering/science subjects that have not traditionally been chosen by girls. Our activity in this area is informed by the research of the Engineering and Society Group. The Marine Institute (MI) organises an annual student conference, in which engineering PhD students and researchers present papers and assist the organising committee. The MI also supports research through annual rounds of funding for small interdisciplinary research projects and travel grants. The School Research Committee also provides annual competitive funding rounds to support small research grants to cover, e.g. PhD studentships, travel and expenses for research visitors.

**Seminars** are organised on a weekly basis by COAST, CCOSE and CAESI, and provide a vibrant programme of talks by visiting researchers and invited external speakers from other academic institutions and from industry, as well as PU staff and PhD student presentations. The School supports this initiative through the Research Committee, providing funding for invited international researchers to facilitate knowledge transfer and collaboration. Research students are required to present their research at the transfer and final stage of the PhD, whilst academic and research staff are encouraged to give seminars on new research initiatives and projects. The group also contributes to the organisation of professional institution seminars, such as the Institution of Civil Engineers, and to regional professional body meetings (ICE, IMechE, IStructE, BGS, etc.).

**Research 'sandpit'** days are organised regularly in response to merging national research initiatives to stimulate new research collaborations and project proposal ideas, to encourage staff to take stock of research aspirations and opportunities and to find collaborative research partners. Individual research plans are discussed and reviewed as part of the PDR and Group plans are discussed through regular research group meetings and seminars. CAESI have a well-established system to support grant applications through peer review that is overseen and supported by the Research and Innovation Division. A sabbatical system allows staff to apply for 3 month relief from teaching and administrative duties in order to focus on research. Raby was awarded a sabbatical in 2011 and Simmonds in 2012, both of which led to new publications being submitted.

## ii. Research students

In line with the unit's overall strategic emphases on marine systems and interactions, and energy generation, PGR recruitment has specifically been directed towards the area of marine renewable energy with research contributions from resource characterisation, both modelling and field measurement (6); device hydrodynamics, including numerical and physical modelling of wave structure interaction for performance and survivability analysis (9); environmental impact, including the influence of marine energy extraction on coastal processes (4); marine structural integrity, including wave impact, scour and corrosion (2); dynamics and control of marine renewable energy systems (2). An example of the breadth of marine research is collaboration between coastal engineering and marine biology on how to design and evaluate coastal defences for the protection of coastal communities and how the protection of coastal habitat can be managed under changing climate conditions. In these multidisciplinary areas, joint supervision involving supervisors from each discipline is standard and has proved a successful model. The number of overseas research students has increased over the REF period, partly through a new initiative in which Iraqi government funded students are sponsored in specific research projects.

The training strategy of the School of Marine Science and Engineering Doctoral Training Centre (**DTC**) is based on the latest PhD pedagogic methodologies of peer-network, student-centred

## Environment template (REF5)

learning, innovatively integrating cross-disciplinary skills training and coaching for individualised development plans. Each PhD student, with support from their supervisory team, defines their *Individual Skills Development Plan (Vitae RDF)* for professional development and sets personal targets. The training programme includes participation in taught and hands-on *Transferrable Skills Modules* chosen from 130 courses in the Graduate School Skills Portfolio mapped to the four Vitae RDF domains of: Knowledge and Intellectual Abilities; Personal Effectiveness; Research Governance and Organisation; Engagement, Influence and Impact - and are integral to the University's HR Excellence Award from the EU. Monitoring of progress and training of research students is provided through the PU Graduate School (ranked first overall out of 35 universities in an international survey conducted by the International Student Barometer, 2011) and conforms to national and EU guidelines.

In terms of training future experts capable of input to the UK's national priorities, the School launched a new MSc in Marine Renewable Energy in October 2010. This new course has been very successful, recruiting 12 students in the first year and 18 in the second year. A secondary aim of using these cohorts to train potential PhD students for the UK has also been met with 3 students from the first cohort embarking on PhD study in marine renewable energy, one at Plymouth. Career progression is encouraged for PhD students leading to post-doctoral research positions and then a research or development career. One recent MSc MRE graduate has been appointed as specialist technician for COAST Lab.

