



Imperial ENGINEER

SUSTAINABILITY & INFRASTRUCTURE
BRINGING FUSION DOWN TO EARTH
CYCLING IN MONGOLIA
DESIGN ENGINEERING
ART CONSERVATION
PHILANTHROPY

For members of City & Guilds College Association
and The Royal School of Mines Association

ISSUE TWENTYTWO SPRING 2015



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Cover: Inside the Joint European Torus (JET). Located at Culham Centre for Fusion Energy (CCFE), JET is the world's largest and most powerful tokamak and the focal point of the European fusion research programme. It is the only device currently operating that can use the deuterium-tritium fuel mix that will be used for commercial fusion power. Read more in Steve Cowley's article (page 22). Photograph courtesy of EUROfusion

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Short URLs at the end of items indicate more details online. All the links in this issue can also be found in our IE22 bundle at: bit.ly/IE22links

STORY IDEAS FOR THE NEXT ISSUE BY AUGUST 17 2015

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In this my second 'report to members', I want to focus on our events ... and issue an invitation.

First of all, I am delighted to report that activity under our new arrangements for departmental connections between CGCA and Department societies that I mentioned last time are bearing fruit. A couple of successful events have been held recently and more are planned. The theme so far has been guidance to students on how to approach their career post-Imperial to complement the many careers presentations they receive from companies wanting to employ the best graduates they can find.

Much of my time recently has been taken up – with organiser Colin Kerr and Teresa Sergot, our support from College – on the Annual Dinner, being held at The Stationers' Hall on 20 March. I am delighted to say that we have 122 booked to attend including many members and their individual guests, and the association's guests, especially principal guests Lord (Tony) Berkeley and Imperial's new President, Professor Alice Gast. My wife and business partner Jean and I will also have a number of personal guests to share in what we are sure will be a splendid evening. We hope to find an equally great venue for next year that will enable even more of our members to attend.

I am also delighted that we have – thanks to Alice Spain and Peter Chase – reactivated our London walks. You can find details on the CGCA website. If you wish to be added to the mailing list to be sent details as the walks are arranged, please contact Alice Spain (see the Diary page 25).

And more events ... Please also see page 25 for details of the Imperial Festival and Alumni Reunion in early May and please volunteer to help us there if you can. Sadly, in one sense, my work will take me to the USA at that time. In addition, please see page 5 and the enclosed flyer for details of the talk at this year's AGM on 20 May. It is to be given by the head of Imperial's newest department, Professor Peter Childs, Head of the School of Design Engineering and the Professorial Lead in Engineering Design at Imperial (see also page 16). We have a long tradition of the AGM talk often being used to showcase recent developments in engineering at Imperial College and this year is no exception – do please put the date in your diary now, fill in the enclosed form, and join us for what I am sure will be a fascinating talk, a lively discussion session, and a very pleasant supper afterwards.

Finally, may I offer an invitation to any CGCA member 'out there' who would like to offer a contribution to the Association's activities to get in touch with me at roger@venablesconsultancy.co.uk. This is no plea of desperation but an open invitation to anyone who believes that they can help to enhance our programme. We recently were delighted to welcome Oliver Broadbent to the General Committee to help us with our communications strategy, and we would like to include more of you in arranging what we do. It could be that you fancy helping with the departmental activities – we have vacancies for departmental reps (we aim for two per department) in Aeronautical, Bioengineering, and Computing. Or perhaps you could offer a talk to such departmental activities – an unusual career path or insights into multiple roles over time. Whatever it may be, please drop me a line, cc'd to our Honorary Secretary Nigel Cresswell (nigel.cresswell@hotmail.co.uk) and one of us will be in touch.

Till next time, have a great 2015



Roger Venables

PRESIDENTS REPORT



John O'Reilly

As one gets older time seems to fly by so much more quickly. This will be my last piece for the Imperial ENGINEER, as President of the RSMA, with my two year tenure soon to end, and it seems no time at all since I was handed the presidential baton. It has been a very gratifying period and a privilege to have served the RSM in this capacity. I have met some wonderful people, alumni, staff and students and also renewed many old acquaintances. It has also been a re-education to see and be involved with the workings of Imperial compared to my time as a student 50 years ago. The students, of course, do not see the enormous changes that have taken place over the decades, due to their relatively short stay at college, but one thing that has not changed is the worldwide respect that the names, the Royal School of Mines (together with IC and the other constituent colleges) still command. Whilst there have been enormous changes, the objectives of the RSMA remain, as embodied in the 100 year old constitution, and long may this continue. i.e. "to foster an enduring link between members of the association and with the staff and students of the RSM thereby providing comradeship and a source of mutual help and advice".

The 130th Annual Dinner, held in November at the Rembrandt Hotel was a huge success with 127 attendees, covering seven decades of RSM students. Guest speaker, Dr Mike Harris, Director Business Development Copper for Rio Tinto, gave a thought-provoking talk on the mining industry which addressed many of the challenges facing current day developers. The strong camaraderie between alumni and students subsequently resulted in a **very** late closing of the union bar!!

In the recent students' sporting contests against Camborne, the Bottle was retained with a comfortable 19-7 scoreline. Victories were also achieved in the mens hockey and squash but we succumbed in the football, ladies hockey, netball and badminton. In November I gave a presentation to the students on the history, aims and membership benefits of the RSMA which was again well attended. The positive response from the students is very pleasing and a good rapport between the RSMA and the students bodes well for the future. It is the ambition of the

RSMA committee that upon graduation, all students continue or take up membership of the Association.

Over the last two years the Association has made funding appeals to alumni and industry for donations to help sustain the Association activities. This has only been partially successful and we will continue in our efforts to ensure the Association has a sound financial footing, so that we endure in perpetuity. Often we are targeting the same people as IC do in their concerted fund appeals which I am sure can be frustrating for appeal recipients, but to all those who have contributed, a sincere thank you. Rest assured your generosity is recognised and will be well managed.

We now have 1882 members on LinkedIn and a strong presence on Facebook. These continue to be excellent outlets for imparting news, renewing contacts and promoting the RSMA. All alumni are encouraged to be involved.

A couple of dates for the diary. The Association AGM will be held on Thursday 25th June, currently planned at 58 Princes Gate at 18.30. Any changes to the venue will be advised on the website. The Imperial College Festival will be held on the 9th and 10th May – the RSMA will again be hosting a stand at the event. This is a great opportunity to see what is happening at the college and some of the research frontiers being tackled, and also to catch up with old colleagues and fellow alumni. As many members as possible are encouraged to attend both events.

In conclusion, a huge thank you to the committee for their sterling work and support over the last two years, and a special thank you from the Association to Paul Holmes who has stood down from his position as secretary due to increasing work commitments. Paul has done a tremendous job for the Association as secretary for the past 10 years. I would also like to offer my personal thanks to Teresa Sergot who made my stint so much easier and more enjoyable.

Feb 2015 - Bottle retained!

The weekend of 20/21st February 2015 saw the annual sporting competition between the Royal School of Mines and the Camborne School of Mines conclude with the Royal Miners retaining the bottle for the fifth year running. Final score was 19-7 at the cold and windy venue of Harlington in West London. Freddy White, RSM Rugby Captain commented "Once again the Bottle proved to be a tough physical match. We had done a lot of preparation for the day but we were naturally a little nervous due to the history of the Bottle Match. Even after going behind in the first 20 and with 2 yellow cards I knew the RSM had the player quality to get the job done. I'd like to thank the entire squad for the effort they put in; many played through injuries and illness, toughing it out for the team." This was the culmination of a successful weekend with a number of wins across the board in a variety of other sports. Scores on the doors are listed in the table (right). A notable mention goes to the men's hockey team who retained the Sharply Cup. Ben Bell, a Men's Hockey Bottle Match Veteran, was quoted as saying "Winning the Sharpley Cup for the second time in as many years was a huge moment for the RSM, since it was only the 3rd time in the recorded history of the trophy (over 40 years) that the RSM have prevailed against a historically much stronger CSM side."

While RSM dominated the squash 5-0, they were not so fortunate in the badminton, winning 3 games, but losing 6. RSM were also unlucky in the netball, with a strong CSM team featuring a particularly tall goal attack pressing their advantage, and the match ending in a 72-22 loss for RSM. A highly enthusiastic but inexperienced RSM women's hockey team had an unfortunate loss and, as in previous years, the football was not particularly auspicious for RSM.

Since 1902 the two Schools have met to play rugby and this latest victory for the Royal School of Mines makes it 47 wins over Camborne's 37. A total of 119 games have been played and there have been 7 draws. The quick will notice that the maths do not add up as there are no records for the remaining 28 games!

Sport	RSM	CSM
Rugby	19	7
Women's Hockey	1	10
Men's Hockey	4	2
Football	0	3
Squash	5	0
Badminton	3	6
Netball	22	72

Nick Farmer
4th year Geology student



RSM Captain Freddy White holds aloft the Bottle to celebrate a fifth consecutive win over CSM

Chem Eng Society win Interhalls Football Final

The Interhalls Football Final took place on 15 March at Harlington Sports Ground. After two tough fiercely competitive terms, the finalists were Southside and Chemical Engineering Society. Finishing at the top of the league, Chemical Engineering Society were firm favourites heading into the final.

Despite that, the game was very tightly-fought, with the battle raging in the mid-field. Chemical Engineering started better but

Southside grew into the game with some decent chances. However, Chemical Engineering were finally able to score after 60 minutes. Southside were unable to equalise and the final score was 1-0 to Chemical Engineering. They finished the league with 28 points from 12 games. The league games have been closely contested and there were only 3 points separating the top 3 teams by the end of the season.

Gold at SET for Britain!



Imperial College

Gold medal winners Yuval Elani (Chemistry), Robert Woodward (Physics), Nasrin Al Nasiri, (Engineering), Peter Buchak (Mathematics)

Since 1997, the final of the SET for Britain annual poster competition has been held at Westminster. Awards are made on the basis of the very best research work and results by an early-stage or early-career researcher together with their ability to communicate their work to a lay audience. It also aims to help politicians understand more about the UK's thriving science and engineering base.

The event is run by the Parliamentary and Scientific Committee in collaboration with the Council for Mathematical Sciences, the Institute of Physics, The Physiological Society, the Royal Academy of Engineering, the Royal Society of Chemistry, the Society of Biology and the Society of Chemical Industry. In order to encourage maximum participation by early-career researchers and Members of Parliament the competition is divided into five subject areas: Biological and Biomedical Science, Chemistry, Engineering, Mathematics, Physics.

Andrew Miller MP, who chairs the Parliamentary and Scientific Committee, said: "This annual competition is an important date in the parliamentary calendar because it gives MPs an opportunity to speak to a wide range of the country's best young researchers. These early career scientists are the architects of our future and SET for Britain is politicians' best opportunity to meet them and understand their work."

This year's final was held on the 9th March and Imperial researchers achieved the best ever performance. The prestigious competition attracted entries from over 200 early career researchers, of whom 29 were shortlisted to present their work in front of MPs, peers and scientists.

Imperial researchers claimed Gold in four out of five categories, each receiving a medal and a

£3,000 cash prize. Dr Peter Buchak (Mathematics) won in the Mathematics Category for his poster: *Lighting the path: the mathematics of imaginary numbers in very real problems of holey optical fibre fabrication*. Dr Yuval Elani (Chemistry) won in the Chemistry category with his poster *Artificial cells as micromachines: the next generation of drug delivery vehicles*.

Dr Nasrin Al Nasiri (postdoctoral research associate in the Department of Materials – Ceramics and Glasses group) won the Gold Award in the Engineering category for her poster *Environmental barrier coating for Si-based ceramic composites*.

Dr Al Nasiri said: "When they announced my name as the Gold medal winner in Engineering I was speechless, overwhelmed and very proud of what I have achieved. This invaluable recognition to my research and communication abilities will definitely boost my enthusiasm to progress in my career as a researcher in engineering and material science."

Robert Woodward won in the Physics category and also secured the top overall award for *Exploiting nanomaterials for ultrafast photonics*, a presentation explaining his research work on the development of ultrafast laser technologies and the remarkable optical properties of nanomaterials.

Robert said: "It was a fantastic experience to share my work at Parliament and to see so much fascinating innovation from young UK researchers. I was delighted and honoured to receive the Physics Gold Medal and Westminster Medal for my laser research, especially as this year marks the International Year of Light – a worldwide celebration of the impact of light science and applications, of which laser technologies play a major role."

bit.ly/IE22-SET4Britain

CGCA – TRUST FUND REPORT

During the last Academic Year CGCA's trust fund (the Old Centralians' Trust) distributed over £34,600 in support of a wide range of student activities, and no less than 145 students benefitted to a greater or lesser extent from awards made by the Trust.

Fortuitously there were no hardship cases notified to the Board during the year, although the Trust will always be ready to consider any case where a student has fallen into financial difficulty through no fault of their own, this being one of the key objects of the Trust since its formation in 1965.

Some seventeen undergraduate students were awarded 'Student Activity Awards', valued at £700 each, in recognition of their deep level of involvement in student society affairs and/or in sporting or cultural activities. Students in their first, second or third year are invited to submit details of their involvement to their departmental senior tutor, and then each senior tutor, in consultation with the Head of Department, nominates to the Trust the two students whose involvement has been judged to be the most deserving. After acceptance of nominations by the Board, each successful student will receive his or her award at the commencement of the next academic year. The intent of these awards is to help meet the inevitable extra costs of an involved lifestyle, whether for accommodation, travel

or other expense.

The Trust was gratified to learn at the start of the year that the Faculty of Engineering had decided to provide financial support to the annual 'Undergraduate Research Opportunities Programme' (UROP), at a level over six times greater than the Trust had been able to provide. It was felt that this justified a decision to re-assign the £9,000 or so formerly contributed to UROP in aid of a broader spectrum of student activities. This was a significant moment for the Trust, as it had been supporting UROP each year for over thirty years – since not long after the scheme's commencement in the early 1980s.

Three significant awards towards student projects were made during the year, the largest of these being a grant of £3,960 towards the annual 'El Salvador' project run by students of civil engineering. A team of twelve students spent six weeks in El Salvador and Guatemala, constructing a prototype earthquake-proof house, to a design that had been prepared by Arup with input from Imperial College researchers and students (see page 12).

A grant of £2,500 was made towards 'Project Nepal', under which a team of ten students, from four Faculty of Engineering Departments, travelled to Nepal to construct a much-needed boarding house for young children, including orphans, who live too far from their

school to allow daily commuting.

Four students who undertook a four-week cycling tour in the northernmost province of Mongolia (see page 8) were awarded a grant of £2,000 towards the cost of their adventurous expedition.

A group of 68 Civil Engineering students, from all four years of the course, were assisted with a grant of £1,360 to travel to Budapest for the purposes of observing civil engineering projects in a different country, and forging links with their counterparts at the Budapest University of Technology and Economics (BUTE).

Under the John Elliott Bursary Scheme, awards were made to six key officers of the City & Guilds College Union (CGCU), to assist with the personal costs involved in serving the union and their fellow students during the year.

For a number of years, a proportion of the available funds has been used to support postgraduates in travelling to overseas conferences to present their papers either through a poster display or a podium presentation. During 2013-14 some sixteen students received assistance under this heading, with an average travel grant of £303. In addition, the Trust also supported two undergraduates who travelled to give papers abroad - no mean feat for them when they had carried out research in their spare time or summer vacation.

In addition to the awards

described above, the Trust provided funding towards the annual Peter Lindsay Memorial Lecture, held each Spring in memory of Peter's most generous bequest, which greatly enhanced the assets held by the Trust in 2007, enabling a significant increase in the scope of its work. This lecture is arranged by his former department – that of Electrical and Electronic Engineering – and in 2014 the lecturer was Dame Nancy Rothwell, Vice-Chancellor of the University of Manchester, best known for her work in the field of neuroscience and stroke research. The object of these lectures is to provide an opportunity for engineering and other students at Imperial to hear a leading academic speak about their work.

The Old Centralians' Trust would not be able to provide such a wide range of awards and bursaries were it not for the generosity of CGCA members, particularly those who have remembered the Trust in their wills. As a registered charity, the Trust can accept gift-aided donations, both one-off and by regular subscription, whilst legacies from UK residents will result in a commensurate reduction in the Inheritance Tax liability on their estate. Please consider whether you could possibly help in any of these ways.

Chris Lumb, Chairman
Old Centralians' Trust Board
(chris19@clgml.plus.com)
March 2015

Join in YOUR AGM!

The CGCA Annual General Meeting, AGM, will take place on Wednesday, 20th May, starting at 17:30 at Imperial's South Kensington campus. Your Committee encourage you to come along and join in this very important meeting. The AGM is the meeting where your Committee members and officers for the 2015-16 year are elected and the Association's accounts are presented for your approval.

But it's not all formal process! Refreshments will be available from 17:00 and once the AGM is finished we welcome Professor Peter Childs who will give a talk entitled 'Do it, sort it, fix it, run off the cliff', an intriguing title and even more intriguing illustrations (below)!



Peter is the head of the Faculty of Engineering's newest division, the School of Design Engineering (you can read more about it in his article on page 12). Former roles include director of InQbate, director of the Rolls-Royce University Technology Centre for Aero-Thermal Systems and professor at the University of Sussex. He is a Director at Q-Bot Ltd and Creative Director at ICeni Labs. Peter tells us his talk will explore some of the fundamental facets of creativity, some tools that can be used readily, and describe approaches taken for an ideas to reality culture. Come along and find out!

And there is more! Once the AGM and talk are finished you can



join your President, Professor Roger Venables for the President's Evening supper in the Queen's Tower Rooms for a hot buffet meal with wine and soft drinks. This is a purely social event and gives you the chance to chat with other members and committee members in an informal setting. Guests and partners are

most welcome throughout. The AGM and talk are free to members and their guests, the supper is £32 per head including meal and drinks. Please use the flyer in the Imperial ENGINEER packaging to let us know you are attending and book your tickets for the supper.

Nigel Cresswell

CGCA on the Web

Just a quick update on our web / social media presence.

Our LinkedIn group, 'City & Guilds College Association', continues to grow and now has nearly 1,200 members. Details of events, reports of past events and discussions are all posted on the group discussions page. Just this year we have successfully found a new departmental rep for Aero entirely through the LinkedIn group. To join the LinkedIn group you need to have a LinkedIn account (it's FREE) so please go to <http://linkedin.com> and follow the joining instructions. Once you are member then search the groups list for 'City & Guilds College Association' and apply to

join. All group members can open and comment on discussions. You do not have to be a CGCA member to join the Group.

CGCA has had a website for well over a decade. The site, <http://cgca.org.uk> is open to public access. Within the last few months we have refreshed key parts of the site. These are the 'Event' details and the area focused on our student members, 'Student Centre'. We are hoping to complete a major refreshment of the site in the coming year. Please take a look and let us have feedback on what works, what doesn't and / or what you would like to see there.

Nigel Cresswell

DEVELOPMENTS AROUND THE ENGINEERING FACULTY

CGCA Past President honoured by US National Academy of Engineering

Emeritus Professor David A Nethercot has been elected as New Foreign Member of the National Academy of Engineering in the USA, which is the country's premier body for engineering. He was made a Member "for contributions to structural steel design and construction and for service to structural engineering worldwide." He is one of only 12 people to be elected as a Foreign Member this year.

Professor Nethercot is the former Head of the Department of Civil and Environmental Engineering at Imperial and former Deputy Principal (Teaching) of the Engineering Faculty. He has more than thirty years of research experience, specialising in advisory work and committee activity in the area of steel, aluminium and composite frames structures. These are fundamental building components that are used in the construction industry.

