

Royal Commission for the Exhibition of 1851

Report of the Board of Management
and Summarised Financial Statements

For the year ended 31 December 2017



The Aims of the Royal Commission

The 1851 Royal Commission's governing document is its Supplemental Charter of 1851, which requires the Commission to *"increase the means of industrial education and extend the influence of science and art upon productive industry"*.

This was originally interpreted as a requirement to create a centre of intellectual excellence, which resulted in the acquisition of the South Kensington estate and its subsequent development with museums, academic establishments and a Hall of Arts and Sciences (the Royal Albert Hall).

Later, in 1890, the emphasis was switched to the support of individuals, starting with the award of Science Research Scholarships from 1891.

Today the Commission runs its own schemes for:

Research Fellowships
Industrial Fellowships
Industrial Design Studentships
Built Environment Fellowships
Fellowships in Design

In partnership with others it supports:

Great Exhibition Scholarships
Enterprise Fellowships

It also supports worthy individuals and appropriate organisations by Special Awards.

The total number of individuals being supported in 2017 was 151

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Chairman's Report

Bernard Taylor, Chairman of the Board of Management

2017 has proved a very successful year for the Commission, with a number of new initiatives launched and a record number of awards made.

The highlight of the year was our biennial Presidential Dinner, held in the splendid surroundings of Armourers' Hall in March, when we were delighted to welcome our President, Her Royal Highness The Princess Royal together with guests from across the legacy estate and our current award holders who together filled the Hall to capacity. As usual, the evening started with a reception where the work of some of our final year fellows was on show. This is a good opportunity to showcase the breadth and depth of research carried out by our Fellows, which this year ranged from understanding the graviton to engineering drug-eluting embolisation systems. This year's dinner was particularly special as our principal guest was 1851 alumnus and Nobel Laureate Professor Peter Higgs, whose extraordinary contribution to science was marked by the President presenting him with the Commission's Medal. It was a memorable evening for us all.

2017 also saw the launch of a fundraising initiative. This was in response to the often expressed desire of our alumni to 'give something back.' Notwithstanding that our investments continue to perform well and our programmes are growing there is always more we could do. We encourage one-off and legacy donations in order to increase our endowment and help us not only to maintain the excellence of our award programmes but also to enlarge them when opportunities of the highest quality justify this.

I wrote to all alumni with whom we are in touch introducing this initiative, taking care to stress that this was not the start of a major fundraising campaign. There has been a very warm response and we have already received some £20,000 of one-off donations (including one in kind) as well as the promise of some legacy income in due course. It is a most encouraging start.

This year saw a significant increase, some 29%, in the value of our postdoc Research Fellowships in order to meet full payroll costs at an appropriate level. Universities were finding it difficult to make up the difference between our grant and the actual cost of employing a Fellow and we were determined that our awards should maintain their premier status. The quality of applications was higher than ever in 2017 and I am pleased to report that, despite the increased cost, we were able to maintain last year's record number of these awards at ten Fellowships.

The Industrial Fellowship scheme attracted a stronger response from industry, alongside some very good applications from those at Centres for Doctoral Training, reflecting the effort that has gone into raising the profile of this scheme. A record number of fourteen Industrial Fellows were appointed, all showing tremendous promise.

The Enterprise Fellowship partnership with the RAEng entered its second year in 2017 with three outstanding Fellows appointed. The scheme is proving an excellent addition to our portfolio and attracting some impressive entrepreneurs who have promising careers ahead of them. Our Industrial Design Students continue to attract plaudits as well, as the record of alumni achievements later in this report shows. These reports demonstrate the extraordinary reach of our alumni, all of whom acknowledge the impact that an 1851 award has had on them. One of the greatest pleasures of being a Commissioner is seeing such successful outcomes from these programmes over so many years; I hope you enjoy reading about them too.

Elsewhere in this Annual Report you will find details of the Special Awards we have granted in the course of the year. Here too we have surpassed previous years in both monetary value and range of activity with some really exciting major projects starting in the New Year. In particular, our partnership with the BBC World Service continues to strengthen: an excellent second programme of 'The Engineers' was recorded in the Science Museum, thus establishing this initiative as an annual event. This year we increased its reach by running a successful schools programme alongside it which we will continue. Plans are in hand for a programme at the Natural History Museum in 2018.

Plans for an ‘Albertopolis Festival’ continue to evolve with the support of all the legacy institutions through the 1851 Group, comprising their Chairmen and Chief Executives. The bicentenary of Queen Victoria’s and Prince Albert’s births in 2019 is a natural aiming point for the inaugural event. Although this is an ambitious timescale, I have been encouraged by the enthusiasm shown by everyone involved to achieving an event to mark this important milestone. I look forward to reporting in more detail next year.

I hope these brief reflections on another busy and productive year will reassure readers of the continuing success and contribution of the Commission and entice them to seek further detail in the body of the report. As always I am very grateful for the hard work of our small staff who maintain the pace of activity and for the strong support provided by the Commissioners and committee members in helping to deliver our programmes. I thank them all for helping to make “The 1851” what it is.

Bernard Taylor CBE DL FRSC

Secretary’s Report

The growing number of programmes and the record number of awards being granted keeps us on our toes. Adding in exciting property developments by our tenants, such as the Royal Albert Hall’s basement project and the Royal College of Music’s Courtyard development, more activity than ever on the legacy estate and a steady influx of applications for Special Awards from a diverse range of institutions and individuals ensures that life is never dull. But while people are always fascinated to hear about the work of the Commission, very few are already aware of its existence so the challenge to raise our profile remains a key one.

As with every other charity in the country, the new Data Protection Regulations, GDPR, which come into force in May 2018, have made us look hard at how we interact with individuals, especially alumni, and caused our standard Privacy Notice to grow from one paragraph to five pages. To ensure compliance we are moving to a new alumni database which brings with it a silver lining of considerably enhanced functionality, enabling alumni to communicate with each other and the Commission more effectively. Through this we hope to build further on the increasing dialogue with our past award holders celebrating their achievements both in the Annual Report and on the website. Considerable effort goes into keeping this up to date so that it becomes a rich source of information about the research activities being supported and successes achieved. Our growing numbers of followers on Twitter further draw attention to our activities while the digitised archive continues to expand and is a valuable resource for those fascinated by the Great Exhibition and its extraordinary legacy.

I hope you enjoy reading this report of a particularly full year for the Commission.

Nigel Williams

The Work of the 1851 Royal Commission

The Commission's aim is to 'make a difference' by providing educational fellowships and studentships to the very best early career scientists, engineers and designers. Success is hard to measure within the confines of a single year, but looked at over the longer term the Commission's achievement is evident, with 13 Nobel Prize winners and over 150 Fellows of the Royal Society among its previous award winners. The case studies of completing fellows and summaries of alumni achievements later in this report also bear witness to the Commission's success.

In addition to its core fellowship schemes, the Commission also provides special awards to its legacy institutions, to other organisations working to encourage STEM (science, technology, engineering and mathematics) education and to organisations that can help facilitate access to its incredible archives. Details of some of these awards and the impact they have made can also be found later in this report.

As well as the grants that it makes, the Commission also itself organises a number of educational and networking events for the benefit of its award holders, alumni, legacy institutions and the general public, which together make a significant contribution to STEM education.

The Commission was originally established by Royal Charter in 1850 under the Presidency of Prince Albert, to organise and stage the Great Exhibition. Held in the spectacular Crystal Palace, constructed in Hyde Park, it was the first ever World Fair, and the most successful. With over 6 million visitors, it also made a substantial profit.

Consolidated by Supplemental Charter, and enjoined to invest the surplus from the Great Exhibition *strictly in accordance with the ends of the Exhibition...[to] increase the means of industrial education and extend the influence of science and art upon productive industry* the Commission purchased 87 acres of land in South Kensington and helped establish its three great museums, the Royal Albert Hall and renowned institutions of learning, including Imperial College and the Royal Colleges of Art and Music.

When this huge undertaking was complete, there remained sufficient funds for the Commission to initiate, in 1891, a programme of fellowships and studentships to support pure research in science and engineering, applied research in industry, industrial design and other projects.

The Commission continues its work to this day, both managing its freehold estate and awarding close to £4m a year in research fellowships, design studentships and other grants. The provision of long leases to the legacy colleges and the Royal Albert Hall also make a very substantial contribution to scientific, engineering and artistic education.

Public Benefit

The Royal Commission ensures that its work is for the public benefit and takes full account of the published Charity Commission guidance. The Royal Commission's events and awards programmes and support of the legacy institutions represent identifiable benefits and are available to all eligible members of the public. They satisfy the primary charitable purpose of the advancement of education.

Grant-making Policies

The Commission primarily pursues its charitable purposes through the award of grants to individuals and organisations. The Commission awards grants under a number of defined programmes. Full details of the terms and conditions for each programme, including application forms and deadlines where appropriate, are provided on the Commission's website. A brief summary of the major programmes which the Commission supports is provided below:

Schemes administered by the Commission:

Post-doctoral Research Fellowships in Science or Engineering

These are intended to give early career scientists or engineers of exceptional promise the opportunity to conduct a research project of their own instigation; an ultimate objective is to contribute to the knowledge base required for a healthy and innovative national culture. Around eight awards are made each year, including the Brunel Fellowship for the highest placed successful candidate who has proposed a project to be pursued in an academic engineering environment. The awards are for up to three years, subject to annual review and encompass an annual stipend and some support for travel and other expenses.

Industrial Fellowships

These are intended to encourage profitable innovation and creativity in British industry. Projects in any science or engineering discipline will be considered. A variable number of awards is available each year depending on the financial value of individual awards granted. An ERA Foundation Fellowship for the electro-technology sector is awarded as part of the scheme. Fellowships are awarded to selected exceptional graduates with the potential to make an outstanding contribution to industry, for a programme of research, supported by their employing / sponsoring company, leading to a patent, product or process improvement in conjunction with a higher academic award. Awards are for up to three years, subject to annual review, and include a contribution towards living costs, a travel allowance, an honorarium for the host university and in appropriate cases a contribution towards university fees or towards the cost of enhancing the research project.

Industrial Design Studentships

These are intended to stimulate industrial design capability among the country's most able science and engineering graduates. Around eight awards are offered each year for outstanding engineers or scientists who wish to develop their capabilities in industrial design by taking a recognised masters course and who aspire to become leading designers in British industry. The award is for up to two years and includes a stipend, materials allowance, travel allowance and contribution towards tuition fees.

Fellowships in Design and the Built Environment

Awarded in alternate years, these Fellowships each provide a stipend for up to two years to enable those at a more advanced stage in their career to explore important current issues, selected by the Commission.

Schemes administered by other organisations:

Enterprise Fellowships

Awarded through the Royal Academy of Engineering (RAEng), these fellowships are open to outstanding UK-resident engineering graduates seeking entrepreneurial success. A package of tailored mentoring, training and grant funding will enable recipients to pursue commercialisation of their technological ideas. Up to four fellowships a year are available.

Great Exhibition Scholarships

Awarded through The Institution of Engineering and Technology (IET), these scholarships are open to UK residents who achieve 3 A grades or above at 'A' level or equivalent joining an IET accredited undergraduate degree. Additional criteria may apply from year to year – full details are available on the IET website. Up to ten scholarships a year are available. Scholars receive an annual stipend.

Special Awards:

Although the educational programmes described above represent the lion's share of its grant giving, the Commission also responds to all those requests for funding that commend themselves through the Special Awards procedure. Here the aim is to assist worthy individuals, organisations or projects whose aims in the broadest sense align to the Commission's, and all applications are carefully scrutinised at an appropriate level according to the amount of support requested. Grants range from a few hundred pounds to over a hundred thousand pounds. While Commissioners retain considerable flexibility in principle, in practice a majority of special awards are made either to institutions on the Commission's legacy estate or for educational outreach work by like-minded organisations seeking to draw the attention of the young to the opportunities presented by science, engineering and design. A small number of grants are also made to facilitate access to the Commission's archives.

