

Royal Commission for the Exhibition of 1851

Report of the Board of Management
and Summarised Financial Statements

For the year ended 31 December 2018



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 2018 was 166

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Chairman's Report

Bernard Taylor, Chairman of the Board of Management

2018 was something of a milestone year for the 1851 Royal Commission. It saw the first addition of land to our core estate since the 1850s and a long held ambition for a festival in Albertopolis start to become a reality. While 'business as usual' was maintained with our core programme of fellowships and studentships, we initiated two significant new awards and strengthened our relationship with past and current tenants with substantial grants to assist with their major development projects in a year that was full of achievement.

We were delighted to welcome our President, Her Royal Highness The Princess Royal, at a Fellows' Evening held in Fishmongers' Hall in June. Fellows and Design Students in their final year provided a vivid demonstration of the depth, quality and range of work that we support. From 3D printed microscopes to diagnose malaria to innovative recoil kneepads they had all made great use of their awards.

Applications for our postdoc Research Fellowships and doctoral Industrial Fellowships were on a par with recent years, although we would like to see more of the latter, particularly from SMEs who we believe stand to benefit most from this scheme. Quality was also maintained, allowing us to make a full quota of awards to some exceptionally promising candidates. We received a particularly strong set of applications for Industrial Design Students allowing eleven awards, a record by some margin, to be made. The field was, as usual, dominated by students enrolled on the Royal College of Art/ Imperial College joint Masters' course in Innovation Design Engineering. While it would be good to see more applications from other institutions there is no doubt that this course is in a league of its own, attracting outstanding students and setting them up for successful careers as entrepreneurs, as many of our alumni bear witness over the twenty years the course has existed.

The Graduate Enterprise Fellowship partnership with the Royal Academy of Engineering, now in its third year, is going from strength to strength, helping recent graduates bring their innovative products to market with support from the Academy's Enterprise Hub. The scheme has now been incorporated into the core programme and we will increase the number of awards from three a year to six by 2021, provided candidates of sufficient quality come forward. It is a scheme that fits nicely with our mission and we are delighted to support it.

November saw the launch of a new partnership with our near neighbour the Design Museum: a design competition for undergraduates known as The Great Competition. We have funded the set up costs and the prize money and if it proves successful we hope to continue to fund the prize. It has attracted considerable interest and a strong entry is anticipated, to be judged in May next year.

It has long been an ambition to expand our reach to the Further Education sector. After several false starts, this year we have teamed up with the Education and Training Foundation to create Technical Teaching Fellowships which launched in the autumn. Modelled on the well-established University Teaching Fellowship, the aim is to encourage exceptional teachers to share their ideas to raise the standard of technical teaching across the sector as a whole. We have started with a targeted pilot scheme to prove the concept and will be watching the progress of the first three Fellows with great interest. There will be a second pilot in 2019 to maintain momentum while we gauge the effectiveness of this new award.

In 2015 the Commission helped facilitate Imperial College London's purchase of the old Post Office building in Exhibition Road and conversion to the Dyson School of Design Engineering. In appreciation of the role we played in this transaction Imperial have transferred the freehold of this land, which we parted with in 1890, back to the Commission in return for a 999 year lease. Although largely symbolic, this generous gesture will help us to ensure that the land continues to be used for the benefit of art and science as Prince Albert intended. The Dyson Building will open fully in 2019 and will include 'the Royal Commission of 1851 Lecture Theatre', in recognition of a Special Award granted last year to fund the theatre's fitting out.

The Commission's name will also grace the new Courtyard being created as part of the Royal College of Music's major development project 'More Music', in recognition of our support for this project. Further afield, our former tenants in South Kensington, The Royal Horticultural Society, have agreed to name their new Herbarium at Wisley, a major centre for plant science, the '1851 Royal Commission Herbarium' in appreciation of a substantial Special Award to help fund its construction. Our aim, in securing all these naming rights, is to raise awareness of our existence in the hope of attracting more to our awards programme.

But above all, it has been a pleasure to see 'The Great Exhibition Road Festival' taking shape through the year. All the institutions on the legacy estate are supporting the event in late June 2019 which builds on the well-established Imperial Festival. What better way to celebrate the 200th anniversary of Prince Albert's birth than a festival marrying art and science and featuring the great institutions that his extraordinary vision brought together.