Professor Nethercot said:



"Yesterday I opened a large package from the National Academy of Engineering in Washington and was delighted to find that it contained news of my election as a Foreign Member. This came as a complete surprise to me. I was not aware that my name had been proposed. It is a great honour and it is wonderful to be recognised for my work in

structural engineering."

Professor Jeff Magee, Dean of the Faculty of Engineering, added: "David has played a pivotal role in Imperial. As Deputy Principal, he made a huge contribution to the practice and profile of engineering teaching. What's great about this accolade is that it also recognises internationally the huge contribution of his research in structural engineering. Well done David."

Professor Nethercot has been responsible for major programmes involving experimental and numerical work that underpin British, European and other national construction design standards. His current research interests include understanding in more detail the progressive collapse of structures, and new construction methods that use light gauge steel. He told Imperial ENGINEER: "Having both retired from Imperial and now being a former President of CGCA it is nice to feel that I am still recognised as part of the Engineering community

– I am certainly still making some contributions to it. An American friend with experience of formal affairs in this country told me that splendid though the inauguration ceremony on Capital Hill in Washington is, the dinner does not compare to an event at a City Livery Company. I will enjoy checking this out."

Election to the National Academy of Engineering is among the highest professional distinctions accorded to an engineer. Academy membership honours those who have made outstanding contributions to engineering research, practice, or education.

Professor Nethercot's election takes the number of New Foreign Members at Imperial to four. The others being Professors Julia Higgins, Geoff Hewett and Roger Sargeant, who are all from the Department of Chemical Engineering. Professor Alice Gast, President of Imperial, is also a Member of the National Academy of Engineering.

Institution of Chemical Engineers awards medals to five Imperial researchers

In March the IChemE revealed the winners of its 2014 medal programme. Five researchers, from Imperial's Department of Chemical Engineering and the Centre for Environmental Policy, received medals, out of a total of 16 presented to academics around the world.

Professor Stephen Richardson Associate Provost (Institutional Affairs) and former head of the Department of Chemical Engineering, along with Professor George Jackson and Drs Camille Petit and Paul Fennell also from the same department received medals. Dr Niall MacDowell from the Centre for Environmental Policy was also recognised as were alumni Ken Morrison and Ignacio Grossman, who both did their PhDs with Emeritus Professor Roger Sargeant from the Department of Chemical Engineering.

Professor Andrew Livingston, Head of the Department of Chemical Engineering at Imperial, said: "These medals underline what we already know in the department and that

is we have a bunch of extremely talented chemical engineers working here. Whether working closely with industry, helping to lead the College, hunkering down on their next research paper or inspiring the next generation of chemical engineers, this year's medallists are some of the best and brightest in their fields. I look forward to raising a glass, or two, with them all in the future to celebrate this fantastic acknowledgement of their success."

The medals cover a broad range of categories including services to IChemE's journals and other publications. The 2014 round for the first time included medals for research excellence in a range of categories. Medals awarded to Imperial researchers were:

RESEARCH MEDALS

Professor George Jackson

Professor George Jackson is world renowned for an approach he developed that permits scientists to make precise predictions about the behaviour for a broad range of liquids including solutions of plastics

and detergents. Professor Jackson was awarded the Guggenheim Medal for "research excellence in thermodynamics and/or complex fluids".

Dr Niall MacDowell

Dr MacDowell's research focusses on modelling low carbon energy systems. Niall was awarded the Nicklin Medal for his "exceptional contribution to the process sciences by an author who has graduated within the last ten years".

Dr Camille Petit

Dr Petit's research group works on developing new materials that could be used in the energy and environmental sectors. Dr Petit was awarded the Warner Medal for showing "exceptional promise in sustainable chemical process technology, nuclear technology and making chemical engineering more accessible".

SERVICES TO THE INSTITUTION

Dr Paul Fennell

Dr Fennell's research focuses on clean and efficient energy production, including carbon capture and storage, where harmful CO gases can be stored underground, and he also works on developing biofuels from waste. He is well known for his outreach activities, presenting and demonstrating at events such as the Cheltenham Science Festival and the British Science Festival. He was awarded the Ambassador Prize for "his broad range of outreach activities, including advising the UK government on decarbonisation,

chairing the new Clean Energy Special Interest Group and helping to promote science and engineering to the general public".

Professor Stephen Richardson

Professor Richardson's research focusses on making the oil and gas industry safer. Among his many achievements, he is a world expert in 'blowdown' – the standard, but often hazardous, procedure carried out by engineers to rapidly depressurise a pipeline or pressure vessels in an emergency. Professor Richardson was awarded the Arnold Greene Medal for "his long-standing engagement with IChemE journals".

It's been a good year so far for Professor Richardson, who was also awarded a CBE for Services to Chemical Engineering Education in the New Year's Honours List. Professor Richardson said: "I am delighted that the citation mentions both chemical engineering and education. I have spent almost my whole working life at Imperial. I regard education as being as important to Imperial as research, and I try to do it as well as I can."



Dr Camille Petit, winner of the Warner Medal



Professor Stephen Richardson

DEVELOPMENTS AROUND THE ENGINEERING FACULTY

3D Graphene

A team of Imperial engineers have developed a method for printing miniature components from graphene, using a new graphene paste.

Graphene is thin, light, durable, and flexible and it conducts electricity, making it an extremely useful material in many industrial sectors. One of the current challenges for engineers is to develop methods for fabricating three dimensional components made from graphene, which could pave the way for its wider use in manufacturing.

Drs Esther Garcia Tunon Blanca, Suelen Barg, Victoria Garcia Rocha and Professor Eduardo Saiz Gutierrez in the Department of Materials have developed graphene paste formulations containing flakes of chemically modified graphene and small amounts of polymers. The team say their pastes could be used to develop a range of new components using 3D printers.

The researchers are working with Imperial Innovations to commercialise the technology and they are currently looking to collaborate with industrial partners, to find new ways of applying their graphene paste product to solve current challenges in manufacturing. For example, one usage might be creating new pressure sensors for applications as diverse as supersensitive "skin" for robots and new health monitors for patients.

Watch a video of Dr Blanca discussing graphene and the potential of their paste at bit.ly/IE22-Graphene

Research Excellence Framework 2014

Imperial has the greatest concentration of high impact research of any major UK university, according to the Research Excellence Framework (REF) 2014.

The four UK higher education funding bodies allocate about £2 billion per year of research funding to UK universities. To distribute funds selectively on the basis of quality, the funding bodies assess universities' research through a periodic exercise. This was previously known as the Research Assessment Exercise (RAE), and was last conducted in 2008. The 2014 REF replaced the RAE. It assessed the quality and impact of UK universities' research in all disciplines and the results will be used to allocate research funding from 2015-16.

In the College's best ever performance in a research assessment exercise, Imperial was judged to have improved in every Unit of Assessment. Highlights of the REF 2014 include:

- The REF's new impact measure ranks Imperial's research the highest of any major university. Moreover, eight of Imperial's 14 REF-assessed research areas are top or joint-top for "outstanding" or "very considerable" impact.
- Overall, Imperial comes fourth out of major UK universities for 4* or "world-leading" research, behind the London School of Economics, Oxford and Cambridge, and just ahead of UCL.
- 91% of Imperial research is classed as "world-leading" (46% achieved the highest possible 4* score) or "internationally excellent"

(44% achieved 3*) – the highest proportion of any major university.

- Nine of Imperial's 14 research areas were in the top three overall, with two taking the top spot: Public Health, Health Services & Primary Care and Civil & Construction Engineering.
- Imperial was ranked top or joint-top for providing an environment conducive to producing "world-leading" or "internationally excellent" research in all of the Units of Assessment to which it made submissions.
- Imperial research quality has improved significantly since the Research Assessment Exercise 2008, with the proportion of 4* or 3* classified research moving from 73% to 91%, and 4* graded research increasing from 26% to 46%.
- 92% of Imperial's eligible staff, a total of 1,257 FTE, took part in the REF, one of the highest proportions in the sector.

Jeff Magee, Principal of the Faculty of Engineering, said: "Overall, the 2014 assessment placed the Faculty of Engineering third in the UK, behind Oxford and Cambridge. However, look behind the headlines and you'll see that Engineering at Imperial produces a larger volume of world-leading and internationally-excellent research than all of our competitors, including Oxford and Cambridge. Moreover, five of our departments achieved the top rating for the impact of their research. These are significant achievements, and say much about the dedication and exceptional talent of my colleagues."

He drew particular attention to the following of the Faculty's results:

- Bioengineering: the top-ranked Bioengineering department in the UK;
 - Civil and Environmental Engineering: top in the UK in the Times Higher Education "research intensity" rankings, with 95% of the research submitted awarded the maximum four-star rating ("world-leading") or the three-star ("internationally excellent");
 - Computing: ranked first in terms of "research intensity" and received the highest quality rating for its research environment;
 - Electric and Electronical Engineering: the top-ranked EEE department and achieved a 100% four-star rating for the impact of its research;
 - Materials: ranked third in the UK, behind Cambridge and Oxford, with 99% of its research assessed as world-leading or internationally excellent;
 - Aeronautical Engineering, Chemical Engineering, Earth Science and Engineering, and Mechanical Engineering were assessed jointly and overall they came a close second after a much smaller Chemical Engineering submission from Cambridge. The departments received the highest rating for the impact of their research, and for the vitality and sustainability of the research environment provided.
- Jeff Magee added that these achievements cement our reputation as one of the UK's foremost centres for the study of engineering.

New flying robot lab founded thanks to donation from Aero alumnus

A new £1.25 million arena for flying the next generation of aerial robots will be constructed at Imperial thanks to a donation from Mr Brahmil Vasudevan an Aero Eng. alumnus. Based in Malaysia, Mr Vasudevan is the founder and Chief Executive Officer of one of Asia's leading private equity firms Creador.

The global market value of unmanned aerial robot manufacturing is expected to reach an estimated \$US 89 billion in the next ten years. These robots have a range of potential applications including search and rescue, wildlife conservation and inspection and repair of industrial facilities, particularly in hazardous environments.

Imperial aims to capitalise on its position as one of the UK's leading centres for aerial robotics research with the development of the new

state-of-the-art laboratory. The Brahmil Vasudevan Aerial Robotics Lab will consist of a two storey laboratory and workshop, hosted by the City and Guilds building, on its roof. It will have teaching facilities for undergraduates and postgraduates, housing a workshop for manufacturing aerial robots and an enclosed arena for safely carrying out test flights. It will also be one of only a handful of facilities in the world that will be able to test hybrid aerial robots that can fly and then dive into water, which could be beneficial in the future for search and rescue missions.

Professor Jeff Magee, Dean of the Faculty of Engineering, said: "The Brahmil Vasudevan Aerial Robotics Lab will be a focal point for our aerial robotics research and education activities. We also want this facility to be a place for prospective students

and school children to visit, inspiring them to become future aeronautical engineers."

Dr Mirko Kovac, Director of the Brahmil Vasudevan Aerial Robotics Lab adds: "Aerial robotics has the potential to become an important industry in the UK, but we need world beating teaching and research infrastructure to make this a reality. Thanks to the support of Mr Vasudevan we will now be able to construct an outstanding facility, which will enable the College to consolidate its position in this field and foster the next generation of engineers. Ultimately, we are aiming to develop flying robots that could improve the way companies do business, save lives and help to protect our environment."

The flight arena will include the latest technology such as sixteen high speed 3D aerial tracking

cameras that will wirelessly control how the robots will fly and also record their flight dynamics, which will be fed in real-time back to computers. A further eight 3D tracking cameras will be positioned in a water tank, which will be used to test the combination aerial robots as they dive into and swim through the water.

The Brahmil Vasudevan Aerial Robotics Lab will also bring the testing facilities into closer proximity with manufacturing facilities at the College used to fabricate components, making construction of the aerial robots more efficient. The new location is also expected to lead to more and varied collaborations between people across different scientific and engineering disciplines at the College and across the UK.

Construction of the lab will begin in 2016.

Mongolian Cycling Expedition

In July 2014, four members of the Imperial College Outdoor Club decided that they needed a challenge. Having been on many weekend trips together with the club, they had shared experiences in a whole manner of activities, from climbing, running and biking to crawling back in a white-out in 70 mph winds (Scotland can be brutal). With some help from the OC Trust (among others) they found their challenge by spending four weeks in the summer cycling off-road and unsupported in Khövsgöl, the northernmost province of Mongolia. This article is based on a summary of their report about the trip.



© Gemma Milman

Crossing one of the many rivers

Khövsgöl is one of the most beautiful and diverse areas of Mongolia and we set out to cycle a route of 800km, across plains and through mountains. We had a subsidiary aim of hiking up some of the mountains in the West of Khövsgöl Aimag (province), but objective peaks were not decided on until we were there as there is little information available. None of the members had been to central Asia before and Mongolia offered a unique environment. It is one of the least densely populated countries so the team would truly have to work together to ensure a safe and successful expedition.

Our pre-departure objectives were to return safely in one piece and still friends; cycle 800km in 28 days, ascending the mountain ranges and tackling the tough off road terrain; meet the local people and experience the nomadic culture; encourage others to get on their bike and go, even if it's just to go safely to the shops.

Terrain, geography and climate

Mongolia is located in Eastern Asia, landlocked between Russia to the North and China to the South. Sparsely populated it has a population just shy of three million and a huge area that includes the Gobi Desert in the South, vast steppe in the middle and East, and numerous mountain ranges in the North and West. We visited Mongolia's northernmost province, described by a local as 'Mongolia's Switzerland', which turned out to be a fairly good description. Khövsgöl Aimag is popular with tourists, both international and particularly Mongolian, for its huge National Park and fresh-water lake. The whole province is situated about 1600m above sea level and has mountains over 3000m. There was one asphalt road in the province, which stretched

between Mörön and Hatgal. All others were dirt tracks of varying quality and cycling in the area required strong mountain bikes and off-road tyres. Our route led us over passes as high as 2800m and across a 50km flat grass plain.

The climate in Khövsgöl Aimag during the summer months is not that dissimilar from the UK, with average daytime highs of a little below 20°C and 80mm of precipitation. However, we found the weather to reach greater extremes and to be quickly changeable. Many days started sunny and required a liberal dollop of factor 50, wind was generally mild, and conditions were pleasant for cycling (although Noah, our token Northerner, struggled with the rays initially). Later in the day the weather often deteriorated with clouds building over the mountains, followed by moderate winds and heavy rain showers.

Mongolia's landscape gave uninterrupted views for tens of kilometres into the distance which allowed us to see when bad weather was on its way – fortunately we were often able to get our tents up just in time! At night the temperature dropped dramatically to around freezing, so our down sleeping bags were a necessity. The super low light pollution and elevated altitude meant breathtaking views of our galaxy on cloudless, moonless nights.

Language and culture

Mongolians use the Cyrillic alphabet and speak Mongolian. The language has many different sounds to English, which caused some difficulty in our learning. In Ulaanbaatar some people spoke English but in Outer Mongolia very few spoke any English. We used the few

translation pages in our Lonely Planet guide and many hand actions to communicate with locals outside of tourist hubs.

Mongolians are known for their hospitality and it is common practice for Mongolian travellers in Outer Mongolia to stay with locals in their *ger* (round white felt-lined tent). Knocking on the door is not part of Mongolian custom – rather, one should shout 'Hold the dog' and walk straight in. We often approached a *ger* in the evening to ask if we could pitch our tents nearby. Every family that we asked welcomed us – and many were bemused to see Westerners on bikes in what seemed to be the middle of nowhere! Most families offered us breakfast in their *ger* – usually bread and cream – and it was custom for us to give a gift in return. When out cycling, we found that many Mongolians would stop on their motorbike to say hello and see what we were doing. Some would ride over from their *ger* on their horse to check us out. This was particularly helpful for directions!

Flora and Fauna

The Khövsgöl Province is a varied landscape consisting of a 2 million year old lake and several mountain ranges interspersed by vast grassy plains. It hosts the southernmost border of the Siberian Taiga forest, populated by the Siberian larch and home for rare wildlife such as wolves, brown bears and wolverines – although you are more likely to see marmots and ground squirrels. Hunting of endangered animals is illegal in Mongolia, and in particular a recent law forbids hunting of marmots; however it became evident that this is hard to enforce when we were offered freshly shot marmot for dinner!

The country boasts 427 species of birds, and though it is a semi-arid country we chanced upon two spectacular waterfowl; the Demoiselle Crane and the Eurasian Spoonbill. Cycling along the shores of Khövsgöl Nuur we wished we had invested in a bird book; the variety and beauty of the animals was incredible, though we struggled to identify anything more than the common crows and



Locals live in gers

© Gemma Milman



Demoiselle Cranes

© Gemma Milman



© Ryan Perkins

ducks. Whilst the country is famous for the golden eagle, we saw only captive ones in and around the capital of Ulaanbataar.

The region we travelled in is home to over 3.5 million head of livestock, and thus we saw plenty of cattle, yak, sheep, cashmere goats as well as domestic and wild horses. Whilst the goat yields most of the income for Mongolian nomads, it is the most damaging to the landscape as it nibbles at the grass roots perturbing regrowth. Where the livestock had not yet grazed, one could see an explosion of wild flowers and long grassy meadows. There are very few fences in Mongolia and so livestock roam freely around the grasslands close to the herders' gers. Consequently, many Mongolians spend a large portion of their day chasing animals. We had no problems with any animals, except mosquitos and horseflies which came in swarms near to the lake. Deet and headnets were a must.



© Gemma Milman

Eurasian Spoonbill

Training

The group as a whole were already fit and could all ride a bike. However there was a range of ability in terms of both cycling proficiency and general fitness. Harriet had not ridden since she was a child, so a particular focus was to get her more comfortable with cycling.

We knew the route in Mongolia would be primarily dirt tracks which could potentially



© Gemma Milman

Resting by the lake

become more hard-going in the mountainous regions. Because of this, all members of the group would need basic off-road skills. Group training days/weekends included endurance training on roads and bridleways, and riding more technical trails to improve off-road skills. Navigation skills could also be practiced. Another aim for these weekends was to

improve group bonding. The group had spent much time together on Outdoor Club trips including in fairly tough conditions so we were confident that we worked well together. However we had not spent five weeks in each other's company, so it was important to learn as much as we could from the training weekends. In terms of general fitness, each

Itinerary

Overall we spent 19 days in the saddle (in the green period below). The remainder were spent in Ulaanbaatar prepping and waiting to extend our visas, travelling by minivan and resting.

Day	Activity	Description
1-2	Depart London	London to Beijing to Ulaanbaatar
3-5	Ulaanbaatar	Government visa office closed for 5 days due to festival, bought enough food for 2 weeks, day trip (day 5) to local national park
6-7	Ulaanbaatar to Mörön	Travel by minivan. Extended visas on the way
8	Mörön	Assembled bikes, bought final supplies, acquired border pass
9	Mörön to Hatgal	100 km on tarmac
10	Rest day in Hatgal	
11	Hatgal to Toilogt	Gravel road and dirt track
12	Toilogt to Jiglegrin Am	Dirt track, some very muddy sections and river crossings
13	Jigleg to Renchinkhümbe	Hard day over a pass, lots of pushing, river crossings and flies!
14	Renchinkhümbe to Tsagaannuur	Vast, flat grassland
15	Rest in Tsagaannuur	Camping by a lake
16	Tsagaannuur to Ulan-Uul	
17	Ulan-Uul to Toom	Pleasant route ending in an epic 12 km downhill
18	Toom to Hatgal	Long day – 85 km, finished after 9pm
19-22	Rest in Hatgal	Harriet ill for four days, so we rested. Gemma, Noah and Ryan explored the East side of the lake by bike (day 21)
23	Hatgal to Toilogt	Attempt to cycle around the lake
24	Toilogt to Jiglegrin Am	
25	Jiglegrin Am to Toilogt	No passage shortly after Jiglegrin Am – forced to turn back
26	Toilogt	Hiking
27	Toilogt to Hatgal	
28-29	Hatgal to Chandmani-Öndör	No rest day needed – onwards in the grim weather! Dirt tracks on the more remote East side of Khövsgöl Nuur
30-31	Chandmani-Öndör to Tünel	Camped by local gers and tried many culinary surprises
32	Tünel to Mörön	Final day of cycling
33-34	Mörön to Ulaanbaatar	By minivan
35	Rest day in Ulaanbaatar	Buffer day in case of delays
36-37	Depart Ulaanbaatar	Ulaanbaatar to Beijing; 18 hours in Beijing; Beijing to London



View of expansive Khövsgöl lake from table top peak

member of the group was responsible for their own weekly training regimes.