Achievements in 2017

The core activity – and primary achievement – of the Commission is identifying early career science and engineering graduates of exceptional promise and supporting their work with its prestigious fellowships and studentships. Full details of the awards made during the year are given on pages 10 to 16.

Some evidence of the success of the various programmes can be gleaned from the achievements of those Fellows who completed their awards during the year and the positions they go on to secure. A representative sample of case studies is provided on pages 17 to 28 and a couple of brief testimonials are reproduced below:

The 1851 Fellowship has been one of the defining aspects of my academic career. It has allowed me to focus on developing my own research program, which will form the basis of my work for years to come, and has been instrumental in establishing my career and research profile. I am truly grateful.

Dr Tom Montenegro-Johnson, Research Fellow 2014

The opportunity to conduct a PhD research program through a Royal Commission for the Exhibition of 1851 Industrial Fellowship has been a fantastic opportunity. It has given me the experience to develop a project which is closely linked to industrial goals whilst also forging strong collaborations with academia. The Royal Commission Industrial Fellowship gave me the freedom and funding to work towards a PhD embedded in industry whilst benefitting from the expertise available within academia. This balance has been vital in the implementation of a fruitful and enjoyable research program.

Stephen McColm, Industrial Fellow 2014

Further evidence comes from the honours and awards bestowed on older alumni – some highlights are given on pages 29 to 31. Many of our alumni tell us that their 1851 award played a significant part in launching their very successful careers. A couple of representative examples are given below:

My 1851 award was very important in the development of my career as a scientific researcher and as a university lecturer. At a time (the 1960s and early 70s) when women were very much in the minority in science and in universities, it allowed me to be seen as a person worthy of support and as a serious scientist, at least the equal of my male contemporaries.

I have worked on research grants and/or as a university lecturer ever since and now, at the age of 74, I am still working at King's College London where I have set up, and now run, a small museum, The Museum of Life Sciences, which is dedicated to illustrating evolution and biodiversity, to conserving the College's heritage in terms of our valuable and irreplaceable specimens, to widening the experience of students in College through practical exercises and a volunteer scheme and finally to widening participation at University level through our outreach work with school groups. We also have occasional Open Days when the public is given access to the Museum.

I feel much of this is ultimately owed to the 'boost' that being awarded an 1851 Fellowship gave me.

Dr Gillian Sales, Research Fellow 1968

The 1851 Fellowship gave me the best ever start to my independent career. Not only did it help me make friends across disciplines with other 1851 awardees of my time, but it helped me connect with the incredible previous Fellows. It helped me identify commonalities of character, attitudes and perspectives of thought leaders in science that I have tried to nurture in my own approach.

Professor Yamuna Krishnan, Research Fellow 2002

The 1851 Fellowship really provided a platform for me to launch my independent research career. There is no doubt that, without it, I wouldn't be where I am today.

Dr Rhodri Davies, Research Fellow 2008

2017 saw a record number of Industrial Fellowships awarded. A recent Fellow and an Industrial Supervisor explain the benefits of the programme:

The industrial fellowship has allowed me to pursue an idea at the intersection of academia and industry that would otherwise have not been possible, carrying out research into hot carrier solar cells. I have been able to travel widely to international conferences and universities, giving invited talks on the work that I have carried out. I have met fascinating people, including prominent academics, MPs and members of the Royal family, giving me the perfect platform to talk about my research and place it in a wider context. The work during the fellowship led directly to two patents and a follow on project developing a spectral sensor, and allowed me to develop the skills to gain promotion to become a lead researcher.

James Dimmock, Industrial Fellow 2013

These awards are extremely valuable for the development of our early stage career scientists, as it means they are offered a clear progression towards senior scientist via a PhD without having to leave the company to undertake the study. We try and align the PhD with company objectives as closely as possible so that much of the daily work remains relevant and often the student can remain based within the company for much of the research period. It also strengthens our relationships with our academic partners and gives us a chance to collaborate on a mutually interesting project without breaking the bank. This is one of the finest schemes of its type and there is a great deal of kudos for any student that manages to gain a Fellowship from the Royal Commission.

Professor Andrew Lewis, BTG plc, Industrial Supervisor

An Industrial Fellow alumnus provides evidence of the longer term impact of the award:

Without doubt, the Industrial Fellowship award provided by the Royal Commission for the Exhibition of 1851 has been a bedrock for my career for over 20 years.

My post-PhD work facilitated early industrial research in the area of Simultaneous Localisation and Map building (SLAM). This technology allows robots to build maps and concurrently use that map to determine their location within it. This has been a main theme of academic research in robotics for a generation. But, more importantly, recent years has seen this technology used in British designed, innovative, large volume, consumer available robotics; namely the Dyson 360Eye automated vacuum cleaner. As a Robotic System Architect at Dyson it gave me great pride, that a technology

I had worked on in my early career, in a different industry, is now, 20 years on used in houses across the globe to make people's lives better. Further, this is a great example of how research supported by the Commission has made a long term contribution to British industry.

Dr Rob Deaves, Industrial Fellow 1994

Our Industrial Design Studentships also lead to great things. A recent alumnus provides a representative example:

Over the past year I spearheaded the development and eventual release of a uniquely healthy retail ready-to-eat popcorn called Pop Zero Popcorn. As a direct result of the Industrial Systems Manufacture and Management MPhil which the Royal Commission's award enabled me to attend (I would not have been able to afford it otherwise) I was able to orchestrate the development of a completely unique manufacture process which allowed the company to work with ingredients that are traditionally not used in a popcorn production process. These ingredients give Pop Zero a nutritional profile that is healthier than all other popcorns and provide the perfect base for flavourings. As well as this the product is all natural, non-GMO and the oils used are sustainable in their production process.

The product was released in April 2017 with Costco being our first customer. Sales grew so quickly that by November the product was in over 300 stores with hundreds more retailers in the sales pipeline. As a result of our one of a kind manufacturing process and the success of the product we were purchased by a Private Equity group called Fifth Partners just before Christmas who promptly named me the CEO of the company and gave us access to contacts, funds and expertise. We have a brand new state of the art multi-million dollar production facility set for completion in April and our product hits the shelves of Albertsons (the second largest retailer in the USA) in May. We have plans to expand nationwide and into the UK in the coming years. I am beyond grateful to the Commission and their pivotal role facilitating my education and development in a way that I would never have been able to do on my own.

Josh Brownlow, Industrial Design Student 2013

As well as its core fellowships and studentships, the Commission also runs a very successful special awards programme, supporting individuals and institutions with similar aims to the Commission. As in previous years, many of the awards reflect the Commission's continuing commitment to raising the awareness of the young to the opportunities presented by science and engineering. They include grants to support the LiveLab demonstration area in Oxford Trust's new indoor-outdoor Science Education Centre; a series of radio broadcasts and YouTube animations by Children's Radio UK to answer 'How's that Made?' for a series of products chosen by primary school children; scholarships for secondary school girls with excellent predicted GCSE grades to encourage them to take maths and physics at A level; and the purchase of Sphero Robots to encourage an interest in coding amongst primary school children in Wales.

Other Special Awards have focused on continuing to develop South Kensington as the premier destination for those interested in science, engineering and design, including grants to support the fitting out of the Dyson School of Design Engineering at Imperial College London and the transformation of the main entrance to the Natural History Museum.

Finally a Special Award to the Royal Collection Trust will facilitate through digitisation public access to the papers of Prince Albert, including those dealing with the Great Exhibition and the early days of the Commission.

Future Plans

The Commission has long been involved in supporting excellence in higher education, but has hitherto had less involvement with further education. As a first step into this domain, Commissioners hope to collaborate with the Education and Training Foundation on a pilot project to explore the scope to introduce Industrial Teaching Fellowships to reward excellence in industrial education and facilitate dissemination of good practice. If successful this could become a core part of the Fellowship programme.

As well as new Fellowships, Commissioners are always keen to explore new ways of supporting STEM education and introducing young people to the delights of science and engineering. Plans are taking shape for Pestival, a major STEM education event exploring science, engineering and design through a focus on insects, to take place in Kensington Gardens, adjacent to the Commission's legacy estate. Commissioners hope to support this event with a mixture of grant and loan funding. Although social and programme-related investments are arguably nothing new for the Commission when you look at the history of its support for its legacy institutions, this would be the first time in recent history that the Commission had experimented with social investment alongside its traditional grant making.

In a similar vein, the Commission will be supporting the Great Exhibition of the North – billed as England's largest event in 2018 - including taking the opportunity to inform its visitors about the original Great Exhibition and the continuing work of the Commission as well as supporting a STEM summer camp for school children.

Finally, as mentioned in the Chairman's report, Commissioners hope to collaborate once again with the BBC World Service in staging an event aimed at the general public, for broadcast on the radio, themed around the impact of engineering. Plans are already well advanced for an event to be hosted by the Natural History Museum.

Awards Granted in 2017

Research Fellows

Dr Felicity Allen

Subject: Powerful CRISPR / Cas9 screens via computational prediction of DNA repair profiles

Wellcome Trust Sanger Institute

This project will make novel large-scale measurements of DNA mutations generated by CRISPR/Cas9 to build a predictive machine learning model of gene editing outcome. This will resolve costly issues of redundant design and inaccurate quantification of powerful genome-wide gene knockout experiments.

Dr Stephen Cox

Subject: Towards predicting the surface charge of electrolyte / solid interfaces

University of Cambridge

Cutting edge simulation methods will be used to elucidate the molecular details that control surface chemistry under realistic conditions. One specific aim is to calculate the surface charge dependence of surface acidity, removing the need for assumptions used to interpret experiments. This may facilitate the design of new electrolyte technologies.

Dr Amin Doostmohammadi

Subject: Living colloidal metamaterials

University of Oxford

Biological matter consisting of elongated individuals such as bacterial suspensions are now classified as a new material, termed 'active liquid crystals'. This project will computationally study how dispersed colloids in active liquid crystals self-assemble into superstructures, revealing novel colloidal interactions, new patterns of self-assembly and the control of active matter at the micro-scale.

Dr Paul Holloway

Subject: A microfluidic model of the neurovascular unit for stroke research

University of Oxford

This project will develop a novel cellular model of the brain using "Organ on chip" technologies. Brain cells will be grown in 3D, fed by artificial blood vessels which can be blocked to mimic stroke, a leading cause of mortality worldwide, enabling new possibilities to investigate therapeutics in human cells.

Dr Paul Knott

Subject: Employing computer algorithms to automate the engineering of quantum states

University of Nottingham

This project will tackle a key challenge in the quantum technology revolution by designing computer algorithms that automate the engineering of useful quantum states. These algorithms will enable the design of novel experiments to bring forward the development of new technologies such as quantum computing, communications and metrology.

Dr Claire McIlroy

Subject: Semi-crystalline materials in additive manufacturing

University of Nottingham

A fundamental understanding of the relationships between the printing parameters, material rheology and mechanical properties is crucial for facilitating additive manufacturing production of structure-critical components and assemblies. This project addresses this gap in current knowledge by providing molecularly-aware models to predict deformation and welding behaviour of semi-crystalline melts.

Dr Zahid Padamsey

Subject: Speed or precision? Dynamics of information flow in the brain *University of Edinburgh*
Theoretically, there exists an optimal trade-off between the speed and accuracy with which information can be efficiently communicated by biological systems. This project will use state-of-the-art imaging, genetic and computational techniques to examine whether optimal speed/accuracy trade-offs are a fundamental feature of information transmission between neurons in the mammalian brain.