**d. Income, infrastructure and facilities**

The **COAST** Laboratory is a major new facility that can facilitate research in coastal and ocean engineering, marine renewable energy, physical oceanography, air-sea interaction, marine biology and other areas. COAST can be used to simulate coastal and ocean environments at scales appropriate for testing the performance of single structures and arrays of MRE devices. The new facility was funded by the South West Regional Development Agency (SWRDA), Department of Business, Innovation and Skills (BIS), Department of Energy and Climate Change (DECC), the Higher Education Funding Council for England (HEFCE) and Plymouth University. COAST comprises an ocean basin, 35m x 15.5m x 3m deep, a coastal basin, 15m x 10m x 0.5m deep, a sediment wave flume, 35m x 0.6m x 0.8m deep and a tilting wave flume, 20m x 0.6m x 0.5m deep. Full details of the various tanks and flumes are provided at <http://www.plymouth.ac.uk/coast>. The new facilities have enabled the award of RCUK research grants EP/J010235, EP/J012866/1, EP/K012177/1 and EP/K024108/1, EU funding through the MaRINET project and new collaborative research projects with industry (eg., SEAWave, ITPower, Trinity House). COAST has also been instrumental in raising the profile of the MRE research at PU and embedding the research groups within the RCUK funded SUPERGEN Marine programme, UKCMER (UK Centre for Marine Energy Research) and more recently EPSRC SUPERGEN Wind. The new £19M Marine Building also houses the Marine Institute, the Marine Innovation Centre MaRIC, research staff in the Coastal Engineering area, research students and postdoctoral researchers, along with maritime studies staff and a £430k ship bridge simulator. There is a strategic focus on increasing the collaboration with other research groups to enhance the national impact of the extensive suite of marine resources owned by the School (e.g., the COAST facility, the research vessel Falcon Spirit and associated ROVs) and this has been supported through the appointment of a Marine Commercial Director with responsibility for such activities.

Numerical modelling capability in the Faculty has been greatly extended by the acquisition of a £300k **high performance computer** purchased through funding gained by coastal engineering and particle physics researchers. The HPC Cluster (HPCC) is used for numerical modelling and highly computer-intensive computational analysis work. Capability is enhanced with specialist software and with support from a dedicated member of the COAST team who has particular skills to support projects using the new computer cluster. An additional investment of circa £200k in 2013 will be used to upgrade Phase 1 of the HPC project.

Through the Peninsula Research Institute for Marine Renewable Energy, PRIMaRE, a European Regional Development Fund project, and with on-going funding from SOWFIA, MARINET and FLOWBEC, **HF Radar and wave resource characterisation** benefits from a unique dataset acquired through field measurements of the wave energy resource at Wave Hub and beach monitoring of beaches in the wave shadow of Wave Hub. This is valuable in resource characterisation, environmental impact studies, and informing and validating laboratory and numerical modelling studies and experiments.

The University is extremely well equipped in its facilities for **materials analysis and characterisation**. University and ERDF investment (circa £1M) in the area of materials characterisation and analysis has created JEOL Centre for Industrial Collaboration housing an atomic force microscope, a field emission scanning electron microscope with electron back-scatter diffraction, wavelength dispersive and energy dispersive spectroscopy analysis, a low vacuum SEM and a new TEM. Another circa £200k has been invested in X-ray CT scanning equipment for composite materials and in enhanced dynamic testing facilities.

The School of Marine Science and Engineering also has the expected supporting facilities concomitant with well-found laboratories covering thermodynamics, fluid mechanics and hydraulics, composites manufacture, mechanical property and structural testing. The School also manages the comprehensively equipped University Marine Station on the Plymouth Barbican, which supports marine research and diving requirements across the School.