Food

Maintaining a sustainable diet is an important factor on a high energy-consumption expedition like cycle touring. During our research we found knowledge of food resources within Mongolia to be scarce. This added to the difficulty of planning our route and was why we bought the extra wheel trailer which, as it turned out, was not necessary.

We cooked in two groups, Gemma and Harriet as one group, Noah and Ryan as the other. This made cooking easier with the pan sizes available and allowed the groups to create an efficient system when setting up and dismantling camp. It also made it easier for Noah and Ryan to consume more calories closer to the recommended 2500 for males.

Initially we planned to buy as much high calorific value food as possible in Ulaanbaatar. However on the advice of our Mongolian hosts we only acquired food enough for 12 days at 2000 calories per person. Our hosts assured us of the quality and quantity of small shops and supermarkets in the areas we would be travelling. Whilst cycling, space was more of an issue for us than weight, which enabled us to carry dense foods and tinned foods e.g. fish



Customary camp fire by the Khövsgöl lake, made using washed out wood collected from the shore

for protein. Cereal bars and malt loaf along with chocolate and other home comforts made the expedition easier.

Transport

Internal transport in Mongolia is something that could not easily be planned in advance so was left to be organised when in Ulaanbaatar. It was decided flying to Mörön, the main town in Hatgal, would be too expensive with bikes and there would be no room for our bikes on the public buses. Online sources had also stated that public buses were known to wait in Ulaanbaatar until full which could take a matter of days. Our host in Ulaanbaatar was very helpful with organising and instructing private drivers for our journey to and from Mörön. He explained the driver's expectations and informed us of our duties to the driver.

We flew from London to Beijing airport with Air China, where we transferred on an Air China flight to Chinggis Khaan international airport. On our return journey we had an overnight transfer in Beijing allowing us to see a little of the city.

Our two day journey to Mörön was in an old Russian minivan which is perfect for the terrain in Mongolia. It was also ideal in that even when the crank shaft fell off the vehicle our driver was able to repair it single-handed on the roadside. The return journey was made in far greater comfort in a Mitsubishi minivan. The bikes were dismantled and enclosed in the bike boxes; these were then strapped to the roof and waterproofed using a shower curtain. All parts of the bike were taped to the walls of the box to keep everything safe. During the drive we were responsible for feeding the driver. We would pull up to eat at a restaurant for breakfast and dinner and the driver would eat the food we provided in the evenings.

Acknowledgements

We would like to wholeheartedly thank all the people and trusts that helped us make this Expedition happen. First and foremost Dr. Lorraine Craig for all her guidance and advice, making us think about the not-so-obvious aspects of expedition planning. Thanks to Christopher Green for helping us manage our finances, Dr Kushalini Ragubathy for kindly offering to be our medical contact and Nick Kay for his help. We would also like to send a huge thank you to all the trusts and grants

for sponsoring us: the Exploration Board, the Royal College of Science Association Trust, the City and Guilds Old Centralians' Trust, The Lord Mayors 800th Anniversary Trust.

The team

Leader and Photographer ~ Gemma Milman

Final year PhD student (Chemistry) Gemma has cycled since childhood but only began mountain biking one and a half years ago and has loved it ever since. Her interest in the outdoors began with climbing, through which she has explored Norway, the Alps and the Pyrenees as well as the more local Scottish and Welsh mountains.

Medical and Equipment ~ Harriet Hillson

3rd year Mech Eng undergraduate Harriet began hill walking in the UK from a young age through Scouts, Outward Bound and D of E award. She became involved in the Outdoor Club as Equipment

Officer (2012-13) and rose through the ranks as treasurer (2013-14) and is now Chair. Outside of the club she has undertaken a community project with Raleigh International in Borneo, alpine mountaineering in Chamonix and Les Ecrins National Park, winter walking and climbing in the Cairngorms, ice climbing in Cogne, Italy and competed in OMM 2014.

Finance and Liaison ~ Ryan Perkins

4th year Physics undergraduate Ryan has been cycling since the age of three and developed a passion for mountain biking aged 15. Since then he has been on numerous mountain biking trips

around the UK, favourites include most of the 7Stanes and Coed y Brenin. He has organised and run many weekend and longer trips as Secretary (2012-13) and Chairman (2013-14) of Imperial College Outdoor Club. A seasoned navigator, with alpine and Scottish mountaineering experience, he has competed in four mountain marathons to date.

Bikes and Training ~ Noah Smith

1st year Geology undergraduate Noah's burning desire to explore was ignited long ago on family holidays to Cumbria and Snowdonia National park, however it was not until Imperial College provided the opportunity, funding and support required that he was fully able to quench his thirst for adventure. Noah loved cycling since he first learnt how to ride a bike aged 7. Since then he has cycled in many of Britain's National parks and trail centres.



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Jubilee Sailing Trust

In the Autumn 2014 issue of Imperial ENGINEER we reported on the donation of a place for an Engineering student to take part in a Jubilee Sailing Trust voyage. The Trust is a charity that takes people of all abilities sailing on tall ships, and the funded place included their Leadership @ Sea programme designed to work on leadership, team building, problem solving and disability awareness. The place was awarded to Jessica Charter, a student from Civil Engineering. We asked Jessica to write a short article for us about her experience.

This summer I embarked on a seven-day Leadership @ Sea voyage. This is a scheme run by the Jubilee Sailing Trust designed to challenge leadership and communication skills and improves one's understanding of different people's strengths and abilities, enabling one to become a better leader and team player.

Arriving at the port, the *Tenacious* tall-ship was a spectacular sight, it looked like something from the *Pirates of the Caribbean*. On the first two days of the trip we were taught by the crew how to sail, and learned a lot of the jargon used at sea, such as Smoko (mid morning and mid afternoon tea and cakes), mess duty (cooking) and Galley (Kitchen).

The hardest thing to get used to was the very strict routine and schedule for each day. We were each put into one of four teams, called Watches, which take turns to be responsible for various tasks on board including keeping watch, even at night. Each watch includes an experienced watch leader and permanent crew who ensure that all the tasks are done safely and correctly. And together, we sailed the ship.

One hour is set aside each morning for all voyage crew to help clean the ship (called "Happy Hour"). One member of each watch is also on mess duty for a 24 hour period. This involves helping the cook to prepare, serve and clear up after meals.

A large crew is needed to sail a ship this size, thus everyone had their roles and duties for



each day. The most difficult but amazing experience was the morning we had to get up at 3:30 am for our morning watch. Half asleep state we stumbled on deck zombie-like to take over from the previous watch. The crisp morning breeze brushed over our faces as we stared into the night. Faint glimmers of fishing ships were dotted in the distance. I looked up and to my amazement, thousands of stars twinkled back at me. Away from the garish city light and human pollution, the true beauty of night was revealed, and time seemed to stand still, peaceful and calm. This has been my favourite watch so far, as the hours tick by the gradual change of colour in the sky can be seen. The highlight of the trip must be the sunrise, as you see the first glimmers of sunshine over the edge of the horizon, splashing colour onto the surroundings.

On the trip we learnt how to lead a team of people with different mental and physical limitations. One of the most rewarding feelings was on the morning of assisted climbs. Assisted climbs are where the rest of the crew help the ones with physical disabilities overcome their fear and try something they didn't think was possible by climbing up to the platform on the mast of the ship, 30 metres in the air. We had a team of 20 people who hoisted a man and wheel chair weighing over 100 kgs up 20 metres into the air onto the first platform of the main mast.

The 8 day journey with the Jubilee Sailing Trust was an incredible experience and one I will never forget. You can read more about the Trust at:

<http://jst.org.uk>

Time	Schedule
7:30 am	Wake up call
8:00 am	Breakfast
9:00 am	'Happy Hour'
10:30 am	Smoko
11:00 am	Leadership training
12:30 pm	Lunch
1:30pm	Watch duty (e.g. Helming, taking readings, keeping look outs)
5:30pm	Smoko
6:30pm	Dinner
7:30pm	Free time
9:00pm	Sleep
3:30 am	Woken for watch duty
4:00 am	Watch duty
8:00 am	Breakfast

A day on board the *Tenacious*



All photographs by Jessica Charter



Jessica Charter is a Kingsbury Scholar in her second year in Civ Eng. Originally from Taiwan she has lived around the world in America, France, Portugal and the UK. She loves dancing (and dances for the Imperial dance team), rock climbing, skiing and any outdoor sports.

She joined the crew of the *Tenacious* on her return from working on the El Salvador project (see overleaf) building an earthquake-proof house using local sustainable materials. Sustainability is a particular interest for Jessica who is striving to pursue a career in engineering focusing on 'green growth'. She has attended several International Sustainable Innovation Conferences and workshops to learn new ways to incorporate sustainability into daily lives.

El Salvador Project 2014

In the Spring 2014 issue of Imperial ENGINEER we featured the El Salvador Project which was set up in 2001 and has been supported by the CGCA's Old Centralians' Trust. This year, for the first time, the project team worked in Guatemala as well as El Salvador. As there was so much interest in the previous feature, we decided that this issue should include a brief update based on the report from the 2014 team.

This year a team of twelve Imperial College students spent six weeks volunteering in El Salvador and Guatemala. The aim of the project was to construct a prototype of a brand new low-cost house design by global engineering consultancy firm Arup for use by the El Salvadorian NGO REDES. The scope of the project included constructing a prototype house (one 3x3m room only) on a shake-table in the Mariano Galvez University in Guatemala, and building a full-scale house within a community in the outskirts of Suchitoto, El Salvador for a family of 17 beneficiaries. The purpose of the prototype was to both publicise the design to prospective donors, and provide valuable engineering data. Building the house in Suchitoto also served as a valuable costing exercise. Existing low cost housing in El Salvador consists of adobe, local wattle-and-daub, confined masonry or reinforced blockwork, the former two not being particularly seismic resistant or durable, and the latter two being quite expensive and not very sustainable.

The new design consists of a reinforced concrete foundation underlying two courses of blockwork, which sit underneath the walls. The entire frame – wall panels and roofing – is made of timber and involves a variety of nailed and screwed connections. Roof sheeting consists of corrugated cement fibreboard sheeting, chosen for its low weight. The wall infill consists of nailing a local cane (locally known as *vara de castilla*) horizontally across the timber panels with a layer of chicken mesh nailed to either side of it. This is then finished with several layers of mortar taking the wall thickness to 60-65mm. The total size of the house spanned an area of 6x7 metres.

During the project our team of twelve students operated as a contractor for the works, working with a resident engineer from Arup and in collaboration with both REDES – who were very interested in the new design – and the Mariano Galvez University, who were very excited due to it being the first major work undertaken on their new shake-table. The house design has been being developed since 2012 by Arup, with input from ourselves and researchers at Imperial College. The design is seismically-resistant and also focuses on using both local materials and construction techniques to ensure its sustainability in the country, the long term view being that it can be constructed by a family of beneficiaries with the presence of a supervising Engineer from REDES.

The 2014 project was the first time the project has been extended to another country.

Working across two countries created a host of logistical challenges that provided a huge learning curve for all of us. Challenges consisted of, but were not limited to: difficulties getting materials across the El Salvador-Guatemala border; material acquisition in Guatemala due to having no established suppliers; and keeping the whole team safe whilst staying in Guatemala City, a city with one of the highest crime rates in the world. Our communication skills were greatly enhanced by daily visits from people in Guatemala who wanted to hear about our work – visitors included the ex-vice-president of Guatemala – which served as a fantastic publicity platform. We also had to be quick to adapt so that we were able to acquire all the materials and equipment we needed for the project without delays, especially when for example we received a shipment of incorrect nails from the US.

Within El Salvador, REDES located a family of beneficiaries in Los Almendros, Suchitoto. The construction of the house in El Salvador lasted four weeks, where we worked with the local community and an albañil (skilled construction worker). By building the house together we were able to learn and exchange knowledge from each other. Although we had more experience on the technical engineering aspects of the house, the albañil had more hands-on experience and was invaluable in teaching us skills in construction techniques such as laying blocks and working with concrete.

Over the course of the trip, we encountered numerous problems and we learnt how to deal with them in a calm and systematic way. One of the most valuable lessons we learnt is the importance of in-depth, forward planning. When there is a very tight schedule to keep to it was sometimes easy to undermine the complexity of the construction process, which often led to critical problems that had to be

fixed. We found that even under severe time constraints, it was better to take the time to plan out the task carefully and get it right, than having to undo the mistakes we made. Another key learning point was that every decision we made had a knock-on effect. One example was for the ground excavations: due to the very poor conditions of the soil on which the house was being constructed, we had to double the depth of the trenches, and this required much more time and higher quantities of concrete for the backfill.

To conclude, we completed the majority of the construction of a prototype room in the Mariano Galvez University, within a two-week time-frame. We had four weeks to construct the full-size house in El Salvador, however we were not able to complete the plastering of the walls or install the gutters. This was left for the beneficiaries and a skilled worker to complete. The main structure, including the frame, roofing and roofing sheets was however fully complete. The project provided us one of the most challenging experiences of our lives, however the lessons learnt and joy at seeing the final project made it a fantastic experience. The project allowed us to bond as a team and with the local community, understanding a vastly different culture to what we experience in London. The learning curve was sharp, the living conditions rough and the work challenging, but it provided the perfect platform for a fantastic learning process to develop all of us as both engineers and people.

Major donations to fund the project came from organisations such as the Imperial College Trust, Old Centralians' Trust, Institute of Civil Engineers Kenneth Watson Award and many other very generous donors. We won a £3,000 award from the RBS ESSA for best use of funds by a University society.

The 2014 team consisted of:

- Orrin Lancaster** – Project Leader
- Fridtjov "Joff" Lea** – Site Manager
- Edrea Pan** – Roofing Section Leader
- Mitesh Patel** – Wall Panel Section Leader
- Karoline Lende** – Quality Manager
- Ignacio "Nacho" Gimenez** – Foundation Section Leader
- Stefon Khan** – Health & Safety Officer
- Marc Ewenz-Rocher** – Treasurer
- Neha Dedakia** – Publicity Manager
- Theo Baissas** – Materials Manager
- Nikita Almond** – Equipment Manager
- Jessica Charter** – Social Planner

The team was also greatly assisted by Sebastian Kaminski (Arup) and Louise Foulkes (Atkins) who both joined the project team for 3 and 1 weeks respectively as resident engineers.



The team in Guatemala in the prototype built on the shake-table

Sustainability and Infrastructure: Crucial Connections & Challenging Contradictions

In this article, CGCA President Roger Venables presents and updates his talk to last year's CGCA AGM in the hope that it will be of interest to – and spark comment from – IE readers. If you wish to comment, please do so to Roger directly at roger@venablesconsultancy.co.uk.

Introduction

I offer this article to IE readers, as I did my talk last June, as a 'thought piece' to inform, stimulate and provoke comment and debate. As I aim to demonstrate, a sustainability-driven approach to life, never mind infrastructure, is increasingly important to many many people. On the other hand, I hope I do *not* need to demonstrate that infrastructure – the provision of energy, water, sanitation and wastewater treatment, transport etc – is literally vital to human life as the developed world knows it, *and* crucial to the development of other regions of the world who do not have access to these fundamentals.

So I want to present you with a journey – from “environmental issues in construction” to “sustainable design, sustainable construction, and sustainable development”. That journey requires us to consider the semantics of sustainability in construction, and the linked delivery challenges. Along the way, I explain the essence of CEEQUAL and how its approach to driving forward sustainability performance and project strategy might help us to identify some useful connections, and some challenging conundrums that we need to

tackle. Examples, connections and challenges are woven in as we travel our journey.

Where I am coming from to this debate?

Currently, I am a Director of Venables Consultancy, Managing Director of Crane Environmental Ltd, and Chief Executive of CEEQUAL, the sustainability assessment, rating and awards scheme for civil engineering, infrastructure, landscaping and the public realm.

My engineering started before my time at Imperial, with George Wimpey & Co Ltd, then a major civil engineering company (perhaps the Skanska or Balfour Beatty of its day), and followed my degree with four more years with Wimpey on site (M6) and in their substantial design office. There I got the bug for technical development and joined CIRIA as a research manager, progressing to run their offshore and underwater engineering group, and then their business development. A diploma in marketing beckoned, by which time my wife and business partner Jean had formed Venables Consultancy. A series of environment-related studies led to the formation of Crane Environmental and, five

years later, to the journey of first creating and then running the CEEQUAL assessment scheme.

Along the way, membership and then Chairmanship of the Institution of Civil Engineers' Environment & Sustainability Committee and a Royal Academy of Engineering Visiting Professorship in Engineering Design for Sustainable Development at Queen's University Belfast both led to an intensive period of learning and development of the interactions between civil engineering, the (rest of) the environment and the societal needs of and impacts on the communities we serve.

This in turn has led over recent years to a transition from our primary concerns being on improving and assessing 'environmental performance' to being on 'sustainability performance' and to consideration of the 'worthwhileness' of any proposed infrastructure, about which more later.

It is from this background that I offer you some thoughts on *Sustainability and Infrastructure: Crucial Connections & Challenging Contradictions*.



Photographs / illustrations © CEEQUAL

Figure 1: A selection of CEEQUAL assessed projects

FEATURES

A first, fundamental and crucial connection: we have only one Planet Earth!

I often feel that, alongside such seminal works as Rachel Carson's *Silent Spring*, our concern for our environment took an upward turn when we first saw a picture of earth from space. I think it helps us to recognise more than ever before that it is Planet Earth that is home, wherever on it we may live, and that it is the human race's life support system. It provides us with air, water, food, energy, space for waste disposal, space for recreation and a whole series of inputs and aspects that help towards, or inhibit, human well-being. It should be collectively obvious not to harm it.

More analytically, the still-new concept and practice of eco-footprinting tells us that if everyone in the world were to live at the same average levels of consumption and wastage as the peoples of North-west Europe, we would need three-and-a-half planets to provide all the necessary resources. Last time we all looked, we still only have one. What this means is that we have been removing resources from the planet at a faster rate than it can cope with, and asking the earth as a system to deal with more waste and pollution than it can cope with. It also means that there are great inequalities in access to fundamental resources, so for no other reason we need to be wise and careful in our own use of resources and minimising pollution, *including* in our use for and creation of civil engineering and other infrastructure.

So the first connection? We need to try to live and work in acknowledgement that we only have one Planet Earth.

Progressive concern to improve environmental performance in the built environment

Although there had been pressures to improve environmental management of construction before the 1990s, it was the publication of the first standard for environmental management systems, BS7750 in 1992 that started to

generate pressure on businesses. The ISO 14000 series followed soon afterwards – and specifically ISO14001 on environmental management systems – and was publicised widely.

We then had a strange period when a number of civil engineering clients and designers, who did not have environmental management systems themselves, decided to require contractors who were bidding to construct infrastructure to, initially, demonstrate that they were developing such systems and then, quite rapidly, to demonstrate that they had certified environmental management systems to apply to the project. The logic was that it would be the contractors in constructing a project who had the potential to cause the most environmental harm. Of course, most of the environmental impacts of such a project had been locked into the works by the decisions of the client and designers, and they were often subject to environmental impact assessments during development of the project design. But it would be some years before environmental management systems became commonplace in clients and designers.