Dr Mark Puttick

Subject: Biodiversity and the sixth mass extinction: lessons from the past *University of Bath*
We face an uncertain future entering a global mass extinction. What can we learn from biotic crises in the past? This project will use novel techniques combining data from living and fossil groups to determine which species are most vulnerable. This will enlighten the origins of biodiversity and aid its conservation.

Dr Nicole Reindl

Subject: Probing the nature of dark matter using hot white dwarfs *University of Leicester*
This project aims to determine the hot white dwarf luminosity function as well as the Galactic distribution of hot white dwarfs. Both help to answer one of the fundamental questions in modern physics: What is the nature of dark matter?

Dr Matthew Wallace

Subject: Elucidation of carbohydrate dissolution and gelation using NMR imaging techniques *University of East Anglia*
Nuclear Magnetic Resonance Imaging (NMR-I) techniques will be developed to gain unprecedented insights into the chemical and physical processes of plant-based soft materials used in healthcare and food applications. The techniques will overcome the severe limitations of conventional analytical approaches and accelerate the design of new materials and processes.

Industrial Fellows

Dina Abdulaziz

Subject: Re-engineering bone
Sponsor: British Glass / The Worshipful Company of Glass Sellers *University of Leeds*
This project will focus on the fabrication and characterisation of physiologically-engineered materials for biocompatibility and biomechanics, before being tested as bone.

Andrew Anderson

Subject: Development of a practical method for manufacturing enhanced heat transfer surfaces on commercial heat exchangers
Sponsor: Oxford nanoSystems Ltd *University College London*
The efficiency of heat exchangers designed to efficiently cool electronics will be enhanced by creating microchannels for the coolant using a novel polymer microbead technique. These will be used as removable masks for etching the underlying metal and can easily be removed by dissolution.

Timur Avkiran

Subject: Discovery of novel small molecule drugs for the treatment of tuberculosis
Sponsor: MRC Technology *University of Warwick*
Infectious diseases are caused by pathogenic microorganisms such as bacteria and represent a global health problem of rising importance. This research project will focus on designing and synthesising small molecules targeting a novel pathway for the treatment of tuberculosis, one of the top 10 causes of death worldwide.

David Dearlove

Subject: The regulatory and downstream effects of supplemental ketosis

Sponsor: TdeltaS Ltd

University of Oxford

This project will, for the first time in humans, explore how ketone bodies affect gene regulation. This may facilitate our understanding of the molecular mechanisms underlying the known health benefits of ketogenic diets and potentially lead to the development of a ‘medicinal ketone drink’.

Laurence Devesse

Subject: Investigation into the use of massively parallel sequencing in forensic genomics

Sponsor: Verogen UK Ltd

King’s College London

This project aims to improve the field of forensic DNA identification, using a massively parallel sequencing (MPS) approach to overcome the limitations currently encountered with traditional methods.

Joshua Elliott

Subject: Integrated ultrasonic imaging for the inspection of near-surface defects in safety-critical components

Sponsor: Rolls-Royce plc

Imperial College London

Super Resolution (SR) imaging has the potential to lead to a step change in the characterisation capabilities of ultrasonic non-destructive evaluation (NDE). This project will research these SR algorithms for their use in the NDE inspections of safety-critical nuclear plant components for the first time.

Ben Janes

Subject: Smart mixing – artificial intelligence in live music mixing systems

Sponsor: Allen & Heath Ltd

Plymouth University

The aim of this project is to develop a musically conscious digital audio mixing system using artificial intelligence. This product would give sound engineers a creative tool to aid the mixing process and transcend live performance quality, or provide an automated mixing solution where there is no resident sound engineer.

Chao Jiang

Subject: Epigenetic reactivation of aged mesenchymal stem cells to proliferate and differentiate into the osteoblast lineage

Sponsor: UCB Celltech

University of Oxford

Mesenchymal stem cells (MSCs) show impaired proliferation and osteogenesis with age. This project aims to identify epigenetic targets to restore aged MSC function. RNA-interference screenings will be carried out using a lentiviral-shRNA library. Identified targets could lead to drugs for replenishing osteoblast number in patients with age-associated conditions such as osteoporosis.

Shaun Mansfield

Subject: Development of a manufacturing process for clinically-relevant cord blood haematopoietic stem cells

Sponsor: Biovault Technical Ltd

University College London

The main focus of this project is the development of a standardised, robust, litre scale manufacture process for umbilical cord blood derived haematopoietic stem cells (UCB-HSCs) increasing cell yield and engraftment ability. Providing a personalised (autologous) and off-the-shelf (allogenic), clinically-relevant HSC product.

Elsa Noaks

Subject: An upstream manufacturing step to remove contaminating cell types from T-cells for immuno-oncology

Sponsor: Autolus Ltd

University College London

Cellular immunotherapies have the potential to cure some of the most devastating forms of cancer. This project aims to create a new process to remove contaminating adherent cells from patient blood fractions in order to enrich the target T-cell population. The process will be compatible with existing cell culture platforms.

George Roberts

Subject: Optical injection locking applied to quantum key distribution

Sponsor: Toshiba Research Ltd

University of Cambridge

This project explores the benefits of injecting light from one laser into another with regards to secure cryptography. A transmitter is being developed that shows promising features to become the standard transmitter for next-generation quantum communications.

Sascha Ruggaber

Subject: New reclamation technologies for the remanufacture of combustion engines

Sponsor: Autocraft Drivetrain Solutions Ltd

University of Strathclyde

This project will be carried out in the field of remanufacturing and aims to answer the question “What technologies can be used to reclaim parts for remanufacturing combustion engines that are currently not in use?” The research will concentrate on the reclamation of major engine parts for automotive applications.

Iestyn Stead

Subject: Reduction of parasitic losses in zero emissions liquid air engines

Sponsor: Dearman Engine Company Ltd

University of Birmingham

The Dearman Engine is a zero-emissions engine powered by liquid gasses. This project aims to reduce the losses in the engine caused by friction. This will be tackled by replacing components and fluids within the engine and improving the design of these components to increase the performance of the engine.

Edward Williamson

Subject: New ceramic coatings for small modular reactors

Sponsor: Rolls-Royce plc

University of Surrey

Nuclear reactor components must survive in arduous conditions for many years. Traditional hard chrome coatings are being phased out due to regulation change. This project focuses on evaluating a number of potential replacement materials for suitability and also exploring the possibilities regarding component redesign during small modular reactor development.

Enterprise Fellows

Guillem Singla Buxarrais

Company: Neurofenix

1 in 6 people will have a stroke in their lifetime. Most survivors lose control of an arm and the best chance to recover is through intensive physiotherapy, but it is very hard for them to access it because public healthcare systems such as the NHS are under-resourced and private physiotherapy is expensive. Neurofenix has developed the solution to this problem: the Gameball Platform. It consists of a low-cost hand training device connected wirelessly to a mobile application. Stroke survivors place their hand on top of the controller and can train their whole upper limb, from fingers to shoulder. The Gameball App lets them play games especially designed to make rehabilitation exercises entertaining, it tracks their progress and allows stroke survivors to share their scores with other survivors, making rehabilitation fun and social for the first time. Guillem’s goal is for every stroke survivor to use a Gameball in their home to accompany them through their recovery journey. The Gameball Platform will connect stroke survivors around the world and Neurofenix will be the leader in providing affordable and engaging neurological rehabilitation. Neurofenix was awarded a Social Tech Seed Award by the Nominet Trust and selected as a top digital health startup by Innovate UK.

George Wright

Company: Vochlea

Vochlea is a music technology company with a focus on audio controlled interfaces for music creation. The launch product is a hand-held device to translate vocalisations into instrumentation; helping people to capture their musical ideas and develop them into audible music. The voice is an incredible tool, and our built-in method for audio expression. We've all practiced vocal expression since birth and consequently we all have a powerful, delicate and rich tool for audio and musical expression. Now with Vochlea there is a technology and device that can understand and interpret these vocalisations. Not only that, it can translate them into the desired sound. Imagine your beatboxing controlling drum samples, in real-time. Or your impression of a brass instrument controlling and crafting the sound of a software trombone. This is the power of Vochlea. The product has been recognised for a number of awards including the IxDA Interaction Design Awards and the SXSW Audio and Music Innovation awards and has been featured in many of the U.K.'s most well-respected publications including Wired, The Observer, and the Sunday Times.

Victoria Hamilton

Company: VH Innovation Ltd

VH Innovation's launch product is the Recoil Omniflex 1.0 knee pad. Recoil knee pads originated as part of a final year design project at The University of Strathclyde. Victoria Hamilton, a final year product design engineering student, responded to the needs of her father, a tradesman, to design a new knee pad that offers better comfort and protection than current solutions available on the market. The idea which she developed utilised a double layer system with springs sandwiched between, with the idea this new design would absorb impact and spread pressure evenly across the knee joint. In addition, the double layer system would provide a flat outer surface providing maximum grip of the ground, while a curved inner surface would cradle the knee and provide maximum comfort. The springs sandwiched between would account for the difference in surface and allow the wearer to have full 360 degree movement without feeling a build-up of pressure on sensitive areas of the knee. Evidence from a study undertaken by the bioengineering department at Strathclyde University has demonstrated that this design is scientifically proven to reduce pressure on the knee by up to 76%, a 20% improvement on the next best gel competitor also tested during the study.

Oluwaseyi 'Shay' Sosanya (ERA Foundation Fellow)

Company: Gravity Sketch

Gravity Sketch is a 3D design software for virtual and augmented reality head sets. Gravity Sketch was initially a graduation project from a team of Innovation Design Engineering students from Imperial College London and the Royal College of Art as part of their final year research. Oluwaseyi Sosanya and the team looked deep into the ways designers and engineers represented 3D ideas and found areas of friction to which a new user experience and immersive technology could bring a solution. Based on sketching, they have developed the most intuitive tool to freely express ideas in 3D. Through their "what you see is what you get" interface, 3D objects appear in real time, creating a new kind of digital authoring experience, bringing a dose of craft to the digital world. From students exploring 3D concepts to designers and engineers visualising 3D ideas in VR and AR, Gravity Sketch democratises digital 3D creation.

Built Environment Fellow

Professor Irena Bauman

Subject: Built InCommon – Manufacturing an Inhabitable City

Mentor: Professor Flora Samuel

The trend in pre-fabricated construction continues to be towards centralisation to leverage economies of scale. This business model has significant drawbacks: the high costs of setting up and subsequent dependence on a reliable pipe line of commissions; inflexibility of the product design – changing machine settings for specials is prohibitively expensive; the large carbon footprint and expense of transporting components to distant sites as well as the limited benefits to local economies, jobs and training.

Alternative, distributed networks of fabrication are emerging that would overcome these drawbacks. Uniquely leveraging recent software and technology advancements, new construction systems are in development that merge design, fabrication, and construction approaches into a single, distributed process enabling new service delivery models at a local level. Designed for affordable customisation these systems offer the benefits of off-site construction but with a cheaper, greener and integrated local supply chain.

These agile systems support fine-grain building and affordable adaptation to difficult sites which makes them attractive to the growing sector of civic builders such as community land trusts, community development trusts, co-housing, social housing partnerships – all those who trade with social rather than financial capital. Offering direct involvement to those in the community with skills and a desire to build, these systems replace commercial benefits of economy of scale for the benefits of sustainable production, circular economy and social engagement.