#### **e. Collaboration and contribution to the discipline or research base**

**International Collaboration:** The Plymouth University team are key partners in interdisciplinary multi-partner national and international collaborative projects in marine renewable energy, such as: Coordinator (Greaves) for the €2M EU IEE project SOWFIA, Streamlining of Offshore Wave Farms Impact Assessment (2010 – 2013); Partner (Greaves) in MERIFIC, Marine Energy in Far Peripheral & Island Communities, Interreg Project; Partner (Greaves) in MARINET Marine Research Infrastructures Network for Energy Technologies (2011 – 2014), Partner (Iglesias) in Atlantic Power Cluster, Interreg ARC Project, COAST Research Group (co-I Simmonds, Fox, Greaves) are part of EU FP7 THESEUS, Innovative coastal technologies for safer European coasts in a changing climate. In addition Raby has taken part in two post tsunami field investigations in Samoa, 2009, and Japan, 2011 and 2013 forming links with the International Research Institute of Disaster Science (IRIDeS) at Tohoku University. Magar is leading the EU INTERREG project OFELIA working with French partners towards understanding the sediment dynamics and coastal impact of offshore wind farms. She is also Co-I on EU INTERREG PEGASEAS, Promoting effective governance of the Channel ecosystem (1.3m euro).

The research activities in structural integrity have a significant international reputation, evidenced via long-term international partnerships and collaborative experiments using the ENGIN-X instrument at the UK ISIS pulsed neutron and muon source; e.g., Cranfield; University of Johannesburg, the SALSA instrument at the ILL in Grenoble, France, and the ID31 instrument at the ESRF, e.g. Nelson Mandela Metropolitan University (NMMU), ESKOM South Africa and the ESS, Lund, Sweden). Other initiatives include a new EU research grant, research in collaboration with Stanford University, USA and Cardiff University and biomaterials research with partners including Liverpool, Sheffield, Manchester, Southampton, Cambridge and Tsinghua in China. A Leverhulme International Network grant (Multiaxial Fatigue Assessment of Aluminium Friction Stir Welded Joints £125k) links James with Sheffield, Ferrara and NMMU. As a result of our international collaboration with Indian Universities, Le has been awarded a UKIERI Thematic Partnership with Anna University (circa £48k) to assess the mechanical and tribological performance of carbon nanotube filled aluminium alloy composite within the next two years. Academic visitors Prof. Greg Rozynski from the Polish Academy of Sciences (2011) and Gullizar Ozyurt from the Middle East Technical University (2011 – 2012) visited courtesy of MI grants. The FP7 InGeCt in-mould gel-coating project (Summerscales) has partners in Sweden, Denmark, Netherlands and Italy. Li is collaborating with partners in Sweden, Italy and China in FP7 - PIRSES-GA-2011-294955 (EU327.6k) on the Development of sustainable electrochemical corrosion protection systems for reinforced concrete structures and Sharma with China through Royal Society funded International Exchange IE121414.

**National collaboration:** Partner (Greaves) in EPSRC SUPERGEN Marine 3 UKCMER (2011 – 2016), Associate Partner in the proposed new EPSRC SUPERGEN Wind Hub, PI and Lead (Greaves) for EPSRC EP/J012866/1, led by Plymouth in collaboration with Bath, MMU, City and Oxford, PI and Lead (Greaves) for EPSRC EP/K012177/1 with Southampton, PI and Lead (Greaves) for EPSRC EP/D077508 with Bath, Oxford, MMU and Manchester; Co-I (Greaves) in NERC: NE/J004219/1, PI (Greaves) in EPSRC EP/J010235/1 with Manchester, Edinburgh and SAMS; Co-I (Greaves) in EPSRC EP/K038303/1, which is a collaboration with the School of Computing and Mathematics and is led by MMU; co-I Raby in EPSRC EP/I01778X/1 with Newcastle and UCL. The team are also working with industrial partners in collaborative projects