CEEQUAL as a proxy for such environmental concerns.

It was against this background that the initial development of CEEQUAL was framed as an *environmental* quality assessment and awards scheme, albeit one that included management of nuisances to projects' neighbours as an environmental issue; the sponsors felt that clients, the industry and professions were not yet ready for a *sustainability* scheme that we have now. The driver for CEEQUAL then was that

- it was acknowledged that the environmental and social performance on all civil engineering projects was not as good as it could or should have been;
- that one could not just look at a project to assess the level of performance on such

matters; and

- one therefore needed a system to assess how well project teams were dealing with the environmental and neighbour issues they faced.

The project to develop what is now CEEQUAL was begun by the Institution of Civil Engineers with support from the then Department for the Environment, Transport and the Regions and by the ICE's own Research & Development Enabling Fund.

This is not the place for a detailed history of the development of CEEQUAL – see www.ceequal.com for more details. Suffice to say that, in terms of assessing environmental and (now) social performance, it covers the comprehensive topic list given in the Box below. It has been progressively developed, since Version 1 created during its initial development, to the current Version 5, and has become a significant influencer (for the better!) of how projects are designed and constructed. It has also become a *sustainability* assessment tool, so we need to address the distinctive attributes of that word before we can appreciate where sustainability in infrastructure has now reached. See Figure 1 for a selection of assessed projects. See Figure 2 and www.ceequal.com/awards_080.htm for the effects that the Blackfriars Station team felt that CEEQUAL had on their project and projects to come.

Sustainability and infrastructure 1: more fundamentals and semantics, and a second crucial connection

'Sustainability' as a concept is relatively straightforward – it means a state, a capacity for continuance (provided the correct and timely inputs are made to whatever the concept is applied to). So the sustainability of a business is related to the continuance of new orders for its products or services, and the continuing availability of all the aspects of a business needed to keep it going – skilled human resources, physical resources, transportation for distribution, marketing channels etc.

But at a world level, sustainability is applied to the capacity of Planet Earth to continue to supply the human race with the resources it needs for survival and progress *alongside* maintaining the ecosystem on which

What effect do we have?
What benefits do we generate?

Blackfriars Bridge & Station Refurbishment

Winner of a CEEQUAL Outstanding Achievement Award 2013 for Energy & Carbon



Whole Project with Interim Award

Project Team
Client: Network Rail
Design: Jacobs Engineering, Tony Gee & Partners
Construction: Balfour Beatty Civil Engineering Ltd

CEEQUAL helped the project to **both measure and drive performance** ... all three organisations were **challenged** in the areas of carbon and material use.

As a result, for the next and final phase of the Thameslink programme, **new targets and objectives** have been established to focus on these areas.

A carbon baseline is being calculated and a carbon policy will be established, **material use plans are now a standard requirement for all contracts**, and Thameslink has established a contractors' sustainable procurement forum.

CEEQUAL Assessment Coverage

- Project Strategy
- Project Management
- People and Communities
- Land Use and Landscape
- Historic Environment
- Ecology and Biodiversity
- Water Environment
- Physical Resources, including materials, components, energy, water, carbon and waste
- Transport



Figure 2: CEEQUAL and Blackfriars Station

we all depend *and* avoiding starving future generations of the resources they will also need for survival and progress.

So 'sustainability and infrastructure' covers the combination of

- creating infrastructure (and buildings) that is fit for purpose, efficient, capable of being effectively and efficiently maintained, and can be mined for useful resources when it comes to the end of its useful life;
and
- doing so with minimum adverse impacts on the environment, in a way that enhances human well-being, enables the communities it is serving to live more-sustainably, and with no or minimum harm to other communities not benefitting from the infrastructure in the first place.

Let's acknowledge at this point that we do seem to have a difficulty in common usage with the word 'sustainable' if not 'sustainability'. It seems as if everything – governments, hospitals, policies, energy supplies, supplies of dog biscuits – needs to be 'sustainable'. This is fine in most respects, but rarely is the term used in this way to also mean the second half of my comments above – minimum adverse impacts on the environment and society etc.

Why is this difficulty with 'sustainable' as an adjective important? Because an important term in the 'sustainability and infrastructure' arena is 'Sustainable Development' for which there are two meanings that we must acknowledge.

For many working on the wider social agenda of sustainability, 'Sustainable Development' is the process for achieving greater sustainability at a planet and wider societal level. But please recognise that 'Sustainable Development' is also used as a descriptor for buildings or civil engineering assets with particular characteristics. These can be all or many of a series of important attributes which include low energy and low

water consumption, efficient use of physical resources, high durability, ease of maintenance and therefore a long potential life, flexibility to change of use where appropriate, broad acceptability from an aesthetic and functional perspective by the communities in which they are placed. And ideally, wherever appropriate a 'wow factor' – there seems little point in creating infrastructure such as a bridge or new underground railway that is not pleasant to look at or use, and even a wastewater treatment plant can be hidden from view by careful and attractive landscaping.

So, a second crucial connection? We create, deliver, maintain and operate infrastructure *for communities and society* not just for its own sake, and we need to do so acknowledging the constraints of that single planet we have. Infrastructure has to work for people, not some abstract systems concept. Our economy works inside society, and society works inside the environment – forget that and irretrievably damage the environment, and where does that leave society?

Sustainability and infrastructure 2: The delivery challenge and a final crucial connection

With all that background, how should infrastructure design and construction rise to the sustainability challenge? It's a conundrum we need to navigate around.

If a designer is challenged to provide a "sustainable design", how do they demonstrate success? If a contractor is challenged to deliver "sustainable construction", how do *they* demonstrate success? And, in view of the substantial amount of non-renewable resources consumed in building anything, surely "sustainable construction" is an oxymoron?

The result of such a way of thinking is that we get hung up on trying to define destinations, when we don't have the tools, the data or futurology to do so; it's the *direction of*

travel that's important.

So my suggestion to help us out of this mire is that "sustainability-driven design & construction" might help us better. And crucial questions we need to ask at concept stage are: "Is our project going to help the communities it will serve to live more-sustainably? If not, why are we doing it?"

What such an approach helps us to do is to

- concentrate on improving positive attributes of our designs;
- minimise the adverse impacts;
- do the best we can within the limits of current knowledge;
- not beat ourselves up when the constraints on our projects – location, neighbours, funding etc – prevent us achieving what might be called pinnacle best practice;
- learn from our current project to feed forward to our next, aiming to lift the performance and worthwhileness hurdles as we do so; and, last but not least
- publicise our journey to better and better infrastructure, serving society more effectively, enhancing the environment as well as minimising adverse impacts, and being so efficient in our use of resources that it enables others to build their projects for which resources may have been scarce.

And how might we achieve such a target? By building multi-disciplinary teams and enabling them to deliver a result that takes their individual skills and experience and combines them to create a stunning result. My final crucial connection is a musical one. Transatlantic Sessions is a series of musical programmes that combine the Gaelic and Country music traditions into something almost magical were it not the almost-perfect example of combining multiple talents into a special result*. In essence, the producers bring together leading singers and instrumentalists in the Scottish and Irish Gaelic musical strands with Bluegrass and Country musicians from the USA. By applying their skills and, crucially, listening to each other intently, they combine to produce wonderful broadcast-quality programmes from a baseline where not all of the assembled musicians know all the pieces in advance.

Multi-disciplinary teams charged with creating special sustainability-driven projects need to do the same thing. The Transatlantic Sessions producers do not try to turn the bass player into a mediocre flautist, but get the musicians to work together to create an amazing sound. Infrastructure project teams should not be seeking to turn civil engineers into mediocre ecologists, but should get them to work with expert ecologists – and all the other professions needed for successful infrastructure – to create something that no single profession can create on their own. See Figure 3 for the two strands of sustainability-driven projects that such teams need to deliver.

* Look for Transatlantic Sessions from time to time on the BBC4 TV schedules, or on iPlayer for music broadcast by BBC Alba.



Figure 3: Sustainability-driven projects

Design Engineering

Imperial College has been engaged in design for a long time, extending from activities in the Departments of Civil and Environmental Engineering and Bioengineering to Mechanical Engineering and Computing. The first ever meeting of the Design Research Society took place at Imperial in 1966.

There has also been the long standing collaboration between the Royal College of Art (RCA) and Imperial on the Innovation Design Engineering joint masters programme. The need for specialisation in the then newly emerging discipline of industrial design was recognised by Professors Misha Black and Frank Height from the Royal College of Art in the 1970s. The joint programme, originally called Industrial Design Engineering (IDE) was brought to fruition in 1980 after six years of planning by Misha Black, Frank Knight and Professor Sir Hugh Ford from Imperial. Since then IDE has gone from strength to strength addressing full-on the long standing ambition and vision of Prince Albert for the South Kensington estate *'to be a place where institutions of science and art can work together for the benefit of manufacturing industry'*.

The original aim of the IDE programme was to improve British consumer and industrial projects by taking graduate engineers and teaching them how to design. 35 years on IDE has an illustrious past, vibrant present and plenty to explore in the years ahead. The programme has seen nearly 600 alumni, and now has a cohort of about 40 students in each

'Design Engineering is the fusion of design thinking, engineering thinking and practice within a culture of innovation and enterprise.'

year studying full time for two years. The programme is noted for the high numbers of alumni who engage in start-ups on exiting the programme, many of which are based on projects they have explored during their time at Imperial and the RCA. Recent examples of companies associated with IDE alumni have included Bare Conductive, Omlet, Concrete Canvas, Loowatt, DIY Kyoto and the Agency of Design. Notable alumni include Duncan Kerr, Laura Taylor, Kursty Knight, Mark Sanders and Alastair Curtis.

With all this heritage there was momentum building and as every engineer knows this is something difficult to stop. In 2008 The Faculty of Engineering appointed a Professorial Lead in Engineering Design based in the Mechanical Engineering Department. Mechanical Engineering had been the Imperial home for IDE and a series of activities in design were kicked off ranging from boosting Imperial's contributions to the IDE programme, introducing a total product design engineering project into the second year of the Mechanical Engineering

MEng curriculum, commencing a new cross faculty module called Design Led Innovation and New Venture Creation and probably the highest profile of all, major exhibitions of student design output, hosted at Imperial. The Rio Tinto Sports Innovation Challenge exhibition of Paralympic innovations resulted in exposure of a design through making and prototyping culture to a wide base of Imperial stakeholders, and subsequent exhibitions included output from the graduating year from Innovation Design Engineering and the Design Art Creativity module.

2012 saw a major conference on engineering education hosted at Imperial. One of the activities was to write a postcard to yourself from the year 2022, stating what innovation you had been associated with in education and what your future position would be. As conference facilitator an example had to be given and in front of a few hundred people, the following card was read – Imperial now offers a MEng in Design Engineering – Peter Childs, Head of School. Little did we know how quickly things would move and as someone commented, 'that's one way to get a job'. 2013 saw the confluence of a pitch to a major OEM for a new research centre in engineering design and within a few weeks this had become a proposal for the School of Design Engineering. In March and April 2014 the curriculum for an MEng in Design Engineering emerged and went through committees that summer, and the School was formally set up in July 2014.

BRUISE

BRUISE – provides a visual indication of impact and possible injury for disabled athletes and other users engaging in high performance sports and activities. BRUISE arose from a joint IDE and GID project as part of the Rio Tinto Sports Innovation Challenge. Following the initial short module, the team has received a series of accolades and follow-on funding. BRUISE uses parameter sensitive materials to provide an indication of injury following a tumble or accident.

We wanted to explore something not usually seen in inclusive design - collaboration with a high end fashion designer. To push BRUISE to the next level of technical performance and desirability we approached Mary Benson (Exhibited in Fashion East 2015), to discuss a redesign. We absolutely loved her work and she and her team were very into BRUISE right from the beginning. Mary developed one prototype in Olympic colours for use by a yet-to-be announced Paralympian, and another even more surreal and beautiful suit for exhibition use. We

split up and downsized the colour-changing patches for greater resolution of where an injury might be and to make changing exposed patches easier. BRUISE will be in the six week 'Health Tech & You' exhibition at the Design Museum from March 10th, and has recently been in both the science museum and a MoMA digital exhibition.



The BRUISE team includes Elena Dieckmann (IDE), Dan Garrett (GID), Lucy Jung (IDE) and Adam Kong (IDE).

All engineers know what engineering is, and we are generally comfortable with defining who we are and what we do. Whether there is a distinction between design and engineering is always worthy of conversation. Engineering can be regarded as the application of scientific and mathematical knowledge in the provision of solutions to a societal need. Design can be used as a noun or verb. In terms of a process, design can be considered to be the process of conceiving, developing and realising products, artefacts, processes, systems, services and experiences with the aim of fulfilling identified or perceived needs or desires typically working within defined or negotiated constraints' (Mechanical Engineering Handbook, Elsevier, Childs (2013)). So what of design engineering? Well the ordering of the words is deliberate and a definition for design engineering has emerged. We wanted something fitting for the 21st Century that built on the heritage of over a hundred years of design at Imperial, resulting in the following definition:

'Design Engineering is the fusion of design thinking, engineering thinking and practice within a culture of innovation and enterprise.'

The School of Design Engineering is undertaking four major activities:

- running a MEng in Design Engineering;
- principal home for the Imperial contribution to the Innovation Design Engineering double masters, run jointly with the Royal College of Art;
- home for the Imperial contribution to the Global Innovation Design double masters, run jointly with the Royal College of Art;
- research in the domain of design engineering and large scale design projects.

Developing the new MEng in Design Engineering has been very exciting. The focus of the programme is deliberately broad ranging from product design, service design, system design and experience design. The curriculum addresses skills in a wide range of functionalities from technical function, aesthetic function, social function, psychological function, economic function, latent and emergent function. The first year includes modules on communication in design addressing skills in sketching and CAD, engineering sciences from mechanics, electronics to energy and design. A strand with a particular focus on physical computing and robotics runs through the programme across Electronics 1 & 2, Computing 1 & 2, Gizmo, Robotics 1 & 2. Another strand on relevant mathematical analysis skills includes

engineering maths, engineering analysis, big data and Optimisation 1 & 2. There are also management, analysis and design strands. The degree is coursework intensive with about 16 major design engineering projects, the majority involving design through making with functioning prototyping. The degree culminates in shows of graduation projects, and the enterprise roll-out module where students will expose one of their previous projects to market reaction. We have had a very positive reaction to date with hundreds of applicants to the MEng. In the words of one applicant on hearing about the degree and journey to set this up:

'what took you so long'

Well we are now here and would value your involvement with us. Do come and visit our exhibitions and meet us – Show Imperial 2015 runs from the 6-10th July 2015 in the main Exhibition Road entrance, exhibiting work from the Innovation Design Engineering and Global Innovation Design graduating students. You would be most welcome. In addition several of our student projects will

be shown in the Sports Innovation Challenge exhibit at the Imperial Festival from the 8-10th May 2015. We will be in temporary accommodation at 10 Princes Gardens for perhaps a year. Our website will provide up to date news. We would very much welcome an approach from the companies you are involved with to take our MEng students on their six month placement which runs from April to September in Year 3. These students will not be available until April 2018 so there is some time in which to enter formal agreements on hosting a placement.

Quoting from a recent personal statement on an application:

'To create Powerpuff Girls, Professor Utonium mixed sugar, spice, everything nice and "Chemical X". That is how I see Design Engineering – as a combination of maths, physics and design. In my fairy tale I want to be Professor Utonium and create something extraordinary'

Karolina Gawlik.

We are domain forming and have the good fortune to benefit from the legacy of Imperial and be part of Imperial's next steps.

The Dot Device



Charlotte Slingsby

**IDEI Individual project work
Charlotte Slingsby**

Designed as a form of directly observed treatment for Tuberculosis Drug Compliance in the townships of South Africa

This handheld device is designed to assist tuberculosis patients to adhere to the lengthy Tuberculosis treatment within the townships of South Africa. It tracks and records the patient's daily drug compliance. It is remotely linked with the cellphone network and is able to issue a reminder via text message to take the medication and reward the patient with free texts for steady compliance.

The concept involves two elements; firstly the computer which reminds and records, and secondly the conductive matrix sticker. The disposable sticker is placed on the blister packet. It is then inserted into the device. Through the rupturing of the blister pack a signal is generated which allows a computer in the hand held device to track the activity.

This was designed as a two part system so that the main expense is the computer, which can be reused and redistributed by the clinics. Thus allowing the underprivileged, who are severely affected by the spread of tuberculosis, to afford such assistance.



Peter Childs is Head of the School of Design Engineering and the Professorial Lead in Engineering Design at Imperial College London. His general interests include creativity tools, product and system design, fluid flow and heat transfer. Prior to accepting his current post at Imperial he was director of the Rolls-Royce supported University Technology Centre for Aero-Thermal Systems, director of InQbate and professor at the University of Sussex. He has been involved in research and development contracts for Rolls-Royce plc, Alstom, Snecma, DaimlerChrysler, MTU, Volvo, Johnson Matthey, Siemens, Industriales Turbinas Propulsores, Fiat Avio, Airbus, Ricardo Consulting Engineers, Ford, Rio Tinto, the EPSRC, TSB and the EU as well as a number of SMEs and has been principal or co-investigator on contracts totalling over £26.5 million. He is a director of Q-Bot Ltd and Creative Director at ICeni Labs.

Science in Art:

A chemical engineer's journey through art conservation

Seven years ago, soon after I'd graduated from Imperial, I packed my bags and left the UK for a PhD in the States. Enrolled as a postgraduate student in the Chemical Engineering department at Princeton, I anticipated a future career in oil and gas, pharmaceuticals, consumer goods, or something else within my known realms of chemical engineering. So I was quite surprised when I found myself one day sitting in an engineering class and learning about art conservation.

The course, titled "Introduction to Materials Science" had been advertised as a postgraduate cross-disciplinary elective for engineers. "But what does art conservation have to do with materials science or chemical engineering?" I'd wondered. Curious to find out, I made an appointment with the professor, a joint faculty member in the Civil Engineering, Chemical Engineering and Mechanical and Aerospace Engineering departments, and amongst whose research interests, I soon discovered, was art conservation. Little did I know that that meeting would mark the start of my

own research and that six years later, I'd be in a position to talk about conservation with others.

Art conservation, in a nutshell, is the preservation of objects and structures that possess cultural heritage value from environmentally induced deterioration. The objects themselves can range from porcelain to paintings, books to textiles and statues to monuments. There are, for example, conservators working on the restoration of Japanese bronze statues, others that work on restoring wood panel paintings and others still that treat old sandstone castles to prevent salt crystallisation. In this field, scientists and engineers make up only one part of a team that also includes art historians, archaeologists, artists and museum curators. The scientist's role is to study the properties of the materials and the deterioration processes that they undergo, and to develop ways of protecting and restoring the materials. The work can be in the form of prevention, whereby the cause of damage is addressed before deterioration occurs, or in the form of treatment, whereby deterioration that has already occurred is mitigated.