As the range of digitally-enabled construction systems grows so does the availability of web-based user guides aimed at the civic builders. However, construction is about physical making and there is a performance gap between the virtually designed systems and the physical experience of building. To take advantage of these new construction systems there is therefore a need to build up construction know-how in the civic housing sector and within the supply chain. A new neighbourhood-based physical infrastructure is required which I have named Built InCommon. This study aims to initiate a thorough research process to accompany the emerging phenomenon, using the insights gained from the pioneering projects to develop a template for a wider network of place-specific Built InCommon factories that could become a standard community facility in the future.

Industrial Design Students

Ruby Childs	Textile Design	Royal College of Art
James Fraser	Innovation Design Engineering	Royal College of Art
Merlin Kafka	Industrial Systems, Manufacture and Management	University of Cambridge
Amos Oyedeji	Innovation Design Engineering	Royal College of Art
Hamza Ora	Innovation Design Engineering	Royal College of Art
Andrea Pisa	Global Innovation Design	Royal College of Art
Wen Han Yap	Service Design	Royal College of Art

Great Exhibition Scholars

James Cummins	University of Leeds
Nikita Dheer	University of Oxford
Faaria Khan	University of Oxford
Adrian Kozhevnikov	University of Oxford
Rosie Sallis	University of Cambridge
Lawrence Tray	University of Cambridge
Emily Wayland	University of Southampton
Holly Whitehouse	Durham University
Tilly Wilks	University of Sheffield
Harrison Wright	University of Cambridge

Special Awards Granted

STEM education and outreach

Royal West of England Academy – My Future, My Choice
Foundation for Science and Technology – Debate sponsorship
Surrey SATRO – Mega Structures Challenge
Armourers’ and Brasiers’ Company – Cambridge Forum
Cambridge Society for the Application of Research – Videoing lectures
STEM Skills Fund – Scholarships
Oxford Trust – LiveLab
XL Wales – Sphero Robots
Children’s Radio UK – How’s that Made?
Sir Misha Black Awards – Anniversary publication
Towards Vision – Year of Engineering roadshow
Great Exhibition of the North – Power Up challenge
Education and Training Foundation – Industrial teaching fellowships
Travel bursaries and conference prizes

Support for legacy estate

Natural History Museum – Planters for main entrance
Imperial College – Dyson School of Design Engineering lecture theatre

Archives and alumni relations

Royal Collection Trust – Digitising Albert

Awards completed in 2017

Research Fellows

Dr Nicholas Bristowe

Project: Designing functionality at oxide interfaces *Imperial College London / University of Kent*

During his Nobel lecture, Herbert Kroemer famously stated “the interface is the device”. He was referring to the success of electronic devices, such as the transistors in the laptop or tablet with which you might be reading this, that are based on interfaces between semiconductor thin films. When an interface is artificially created between materials, the local environment in the interface region can be substantially different from any natural arrangement of atoms. Sometimes this unnatural atomic environment acts like a new two-dimensional compound with either enhanced properties, such as electrical conductivity in semiconductors, or even novel properties not seen before in either separate material. By replacing traditional semiconductors with more complex materials, interfaces can show spectacularly unexpected behaviour, with potential use for device applications of the future.

In spite of developments in experimental growth and characterisation of such interfaces a fundamental understanding of the underlying physics is often lacking. Nicholas’s fellowship has attempted to design new “functional” interfaces using theoretical simulations. These simulations, based on quantum mechanics, can provide the fundamental understanding, and hence rational design, of real materials without entering the laboratory. Highlights of these predictions include inducing metallic behaviour between nominally insulating materials, creating permanent magnetism that is controllable with electric fields by combining non-magnetic materials, and creating layered materials which unusually contract with temperature from building blocks of materials which show normal thermal expansion. Whilst these predictions may not themselves revolutionise the electronics industry, the underlying mechanisms and hence rational design could pave the way for future breakthroughs.

Nicholas is now a Lecturer in Chemistry at the University of Kent and an Honorary Lecturer in Materials at Imperial College London.

Dr Luke Butcher

Project: Energy in curved spacetime

University of Edinburgh

Luke’s research explores the often-tangled relationship between energy and gravity: he studies the energy carried by gravitational waves, the negative energy required by wormholes, and the mysterious dark energy that drives the expansion of the universe.

We do not know whether traversable wormholes are allowed or forbidden by the laws of nature. If they can exist, these bridges of curved space would allow faster-than-light communication and time travel, upending our understanding of causality. Luke’s work on traversable wormholes has tackled the question of their existence from both directions: he aims to either describe a physical mechanism by which one could form and be maintained, or to formulate a rigorous argument that forbids their existence altogether. In the first direction, he showed that a long thin wormhole can create the negative energy it needs to survive, at least for a short time. By inducing a negative energy state in a quantum field, the wormhole can maintain itself long enough that a message can cross the throat. This research excited considerable interest in the popular press, culminating with Luke presenting the work on the popular-science television programme *Through the Wormhole with Morgan Freeman*. On the opposite side of this issue, Luke proved that a classical scalar field can never support a static spherically symmetric traversable wormhole, even when the field has negative energy.

The universe is expanding at an accelerating rate, seemingly driven by an invisible dark energy at every point in space. A controversy had recently arisen as to whether the simplest form of dark energy (a cosmological constant) altered the way light is bent by a gravitational field. With the aim of re-establishing a consensus on this issue, Luke conducted a comprehensive analysis of the Schwarzschild-de Sitter spacetime (a black hole in an accelerating universe) and definitively demonstrated that a cosmological constant does not alter the power of a gravitational lens. He has since begun to develop a new theory of cosmological acceleration that does not require dark energy. The model is based on a subtle quantum force he has derived, arising whenever a system undergoes a change in the amount of information it can store.

Luke remains a postdoctoral research fellow at the University of Edinburgh.

Dr Helen Leggett

Project: Virulence in a natural host-parasite system: an experimental approach

University of Cambridge

Why do some parasite species such as *Bacillus cereus* cause us mild nausea and diarrhoea for 24-48 hours, when others such as *B.anthraxis* (Anthrax) kill 90-100% of infected people, often within 48 hours? Understanding why parasites like Anthrax evolve to be virulent (harmful) would be an important step forward in our fight to predict and control infections. However, data are scarce. Significant contributions Helen has made include compiling a large data set of over 60 human parasites to investigate parasite interactions with the immune system, and how this can affect parasite life history. This work highlighted that parasite growth, transmission, dose and virulence can be influenced by mechanistic details such as the distance at which molecules act and route of infection. In addition, Helen developed a novel hypothesis that fast-killing parasites could transmit slowly, and provided proof-of-principle of this theory with experimental evolution of bacteriophage, which has broad applicability to the many other viruses and parasites that must kill their hosts to transmit.

During the course of this fellowship, Helen also investigated the devastating spread of Deformed Wing Virus (DWV) in global honeybee populations. Her research suggests honeybees are undergoing a DWV pandemic, being driven by the global spread of European honeybees and the coinciding emergence of the Varroa mite; which has important implications for modern apiculture.

Helen will continue her research as a newly appointed Lecturer in Evolution and Medicine at the Department of Zoology, University of Cambridge, where she hopes to transmit the importance of parasite evolution and virulence to the next generation of vets, medics and natural scientists, and develop a new experimental system for studying the importance of host microbiota on parasite evolution.

Dr Thomas Montenegro-Johnson

Project: Foundations of biomedical micro robots

University of Cambridge / University of Birmingham

Imagine a world where tiny objects could self-assemble from component microbots to perform a specific task, and then disassemble when no longer required; where chemotherapy is delivered directly to the site of tumours; and where heart surgery amounted to a simple injection. This is the great promise of a novel technology: the artificial swimming micromachine.

However, the current generation of swimming micromachines has a fundamental flaw: it is not possible to effectively control individuals within a large group. Without this precision control, it will be impossible for this technology to perform precision navigation through the complex, inhomogeneous environment of the human body.

Current designs of artificial microswimmer can either be described as “externally-driven”, usually by a magnetic field, or self-propelled via “fuel” in the local environment. Externally-driven swimmers give users direct control over the navigation of individual swimmers, but it is not possible to control these individuals within a large swarm. Fuel-based microswimmers currently afford no active user control, but are cheaper and easier to manufacture.

Over the course of this fellowship, Tom examined how nature overcomes the challenges of precision navigation through complex environments, and began to focus on fuel-based “autophoretic” microswimmers, driven by self-induced chemical gradients of a surrounding solute. By combining current designs with elastic transformations afforded by shape-memory polymers, he has theoretically predicted a means to achieve precision navigation of fuel-based swimmers, which he now intends to assess experimentally.

Tom published 15 papers during his fellowship, with 3 journal front covers, and a further publication to be submitted shortly. He is now a Lecturer of Mathematical Biology at the University of Birmingham, and has recently been awarded EPSRC *Bright Ideas* Grant EP/R041555/1 entitled *Artificial Transforming Swimmers for Precision Microfluidics Tasks* to continue ideas developed during his fellowship.

Dr Johannes Noller

Project: Massive, modified and multi-gravity: understanding the graviton *University of Oxford*

Our understanding of gravity is presently undergoing a radical transformation. The clearest manifestation of this change can be seen in our picture of ‘gravitons’ – essentially the particles mediating the force of gravity, just like photons mediate the electromagnetic force. Previously it was thought that, in order to construct a consistent theory of gravity, there could only be one type of graviton (not several) and that it had to have zero mass. This line of thinking essentially singled out General Relativity as the unique viable theory describing the graviton sector. However, over the last four years it has become clear that this is not the complete picture, culminating in the realisation that a far wider range of theories of gravitons can consistently be constructed. This new landscape of theories now promises to help address several of the long-standing (theoretical and observational) problems and challenges in our understanding of gravity.

Johannes’ fellowship aimed to explore this exciting new research window and develop the tools and frameworks necessary to fully map out and understand the associated new landscape of gravitational theories. During the fellowship, he indeed established a systematic and comprehensive framework to classify and understand this landscape, leading to a slew of other results (e.g. the discovery of new ways for gravitons to interact with matter, new kinetic interactions for gravitons and new ‘dualities’ for gravity, identifying seemingly different theories as physically identical).

In the future Johannes will continue pursuing this and other related work at ETH Zurich, where he has been appointed Junior Fellow at the Institute of Theoretical Studies.

Dr Mark Senn

Project: Understanding microscopic mechanisms in multi-ferroic materials

University of Oxford / University of Warwick

Multiferroics are a promising class of functional materials for data storage and sensing applications. In these materials, magnetic (north-south pole) and ferroelectric (positive-negative dipole) orderings coexist. Much excitement surrounds technologies where these two phenomena are coupled together such that positive-negative dipoles can be detected magnetically, facilitating next-generation data storage devices. Mark’s project has focused on gaining fundamental insight at the atomic length scale on the origins of these couplings between the magnetic and ferroelectric orderings. Using state-of-the-art central facilities, Mark has conducted a variety of in and ex situ X-ray and neutron scattering experiments in order to precisely determine atomic and magnetic orderings in a variety of multiferroic materials. Possibly one of the most exciting results from Mark’s fellowship concerns the most widely used ferroelectric material, Barium Titanate. By studying local atomic length scale arrangements of positive-negative dipoles, Mark’s work has helped resolve long-standing controversy regarding the origin of its ferroelectric properties.

Throughout his fellowship, Mark has also been involved in studying a new kind of “hybrid” ferroelectric behaviour, working on a variety of different systems, which show great promise for application as future multiferroic materials. This work has led him to have an increased interest in using symmetry as a predictive tool for rationalising and designing novel functional materials. He has developed this idea further to also study functional properties such as superconductivity and the thermoelectric effect, and will continue to pursue this research as part of a Royal Society University Research Fellowship at the University of Warwick.