These brief reflections cover just some of the highlights of a very busy year: there is more in the body of this report so do please read on. As always I am grateful for the continuing hard work of our small staff and the strong support of Commissioners and committee members who enable the Commission to maintain and, more importantly, expand its work.

Bernard Taylor CBE DL FRSC

Secretary's Report

2018 saw the launch of a new alumni relations system which has surpassed all our expectations. Hosted by 'Hivebrite' it enables our alumni to interact with each other, report achievements, seek support and share their plans. With a membership of over 700 already, the great majority of our living alumni have signed up and it has generated great enthusiasm. Less exciting, but just as important (and even more demanding) was the migration to a new online application system for our awards. The previous system had served us well for over ten years but had become unsupportable so the move was essential. The new system, FlexiGrant, is used by other funding bodies so we are hoping for a smooth transition. 2019's application round will be the acid test!

As the Chairman has summarised, there was plenty going on this year: with the Great Exhibition Road Festival and Prince Albert's 200th birthday coming up, I don't expect next year to be any quieter! I hope you enjoy this report.

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 makes 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 to ten 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. The Commission's 5-year commitment to this scheme ended in 2018 when ten scholarships were awarded. These scholars will graduate in 2022. Similar scholarships continue to be available through the IET.

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 2018

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 9-15.

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 16-29 and a few testimonials from recent Industrial Fellows on the impact of their awards are given below:

The award of the Industrial Fellowship was made at a key moment in both Q-Bot's and my personal development. Although we had a working prototype it was not yet fully proven, accredited, scalable and had not secured significant customer traction. As with any early stage company, funding was tight and the award allowed me to devote myself fully to Q-Bot's goals, significantly increasing the chance of success. Without the award of the Fellowship this may not have been possible and the company certainly would not have been able to put in place collaborative research projects with key partners to solve these challenges. Therefore, I believe that we owe the Royal Commission for the Exhibition of 1851 a significant debt and credit for the success of the company so far.

Mat Holloway, Industrial Fellow 2014

The funding from the Commission has been truly transformational to both my PhD research and my career going forward. In terms of my PhD research, the additional funding allowed me to develop bespoke scientific apparatus which is one of a kind in the world and will continue to allow my group to perform world-leading research in the field of liquid crystal elastomers for years to come.

In terms of my career going forwards, this Industrial Fellowship has simply been an amazing springboard. The Fellowship has: provided the resources for me to develop a wide and unique range of research skills; allowed me to establish my own reputation within the liquid crystals and auxetics research communities; allowed me, through conferences and Commission events, to develop a network of researchers with whom I hope to collaborate in my future career; and provided opportunities for me to learn about research outside my immediate field of interest.

I have no doubt that the support of the Commission, and the aspects of my personal development which are attributable to the Commission, have been key factors in my securing a Lindemann Trust Fellowship for the next stage of my career.

Dr Devesh Mistry, Industrial Fellow 2015

Arctoris is a cloud laboratory for cellular and molecular cancer research. Using a centralised robotic facility, we conduct fully automated cancer research experimentation, putting cutting-edge research capabilities at the fingertips of scientists worldwide. The Commission allowed me to spend considerable time during my PhD conducting research in leading industry pharmaceutical and contract research organisations where I gained hands on experience establishing automated research processes. The network, knowledge and experiences afforded by the Commission continue to be a powerful driver for our commercial progress and innovation. I am very grateful to the Commission for supporting me in my endeavours.

Tom Fleming, Industrial Fellow 2016

Further evidence comes from the honours and awards bestowed on older alumni – some highlights are given on pages 30-31. Many of our alumni tell us that their 1851 award has had an ongoing influence; a representative example is given below:

I was the Rome Scholar in Architecture in 1990 at the British School at Rome... researching the development of Rome after 1870 when that city became the capital of the newly united country of Italy. My time at the BSR changed my life and has had a significant ongoing influence upon my professional career.

Subsequent to returning to the UK I developed a phased masterplan to restore, adapt and extend the BSR – a listed building by Sir Edwin Lutyens...[and] raised money for the Architecture Scholarship... to ensure that young designers were able to share in the experience I had enjoyed in my youth.