## Environment template (REF5)

including: OWEL (Offshore Wave Energy Ltd) Marine Demonstrator, TSB with IT Power; EPSRC Industrial CASE with Arup, Great Western Research Studentships with tidal turbine and wave energy developers (Sperboy and International Power/Rolls Royce/ITPower); TSB project with Witt Associates, Mojo Maritime and A&P (2013); research collaboration and collaborative bids to TSB and DECC with Sea Energy Associates (2012, 2013). Development of In-Mould Gel casting for composites via a patented novel process was funded by TSB (£230k) /then FP7 R4SME in GeCt (€1.4M). In addition, in excess of 8 Knowledge Transfer Partnerships (KTPs) worth circa £1M since 2008, industrial PhD studentships (£72k) and FP7 R4SME grant (€420K) have supported the composites research. MIDAS Group research has been supported by EPSRC (EP/I012923/1, £354k) and PhD studentships from TSB and ESF (£107k) since 2008. James has longstanding and productive links with Liverpool in Crack Tip stress Characterisation (3 shared PhD projects and circa 11 papers since 2008). Rafiq is collaborating with Universities of Bath, Birmingham and Newcastle in the joint EPSRC project, eViz EP/K002465/1.

**Regional/ local:** Working with the University of Exeter, PU has led PRIMaRE since 2007. Pump-priming funds of circa £10 million over a period of three years were provided by the South West RDA and European Regional Development Funding to support investment in new staff and research infrastructure and equipment. PRIMaRE continues in 2012 as the research arm of the SouthWest Marine Energy Park. Outreach activities are carried out by members of CAESI within local schools and a Headstart programme in engineering for school children is hosted at Plymouth University. CAESI are actively engaged in consultancy and this is assisted through the Enterprise Solutions support team.

**List of esteem and impact indicators:** All academic staff perform reviewing for an extensive list of journals and are actively involved in professional bodies, research funding review panels nationally and internationally, external examinations, and contributions to the communication of their research to the academic and wider community. In summary, team members have made significant contributions in the following areas: **Journal and proceedings editorships:** Journal editors (9); Proceedings editors (8); Book chapters (7). Examples are Magar as Academic Editor for PloS One, Chadwick on the editorial board for Maritime Engineering, Greaves on the Editorial Board of the International Journal of Marine Energy, James as Co-Editor of the International Journal of Fatigue, Rafiq on the editorial board for the International Journal of Advanced Engineering Informatics as co-author of the special issue of the Journal of Advanced Engineering Informatics, Li as proceedings editor for the International Journal of Structural Engineering and Magazine of Concrete Research. **Honorary or Visiting professors** (5), including James who is honorary professor at Nelson Mandela Metropolitan (South Africa) and Southwest Jiaotong University in Chengdu, Iglesias at Delaware, Le at Tsinghua University and Zhengzhou Institute of Aeronautical Industry & Management, and Toffoli at KU Leuven and Swinburne University of Technology. **Research bodies, Government and International Committees** (5), including Greaves who is a member of OEEER (Offshore Energy Environmental Research) and OETR (Offshore Energy Technical Research) in Canada and of the DECC Marine Energy Action Plan Working Group, Chadwick who is Government and International Committees Advisor to the Environmental Management Agency, Trinidad and Tobago, James who is a Member for the Exact Sciences and Engineering panel of the Portuguese Foundation for Science and Technology, Raby who is co-opted member of the EEFIT (Earthquake Engineering Field Investigation Team) Management Committee, and Greaves who is part of an EPSRC delegation on Marine Renewable Energy to China in 2013. **Fellowships and Professional memberships** (8), **Awards, invited lectures and media** (9): In addition to 6 plenary or keynote lectures given by James at international conferences since 2008, the COAST lab featured on the BBC1 One Show (2013, Simmonds), in a documentary on tsunamis in 2013 for National Geographic Channel (Raby), on Radio 4 You and Yours, 2011 (Greaves), and was officially opened in 2012 by HRH Prince Philip. Summerscales won the South West Regional Award 2010 for Knowledge Transfer Partnership. Toffoli won the Gold medal prize for the best paper at Congress of the Aerospace and Maritime Technical Association. Magar's co-authored paper was selected as an outstanding contribution to ICCE2012 by the Coastal Engineering Research Council, Iglesias was awarded best oral communication at the International Conference on Coastal Conservation and Management, ICCCM2010, Rafiq won ASCE best paper award 2013, and is organiser for the IStructE Branch and won IStructE Best branch Journal in 2008.