Industrial Fellows

Benjamin Chamberlain

Subject: Modelling the flow of influence in social networks using distributed Bayesian nonparametric methods

Sponsor: Starcount Insights Ltd / Asos plc

Imperial College London

Ben’s research focused on learning properties of individuals interacting in large networks.

Specifically, he addressed how to represent and learn attributes of individuals who interact either in digital social networks or e-commerce co-purchasing networks. He produced an efficient method for detecting communities in large social networks that imitates the function of market research operations such as focus groups, but using a fraction of the time and cost. He later studied the problem of learning attributes of Twitter users, developing effective methods for estimating age and income. During this time, he used a technique called a neural embedding to represent Twitter users. He was able to apply a similar technique to successfully predict the lifetime value of ASOS customers based on their interactions with products.

Having become interested in neural embeddings as a method to represent individuals he developed an extension of the concept by shifting the underlying geometry from Euclidean to hyperbolic space. Hyperbolic geometry is a better continuous analogue to the structure of complex networks than the previously used Euclidean geometry and he demonstrated that using hyperbolic geometry provides more compact representations that outperform Euclidean geometry when applied to vertex attribute prediction tasks.

Ben is now the lead data scientist at ASOS.com. He works on applying machine learning methods on large datasets to provide personalised shopping experiences for the 17 million active customers of ASOS.com.

Radu-Stefan Dragan

Subject: Magnetically geared electrical drives for industrial applications

Sponsor: Magnomatics Ltd

University of Sheffield

The Pseudo Direct-Drive (PDD®) is an innovative new type of electrical machine with a magnetically and mechanically integrated magnetic gear element. This novel machine topology is attractive to the aerospace industry due to its low mass, high torque density and in-built passive anti-jamming mechanism capable of protecting the mechanical drive train from shock-loads. Although the technology has previously been considered for renewable energy, oil and gas and marine propulsion markets, there remain a number of significant barriers to its introduction into the aerospace market. The aim of this research project was to increase the TRL or “Technology Readiness Level” for this market by overcoming these technical challenges and to develop a new range of fault tolerant PDD motors for primary flight control actuation.

The electromagnetic design aspects of the project focused on developing new tools and models to optimise the PDD for high torque density with reduced output rotor inertia and cogging torque while incorporating fault tolerant and energy damping characteristics required for flight control actuation. Initially, two prototype magnetic gear units with two different output rotor topologies were built and tested in order to validate the electromagnetic models and de-risk the rotor design, thermal performance and the small scale mechanical design. The final design also benefited from the results of adhesive, coil winding and encapsulation trials conducted to improve the performance and reliability of the fault tolerant PDD motor during high temperature operation. Processes which resulted from the electromagnetic and thermal modelling as well as build trials are now being used by the company in the development of magnetic gears and PDD motors/generators for a wide range of applications.

Specific test routines were developed and used to characterise the five fault tolerant PDDs developed under this project. This included no-load/on-load, loss, torque transmission and fault current measurements together with drive cycle thermal performance under healthy and faulty conditions. All the prototype validation was done at Magnomatics, on a custom design test rig which now enables the company to extensively test small scale electrical machines and also serves as a demonstrator platform for new customers. PDD prototypes were delivered to Triumph Group and the Electrical Machines and Drives group at the University of Sheffield for drive train integration and actuator control system testing. The results demonstrated the high torque density, high achievable bandwidth, overload protection and low output rotor inertia of the fault tolerant PDD topology. Two academic publications have resulted as part of this fellowship presenting the electromagnetic design and control of fault tolerant PDD motors.

Following the project, Radu-Stefan remains as a key member of the design team and technical authority on fault-tolerant machines. He is now applying the knowledge transferred from the academic partner to a wider range of technologies and sectors, whilst also helping to drive Magnomatics' strategic move into this emerging market.

Pavel Guzanov

Subject: Inhibitor development for ERAP1 for advanced research of Ankylosing Spondylitis

Sponsor: Novartis AG

University of Oxford

Endoplasmic Reticulum Aminopeptidase 1 (ERAP1) is an enzyme which plays an important role in the adaptive immune system. It has been associated with a set of immune-mediated diseases such as Ankylosing Spondylitis. The absence of a selective and potent ERAP1 inhibitor at the moment slows down the detailed research of this enzyme's biological functions and role in the diseases. Thus, the aim of this drug design DPhil project was to discover ERAP1 inhibiting hits, establish their structure-activity relationship (SAR) and, ideally, design a potent and selective ERAP1 inhibitor using a novel Fragment Based Drug Design approach.

The hits have been successfully identified and their SAR has been explored. The main hurdle of the project was obtaining structural information about the hits binding mode to the ERAP1 using X-ray crystallography. Four different approaches have been tried to obtain ERAP1 crystals and none of them was successful. On the other hand, a reported Insulin-Regulated Aminopeptidase (IRAP) inhibitor has been identified as a potent ERAP1 inhibitor. Hence a novel ERAP1 inhibitor scaffold has been discovered. A set of 31 analogues of this inhibitor has been synthesised and screened against ERAP1. Thus, very interesting SAR information has been discovered, providing a solid basis for further research in this area.

Pavel is now pursuing a career in management consulting.

Alice Hagan

Subject: Engineering drug-eluting embolisation systems and mechanistic insights into enhanced local delivery

Sponsor: BTG Biocompatibles

University of Brighton

Drug-eluting beads are microspheres designed to block blood flow to liver tumours whilst simultaneously releasing locally high doses of chemotherapy. However, blocking oxygen supply to tumours can contribute to resistance to currently used drugs and promotion of new blood vessel growth (angiogenesis), which is a cause of tumour recurrence. Vandetanib is a novel targeted drug which disrupts the cellular pathways involved in angiogenesis and tumour proliferation. This project aimed to evaluate vandetanib as a candidate for loading into drug eluting beads, with hopes of providing an improved and durable response to treatment with minimal toxicity.

Optimisation of the formulation of vandetanib loaded beads was performed at BTG's research and development labs, utilising novel radiopaque bead technology to come up with a product that could contain a high dose of drug and was visible under X-ray to help physicians visualise bead placement during and after the procedure. Alice also used new *in vitro* elution models to help predict the rate that drug will be released from the beads.

Vandetanib proved to be efficient at inhibiting the growth of endothelial cells and cancer cells when studied *in vitro*, even when low oxygen conditions were used to mimic the effect of blocking blood supply. In animal models, the beads demonstrated anti-tumoural activity, with low systemic exposure to the drug, meaning a reduced chance for side effects.

The translational research in this project led to the initiation of the first clinical trial to assess safety and tolerability of vandetanib loaded beads in patients with liver tumours. The first clinical trial patient was treated in August 2017.

After completing her PhD at the University of Brighton, Alice will continue to work at BTG on the further development of drug-eluting beads and other interventional oncology projects.

Misty Haith

Subject: Improving reliability of radiography through image processing

Sponsor: BP plc

Imperial College London

Misty's EngD research focussed on improving subsea radiography through the use of image processing and simulation. Subsea pipeline radiography is a relatively new technique used for detecting and characterising defects such as corrosion on the inside pipe walls. There is a lack of detailed research into different subsea radiographic inspection techniques, partly due to the difficulty and cost associated with obtaining experimental data.

Simulation is one of the key ways of assessing inspection techniques without requiring experimental data; however radiographic simulation models have not been validated for subsea techniques. In stage one of this project, the accuracy of a radiographic simulation model for subsea techniques was investigated and differences analysed. Stage two involved development of a new defect characterisation method. When defects are found in a subsea pipeline it is crucial that they can be accurately characterised so that the remaining lifespan of the pipe can be calculated. Use of the characterisation software developed in this project can significantly improve the level of detailed information available from radiographic images, with the potential to reduce overall time and costs associated with an inspection.

Misty is now working at Rolls-Royce Submarines where she is the Assistant Chairwoman of the Inspection Qualification Body, working on development, validation and quality control of ultrasonic inspections.

Stephen McColm

Subject: A new tool for synthetic biology: application to industrial manufacturing

Sponsor: Ingenza Ltd

University of Edinburgh

Due to climate change and uncertainties in global fuel prices, there is a need to adopt biomass derived feed stocks for sustainable manufacturing of fuels, chemicals and pharmaceuticals. As a result, many major industrial manufacturers are now seeking routes to their products that are sustainable, more efficient, and less waste or energy intensive. The replacement of conventional processes to manufacture valuable industrial products and the selection of optimal biosynthetic routes requires the construction, and in most cases subsequent context-dependent evaluation, and optimisation of multicomponent biosynthetic pathways to generate commercial end products. Stephen's project has focused on the development of a platform for microbial strain improvement which addresses the persistent limitations associated with today's iterative and empirical approaches. To achieve this Stephen developed an enhanced DNA assembly approach coupled to mass spectrometry based proteomics techniques and direct screening methods to identify strains with improved process efficiency.

The innovative DNA assembly technique is state of the art, enabling the combinatorial assembly of up to ten DNA fragments for large scale gene/pathway assembly and optimisation. Obvious synergy exists between this approach and label free quantitative proteomics coupled to versatile, solid phase screening and selection. These methods can identify engineered cells of interest, pathway bottlenecks and guide subsequent rounds of pathway optimisation. Liquid chromatography, MS and data analysis methods have been developed to identify and quantify many key cellular proteins from engineered strain lysates. The integration of these approaches for pathway engineering and analysis creates a step change in the speed and predictability with which microbes can be engineered for industrial applications. Ingenza is currently applying this platform to synthetic biology programs for the bioproduction of plastic, nylon and rubber, amongst other products.

Stephen is now a Senior Scientist with Ingenza's Molecular Biology department exploiting the platform developed during his fellowship.

Industrial Design Students

James Bevan

Course: Industrial Systems, Manufacture and Management

University of Cambridge

James undertook four paired live commercial projects and a major research project. For the first project he successfully undertook the design of a new tool to predict the time required to overhaul a TP400 aero engine at Rolls-Royce. The new model enables effective prediction of Manufacturing Engineering engine overhaul time, and due to its success, is intended to be used on other engine programmes within Rolls-Royce.

The second project tasked James with reducing the costs of a high performance automobile component at Titan Motorsport. He analysed materials data to determine the specific costs of manufacture and so explore and suggest cost saving options, resulting in an 8.3% reduction in annual costs achieved through insourcing a polishing process and re-designing the machining process.

James' third project was to design the business plan and route to market for a computer programme developed by Cambridge University Neurological Department. The programme provides real-time, multimodality monitoring and analysis in intensive care environments. Analysis was undertaken to design the most effective means of distributing and utilising the product whilst maintaining its profitability.

The fourth commercial project improved the overall performance effectiveness of filling lines at paint and coatings company Akzo Nobel. James used data analysis techniques to identify the root cause of inefficiencies and to quantify and rank potential improvements. Improvements of 9% were achieved across all lines with minimal investment required.

James' major research project focused on the role of battery storage within the UK in creating a more flexible energy system that is affordable and secure for all users within a low carbon future – an area James is passionate about. The research involved interviews with key stakeholders to ensure principal views were obtained. Areas investigated covered the design of regulatory frameworks, technological developments, awareness, and capability.

James is currently travelling across the Middle East, India and South East Asia before starting work with PA Consulting in London. His role will be within the Implementation Division working to deliver innovative, creative and complex change programmes.

Alex Bygrave

Course: Design Interactions / Design Products

Royal College of Art

Starting at the RCA on the Design Interactions platform, Alex explored speculative design methodology as a way to examine and communicate the impending social impact of environmental change. As a result of course closure, he finished his masters on the Design Products platform where he combined his background in product design engineering with speculative design exploration and communication.