The lab I worked in, during my PhD,

studies stone conservation. Stones such as marble and limestone are composed of the mineral calcite, and have been important materials in art and construction for centuries. Unfortunately, however, stones are susceptible to weathering in the outdoors. Limestone is porous and is thus vulnerable to a host of environmental processes, such as freeze-thaw cycles, salt crystallisation in its pores and acid attack, which all cause the stone to weaken. Marble, on the other hand, is almost non-porous and therefore much less vulnerable to most forms of weathering, but is still susceptible to acid attack on its surface. Since the onset of industrialisation, acid rain has been a major environmental issue, with some of the most polluted cities in the world being home to many of our most valued marble structures, such as the Taj Mahal (Agra) and the Parthenon (Athens). Marble is susceptible to dissolving in rain because calcite is extremely soluble in acid. At the pH of normal rainwater (pH 5.6), it will dissolve at a rate of about 1.2 mm per century, assuming rainfall occurs 1% of the time. If the pH decreases to 4.6, which is not unrealistic in many urban areas, the dissolution rate becomes 1.2 cm per century – all it would take are a

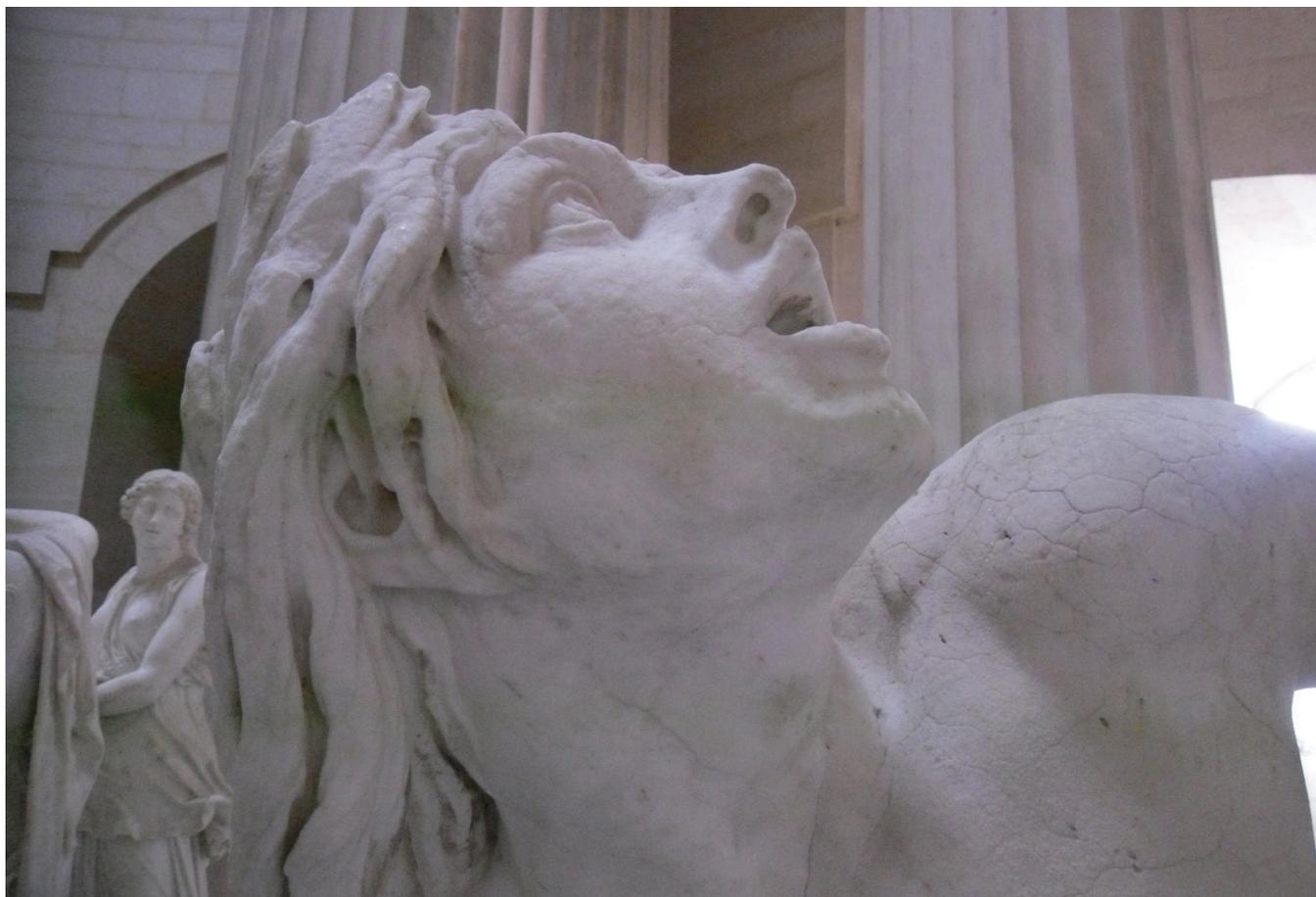


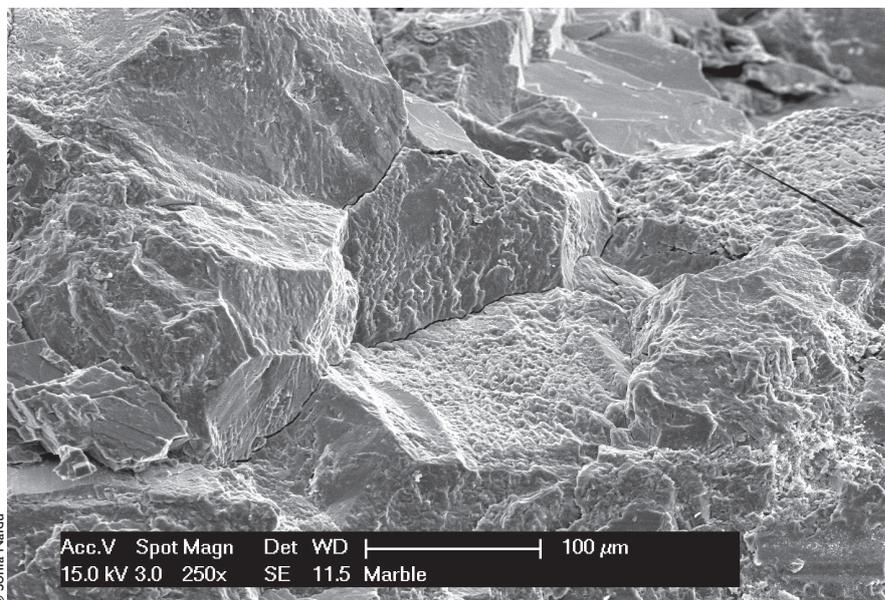
Image of a marble statue inside the conservation workshop at the Palace of Versailles.

Damage caused by exposure to the elements can be seen in the form of cracks, stains and acid etch marks on its surface.

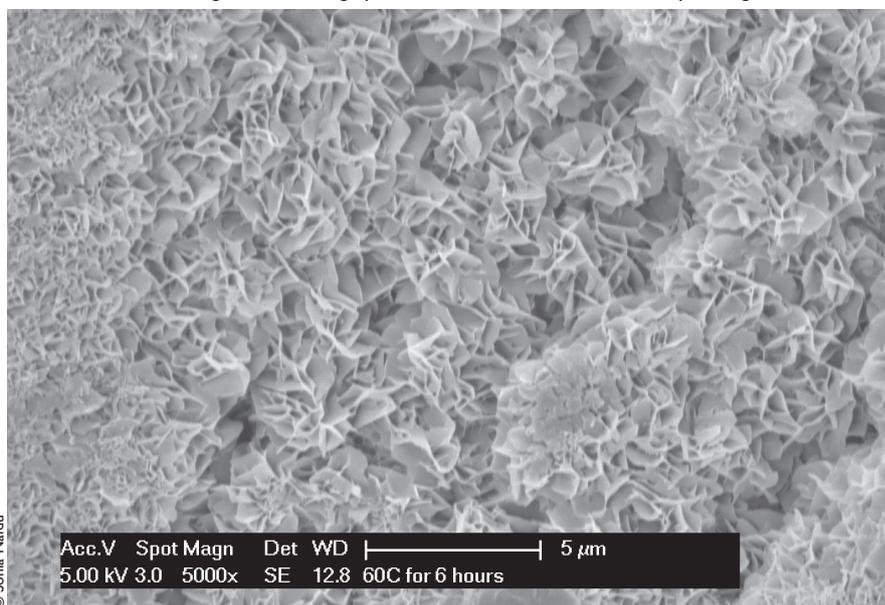
few decades to destroy the intricate details of some of our most precious monuments, as we have already observed. Unfortunately, despite the development of several commercial treatments, none are particularly effective at preventing this.

In 2008, my supervisor, George Scherer, and a colleague, Robert Cava (Dept. of Chemistry, Princeton University), came up with the idea of testing hydroxyapatite, the mineral that makes up human teeth and bones, as a protective coating for marble. In theory, by reacting marble with certain salt solutions, impervious coatings of hydroxyapatite could form and prevent the stone from coming into contact with acid. The coatings themselves would remain transparent or translucent, thus not altering the stone's appearance. "Why hydroxyapatite?" one might wonder. Well, the mineral is highly insoluble and dissolves about 10,000 times more slowly than calcite - which is why our teeth can sustain copious amounts of lemon juice without disintegrating. It is also chemically and structurally compatible with calcite, which means that depositing microlayers of hydroxyapatite on marble should be fairly easy to do.

My postgraduate work involved investigating the use of hydroxyapatite to a) consolidate damaged limestone and b) reduce acid attack on marble. I spent a lot of time synthesising coatings, chemically modifying them and characterising samples using techniques such as electron microscopy, X-ray diffraction and nuclear magnetic resonance spectroscopy. I developed an accelerated lab technique to test the performance of the coatings under acid attack, which revealed that the treatment was only moderately effective at preventing attack. The limited effectiveness has been attributed to hydroxyapatite's preferred crystal growth habit (see image), which is flowery in nature and consequently leaves gaps that allow the acid to access and dissolve the underlying marble, albeit more slowly. Current work is focused on improving the quality of the coatings. My supervisor and I conducted the limestone consolidation work in collaboration with researchers at the University of Bologna, Italy. Interestingly, hydroxyapatite was found to be far more effective at binding and consolidating limestone than it was at coating marble, and it displayed superior performance to commercially available treatments. Our research succeeded in gaining the attention of the international art conservation community. In 2011, I met a conservator at the Palace of Versailles, who invited me on a tour of the conservation workshops there, and subsequently became a field collaborator; the treatment we developed is being tested on



Scanning electron micrograph of the surface of marble, without any coating



Scanning electron micrograph of a coating of hydroxyapatite crystals on Carrara marble

marble statues at the palace. Colleagues in Athens have also started collaborations, and are testing the same treatment on some of their samples. I have since graduated, but the research continues under the direction of my PhD supervisor, and I try to stay updated on its progress.

My work in art conservation opened my eyes to the variety of possibilities in engineering. Working on important scientific questions on a microlevel, in order to address critical art conservation issues on a macrolevel had a truly interdisciplinary feel to it. It allowed me to interact with people from extremely diverse professional backgrounds, to meet scientists

and conservators working at World Heritage Sites and to visit such interesting places as the underground conservation labs at the Metropolitan Museum of Art (New York), that I probably never would have otherwise been able to see. At some point, I also became that person who takes close-up pictures of cracks and stains on the facades of the Taj Mahal, while everyone else positions themselves for selfies. The interdisciplinary nature of science and art in my work revealed to me how the boundaries of our fields are not always as rigid as we may think, but can often be flexible, and the range of career possibilities open to us are probably wider than we are aware.



Sonia Naidu graduated with a MEng in Chemical Engineering from Imperial College in 2008 and a PhD in Chemical and Biological Engineering from Princeton University in 2014. She now works as a postdoctoral researcher in Materials Science at Rutgers University. Her current work involves developing environmentally friendly building materials, known as "green cement" and "green concrete", which reduce greenhouse gas emissions and help sequester CO₂. She is passionate about a variety of causes, including environmental sustainability, human rights and wildlife conservation. She can be reached at sonuschka.naidu@gmail.com.

Developing Thorium-Based Nuclear Energy to End Global Dependence on Fossil Fuels

In the last issue of Imperial ENGINEER we included the winning essay in last year's RSMA Essay Prize competition. The judges commended the runner-up Yehia Amar and suggested we include his entry.

As the world population grows and is on track to reach 9.6 billion by 2050^[1], I believe that a main global environmental challenge is how to meet growing energy needs without exacerbating climate change. Nuclear energy is increasingly being regarded as a source of energy that can alleviate the global energy problem through its promise of clean, carbon-free base-load power.

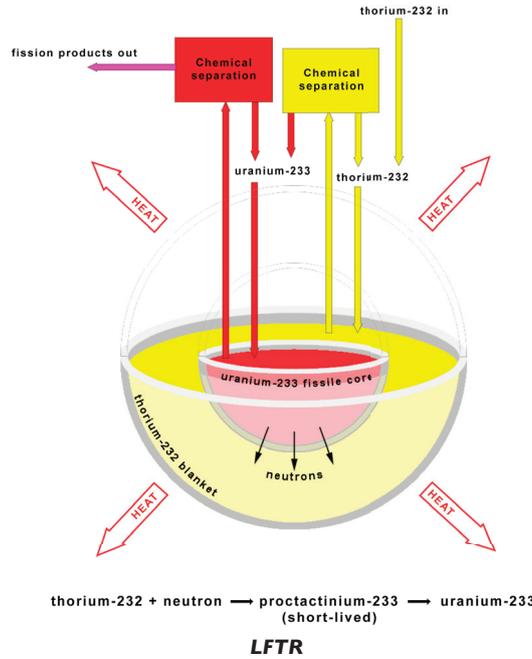
In this essay I shall investigate the advantages and disadvantages of the promising Generation-IV design molten salt reactor (MSR). The major findings are that it acts as a viable replacement for current, ageing nuclear reactors and an alternative to fossil fuels-based energy. I will examine how the safety features of its class of reactors preclude an environmental catastrophe such as the Fukushima Daiichi nuclear disaster of 2011. This will be followed by a discussion of developments in the nuclear energy policies of various countries. As my academic focus is nuclear engineering and as I prepare to embark on my internship in the field of nuclear waste reprocessing, this analysis touches at the heart of my studies and research.

The best way to judge a nuclear reactor is by considering a combination of the following factors: safety, proliferation resistance, long-lived waste issues, resource sustainability, cost and technological certainty. Currently, most of the world's nuclear reactors are light water reactors (LWRs). Considering the six factors mentioned, however, there is great potential in a technology that was born at the Oak Ridge National Laboratories (ORNL) in 1965, the MSR.^[2]

Introducing the MSR.

The most popular and most-researched MSR is the liquid fluoride thorium reactor (LFTR, pronounced 'lifter'). The LFTR's reactor core consists of fissile ²³³U, surrounded by a fertile blanket of liquid thorium which 'breeds' ²³³U upon absorption of its fission neutrons (see the diagram). Both elements are in a molten liquid salt complex that includes fluorine, lithium and beryllium. A significant advantage of having liquid fuel is the lack of expensive fuel fabrication (a complex and lengthy stage in the uranium fuel cycle). In addition, one of my nuclear energy professors used to say, "All nuclear engineering problems are at heart 'materials' problems". This is certainly the case for solid fuel rods, which undergo structural damage (in ductility, yield-strength and probability-to-fracture) resulting from heat and irradiation^[3]. Liquid fuel does not present this challenge. Another attractive feature of liquid fuel is online refuelling: whilst LWRs typically undergo refuelling every 18 months

which involves manual shutdown of the reactor, in MSRs these expensive operational transients are not needed, which saves money and the hazards that accompany them.



Thorium as nuclear fuel

Many of today's operational LWRs use mixed oxide (MOX) fuels as nuclear fuel, consisting mainly of uranium dioxide (UO₂)^[4]. In LWRs this fuel is typically enriched 3-5% in ²³⁵U, the fissile isotope of uranium. An estimated figure for the world supply of uranium is 5.3 million tonnes^[5], which at the present consumption rate would be used up in 80 years, making uranium a finite and potentially scarce resource^[6]. Thorium is a viable alternative to uranium as fuel: it is estimated to be four times as abundant as uranium on the planet^[7] and much more evenly distributed amongst the world's nations, allowing for a more levelled market and lower geopolitical risk resulting from dependency on a small handful of countries.^[7] The latter point, in my opinion, provides potential for developing and emerging markets to be players in the nuclear industry, as exporters of thorium fuel.

On waste

The issue of dealing with waste is a big debate in the UK, which has the world's largest stockpile of plutonium^[8]. As radioactive half-lives are often longer than human lifetimes, subsequent generations will have to solve waste problems that we initiate today, which is morally questionable. Spent nuclear fuel contains waste that may be placed in two categories: long-lived transuranic elements and

short-lived fission products. Fission products such as xenon, which make the reactor less efficient by absorbing neutrons and thus slowing down fission, are highly radioactive and must either be stored (in dry-cask storage)

for several millennia or reprocessed at a repository. The other waste species are transuranic elements such as plutonium, which are significantly less radioactive and can be utilised in fast reactors (upon being separated from uranium by the PUREX process). In LFTRs, fission products are removed continuously, which improves the fuel utilisation as much higher burnup is achieved. In addition, all fission products in LFTRs are 'less long-lived' than other designs (decaying to benign levels after only 100s of years)^[9].

On proliferation

On the issue of nuclear weapons proliferation, MSRs are extremely robust. The use of thorium as fuel means that spent fuel does not consist of weapons-grade material, rendering this technology ill-suited for organisations or states with illicit intentions to attain a nuclear weapons capability. The ²³³U bred from thorium contains some ²³²U, which produces decay products that include strong emitters of high-energy gamma radiation. These emissions are easily detectable and highly destructive to ordnance components and circuitry. ²³²U is chemically identical to – and essentially inseparable from – ²³³U^{[5][9]}. This issue sways many nuclear sceptics who express concerns regarding proliferation, and it also improves the public perception for nuclear power as a peaceful source of energy.

Where are the world's LFTRs?

So, the attractiveness of LFTRs begs the obvious question, why is this technology not conventional? The real disadvantage, in my judgement, lies in the fuel-cycle cost and need for R&D. Given the nature of the nuclear industry, companies are reluctant to embark on an untried venture when proven and tested ones exist. For large organisations with decades of experience in LWR technology, a shift in technology is unlikely. Embarking on new projects in the nuclear industry is notoriously difficult, with significant amounts of R&D needed before regulatory commissions grant licenses for operation. A serious research effort must continue in the area of materials and corrosion issues before construction can begin.

However, there are encouraging developments in China on MSRs. With the government declaring a "war on pollution" and fostering a nationalistic feeling of competition with other economic superpowers, the

deadline for the Chinese Academy of Sciences' research programme on molten-salt thorium reactors has been brought forward by 15 years; they plan to develop the first such reactor by 2024^[12]. Interestingly, this energy policy is taking place at a time when the epidemic of photochemical smog in cities like Beijing has worsened and is becoming a human health crisis^[13].

This development led me to study other governments' energy policies in response to environmental crises. Unsurprisingly the World Nuclear Association has reported that Germany's CO₂ emissions have increased this year for the second year in a row^[14], departing from a previously reducing trajectory. This suggests that the post-Fukushima energy policy of phasing out German nuclear plants is adversely affecting the environment because the energy need is being met by brown coal instead. I hope and expect that this will serve as a wake up call that today's climate change renders nuclear energy a necessity rather than a luxury.

Japan has recently taken a different route, reversing the previous government's efforts to phase out existing Japanese nuclear plants^[15]. Moreover, the UK announced in October 2013 that new build would commence in England for the first time in decades.^[16]

In conclusion, it is an interesting time to examine how the state of the world's environment is affecting the nuclear energy industry. The topic of my essay, thorium reactors, has been a subject of scientific study since the 1965 MSR experiment at ORNL, but has yet to become mainstream technology. With the urgency of nuclear energy becoming clearer every year, it is my hope to contribute to the design and study of these new nuclear technologies, with the vision that nuclear energy's share of the energy economy will grow and lead to a healthier relationship between human beings and our environment.