For his first solo project, 'IKENERGY' he worked in conjunction with Space 10, IKEA's think tank. Within this project, he explored how IKEA might go beyond its 2020 100% renewable energy target by facilitating peer to peer local energy trading over the existing power grid, using solar panel systems currently sold by IKEA. The project explored a roadmap of future products and innovations around plug-in home energy generation, and plug-in devices to help balance demand on the grid, resulting in a comprehensive breakdown of the peer to peer energy trading system and a future scenario where IKEA had used its scale and customer base to drive the development and adoption of renewable home energy generation.

For his second solo project 'Origami' he explored how life on urban canals, rivers and waterways might transition from one of the most polluting modes of urban living (per m²) to one of the most sustainable. Informed by our near certain future of land lost to water (or sometimes water), rising future population in cities, a present shortage of affordable housing, the dire need to reduce consumption and the already existing 'consumption conscious' community of an estimated 20,000 boaters in London, the project aimed to provide a platform to communicate and explore a future of urban living with water, whilst also helping to address the present day environmental impact of life on the waterways.

Focussed on the re-design of the vessels themselves the project culminated in the creation of a new 'typology' of canal boat designed to eliminate the use of coal as the primary heat source and facilitate low-impact urban living. Using less energy to heat than the average Passivhaus (modern eco home) at a fraction of the cost and embodied energy, the vessel would require minimal maintenance and provide a standard of comfort similar to that of a modern home.

His work on 'Origami' was awarded the RCA / Eddie Mundy "Brilliant" Award 2017 and was nominated for both the Helen Hamlyn and Lucien Day Foundation awards.

Alex is currently working as a consultant designer, engineer and artist. Continuing the development of 'Origami' his aim is to realise the project and help make life on London's waterways a benchmark for low-impact urban living.

Arthur Carabott

Course: Global Innovation Design

Royal College of Art

Arthur's work focused on tools for creative practitioners, in particular, musicians.

His first project was the Musician's Mirror, a computer vision based system to provide feedback on a musician's posture and technique. He developed a working prototype allowing the musician (or their teacher) to train the system to recognise bad habits such as slouching or tensing of the shoulders. The system would then provide real-time feedback if they fell into these bad habits. The prototype was tested with professors and students at the Royal College of Music, who received it enthusiastically. Musician's Mirror won the Silver Prize at the TechInk Industrial Design Student Awards 2017.

His second project was a critical exploration of human computer interaction design. Taking the fundamental interaction of inputting a number, he explored the seemingly simple interaction using software, hardware, augmented reality and artificial intelligence. The project aimed to look at both how these interactions could be done with emerging technologies, and to criticise how interaction design for new mediums is often done: by crudely imitating the past (e.g. screen based emulations of mechanical devices).

Arthur spent the summers of his studies at YCombinator Research in California, where he explored the future of tools for music creation, and at Microsoft Research in Cambridge where he designed interactions using their HoloLens augmented reality system.

Arthur is now working as a designer and programmer of new technologies for music, working with music software companies and artists. His goal is to create practical tools that enable new forms of music, and to spread new ideas that influence the next generation of music making tools.

Benjamin Moffatt

Course: Innovation Design Engineering

Royal College of Art

Ben's final year project experimented with the physicalisation of digital security. The final output, Shy, is a contactless card that requires the knowing touch of the owner in order to activate, using precise pressure points on the face of the card. Cheap to manufacture and 100x more secure than standard contactless cards, the design can be used to secure everything from your contactless bank card to electronic hotel key. Beyond the support from the Royal Commission for the Exhibition of 1851, Ben was awarded the Imperial College Advanced Hackspace Enterprise boost grant for the project enabling him to patent his technology, and in October 2017 the design was exhibited at Dutch Design Week in Eindhoven.

Upon graduating, Ben worked with the RCA x IIS Tokyo Design lab in Japan, a joint collaboration between the Royal College of Art and the University of Tokyo. In partnership with Ikeuchi Lab, a brain neuron research lab, and three other recent Royal College of Art graduates, his project aimed to introduce design that could facilitate new research directions and deployable innovations. The output was 'Aura', a concept for bio-sensing. It incorporated a new method, co-designed by Ben, for growing three dimensional neural networks in the lab using precise 3D printed structures. This design opens the potential for creating simple bio-sensing neural networks. His work has since been exhibited at the University of Tokyo and symposiums run at the Royal College of Art and Toranomon Hills Mori Tower, Tokyo.

Currently, Ben is working as an Innovation Designer for Ford Motor Company.

Robert Rouse

Course: Innovation Design Engineering

Royal College of Art

Robert undertook projects surrounding the use of technology in addressing environmental and sustainability issues. He established his design ethos, based upon creating efficient, engineered products with high desirability to reduce product turnover, and counteract excessive consumerism. He received a distinction and award for outstanding academic achievement.

For his main project, Remora, Robert worked on the issue of plastic pollution plaguing marine environments; his efforts resulted in the development of a turbo-machinery unit, delivering power output, coupled with a self-cleaning filtration system to target microplastics. As a commensal technology, the technology can tackle microplastics through standard operation, a principle that addresses the issue in scalable and financially viable fashion.

Following the completion of Robert's studies, the Remora project was used to launch a start-up, based in London, called Remora Marine, which continues to focus on the issue of marine plastic pollution through commensal technology. Simultaneously, Robert is working on his PhD at the University of Cambridge in the field of future infrastructure and built environment. He also continues to expand upon his design practice and is on track to sell his first product design this year.

Enterprise Fellows

Ming Kong

Technology: Tactile sensing

TG0 (formerly Tangi0)

Ming considers being awarded the 1851 RAEng Enterprise Fellowship the most prestigious highlight since he started TG0 as a business delivering tactile sensing innovations. Alongside tangible support packages that enabled him to secure the IP and work with highly experienced people at an early stage, the long-lasting mentorship helped him navigate through several strategic decision-making points running the company.

The Enterprise Hub has continued to play an important role following completion of the formal programme, especially in helping Ming promote the new technology which can take time for people and businesses to start to appreciate. Having the Fellowship added tremendous credibility for future investors and potential customers.

TG0 has now secured close to half a million pounds of seed investment to commercialise its novel tactile sensing technology which intends to replace all complicated sensor networks with just one functional material. The company has already started generating revenue, having prolific brand partners and clients on board to make the next generation of smart sensing surface in multiple markets. TG0 has also built a team of 8 talented engineers, designers and scientists and is planning on launching its own product soon.

Ming is grateful for the recognition and the support the Commission has offered and would absolutely encourage aspiring entrepreneurs, graduates and academics to pursue such amazing opportunities.

Yang Lu

Technology: AI cameras for intelligent transport

Vivacity Labs

Vivacity Labs produces a Machine Learning powered camera unit. The camera does not record video like CCTV does; instead the camera feeds live video through to an AI processor, where cutting-edge machine learning techniques are used to extract useful data from the video feed. In short, the camera is capable of perceiving the environment it's looking at rather than recording video from it. This helps to gather complex real-time data without privacy or surveillance concerns. 2017 was a very exciting year for Vivacity Labs. Early in the year, with help from RAEng and the Commission, Vivacity was able to secure a £1.3 million investment round. In addition to this, Vivacity won a £1.9 million grant to deploy the smart traffic technology at a city-wide scale in Milton Keynes. Since then Vivacity has deployed over 2000 sensor units and has started analysing the data and developing machine learning driven prediction for city-scale traffic in an unprecedented way. The company has grown to nearly 30 people. Through 2018 Vivacity will take its technology further and explore the future of intelligent traffic control and integration with connected and autonomous vehicles.

Henrik Hagemann

Technology: Water purification

CustoMem

CustoMem products are next generation water purification materials in the shape of granular products that remove persistent pollutants in industrial wastewater cost competitively. CustoMem have tailored the granular products to address an unmet need for water treatment removal of synthetic organics that cannot be oxidised or biologically degraded. The first granular medium is focused on highly toxic persistent industrial chemicals used in semiconductors, airports, firefighting foam and high-performance coatings, called Per- and polyfluorinated Substances, PFAS.

Besides the obvious contribution to fundraising, where CustoMem has secured £1.5m to date, the 1851 RAEng Enterprise Fellowship has added tremendous value via mentorship and networking. The mentorship directly influenced the format of CustoMem's first product, which might not have happened otherwise. It was tremendous to observe the influence of such input: Customised Membranes became Customised Granular Media (CGM), which fits industry standard processing tanks. During the Enterprise Fellowship, CustoMem tested CGM, with 3 commercial entities including a London airport and won the BioStart 2017 award given to the best emerging biotech start-up in the UK. CustoMem's tests demonstrated 10x better performance for capture of PFAS at half the cost of activated carbon. CustoMem have two water companies requesting validation of the test, with the first one starting in April in Germany.

Crucially, the Enterprise Fellowship provided essential commercial training to transition from an engineering role to being a commercial lead with engineering understanding. This facilitated Henrik's transition from engineer to CEO, which means he can now confidently lead his 6 FTEs including 4 PhD graduates and 4 part-time team members. It also trained him to lead CustoMem's board, recruit senior board members and advisors like the former Technical Director of water adsorbents at a FTSE100. This has already proven crucial to CustoMem's current scale up and will be important in the future too, as CustoMem pushes to contribute its part to bringing UK engineering to commercial scale for the benefit of society.

Jack Hooper

Technology: Stress reducing wristband

doppel

doppel is a wristband that has been shown to reduce stress and increase focus within minutes. It works by creating a silent vibration on the inside of the wrist which feels just like the ‘lub-dub’ of a heartbeat. Slower rhythms are calming, and faster rhythms help you feel focused – like music. It is built on unique understanding of psychophysiology and how signals from the body affect how we feel and behave. You can use doppel to stay calm under pressure, focus on the task ahead of you and keep going when you need to.

The Enterprise Fellowship has been fantastic both for doppel and for Jack personally. It came at a challenging time for the company, which was experiencing manufacturing delays and needed to raise money to continue operating. By becoming an Enterprise Fellow Jack was given access to an incredible mentor, help and training across any and all aspects of business and an instant network of both fellow entrepreneurs and leaders across all sectors of industry. During the fellowship doppel raised £350k, produced its first batch of doppels and had a study published in Nature Scientific Reports demonstrating doppel’s efficacy in calming people in stressful situations.

doppel is now closing a further investment round of £750k, much of which has been sourced from the Fellowship networks, and has just shipped the first batch of doppels to its pre-order customers. doppel has grown to have five full time employees and five regular contractors and has become a multi-national, with a subsidiary in the US, its primary market. From here the company is in a strong position to launch doppel and bring calm and focus to those who need it most.

Built Environment Fellow

Anna Minton

Project: Towns and Cities in Shock

Mentor: Helen Conford, Penguin Books

The 1851 Fellowship was an unparalleled opportunity for Anna to spend time researching a follow up book to her critically acclaimed *Ground Control*. This culminated in her book on the housing crisis, *Big Capital: Who is London for?* published by Penguin in 2017.

The Fellowship was a very prolific period for Anna as she used the first year to prepare a number of studies for the book, including three reports on different aspects of the crisis, which investigated related aspects of the topic, from the role of the public interest in the planning system to the democratic deficit in local government. The reports were published by different think tanks and received considerable media coverage.

During the second year, Anna embarked on writing a book proposal and the time and freedom to explore different directions meant that she completed the Fellowship with two proposals including the material for Big Capital.

As a result of the Fellowship, Anna has shifted her career direction from journalism and policy consultancy to academia, having been appointed Reader in Architecture at the University of East London when the Fellowship ended.

Anna now hopes to complete the second book she worked up during her Fellowship, on the psychology of the city. In this regard, the legacy of the Fellowship has still more to offer.

Alumni Awards, Honours and Achievements

A selection of the alumni appointments, publications, honours and awards notified to the Commission. The Commission encourages all alumni to keep their alumni profiles up to date so that their successes can be celebrated.

Overseas Scholars

Professor David Black (1960-1963)

– Awarded David Craig Medal, Australian Academy of Science

Professor Subhash Lakhota (1971-1973)

– Appointed Distinguished Professor, Banaras Hindu University, Varanasi, India

– Elected Senior Fellow, Cell Stress Society International

Professor Kwok-Chan Lun (1971-1974)

– Awarded François Grémy Award of Excellence, International Medical Informatics Association

Professor Jennifer Martin (1986-1989)

– Made a Companion of the Order of Australia *for eminent service to science, and to scientific research, particularly in the field of biochemistry and protein crystallography applied to drug-resistant bacteria, as a role model, and as an advocate for gender equality in science*

– Elected a Fellow of the Australian Academy of Science

– Awarded Wunderly Oration and Medal, Thoracic Society of Australia and New Zealand

– Appointed Bragg Member of the Royal Institution of Australia

– Elected an Eminent Fellow of the Royal Australian Chemical Institute

Professor Mark Tester (1985-1988)

– Cover article, *Nature*, February 2017 on the quinoa genome

Professor Ian Woodrow (1979-1981)

– Appointed Head of the School of Ecosystem and Forest Sciences, University of Melbourne

Research Fellows

Professor Adebayo Adeloje (1987-1989)

– Appointed Visiting Professor in Water Management, China Agricultural University, Beijing

Dr Michalis Agathocleous (2011-2014)

– Appointed Assistant Professor, University of Texas Southwestern Medical Center

– Appointed Cancer Prevention and Research Institute of Texas (CPRIT) Scholar

Dr Alex Bartel (2012-2015)

– Appointed Senior Lecturer, Department of Mathematics, University of Glasgow

– Awarded EPSRC Early Career Fellowship

Dr John Biggins (2010-2013)

– Appointed Lecturer in Applied Mechanics, Department of Engineering, University of Cambridge

Professor Katherine Blundell (1998-2000)

– Appointed OBE *for services to astronomy and the education of young people*

Professor David Cumming (1996-1997)

– Elected Fellow of the Royal Academy of Engineering

Dr Rhodri Davies (2008-2010)

– Awarded Anton Hales Medal, Australian Academy of Sciences

Dr Alex Dunhill (2012-2015)

– Appointed Lecturer, School of Earth and Environment, University of Leeds

Dr Kallol Gupta (2013-2015)

– Appointed Assistant Professor, Department of Cellular Biology/Nanobiology, Yale University

Professor Yamuna Krishnan (2002-2004)

– Awarded Infosys Prize for Physical Sciences

Professor Tom Lancaster (2006-2008)

– Appointed Professor of Physics, Durham University

Dr Stephen Montgomery (2011-2014)

– Awarded ERC Starter Grant to study the evolution of expanded mushroom bodies in *Heliconius* butterflies

Dr Gavin Morley (2009-2012)

– Appointed Reader in Physics, University of Warwick

Dr Jennifer Noble (2011-2014)

– Named Young Distinguished Member, Société Chimique de France

Dr Elizabeth New (2009-2011)

– Awarded ChemComm Emerging Investigator Lectureship, Royal Society of Chemistry

Professor Peter O'Brien (1995-1996)

– Awarded AstraZeneca, GlaxoSmithKline, Pfizer & Syngenta prize for Process Chemistry Research

Professor Sir Stephen Sparks (1974-1976)

– Knighted *for services to volcanology and geology*

Dr Jamie Wood (2001-2003)

– Cover article, *Significance*, June 2017, on the application of Bayesian thinking to history

Industrial Fellows

Dr Rob Deaves (1994-1997)

– Awarded a Royal Academy of Engineering Industry-to-Academia Visiting Professorship (2017-2020)

– Appointed Visiting Professor of Robotic System Architecture at Imperial College London

Dr Brianna Stubbs (2013-2016)

– Lead researcher, HVMN (launched HVMN Ketone ester drink)

Dr Ruth Tunnell (2011-2014)

– Appointed Team Leader, Energetic Materials Analysis 2, QinetiQ

– Awarded John Benjamin Memorial Prize

Industrial Bursars

Patrick Geraets (1982-1984)

– Successfully completed Innovate UK funded feasibility study of *SENSE Wind's* new offshore wind turbine installation system

Industrial Design Students

Yusuf Muhammad (2006-2008)

– Featured in BBC2 documentary, *The Big Life Fix*

Graham Pullin (1991-1993)

– Awarded Stephen Fry Award for Excellence in Public Engagement with Research for his research project *Hands of X*

Daniel Watson (2009-2011)

– Named an Innovator Under 35 in Europe by the MIT Technology Review

– Winner, Pitch@Palace 7.0, for *SafetyNet Technologies*

Design Fellows

Adrian Westaway (2009-2011)

– Registered patent on new user interface system

Research Fellow CAD

Dr David Trafford (1980 – 1983)

– Published *Beyond Default – Setting Your Organisation on a Trajectory to an Improved Future*

Alumni Pledges and Donations

On occasion, the Commission is fortunate to receive donations and bequests from alumni. In 2017, the Commission received donations from Professor Mario Onyszchuk (Overseas Scholar, 1954 – 1956), Dr George Williams (Overseas Scholar, 1963 – 1966) and an anonymous benefactor. Commissioners were also notified of a legacy pledge from Dr Chris Town (Industrial Fellow, 2001 – 2004). The Commission also received a painting from and by Carole Robb (Rome Scholar, 1979). The Commission extends its grateful thanks to all those who have provided support or who have pledged to do so in future.

Report by the Chairman of the Finance Committee

Executive summary

The net assets of the Commission stood at almost £116m at 31 December 2017 compared with just under £105m at 31 December 2016. The total expenditure on charitable activities during 2017 was £4.2m, an increase of £1.3m on the previous year. For the last six years a strategic asset allocation biased heavily in favour of real assets has been consistently pursued by the asset managers appointed and regularly reviewed by the Commission. This policy has aligned itself with the value expansion in equity markets with the result that the value of the Commission's portfolio has grown at an average annual rate of approximately 9.3%.

Organisation

The Board of Management has appointed the Finance Committee as a sub-committee to supervise the Commission's finances and investments; this Committee meets at least twice a year and during 2017 met two times. On 1 January 2017, Ms Sarah Arkle and Ms Jane Tufnell joined the Committee, significantly strengthening the Commission's in house investment expertise. I would like to thank all members of the Committee for their sterling work in overseeing the Commission's finances.

Sources of funding

The Commission's income and gains derive primarily from its investment portfolio. In 2017, property (the Commission's estate) made up 14%, cash 1% and stock market investments and bonds 85% of the capital assets (for 2016 the corresponding figures were 15%, 1% and 84% respectively).

Reserves policy

The total funds at the balance sheet date were £115,964,957 (2016: £104,944,474).

As noted above, these funds originated from the surplus arising from the Great Exhibition of 1851 and have been enhanced by careful stewardship of the assets invested over many years. They are technically unrestricted, giving the Commissioners the ability to spend the funds as they wish in fulfilment of the charitable objectives of the Commission. None of the funds are in assets that cannot readily be realised.

In order to balance the needs of current and potential future beneficiaries of the charity, the Commissioners recognise the need to maintain a strong capital base so as to deliver an appropriate level of return to enable the Commission to continue to fulfil its charitable objectives on a long term basis. Accordingly, all of the Commission's funds are invested in line with the investment policy described below and normal expenditure commitments are set to match the assumed average return above inflation delivered by the portfolio.

Given the Commission's flexibility to spend capital if required, the Commissioners do not consider that there is any merit in identifying an optimum level of free reserves that might be readily available if required, but will respond appropriately to spending needs identified as and when circumstances arise.

Investment policy

The Commission's overall investment objective is to achieve sufficient total returns to fund its existing award programmes whilst also protecting the capital value of its portfolio for the benefit of future beneficiaries. The Commission reviews its asset allocation and manager selection on a regular basis with this objective in mind.

The Commission has determined that a strategic asset allocation biased heavily in favour of ‘real’ assets (equities, properties, commodities, etc.) as opposed to ‘nominal’ assets (cash, bonds etc.) gives it the best chance of meeting its overall investment objective. In order to ensure sufficient liquidity that grant commitments should always be able to be met without the need to sell assets at distressed prices, Commissioners have determined that a minimum of £5m should normally be held in ‘nominal’ assets such as cash and bonds; beyond this, it is expected that the portfolio will normally comprise ‘real’ assets.

As at the balance sheet date, the Commission’s portfolio was spread across three investment managers: a global equity fund of approximately £59.5m managed by Schroders (C.I.) Ltd; a portfolio of exchange traded funds of approximately £35.9m actively managed by Charles Stanley Pan-Asset and an investment of approximately £8.6m in a strategic bond fund managed by JP Morgan Asset Management Ltd. The Commission also owns the freehold of various properties on its legacy estate in South Kensington valued at £17.1m.

The overall portfolio targets an absolute annual return of RPI + 4%, after all charges; there is no income target although the composition of the portfolio is such that income of around 2 – 3% pa is expected. Each fund manager also compares performance against appropriate market and sector benchmarks.

The Commission expects its investment managers to take governance considerations into account when evaluating investments but has not adopted specific social, environmental or ethical criteria as its charitable purposes and activities encompass support for all legal enterprises that involve a scientific, engineering or design element.

Disbursement policy

The Commission’s long term aim is to disburse approximately 4% per annum of the trailing three-year average closing capital value of its investment portfolio.

Liquidity is maintained at a sufficient level to ensure the cash outside the investment portfolio is enough to cover short-term expenditure.

Comments on the results for the year

The Commission manages its assets on a total return basis. In 2017, the portfolio generated returns of £15,835,877 (2016: £15,764,019). After total expenditure of £4,804,679 (2016: £3,455,584) and actuarial losses of £10,715 (2016: £63,422) this resulted in a net increase in funds available to finance future grants of £11,020,483 (2016: £12,245,013).

The total return comprises income and gains. The annual income generated in 2017 by the Commission’s assets was £2,427,679 or approximately 2.2% of opening portfolio value, slightly lower than the previous year (2016: £2,597,909, 2.7%). Given the structure of the portfolio, relatively stable income can be expected from year to year in absolute terms, but with the yield varying somewhat as capital values rise and fall. Stock market volatility means that the level of investment gains is unlikely to be as stable over time, although performance this year and last has been similar and over time gains should outweigh losses. In 2017, the Commission’s liquid investment portfolio enjoyed gains of £12,206,038 (2016: gains of £12,304,743) with a further boost from revaluation gains on directly held property of £1,185,710 (2016: gains of £858,367).

Expenditure on raising funds – which primarily comprises investment and property management fees – increased from £544,610 to £559,396. This increase primarily reflects increased investment management fees which are linked to the increase in value of the portfolio.

Total expenditure on charitable activities of £4,245,283 was £1,334,309 more than the previous year. This reflects a number of factors including a move to cover full payroll costs in respect of Research Fellowships, the award of a record number of Industrial Fellowships, and some high value Special Awards, in particular those to support the Dyson School of Design Engineering at Imperial College and the digitisation of Prince Albert’s papers by the Royal Collection Trust.

Overview

2017 was another good year for equity investors, with synchronised global growth providing healthy returns across most major markets.