References:

- 1 United Nations (2012) – 'World Population Prospects, the 2012 Revision' Available online at <http://esa.un.org/wpp/>
- 2 Oak Ridge National Laboratories (Feb 1964) – 'MSRE Design and Operations Report' Available online at <http://web.ornl.gov/info/reports/1964/3445606043171.pdf>
- 3 American Scientist, **98**, (2010) Hargraves, Robert; Moir, Ralph
- 4 World Nuclear News (May 2013) – 'Mixed Oxide Fuels (MOX)'
- 5 World Nuclear Association (Aug 2012) – 'Supply of Uranium' Available online at <http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Supply-of-Uranium>
- 6 Weinberg Foundation (June 2013) – 'Thorium-Fuelled Molten Salt Reactors'.
- 7 United States Geological Survey (2013) – 'Thorium' Available online at <http://minerals.usgs.gov/minerals/pubs/commodity/thorium/mcs-2014-thori.pdf>

Case study in reactor safety: Fukushima Daiichi, 2011

Let us explore the sequence of events that lead to the disaster in Fukushima, which eventuated in the release of radioactive noble gases following a hydrogen explosion that blew off the top of reactor containment buildings. The Fukushima Daiichi nuclear power station consisted of six, decades-old Generation-I Boiling Water Reactors (BWRs) at the edge of the sea. The earthquake resulted in the loss of off-site power, upon which the reactors were shut down. Subsequently, the emergency diesel generators (the function of which was to supply power for post-trip cooling, powering pumps to wash away the decay heat of the fuel) were swamped by the tsunami. A lack of emergency power leaves no way to prevent the fuel from melting. Whilst reactors 4, 5 and 6 had safely defueled at the time of the accident and were in cold shutdown mode, reactors 1, 2 and 3 had experienced a full meltdown.^[10]

When nuclear fuel melts, the surrounding cladding fails, leading to a zirconium-water reaction that releases hydrogen in the steam. The combination of fission products, steam and hydrogen rose to the top of the containment building of the reactors, resulting in an explosion. In summary, the key failure was the lack of sufficient decay heat removal, which resulted in the meltdown and radioactive fission product release.

This scenario is absolutely inconceivable in current reactor designs and certainly not in the inherently safe MSR, where post-trip cooling is an issue dealt with at the *design stage*. In the design of Generation III+ and IV reactors, the focus is on passive safety systems that rely on natural phenomena, such as gravity and buoyancy, to provide

cooling instead of potentially unreliable add-on systems. If a LFTR shuts down and the circulation of coolant is disrupted, the hot fuel melts a frozen plug of salt beneath the core, allowing the molten salt to drain to separate tanks where the liquid fuel cools down and solidifies. This whole process takes place without operator intervention, eliminating potential for human error (noting that operator errors contributed largely to Three Mile Island-II and Chernobyl).

In addition, temperature regulation in MSRs is also passively controlled, obviating control rods. Control rods have the function of slowing down neutrons to the thermal state; these rods are made of highly neutron-absorbing elements like boron, carbon or hafnium. The reason control rods are unnecessary in MSRs is the '*negative temperature coefficient*' of the core, which means that heat from fission makes the molten salt expand, which, in turn, slows down the fission rate. This means that when temperature rises, reactivity decreases, stabilising power levels and preventing the core from overheating. Finally, the absence of large pressures in LFTRs precludes any pressure explosions, cuts the cost of maintaining extreme pressures and obviates the need for a containment dome.

Nuclear safety today is far more sophisticated than ever before, especially given the developments of simulation tools that can model Richter-10 earthquakes, tidal waves, aircraft crashes etc. In addition, nuclear energy is, in terms of number of deaths per TWh, the safest technologically certain energy source, 4000 times safer than coal.^[11]

- 8 International Panel on Fissile Materials (2011) – *Sixth Annual Report* Available online at <http://fissilematerials.org/library/gfmr11.pdf>
- 9 LeBlanc, David (May 2011) - 'Thorium Energy Alliance Conference', Lecture.
- 10 Japan Office for Nuclear Regulation (Sep 2011) - *Japanese earthquake and tsunami: Implications for the UK nuclear industry* Available online at <http://www.onr.org.uk/fukushima/final-report.pdf>
- 11 World Health Organisation (2011), data compiled by blogger at <http://nextbigfuture.com/2011/03/deaths-per-twh-by-energy-source.html>
- 12 Stephen Chen (March 2014), South China Morning Post, article Available online at <http://www.scmp.com/news/china/article/1452011/chinese-scientists-urged-develop-new-thorium-nuclear-reactors-2024?page=all>

- 13 Jeff Rubin (April 2014) – 'China's war on smog will rein in global coal demand' Available online at <http://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/chinas-war-on-smog-will-put-the-reins-on-global-coal-demand/article18182024/>
- 14 World Nuclear News (March, 2014) – 'Coal taints Germany's energy mix'
- 15 World Bulletin (April 2014) – 'Japan approves energy plan reinstating nuclear power' Available online at <http://www.worldbulletin.net/news/133507/japan-approves-energy-plan-reinstating-nuclear-power>
- 16 World Nuclear News (October 2013) – 'Strike price deal for Hinkley Point C' Available online at http://www.world-nuclear-news.org/NN_Strike_price_deal_for_Hinkley_Point_C_2110131.html



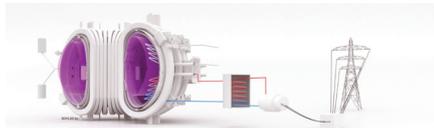
Yehia Amar, 20, is about to complete his MEng in Chemical with Nuclear Engineering, expecting a 1st class degree. He will return to his home, Frankfurt am Main, this summer, to pursue a Visiting Associateship at The Boston Consulting Group before embarking on PhD studies at University of Cambridge in October 2015. His interests include energy, healthcare, politics and consulting; outside of academia he is passionate about reading, languages, culture, debating, film, drama and singing. His life motto: dream big and pursue them tenaciously.

Bringing fusion down to Earth

In the last issue of Imperial ENGINEER we reported that Professor Steve Cowley from the Department of Physics had been elected as a Fellow of the Royal Academy of Engineering. Alongside his academic role, Steve is Director of Culham Centre for Fusion Energy (CCFE) and CEO of the UK Atomic Energy Authority. He agreed to tell us about the challenges to Fusion Energy that CCFE is helping to overcome.

Introduction

Stephen Hawking, when asked which scientific discovery or advance he would like to see in his lifetime answered "I would like nuclear fusion to become a practical power source. It would provide an inexhaustible supply of energy, without pollution or global warming". And, indeed harnessing the power source of the Sun and stars is, in so many ways, the perfect way of generating electricity – offering carbon-free and safe energy production from abundant fuels without long-lived radioactive waste products.

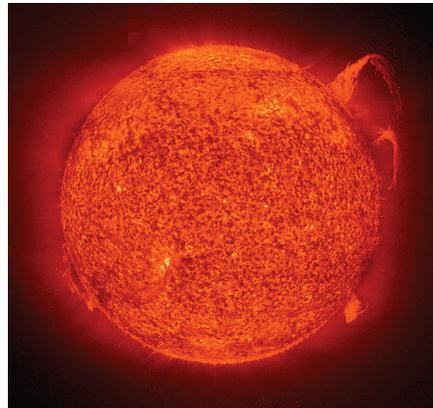


So, why aren't there any fusion power stations on the grid? Simply because it is hard to do – very hard in fact. Start with the fusion reaction – forcing light nuclei to stick together, making larger nuclei and releasing energy in the process. Unlike splitting heavy atoms (fission) which happens at room temperature, nuclear fusion requires light positively-charged nuclei to move very rapidly, to overcome their repulsion and get close enough to attract. This requires enormous temperatures in the ionised gas (or plasma) of fuels. At the temperature of 15 million °C in the centre of the Sun, fusion of hydrogen occurs very slowly – generating only 275 W/m³. So, efficient power production requires a different nuclear reaction; one between the two hydrogen isotopes deuterium and tritium and at ten times the Sun's central temperature. Remarkably, these temperatures are now possible in experiments – the challenge remains to engineer a viable reactor.

Fusion experiments

Since the 1950s, scientists and engineers have been investigating two main ways of creating the conditions for fusion to occur. In 'inertial confinement' fusion, powerful lasers are fired at small solid targets containing fusion fuel. The fuel is compressed and heated so that fusion occurs before the target blows itself apart in a nanosecond. Good progress is being made at the National Ignition Facility experiment in the United States, where for the first time more energy from fusion was generated than was absorbed in the very core of the target – an important step forward but some way from energy breakeven. Its French counterpart, the Laser Mégajoule facility, is due to be switched on later this year.

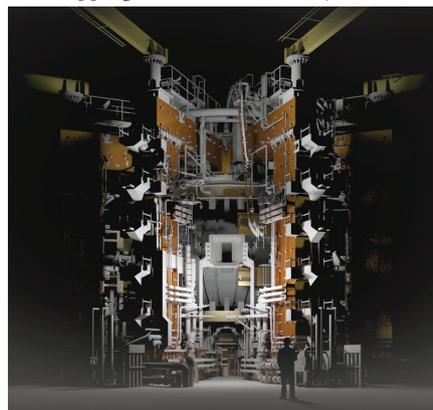
The other fusion approach is 'magnetic confinement', in which hot plasma is contained and squeezed by electromagnets. Inside this



**The Sun, 15 million °C in the centre.
Too cold for efficient power production**

magnetic 'cage', heating from fusion reactions overcomes the turbulent heat losses. Hidden away in rural Oxfordshire is Culham Centre for Fusion Energy (CCFE), home to two of the world's leading magnetic confinement experiments. JET is the world's largest tokamak (a toroidal magnetic cage) and it is operated by CCFE on behalf of EUROfusion – a consortium of fusion research institutions across Europe. JET holds world records for fusion performance – generating 16MW of output power (70% of the power used to heat the whole plasma) and temperatures of 200-300 million °C. In addition, MAST is the UK's own fusion experiment – a more compact 'spherical' tokamak – leading investigations into smaller, cheaper and more efficient configurations.

Beyond JET, ITER – the project that will assess the viability of fusion as a future source of electricity – is now underway on a construction site the size of 60 football pitches, at Cadarache in southern France. ITER is a multi-billion Euro experiment backed by Europe, China, India, Japan, Russia, South Korea and the United States. One of the largest international science endeavours in history, it aims to act as a stepping stone between today's tokamak



JET

devices and the first fusion power plants. ITER, which is expected to begin operating in the early 2020s, will produce 500 megawatts of fusion power. This is more than ten times the power needed to heat the plasma. Indeed most of the plasma heating will come from the fusion reactions themselves – a fusion "burn". ITER will use superconducting magnetic coils to run much longer plasmas than JET. Although it will not be connected to the grid itself, a successful ITER would enable the project's partner nations to proceed with plans for fusion power stations using the tokamak machine design. Indeed China is planning a first electricity producing plant in the 2030s – Europe's roadmap to fusion aims to produce power by 2050.

In 2010-2011 JET was upgraded using remote (robotic) handling to replace the carbon composite wall with one comprising beryllium and tungsten. With this change, JET has essentially been turned into a 'mini ITER' so that physicists and engineers can get as close as possible to ITER conditions and use JET as a test bed for its larger successor. JET is currently preparing to operate again with tritium fuel and break its own records.

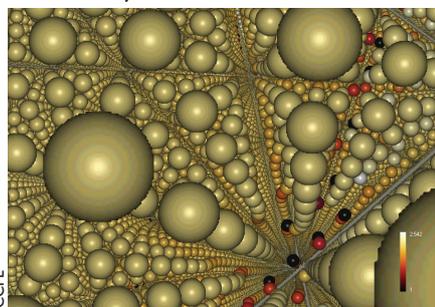
A material world ...

There are many challenges facing fusion research. Developing new materials to cope with the very harsh environment in a tokamak is one of the biggest. The deuterium-tritium reaction has two products: a (3.5MeV) alpha particle (helium nucleus) and a fast (14.1MeV) neutron. The alpha particle heats the plasma but the very fast neutron escapes from the magnetic field of the tokamak and needs to be slowed down in the tokamak walls to generate electricity. It is envisaged that most of the neutrons will be slowed in a specially-designed blanket containing lithium. As the neutrons slow and give up their energy to the blanket, it will be heated to 400-500°C. In future power stations, this will, via a helium-cooled heat exchanger, make steam and generate electricity via conventional steam turbines.

The blanket is also designed to serve a second purpose – to breed tritium. Of the fusion fuels, deuterium is readily available (and easily extracted) from water where it makes up 1 in 6400 of the hydrogen atoms. However, tritium is much less common as it is radioactive with a half-life of only 12.3 years; natural reserves are non-existent. Reacting the fast neutron with lithium (mostly the lithium isotope ⁶Li) breeds helium and tritium – the latter to be fed back into the main fusion reaction. Lithium blankets therefore have to be designed to maximise thermal efficiency in terms of heat extraction, but also to enable the

tritium that is bred to be easily extracted from the blanket. Future fusion power stations must breed enough tritium to make themselves entirely self-sufficient; this is a considerable engineering challenge. Designs postulated are as diverse as pebble beds and flowing liquid lithium lead. In total, six breeding blanket modules will be tested on ITER.

The neutrons, however, cause serious problems. Repeated fast neutron bombardment of the tokamak vessel walls will displace atoms in the atomic lattice structure, causing embrittlement and the formation of voids. A typical reactor flux of 2MW per square metre will displace each atom in the wall 20 times in a year. Ten times more energetic than neutrons from fission processes, neutrons from fusion will also transmute the nuclei in the wall – turning tungsten into osmium and rhenium for example. Candidate materials for the vacuum vessel, including various stainless steels and vanadium are being modelled by increasingly complex neutronics codes – work being pioneered by scientists at CCFE, Imperial College and other UK Universities. Experimental testing will also be needed and plans are underway for the construction of fast neutron bombardment facilities to test the materials proposed for future fusion power stations. The Materials Research Facility at Culham (funded as part of the National Nuclear User Facility) is a new laboratory that tests the mechanical strength of materials on a microscopic scale. Neutron-irradiated samples will be tested for fusion and advanced fission research purposes in this facility.



CCFE

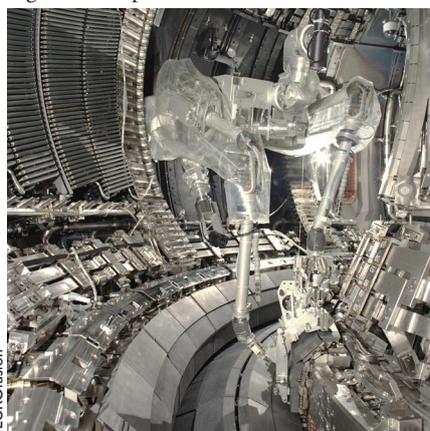
Atomic lattice is damaged by neutrons

An exhausting process

The materials issues don't end there. The "first wall", which faces the plasma, has different challenges. The powerful magnetic fields in a tokamak ensure the plasma is kept largely separated from the wall tiles, but plasma-wall interaction cannot be completely negated. Hence, traces of the wall material will contaminate the plasma; likewise deuterium and tritium from the plasma will be absorbed in the wall. Contamination of the plasma by wall materials needs to be kept low to minimise radiative cooling – high atomic

number materials are particularly problematic. Tokamaks have typically adopted a carbon first wall (low in atomic number and physically tough) but carbon has one big problem. It absorbs far too much deuterium and tritium; the latter increasing the activation in the first wall and creating a potential hazard.

And there are further challenges with the plasma exhaust system – the divertor. This is a region (typically at the bottom) of the tokamak vessel where the edges of the plasma are magnetically 'diverted' to impact onto special tiles and be pumped away. This exhaust system is essential in future fusion powerplants to prevent a build-up of helium "ash" (from the fusion reactions) in the plasma. It must also exhaust excess heat from the plasma. Unfortunately power loading in a reactor is calculated to be very high (typically >30MW/m²) leading to unacceptable erosion of the tiles.



EUROfusion

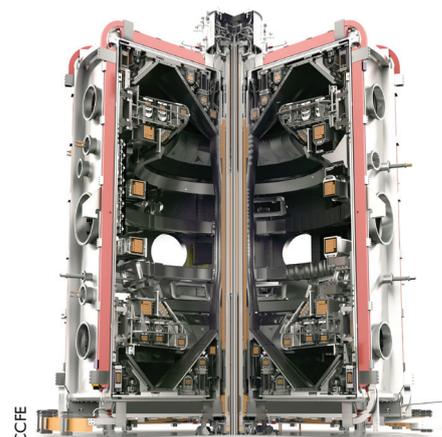
Remote handling in the divertor

JET has been prominent in facing up to the first wall challenges. JET changed all the wall tiles from carbon to beryllium on the first wall and tungsten in the divertor back in 2010. Experiments since then have showed that the new wall retains ten times less of the fusion fuels compared to carbon. Indeed, experiments were so convincing that ITER has decided to adopt a beryllium/tungsten wall from day one of operations saving the project several hundred million Euros.

Smaller may be better

Developing conventional tokamaks beyond ITER to the point of commercial power stations will result in large and very complex devices. This will impact adversely on reliability, efficiency and the ultimate cost of electricity. Predictions based on analysis of conceptual designs suggest that electricity costs in such devices will be competitive with other forms of generation. However getting such expensive devices financed will be very challenging. Doing fusion on a smaller scale and with reduced complexity is therefore very attractive and is being actively investigated.

The UK's own MAST fusion experiment at Culham is foremost in these investigations. MAST is a so-called spherical tokamak (ST) – where the central 'core' (the hole in the doughnut) is made as small as is possible; the plasma shape is more like a cored apple than a car tyre and operation is inherently more efficient as the requirements for magnetic fields are significantly reduced. But we don't yet have confidence in reactor performance predictions for this configuration. Hence after thirteen years of operation, MAST is currently undergoing a major upgrade – the new MAST-Upgrade experiment will nail down the crucial scaling to a reactor.



CCFE

MAST Upgrade

One of the challenges for STs – with more compact plasmas – is increased power loading on the divertor. MAST will actually use two divertors at the top and bottom of the vessel and each will use a new so-called super-X configuration. The magnetic field in each divertor will be orientated to direct the plasma along a longer path before being spread over a larger area of pumped tiles; thus reducing power loading by a factor of 4-10. Successful operation of this innovative feature may prove beneficial to all tokamak designs and will provide additional confidence that reducing the size (and cost) of fusion devices is feasible.

The perfect energy source

Fusion is difficult – after all you are making a miniature Sun on Earth. And sometimes, it is all too easy to get caught up in the challenges and the delays. But realising fusion, is an essential element in a truly long term, sustainable low-carbon future for mankind. As the leader of the Soviet fusion programme in the 1960s and father of the tokamak, Lev Artsimovich said "Fusion will be ready when society needs it." Society needs it soon and JET and MAST are pushing the boundaries to make that happen ...

bit.ly/IE22-CCFE



Steven Cowley became Director of CCFE in September 2008 and was appointed as CEO of the UK Atomic Energy Authority in November 2009. He received his BA from Oxford University and his PhD from Princeton University. Professor Cowley's post-doctoral work was at Culham and he returned to Princeton in 1987. He joined the faculty at the University of California Los Angeles in 1993, rising to the rank of Full Professor in 2000. From 2001 to 2003 he led the plasma physics group at Imperial College. He remains a Professor at Imperial and a member of the Plasma Physics Group. In 2012 he was awarded the Glazebrook Medal of the Institute of Physics. In June 2011, he was appointed to the Prime Minister's Council for Science and Technology, in May 2014 he was elected a Fellow of the Royal Society and in November 2014 he was elected a Fellow of the Royal Academy of Engineering.

Philanthropy: Your Support is important!

Nic Katona has recently joined the Faculty team to take on the newly created role of Head of Development. We asked him to tell us what he is hoping to achieve.

Fundraising and donations have always been important to higher education, but it is only in recent years that Imperial's development team has, well, developed. Last year saw the College secure gifts totalling £54m, shooting up dramatically from £9m the year before.