Overall the Commission achieved a total return net of fees of approximately 13.5%, comfortably ahead of the RPI + 4% target for the year of 8.3%, peer group indices such as the ARC Equity Risk Charity Index (11.5%) and of course LIBOR (0.26%) and broadly in line with stock market indices such as the MSCI AC World (13.1%) and IA Global Equity Index (13.8%). In 2016 the Commission achieved a total return of approximately 16%, compared to a target of 6.5%, an MSCI AC World return of 29.1%, an IA Global Equity Index return of 24%, ARC Equity Risk Charity Index of 10.7% and LIBOR rate of 0.38%.

Looking at the last six years together, since the current investment policy was established, the value of the portfolio has grown by approximately 9.3% pa, well above the 2.5% pa rate required to keep pace with inflation. Clearly, the financial position and performance of the Commission year to year is sensitive to movements on world stock markets but the outperformance over recent years means the Commission's financial position is extremely strong. Moreover, while volatility will affect short term performance, the portfolio is well positioned to capture returns over the long term.

Disbursements during the year increased significantly to 4.3% (2016: 3.3%) of the trailing three year average closing capital value of the portfolio compared to a target of 4.0%. This is the first year since the current investment and disbursement policies were adopted that the disbursement target has been met (indeed slightly exceeded). This reflects work over several years to improve the financial competitiveness of the Research Fellowships, increase the take-up of Industrial Fellowships and identify major Special Awards worthy of support. The cumulative underspend remaining of approximately £1.7m will be carried forward for future use, with Commissioners remaining mindful of the scope to increase disbursements over the coming years.

The Commission's Auditors

In 2008, Kingston Smith LLP was appointed the Commission's auditor following a competitive tender. The audit partner meets with the Finance Committee at least once each year. In the interests of good governance the audit manager changes at least every five years and the audit partner at least every ten years.

Sir William Castell LVO

Royal Commission for the Exhibition of 1851

Summarised Statement of Financial Activities for the Year Ended 31 December 2017

	2017 £	2016 £
Income		
Donations	16,450	3,000
Investments	2,422,621	2,593,945
Other	5,058	3,964
Total income	<u>2,444,129</u>	<u>2,600,909</u>
Gains and losses		
Gains on property	1,185,710	858,367
Gains on investments	12,206,038	12,304,743
Actuarial losses on defined benefit pension scheme	(10,715)	(63,422)
Total gains and losses	<u>13,381,033</u>	<u>13,099,688</u>
Total resources available	15,825,162	15,700,597
Expenditure on:		
Raising funds	559,396	544,610
Charitable activities	4,245,283	2,910,974
Total expenditure	<u>4,804,679</u>	<u>3,455,584</u>
Net movement in funds	<u>11,020,483</u>	<u>12,245,013</u>
Total funds brought forward	<u>104,944,474</u>	<u>92,699,461</u>
Total funds carried forward	<u><u>115,964,957</u></u>	<u><u>104,944,474</u></u>

Royal Commission for the Exhibition of 1851

Summarised Balance Sheet as at 31 December 2017

	2017 £	2016 £
Fixed asset investments		
Investment properties	17,127,155	16,520,685
Listed investments	102,564,327	90,855,103
Cash held as part of the investment portfolio	1,014,555	1,361,833
	<u>120,706,037</u>	<u>108,737,621</u>
Current assets		
Debtors	589,480	146,074
Cash at bank and in hand	614,854	795,124
	<u>1,204,334</u>	<u>941,198</u>
Liabilities		
Creditors: Amounts falling due within one year	(3,154,946)	(2,496,239)
Net current liabilities	<u>(1,950,612)</u>	<u>(1,555,041)</u>
Total assets less current liabilities	118,755,425	107,182,580
Creditors: Amounts falling due after more than one year	(2,242,468)	(1,679,106)
Net assets excluding pension liability	<u>116,512,957</u>	<u>105,503,474</u>
Defined benefit pension scheme liability	(548,000)	(559,000)
Net assets	<u><u>115,964,957</u></u>	<u><u>104,944,474</u></u>
The funds of the Charity:		
Capital Funds		
Balance as at 1 January	104,944,474	92,699,461
Movement in year	11,020,483	12,245,013
Balance as at 31 December	<u><u>115,964,957</u></u>	<u><u>104,944,474</u></u>

Royal Commission for the Exhibition of 1851

Note to the Summarised Financial Statements for the Year Ended 31 December 2017

1. CHARITABLE ACTIVITIES

The total costs of charitable activities are:

	2016 £	2015 £
Grants	3,772,108	2,507,641
Direct costs	189,693	151,633
Support costs	283,482	251,700
	<u>4,245,283</u>	<u>2,910,974</u>

Analysis of grants and awards committed in the year:

	2017 No.	2017 £	2016 No.	2016 £
Research Fellowships	10	1,360,410	10	1,038,398
Industrial Fellowships	14	1,111,869	10	567,880
Industrial Design Studentships	7	236,614	8	350,141
Built Environment Fellowship	1	100,000	–	–
Design Fellowship	–	–	1	100,000
Enterprise Fellowships	3	187,795	4	187,500
Great Exhibition Scholarships	10	43,500	11	60,000
Special Awards	19	731,920	22	203,772
	<u>64</u>	<u>3,772,108</u>	<u>66</u>	<u>2,507,641</u>

Administrative Information

Structure, Governance and Management

The Commission is constituted as a limited company incorporated by Royal Charter. Its governing documents are the original Charter dated 3 January 1850 and a Supplemental Charter dated 2 December 1851.

The Commission may have up to twelve trustees, known as Royal Commissioners, at any one time, who together constitute the Board of Management, which meets formally twice a year. Commissioners are chosen to bring wide experience in areas relevant to the Commission's work – science, engineering, industry, design, architecture and finance. To maintain an appropriate balance of skills, Commissioners normally serve for 10 years, and Commissioners themselves identify possible successors, who may serve on a committee prior to election. Following election by the Board of Management, Commissioners are only appointed with the approval of the President.

All other committees are advisory in remit, are subordinate to the Board of Management and report to it, and all committee Chairmen are Commissioners. *Ad hoc* committees may be formed for limited periods and specific purposes. Any committee other than the Board of Management may have non-Commissioners as members subject to the wishes of the Chairman of that committee. All committees, except *ad hoc* committees, meet at least once annually. All committees are serviced by the Secretary and, where appropriate, by the Finance Director.

The Secretary also provides full briefing and induction programmes for all new Commissioners and committee members when appointed. As part of this introduction Commissioners are provided with a Governance Book containing full details of the Commission's history, role, strategy, procedures and Commissioners' responsibilities, as well as the relevant Charity Commission guidance for trustees. During their tenure, further opportunities for Commissioners to develop their knowledge of areas relevant to the Commission's activities are provided as appropriate.

Day to day running of the Commission is delegated to the Secretary, assisted by a small staff team. Matters of strategy, and all grants greater than £5,000, are decided by Commissioners.

Full details of Commissioners and Committee members in post during the year, as well as the small staff team, are provided on pages 40 and 41. Details of the Commission's professional advisers are provided on page 42.

Remuneration

Commissioners are not remunerated in their role as trustees of the charity and do not receive benefits other than reimbursement of expenses incurred in attending meetings.

In order to maximise funds available for grant making, Commissioners are determined to keep staff numbers and associated office costs to a minimum. To attract and retain experienced staff of the right calibre, however, Commissioners recognise the need to set salaries in line with those for other grant-making charities in the London area, based on sector benchmarks and other publicly available data.

Salaries for all staff, including key management personnel, are reviewed annually by the Chairman of the Board and the Chairman of the Finance Committee as part of the performance appraisal process. Pay awards are dependent on performance and set based on increases in the cost of living and average salary increases for the sector. There are no automatic increments and no bonus scheme.

Commissioners recognise the importance of helping employees make adequate provision for retirement. All employees, including key management personnel, are therefore eligible to receive a 15% employer pension contribution to the pension scheme established for auto-enrolment purposes or a personal pension of their choice. At their absolute discretion, Commissioners may pay a nominated beneficiary a lump sum equivalent to 18 months' salary if an employee dies while employed by the Commission. All employees are also entitled to an interest free season ticket loan. Employees do not receive any other benefits.

Risk Policy

In discharging their responsibilities for the management of risk, it is the policy of the Commissioners to identify, analyse and seek to manage any risks to the ability of the Commission to carry out its rôle effectively and meet the obligations of its Royal Charter.

To this effect the Commissioners have given consideration to the major risks to which the Commission is, or may be, exposed. A full risk register has been drawn up, which is reviewed regularly. Insurance brokers have been appointed to advise on areas where risk can be effectively mitigated through insurance. Compliance risks are mitigated through taking and following appropriate professional advice.

The main remaining areas of strategic and operational risk and the steps taken to address them may be summarised as follows:

Investments: security, performance, liquidity

The Commission has a diversified portfolio, both in terms of investments held and managers appointed. It has adopted investment and disbursement policies designed to maintain the real value of the portfolio over time and hence the support available to current and future beneficiaries. Sufficient liquidity is held outside the portfolio to meet short term commitments. Commissioners have delegated review of investment performance to a Finance Committee comprising individuals with relevant expertise.

Grant making: applications, assessment, administration

Commissioners have appointed specialist committees to review fellowship applications, work closely with other organisations active in the STEM arena to avoid unnecessary duplication or administrative effort and have appointed a communications company to assist with marketing of the awards to ensure they are brought to the attention of eligible recipients. Commissioners regularly seek feedback from potential applicants and other stakeholders to ensure the awards remain relevant.

Legacy estate: character, experience, relevance

Commissioners take an active interest in the estate, seek to facilitate relevant initiatives across legacy institutions and provide financial support where possible to ensure the estate remains a beacon of excellence and inspiration in the worlds of science, engineering and design.

Commissioners and Committee Members

President

HRH The Princess Royal

Commissioners (and Board of Management)

Bernard Taylor CBE DL FRSC *Chairman, Board of Management*

Professor Sir Richard Brook OBE FREng

Stuart Corbyn FRICS

Sir William Castell LVO

Professor Dame Kay Davies DBE FRS FMedSci

Jim Eyre OBE

Professor Sir Christopher Frayling FCSD FRSA FRIBA

Professor Lynn Gladden CBE FREng FRS

Professor Lord Mair CBE HonDSc FREng FICE FRS

Sir John O'Reilly DSc FREng FLSW

Professor Sir Michael Brady retired as a Commissioner on 19 September 2017

Ex Officio Commissioners

The Lord President of the Council

The First Lord of the Treasury

The Chancellor of the Exchequer

The Secretary of State for Business, Energy and Industrial Strategy

The Secretary of State for the Environment, Food and Rural Affairs

The President of the Institution of Civil Engineers

The President of the Geological Society

Finance Committee

Sir William Castell LVO *Chairman*

Sarah Arkle

Stuart Corbyn FRICS

Nicholas Moakes CFA

John Manser CBE DL FCA

Adam Taylor-Smith

Jane Tufnell

Sarah Arkle and Jane Tufnell were appointed to the Committee
on 1 January 2017

Science and Engineering Fellowships Committee

Professor Sir Richard Brook OBE FREng *Chairman*
Professor Andrew Briggs
Professor Neil Champness FRSC FLSW
Professor Dame Kay Davies DBE FRS FMedSci
Professor Anne Dell CBE FRS FMedSci
Professor John Dewey FRS
Professor Sir Christopher Dobson FRS FMedSci
Professor David Ewins DSc FREng FRS
Professor James Feast CBE FRSC FRS
Professor Sir Charles Godfray CBE FRS
Professor Douglas Gough FRS
Professor Cyril Hilsum CBE FREng FRS
Professor Jane Langdale FRS
Professor Stephen Muggleton FREng
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