Even excluding Michael Uren's generous donation of £40m, this still represents a huge upturn in philanthropic activity, which Nic attributes to Imperial's strong track record of success and its focus on implementing a successful development and alumni relations strategy.

"We're advantageous and will continue to pursue the quick wins," he explains, "but our focus is on helping people to grow with us as we match the interests of our alumni and potential supporters with the specific priorities of the Faculty."

This donor-centric approach allows Nic

to cultivate ongoing relationships through recognising the needs of both sides and finding agreements to suit all. "I play a matchmaker role, identifying and cultivating those who could support the College, and matching their interests with our mission."

Generating these sizeable donations can be a long term process, "It can take 18-24 months to secure a significant philanthropic gift," Nic explains, "but this fits in with our strategy around long term alumni engagement and sustainable philanthropic giving." It's over these longer periods that Nic hopes to build up a "pipeline of supporters", through which unique, personalised approaches are used to translate broad levels of interest in the College's work into established, ongoing relationships.

"You have to work with people on an individual level, and be able to develop different strategies for each relationship,"

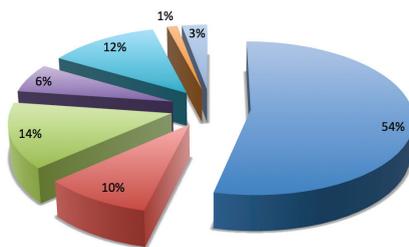
Nic explains. "It's a combination of science and art, where data collection and analysis helps us to identify potential donors, but it's through the art of relationship management that effective gains can be made. We want our alumni to be engaged and excited to support the Faculty. It doesn't happen overnight but we are committed to strengthening these vital relationships!"

Nic is embedded in the Faculty and works closely with the College's Development team. The Development team works tirelessly to engage alumni, to share with them the continued growth and excellence at Imperial and help match their passions and interests with the goals and vision of Imperial. It is all about relationships and helping all our donors feel a part of the Imperial family.

Help support our engineering students and faculty by making a gift today at www.imperial.ac.uk/giving

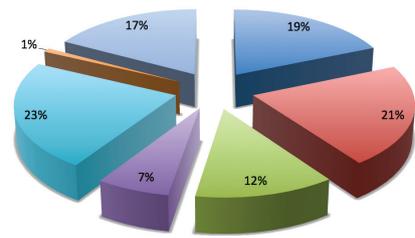
Changes in funding for Imperial

1985 revenue streams



- **Grants – 53.72%**
- **Research Grants & Contracts – 29.73%** (of that 46.68% was from Research Councils and 20.79% from Government)
- **Academic Fees & Support Grants – 12.50%**
- **Endowments, Donations & Subscriptions – 1.18%**
- **Other – 2.87%**

2013/14 revenue streams



- **Grants – 18.65%**
- **Research Grants & Contracts – 40.54%** (of that 30.86% was from Research Councils and 16.24% from Government)
- **Academic Fees & Support Grants – 22.85%**
- **Endowments, Donations & Subscriptions – 0.86%**
- **Other – 17.10%**

What do these numbers tell us?

Imperial continues to maximise its funding through research grants and contracts. This increase is due to the exceptional work of Imperial academics and students. This however is a finite funding stream. As you can see, funding from Research Councils and Government has declined in percentage as Imperial's budget has grown. It is not because these entities do not believe in or support the

work of Imperial but their resources are limited and they must spread them throughout the UK educational community and can't be seen as playing favourites.

Academic fees have increased as the cost of education continues to rise and to offset the decline in government and grant funding. The increase of academic fees adds a new factor for our students that many Imperial alumni did not face during their time here. Imperial

is mindful of fee increases and works to keep those to a minimum. Thus the focus on philanthropic funds. **The greatest opportunity for growth for Imperial is within philanthropic giving amongst individuals, corporates and trusts/charities.** This includes regular annual gifts at any amount to College as well as transformative gifts in the five, six, seven and eight figure range.



Nic Katona is Head of Development for the Faculty of Engineering. He is passionate about connecting the interests of donors with the needs of the Faculty. He joined the Faculty in September 2014. He works closely with Faculty leaders, academics and students to promote and support the strong research being done to address global issues. Prior to joining Imperial, Nic served in key leadership roles and oversaw the establishment and growth of development programs in a number of accredited Universities throughout the United States. He is looking forward to working with alumni to strengthen their relationships and increase support for Imperial. If you have a particular development opportunity that you would like to discuss, please get in touch with Nic at n.katona@imperial.ac.uk

DIARY

Saturday, 9-10 May 2015

Imperial Alumni Weekend
alongside Imperial Festival

Wednesday, 20 May 2015**CGCA**

AGM and President's Evening
Venue: Read Lecture Theatre,
Sherfield Building
17:00 for 17:30

Thursday, 25 June 2015**RSMA**

AGM/Final Year BBQ
Venue: 58 Princes Gate
18:30

Friday, 27 November 2015**RSMA**

131st Annual Dinner
Venue: The Rembrandt Hotel,
11 Thurloe Place,
Knightsbridge,
London SW7 2RS,
19:00 for 20:00

Saturday, 28 November 2015**CGCA/RSMA/RCSA**

Decade Reunion 2015
Venue: Queens Tower Room C,
Sherfield Building
12:30 for 13:00

London Walks

Next walk details not yet finalised.
Please see the website at:
bit.ly/LondonWalks

**For more information
or booking for
any events,
contact
Teresa Sergot
t.sergot@imperial.ac.uk
or phone
020 7594 1184**

ALUMNI

NEWS & VIEWS

Who's doing what and where



Once again the Imperial Alumni Reunion takes place alongside Imperial Festival, which is returning for its fourth year and continuing to grow in popularity. Imperial Festival will be held for the first time over the full weekend of Saturday 9 May and Sunday 10 May 2015. With visitors expected to increase beyond the 10,000 of 2014, a jam-packed schedule of performances, activities and ways to get involved with the best in science and arts at Imperial is being finalised by the Festival Team. As we go to press, the Festival Programme is not yet public (and they wouldn't even let us have a sneaky peek!) But the details will soon be available on the website at:

bit.ly/impfest_2015

Exclusive preview of the Imperial Festival Research Zone	"Labs and landmarks" – behind the scenes tours	Special gift package for alumni and kids	Relax and network in the Alumni Hub
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[→ View the full programme](#)



A great, fun day ...
I'll definitely be back.

*Tim Griggs
(Materials 1974)*



I attended the reunion with my daughter. It was an excellent experience; the program was splendid.

*Dr Ibiroko Sodeinke née Abari
(Medicine 1994)*

The experience was awesome.

Igho Ogonor (MSc Earth Science and Engineering 2013)

Imperial College Alumni Mentoring Scheme Launched

The Imperial College Careers Service launched a new Alumni Mentoring Scheme in October last year. The aim of the Scheme is for mentors to help develop the knowledge of current Imperial students in relation to the professional workplace, discuss potential careers open to them and share their insights with their student mentee. In the last issue of Imperial ENGINEER we presented a short introduction to the Scheme and asked for mentors to take part. In this issue we would like to share with you an update on how the scheme has progressed in the first few months since its launch.



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With a larger than expected number of student applicants, we have created 66 successful mentee / mentor pairings. Over half of the matched students are from departments in the Faculty of Engineering. Matching was based on degree background, academic department and career interests. The motivation of the applicants was also measured and priority was given to students from disadvantaged backgrounds and under-represented groups, in line with the College's outreach criteria. As this was the pilot year we are very happy with

the number of successful pairings and hope to increase this number in the next academic year.

This month we received feedback through our first mentee questionnaire and will receive a more detailed feedback survey at the Scheme's midpoint. Feedback from students is, overall, extremely positive and there appear to have been a number of career benefits even at this early stage, from improved networking contacts to application advice. Students have had the opportunity to increase their employability and visit their mentor's workplace through work shadowing and information interviewing opportunities.

Luke Clapson, a second year chemical engineer has secured a spring internship since starting the Scheme: *"The Scheme has provided me with an invaluable contact in my target industry. Before I met my mentor, I didn't really know a great deal about the specifics of the sector, such as the work-life balance, the different business areas or the tasks I might need to perform on a day to day basis. Due to all of these interactions and the advice I was given, I have since been able to obtain a spring internship. I am extremely grateful for being provided the opportunity!"*



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Sergiu Iliev, a third year aeronautical engineer, commented on the benefit of his mentor's insights: *"My mentor brought energy, enthusiasm, wisdom and insight into life after university. I found that knowing somebody who experienced the same process of job applications in my chosen profession is an invaluable advantage. I would love to join this wonderful process as an alumnus in a couple of years."*

The Scheme had 89 alumni volunteers to be mentors, of which 39 were from Faculty of Engineering disciplines. Organisations across

for meetings and to be clear in what they want from the mentoring partnership. At our launch event, mentees were given an induction talk to help them understand their responsibilities and create realistic expectations for the scheme. At the launch there was also an opportunity for student mentees to meet and network with mentors on the scheme.

Mentors are asked to commit to at least six meetings with their mentee (2 of which should be face to face, or over Skype if based outside the UK). The Careers Service advised mentors and mentees to set up a mentoring agreement soon after being matched. This should define their expectations of the Scheme and agree how regularly contact will take place.

Nikolaos Mavropoulos, an Electrical Engineer at Elektta, is a mentor on the current Scheme. He explains how impressed he has been with his mentee's commitment and planning during their mentoring partnership: *"I have met once with my mentee. I appreciated the fact that she came with detailed notes and a lot of questions to ask about the industry, jobs, applications and my experiences."*

From the summer, the Careers Service will launch a call for alumni mentors for the 2015/16 academic year. Becoming a mentor provides a great way to give back to the Imperial community. It is an opportunity to promote your work and the sector as a whole to motivated Imperial students, as well as a chance to use and develop mentoring and coaching skills which may be useful in your own career.

To register your interest in being a mentor, or for further information please contact the mentoring team on mentoring@imperial.ac.uk. You can also visit the mentoring website:

www.imperial.ac.uk/careers/mentor

"I would love to join this wonderful process as an alumnus in a couple of years."



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the oil and gas industry are represented in our mentors, including Schlumberger, BP, Subsea7 and Centrica. Other sectors of engineering are also represented by organisations such as Airbus, Rolls Royce, Elektta and Air Products Ltd. Other industries such as banking, management consulting and IT are represented, as well as alumni who have gone on to work in start-ups and the charity sector.

Ultimately it is the mentee's responsibility to lead the partnership and initiate contact, set the agenda

45th Triode meeting

2nd January 2015

Again fourteen Triodes appeared at the George, braving the remnants of New Year's Eve parties and leaving their loved ones at home. All that was forgotten after a few pints (of Winter Cheerer) plus great conversation and then we moved on to have dinner at the Thai Square. As tradition dictates, we stopped at the Triode Loo to convince some poor passer-by to photograph us! The result is shown to the right.

The next Triode reunion will be on Friday 8th January 2016 at The George, Fleet Street, from 7 pm-ish. (Because the first Friday is a bank holiday – Triode rule 2B). The following year's reunion will be on Friday 6th January 2017.

There were 14 of us on the 2nd January.

Peter Cheung remains Head of EEE at Imperial; recently they had the latest research assessment results (known as REF 2014) and Imperial was rated as the top EEE Department in the UK for research. It looks like Peter will be stepping down as Head at the end of September after seven years. However, his offer of a "free lunch" for any Triode visiting Imperial may now be extended indefinitely! As is his offer of the use of the labs (and a few spare students?).

Peter Wright is still with the Scouts – he is District Secretary, Appointments Chair, and various other roles. Also he is in the midst of refurbishing an apartment for an elderly relative – he told me that toilets and baths are now one of his specialities! He went walking in Austria with Pete Marlow in what turned out to be the wettest and coldest August ever. But he said the simple, unpretentious pubs (with pine tables, tiled floors and vaulted ceilings) with hearty, filling meals of pork, potatoes, dumplings and the like were very handy to keep out the cold and (especially the bread dumplings) for soaking up large quantities of beer!

John Harding remains working as a consultant with CACI. He's been working with the bigger mobile operators in the UK, advising on OSS deployment. His wife Anne has finally retired from helping people with their money problems and is now a lady of leisure (creating money problems for John?).

Dave Mansfield is still spending much of his time in retirement looking after his 95 year old father who has severe dementia but they do now have a carer visiting every day. He has also helped his elder



Picture (left to right): Peter Cheung, Peter Wright, Sid Seth, Alice Spain, Peter Marlow, Joan Clemow, Graham Castellano, Pat Mason, Dave Mansfield, John Harding, Martyn Hart (on knee), Martin Clemow, Nick Hiscock and Ian Heap.

son buy his first property (in the London area) and is now spending most weekends renovating that to save his son more expense.

First time for Ian Heap who has been working away from London for too long; he said meeting us all again after so long was a little surreal! He is retired! That's after 27 years of commercial management at ABB and he says he is enjoying his freedom from formulaic procedures, telephone conferences and Lotus Notes. He is now writing a novel where something extraordinarily nasty will befall the legal counsel!

Patrick Mason says he is part of the new wave not planning to retire by 65, as the thought of 20-30 years of golf and daytime TV fill him with dread! Now, late in his career, he's co-founded a start-up internet payment business and that is keeping him busy and challenged! So anyone looking to send money overseas please consider www.globalwebpay.com – cheaper than the banks and with expert service and advice too. Other than that, he is looking to start beekeeping after attending a course and also to downsize now his kids have flown the nest.

Some 10 years ago Graham Castellano took a package after 27 years with IBM, where he had been their SME on hard drives and storage. This had included three exciting years based in Vienna, selling into a fast-disintegrating Soviet Union. He then set about re-wiring his own house and found he needed to be registered under the IET Wiring Regs before he could connect; so he took the exam, passed (of course), became registered and started an electrical business. He said it's too

much manual work for him now so he's just stopped and is focusing on retiring gracefully. No grandchildren yet, so sadly he has to spend his spare time dinghy sailing and skiing!

Joan Clemow retired two years ago after teaching for 20 years, latterly at Yeovil College. She is now very busy looking after her grandchildren, volunteering for the National Trust and other activities. She looks forward to seeing us next year!

Martin Clemow says that he is not yet retired! He is still working in the data recording field. As a reminder, he joined SE Labs (part of the EMI Empire) in 1980 as a contract electronics design engineer and he has worked for a number of companies, all of which have been linked in some way or other, since then. The latest is a start-up with only three members of staff. They provide recorders which are specifically designed for use in the Air Traffic environment. He still lives about three miles from Wells, Somerset, quite close to three of his four children which means that he gets to see his four grandchildren on a regular basis.

Although Alice Spain took early retirement in 2011 she said she always wanted something to get her teeth into. She has it! She has taken a derelict property in Norfolk needing much restoration and is living on site to oversee the significant major renovation. She brought a book with her showing a photographic record of the first year of restoration of "The Grange" – eat your heart out Kevin McCloud, this is the real thing! It was an old retirement home with 11 bedrooms

so maybe the Triodes will be invited for a summer holiday (bring a paint brush or a spade, as the garden needs more work too!)

Peter Marlow still runs Softcopy Limited and is mainly occupied managing IT projects for Government. His daughter did run in the London Marathon. He took three months off in the summer, had a great relaxing time he said, and also marched around Austria with Peter Wright.

Nick Hiscock remains retired. His major activity is walking "failed" Irish gun dog Hunter which keeps him fit; and out-thinking Hunter is good mental training! He continues collecting and refurbishing antique weapons and when bored with that he goes off to run the bar at Warsash Sailing Club and swap salty stories. Wife Sue successfully managed to cut back vetting to three days a week, though it still grows to a 36 hour week and clients are used to Sue ringing them about their sick pooches after 9pm. Daughter Pippa (25) has just passed her Maths PhD and has started her first proper job at Roke Manor Research which is part of the Chemring Group. Daughter Jenny (28) is about to take up a Chemistry Research Fellowship at the University of Kent to launch her into her own independent research career. She still creates molecules!

Sid Seth is still working on his new innovations. The identification of assets business has taken some shape and he is now developing higher definition tagging equipment (maybe you should have a chat with Peter Cheung?). He also has two other projects running but they are, of course, secret!

Martyn Hart is now working three days a week in the public sector, mainly in the commercial area (large outsourcing/framework contracts). He has just moved to Ingatestone in Essex, where he is renovating a triangular house – it's certainly the only one of its kind he says.

Contact Martyn Hart for a more detailed report, including news from some who couldn't make it to the George: Phil Harris, Chris and Daphne Giles, Hari Singh, George Gabrielczyk, Steve Glenn, Hugh Culverhouse, Richard Lewis, Tony Godber, Rut Patel.

We haven't heard from: Tim Dye, Geoff Banks, Jacquie Buzzard (can anyone help?)

Martyn Hart
Arch Triode

Is Working more stressful than being a Student?

On 17th February, about fifty undergraduates of the Mechanical Engineering Department gathered in a lecture theatre in the City & Guilds Building to attend an 'Alumni Insights Event', which had been organized jointly by the student-led Mechanical Engineering Society (MechSoc) and the City and Guilds College Association (CGCA). They were there to listen to three Imperial College Mechanical Engineering graduates each give a short talk about their career.



Warwick Faville

First up was **Warwick Faville (ME, 1965)**, who, as he told the audience, started his career as an apprentice with Rolls-Royce in Derby and was still there when he completed his degree at Imperial. Soon after this he joined Atkins before finally becoming a freelance consultant aged forty, which he has been ever since. He has worked on many and varied projects, often at the boundaries of civil and mechanical engineering, including advising the UK government on its policy for nuclear power stations and making a telling contribution to the construction of the movable roof over Centre Court at Wimbledon. Warwick's main message to the students was that they should make sure to keep in touch with fellow students and work colleagues as these could well be the source of their next job!

Next to talk was **Guy Schofield (ME, 2014)**. He started as a graduate engineer with Jaguar Land Rover (JLR) in September. Guy related how, during industrial placements on his degree course, he



Guy Schofield

had discovered the joys of product design, and decided to pursue that discipline as a career. At JLR, he has helped to develop tools to organize better the process of exhaust system design, particularly with regard to the computer aided engineering that validates the designs before the prototypes are built. This year, he has been investigating the potential for utilising new materials to save weight in the exhaust systems and is assisting a project to enhance their sound qualities. Guy advised students to take those courses in which they are really interested and which will shape them into the type of engineer that they want to be. He also stressed that they should look to work for a company that can demonstrate that it has a graduate scheme that meaningfully develops its employees' careers. When asked whether he found that work was stressful, he replied that it was less stressful than studying mechanical engineering at Imperial, though he did admit that he was in an early stage in his career!

Finally, **Dr Daniel Plant (ME,**

1997) gave an illuminating insight into his career to date. Whilst at Imperial, he worked on the first commercially available, wearable electronic jackets and his three internships all resulted in job offers but he turned them down to pursue his love of design, and instead took an MA in Industrial Design Engineering at the Royal College of Arts. Dan's doctoral thesis was in the development of strain-rate sensitive materials and he has explored the field of advanced, active materials and smart textiles for the last fourteen years. Amongst his many clients is NASA, for whom he has designed advanced materials for use in space suits. He is Managing Director of Armourgel Ltd. and has recently been elected Fellow of the Royal Academy of Engineering. Like Warwick, Dan stressed to the students the value of maintaining good relationships throughout one's career, and, like Guy, told the students that it was important that they choose work that they enjoy, and then perform it to the best of their abilities.



Dr Daniel Plant

After the final round of questions, students and speakers retired to the City & Guilds College Union (CGCU) offices for some refreshments and a discussion on what had been an enjoyable and informative event. The informality of the talks and the lack of a 'sales' element to them were favourably commented on by some students. Although formal feedback has not yet been gathered, the vibe from the students afterwards was very positive and the talks seemed to be much appreciated by the attendees, at least some of whom expressed the hope that the event would be repeated regularly, which is also the desire of the CGCA and MechSoc. Indeed, last year's creation of departmental representatives in CGCA was partly done to facilitate this type of event and the success of this one should encourage other departments to do the same. If you are asked to give a short, informal talk on your career to current students of your department, please give it some consideration as it is highly valued by the departments and the students. If you would like to volunteer to give such a talk please contact the CGCA who would be



Yeong Tsai

very happy to hear from you.

Thanks are due to many. Aside from the three speakers, one of whom (Warwick), as a CGCA departmental representative for Mechanical Engineering helped to organize it, the event would not have taken place without support from the Department (Dr Catrin Davies, in particular), from MechSoc (whose secretary Yeong Tsai efficiently sorted out the logistics with Rachel Castola its Chair, who also introduced and closed the event), from Imperial's Alumni Engagement Officer, Jessica Adams, and from Helen Vaughan of the Careers Service. More pictures at

bit.ly/1E22-MechSoc

WE WANT YOUR NEWS

Let us know your news or stories

Contact Teresa Sergot (address and deadlines on page two)

Chemical Engineering 57-60 Reunion



The annual reunion of the IC Chem Eng 57-60 group took place on the 10th February this year. There were 8 attendees, who were from left to right in the photograph : Barry Daniells, Don Latimer, Alan Cleugh, Tony Davis, Richard Lee, Alan Nethercott, Malcolm Cross and Paul Gallagher. Although numbers were a little lower this year the usual congenial discussions took place over drinks and lunch.

We are all finally retired now but many of us are kept busy with our family commitments. There was some discussion about organising a visit to the Rubens exhibition at the Royal Academy and Richard Lee was going to celebrate the Chinese New Year before returning to Honk Kong. I returned back home to Lymington to pursue my sailing interests.

Barry Daniells

Alumni Recognised in New Year's Honours

Thirteen Imperial alumni were recognised in the New Year's Honours.

OBEs were awarded to the following: Professor Gwyneth Stallard (PhD Mathematics, 1991) for services to engineering; Cecil Balmond (Civil Engineering, 1970) for services to architecture; Alastair Campbell (Environmental Management, 1998) for services to financial services and charitable fundraising; and Professor Paul Ekins (Electrical Engineering, 1971) for services to environmental policy.

Four alumni received an MBE: Subhash Chaudhary (Chemical Engineering 1974) for services to biotechnology manufacture in North East England; Reverend Dr Richard Hills (Natural Sciences, 1964) for services to industrial heritage; Claire Milne (Mathematics, 1973) for services to the telecommunications sector; and Andrew Panter (Civil and Environmental Engineering,

1965) for services to charity and the community in Berkshire.

Professor Timothy Noel Palmer (Medicine, 1980) was awarded a CBE for services to science, while Professor Rosalind Smyth (Medicine, 1983), Director of the Institute of Child Health, was awarded a CBE for services to regulations of medicines for children.

A further three alumni received a British Empire Medal: Valerie Gill (Medicine 1972) for services in the community in Slyne and Hest Bank in Lancashire; Rebecca Jeffery (Taxonomy and Biodiversity 2006), co-founder of the Women's Network at the Department for Energy and Climate Change, for services to gender equality in the workplace; and Franklin Boucher (Electrical Engineering, 1960), a volunteer for the Royal National Institute of Blind People, for his services to the blind and partially-sighted.

Alumnus to Chair Imperial's Council



Imperial College

Leading engineer and businessman Sir Philip Dilley, former Executive Chairman of Arup Group, has been appointed as the next Chair of Imperial's governing Council for an initial four-year term. He takes over in May and succeeds Baroness Manningham-Buller, Chair since July 2011, who will become Chair of the Wellcome Trust this autumn.

Sir Philip is the 12th Chair of Imperial's governing and executive body and the first alumnus of Imperial to hold the position. He graduated from Imperial with a First in Civil Engineering in 1976, and spent his engineering career within Arup Group, rising to become its Executive Chairman from 2009 to 2014. He continues to advise the firm, and since September 2014 has been Chairman of The Environment Agency.

Sir Philip has already served

on Council since 2011, and is a member of the Imperial West Syndicate and the Nominations and Remuneration Committees. He said: "It is a great honour to be asked to chair Imperial's Council and I am delighted that I will be able to serve the College as its Chair at such an exciting time in its development."

Baroness Manningham-Buller said: "I am sad to be leaving Imperial as it is a fascinating place, bursting with outstanding people and exciting ideas. It has been most rewarding to be involved with such a great university, and I feel privileged to have chaired its Council and Court since 2011. I am delighted that Philip is my successor. I think the College has made an excellent choice and that it will continue to thrive and develop under his chairmanship. I shall always value the friendships I have made in the College."

Alumni gather in Los Angeles

In October, around 50 alumni and guests gathered in LA to network and hear the latest from Imperial.

Professor David Gann, Vice President (Development and Innovation) delivered a presentation which highlighted key College developments. This included the news that Imperial's new President, Professor Alice Gast, who was once an undergraduate at the nearby University of Southern California, commenced her leadership of the College at the beginning of August. Alumni were also updated on the groundbreaking at Imperial West and the launch of the Althea-Imperial programme.

Following the efforts of local alumnus Richard Chamberlain (Mechanical Engineering 1980), alumni were encouraged to step forward to assist with the formation of an association in the area.

Alumni, Students, Staff and their immediate families living in Central and Southern California are welcome to join the Imperial College Club of Southern California. Anyone interested in joining can sign up online at: bit.ly/IE22-SoCalSignup

After the presentation, teams of six tested their knowledge of the College with a pub quiz that capitalised on the competitive spirit

in the room. The multiple-choice quiz included a question on the height of the Queen's Tower. As the answers were given, the group burst into laughter when a heckler, who had guessed incorrectly, called across the room, "It wasn't that tall when I was there!"

A question on the sister publication of Imperial's student newspaper, Felix, prompted another surprising revelation – an alumnus present had written an article in 1951 which explained how to transmit television signals using a 'cat's whisker'.

The conversations continued over drinks and dinner, with Imperial alumni from across the Los Angeles area enjoying the chance to meet fellow alumni, and to extend their professional and social networks.

Professor David Gann said, "It was exciting to have so many alumni gather in Los Angeles for an excellent evening exchanging ideas about Imperial's future, of fun and reminiscing. We look forward to seeing a new association take shape to help guide the growth of Imperial's collaborations and the growth of its reputation in the USA."

You can try your hand at the Imperial knowledge quiz at

bit.ly/IE22-ImperialQuiz

HELP! – CGCU Shields missing

Do you remember all the Shields that used to hang in the Mech Eng building, now the City & Guilds College building? CGCU President Tim Munday needs your help to find some of them!

When they were taken down, it appears that they were distributed

around various stores at College. Most were brought back together soon afterwards and more were found quite recently. But around 21 are still missing. If you have any inkling of where the remainder might be, please contact Tim:

guilds@imperial.ac.uk

Always enthusiastic for new challenges

DEREK JULIAN BARR (Chem Eng 1963-66)

Born on 16 September, 1945, Derek Barr died on 25 January, 2015, aged 69.

The following Obituary has been provided by his friend and near-contemporary, Warwick Faville (Mech Eng 1962-65, 65-66):

Derek was enthusiastic for a new challenge whether technological, on the ski slopes, automotive, musical or just for life. He was born and brought up in southwest London and attended St Paul's School before entering Guilds. This was before the days of a first college year in hall, but even though he lived at home, he participated fully in student activities. He was good in a tight spot and it is said that if he did not actually have the answer he would bluff with such conviction that no one would question him. A prime

example of this skill was when, as captain of the college riding team he introduced his sister to take an unfilled team place. Despite her still being at school, he made her the fourth member claiming she was studying fluid mechanics. Why fluid mechanics? Because no one understands what it is, so would not ask any questions!

Derek studied chemical engineering but was attracted to a career in law. On graduation, these thoughts were put aside by his father's need for help in building the engineering firm he had co-founded. This was Barr & Murphy, which specialises in industrial equipment for the process industry. There can be very few people in the country who have not had food or other material that has been through one of the firm's dryers. The range included flash, ring, fluidised

bed, rotary, superheated steam and column dryers. The range of applications included products in the agriculture, food, mining, mineral, fertilizer, and chemical industries and some less common materials such as algae, lignin, manure and specialised wood pulp. Some of the equipment makes the products of a certain cyclonic vacuum-cleaner company look relatively simple. Barr & Murphy won the Queen's Award for Export Achievement in 1976. Derek, who was managing director, was also noted for his teambuilding skills. He travelled extensively for work and was able to add a pleasurable element to his time on the move. He enjoyed exploring different cultures and had a gift for languages, collecting at least a few phrases wherever he went. This comfort with all corners of the world was fortunate as some of the company's

equipment ended up in such diverse places as northernmost Maine in a potato works, and a corn processor in deepest China. Staff sent to manage these contract installations often had their engineering "coming of age".

A company restructure in 1996 allowed him to relax more and take up other interests. He became a mediator, which satisfied some of his earlier aspiration for the legal profession. He also acted as a business angel with a number of investments, several of which have proved successful. Working with start-up companies, he shared his business expertise in guiding them through challenging periods, and developed the role of 'company friend'. During this last part of his career, he could occasionally be seen around College, seeking an interesting opportunity.

Passion for family, friends and life

NIGEL CHARLES GRAVETTE (Metallurgy 1960-63, Chemical Technology 1964-68(PhD))

Nigel passed away on 1 November, 2014, aged 73, after losing his battle with cancer. "Gravy" as he was affectionately known at College was President of the RSM Union in 1963-64, whilst studying for his PhD, on Corrosion in Royal Navy Boilers, in City and Guilds! He had graduated in Metallurgy at the RSM in 1963.

Born in Iver, Buckinghamshire he was schooled at the Royal Grammar School in High Wycombe and came to IC along with two school friends, Mike (Slim) Coward (RSM) and David (Ghosty) Craft (Physics).

Whilst at College, Nigel was involved in many memorable incidents. A keen caver he, together with pal John (Ben) Goode, did their own version of Prince Consort Road caving. At around 1am they pried open a manhole cover outside the RSM entrance and disappeared into the bowels of the earth. They sloshed their way to a major tunnel

system at Queens Gate, exploring to North and South, returning to the RSM a couple of hours later. Back on surface, they headed to Beit for a clean up and refreshment. Nigel found some potassium permanganate to pitch into the bath water as a disinfectant, resulting in fine suntans as a by-product of nocturnal caving.

Unusually for that era, Nigel had a car during his time at RSM, a 1935 Ford. At one time, he showed his scientific flair and had the petrol tank tied onto the roof with a gravity feed into the carburettor. Once, after a heated discussion on the relative merits of their cars, he left Ben with severely damaged pride after a race down Prince Consort Road, from the starting grid of Exhibition Road to the chequered flag of Queens Gate, thoroughly outpacing Ben's sporty-looking but thoroughly clapped out, 1928 MG "M".

Nigel was a member of the London University Air Squadron, got

his colours for rowing at RSM and was a member of the Chaps Club.

In 1968, after completing his PhD, he and his young family headed off to the Zambian Copperbelt, where he worked for Anglo American on the Rhokana smelter and cobalt plants. In 1972 he gave up metallurgy to go farming in Rhodesia/Zimbabwe where he stayed until 1989. After returning to the UK from Zimbabwe, he worked as Quality Manager for Doig Springs in Maidenhead until his retirement in 2008.

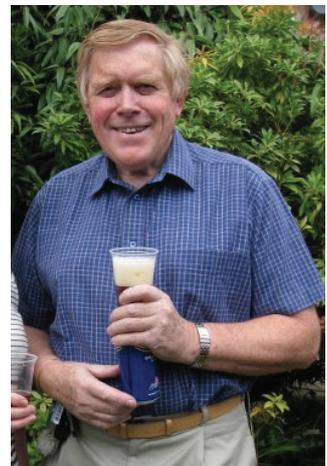
First and foremost Nigel was a family man, having married Pat, his wife of 52 years, in 1962, whilst at RSM. He was fiercely passionate and caring about his family and is survived by Pat, three sons, an adopted daughter and eight grandchildren, who all miss him tremendously.

Aside from his family, Nigel had many passions and accomplishments. Wherever he went he collected friends with whom he always made an effort to maintain contact. He had a flair for acting and for the last 24 years was a member of Buckinghamshire's Richings Players. Even whilst in the Zimbabwe bush he continued to bring a touch of culture to the rough and tough farming community. He was always singing and lived his passion as a member of the successful Royal Harmonics since 2005, and had been awarded the Royal Harmonics, "man of the year". He relished his time with this marvellous group of gentlemen who were also a great support to him during his various treatments. Neither did he lose his love for tilling the soil after returning from Africa, and loved

pottering in his allotment producing kilos of fresh produce, giving Pat much food for thought. His thirst for knowledge saw him involved in the University of the 3rd Age. Here he found a wonderful mixture of academic research that he could combine with his flair for dramatics which made his lectures particularly popular. Up to the time he died, he was working on a planned lecture about Earth, "The Goldilocks Planet – not too hot, not too cold, just right!"

At his funeral, his son Rod said "Nigel Gravette was a man who loved life and loved those who shared it with him. Never seeking the limelight or to be the rock star but was always the rock that you could rely on or depend on".

A tremendously apt description.



Nigel was one of those characters who seldom come around. A great family man, great minesman, a friend to many, multi-talented, he will be sorely missed.

John O'Reilly



A military man

F R STOODLEY (Chem Eng 1958-61)

Born on 12 September, 1937, Frank Richard Stoodley died on 31st August, 2014, aged 76.

The following Obituary has been provided by his friend and contemporary, Peter Turner (Chem Eng 1958-62).

Richard (normally called "Dick" during his College days), did his National Service between 1956 and 1958 before entering College. During that time, he held the rank of 2nd Lieutenant in the Royal Artillery and was posted to Cyprus during the problems of the mid 50s. When we met at college I remember him

telling me that he had to fight the instinct to dive for cover if there was a sudden noise, not so easy when you are 6' 7" tall.

After graduating, he started his career in the oil industry with Shell Refining working at Heysham and Shell Haven. After 5 years, he changed to the pharmaceutical industry, working with Pfizer at Sandwich in Kent, and at Cork in Ireland. Five years later there was another change of career, this time to Charter Consolidated and later Zambia Engineering Services, based in Ashford in Kent, working with the copper industry. During this 15-year spell, some time was spent

living in Zambia. His last 10 years of employment were spent with CDC, advising on a variety of projects in many countries overseas.

His involvement with the military had continued, when possible, throughout his working career, and he became a captain in the TA. On retirement, his role as a case worker for the Soldiers, Sailors, Airmen and Families Association, assisting ex-servicemen and their families who had encountered difficulties, provided some interesting challenges. Since childhood, he had collected military equipment, starting with radio and radar equipment and culminating in a 25-pounder field gun, complete with limber (ammunition trailer) and quad (towing unit). This was regularly displayed at various events around Kent, and the quad was driven to Normandy and back for the 65th anniversary of D-day. The family intend to continue to keep the artillery equipment whilst the radio equipment is being donated to the Imperial War Museum at Duxford.

During his time working in Ashford, he and his wife Barbara, with their two daughters, Cathy and Vicky, established the family home at Egerton in Kent. They lived there for



40 years and became well known and active members of the community. Always a devoted family man, besides his wife and two daughters, he leaves five grandchildren.

Those who knew him will miss his kindness, compassion and sense of humour.



Tin Mining in Malaysia

CHARLES DAVID PALMER (Mining 1950-53)

Charles David Palmer died peacefully in Malaysia, at the age of 82, on Tuesday 9 December, 2014, after a lengthy battle against prostate cancer.

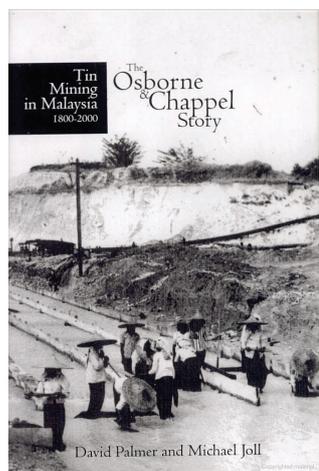
Graduating from Imperial College in 1953, as a mining engineer, David worked in the coal mines in North Staffordshire for 7 years and qualified as a Colliery Manager in 1957. In 1960, he left for Malaysia to work for Osborne & Chappel (O&C), a well established firm of mining and consulting engineers who had achieved fame and fortune as a promoter of alluvial tin mining during the early colonial days of the 1890s.

He started there as an engineer, but soon rose to be assistant mine manager and mine manager of the various mines managed by O&C. In 1969, he was appointed a director and, subsequently, in 1977 he, together with two of his colleagues, bought out the firm. They continued to manage the surviving mining companies when tin prices fell and in the meantime commenced promoting O&C's expertise in alluvial mining around the world. They were successful in

obtaining a wide range of dredging and engineering works on five continents.

David became a permanent resident of Malaysia and continued to reside there, with his wife Mai, after his retirement.

In 2011, he and another ex-O&C colleague, Michael Joll, wrote a book based on the history of O&C:



"Tin Mining in Malaysia 1800-2000: The Osborne & Chappel Story" published by Gopeng Museum, Malaysia.

NOTICES IN BRIEF

NORMAN CARLISLE BRITTAIN (Mech Eng 1934-35). Born in 1913, Norman Carlisle Brittain has died aged nearly 100.

RAYMOND ARTHUR CRAY (Mech Eng 1950-53). Born on 6 May, 1930, Raymond Arthur Cray has died in his early 80s.

ROY PHILLIPS GLOVER (Elec Eng 1930-33, '33-34). Born on 1 May, 1911, Roy Phillips Glover died in 2014, aged 103.

COLIN DEANE HARRIS (Civil Eng 1942-45). Born on 26 Jun, 1925, Colin Deane Harris died in 2012, aged 86.

GEORGE RICHARD HOFFMAN (Civil Eng 1938-40). Born on 29 Feb, 1920, George Richard Hoffman died in 2014, aged 94.

DAVID EDEN HUTCHINSON (Mech Eng DIC 1963-64). Born on 16 Jan, 1937, David Eden Hutchinson has died in his 70s.

REX EDWARD NELSON (Elec Eng 1949-52). Born on 3 Mar, 1927, Rex Edward Nelson died on 13 Nov, 2012, aged 85.

DEREK PAGE (Civil Eng 1950-53). Born on 13 Jul, 1931, Derek Page has died in his early 80s.

JAMES GIFFORD REID (Mech Eng 1935-38, '38-39). Born on 6 Nov, 1917, James Gifford Reid died on 26 April, 2013, aged 95.

JOHN LEONARD SLOW (Elec Eng 1941-43). Born on 10 Apr, 1924, John Leonard Slow has died in his 80s.

ANTHONY JOSEPH SMALLMAN (Civil Eng 1944-46, '46-47). Born on 7 Apr, 1926, Anthony Joseph Smallman has died in his 80s.

FRANK RICHARD DAVID COLIN WAKEFIELD (Elec Eng 1955-58). Born on 7 Jun, 1937, David Colin Wakefield died on 7 Aug, 2014, aged 77.

DAVID KINGSLEY WARREN (Elec Eng 1948-51). Born on 14 Aug, 1927, David Kingsley Warren died in 2012, aged 85.

ANDREW ALEXANDER WILSON (Phys 1968-71, EEE 1971-73 (MPhil, DIC)). Born on 6 Mar, 1950, Andrew Alexander Wilson died on 9 June, 2014 aged 64.