Returning to practice... I do a lot of urban design work with landed estates. In Cornwall I am working with The Duchy of Cornwall on a 4000 house urban extension at Nansledan in Newquay. The project was cited by the Prime Minister last autumn as an exemplar in the delivery of tenure blind affordable housing. Another Duchy site in Newquay at Tregunnel Hill won the INTBAU Award for Excellence in Urban Design; A UK Property Award; A Planning Award, and The CNU Award for Urban Design.

Hugh Petter, Rome Scholar 1990

In all its grant making, the Commission aims for simplicity, flexibility and an absence of bureaucracy. It is gratifying that feedback from Fellows suggests that they at least experience the benefits:

I would like to thank the 1851 commissioners and staff for this opportunity. It has been a life changing experience to have had the freedom the fellowship offered. Every interaction with the staff has been excellent and the fellowship runs like a well-oiled machine (at least from the Fellow's perspective) due to their efforts.

Dr KC Sivaramakrishnan, Research Fellow 2015

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. As well as those mentioned in the Chairman's report above, they include grants to support a new residential course in Humanitarian Engineering run by the Smallpeice Trust; panels explaining the science behind conservation at the Prince Philip Maritime Collections Centre; Maths on Toast's child maths advocates; a mobile maker space for Bright Box in Sheffield; role model videos produced by Engineers Without Borders UK; an Open City Lab at We the Curious in Bristol; and extended reality equipment for the National Space Centre in Leicester.

As the examples above illustrate, the Commission funds a wide range of innovative STEM outreach programmes at varying scales, recognising that not all will achieve huge success but in the hope that most will transform individual lives and some will go on to have considerable reach. Feedback from grant recipients suggests the programme is largely achieving its aims. To take a couple of recent examples: in 2016 the Commission made a grant to the British Science Association to fund the development of a ‘projects portal’ for their flagship education programme, the CREST Awards. The result, following extensive user testing, was a resources library that was available for use via its own microsite from the start of this academic year. It has received excellent feedback from teachers and has been successful in attracting visitors and stimulating downloads of CREST resources. Already there have been over 11,000 users, 137,000 unique page views, over 1,000 downloads of the primary resource collections and over 100 downloads of several of the most popular individual secondary resources. At a smaller scale, in 2017 the Commission funded Surrey SATRO, an educational charity bringing together educational establishments and businesses in the delivery of work related learning programmes across Surrey and the South East. The Special Award funded 12 Mega Structure challenges, in which teams of six worked together to design a structure on a themed topic such as bridge building, in 12 schools reaching 1,440 young people. The challenges received enthusiastic feedback from teachers and supporting volunteers from industry and all the students reported very positively on the experience. Anecdotal evidence suggests that it is interventions such as these that can make all the difference in stimulating young people to become the scientists and engineers of tomorrow.

The Commission also makes Special Awards focused on continuing to develop South Kensington as the premier destination for those interested in science, engineering, art and design. This year they included a major grant to support the Royal College of Music’s ‘More Music’ redevelopment plans, which will see the College, which is already ranked as the top performing arts institution in the UK and Europe, improve its existing spaces, build new spaces (including an 1851 Royal Commission Courtyard), expand its outreach programmes, grow its scholarship funding and develop its online resources.

Future Plans

The Commission is committed to raising the awareness of the public to the opportunities presented by science, engineering and design. Commissioners were disappointed that financial difficulties prevented the Festival event from taking place in 2018 but are very excited that 2019 will see the first Great Exhibition Road Festival – a major public engagement event involving all the Commission’s legacy institutions and providing an unrivalled opportunity to raise public awareness of both the Commission’s continuing role and the tremendous breadth of work in science, engineering and design taking place on the legacy estate.

As part of the Great Exhibition Road Festival, the next in the series of *Engineers* events hosted in conjunction with the BBC World Service will take place at Imperial College, focussed on space engineering. This now annual event is also a tremendous way to raise awareness of the Commission’s existence and the role played by engineers in creating the world around us.

As well as raising awareness of the importance of science, engineering and design, the Commission is keen to raise awareness of its own awards programmes and the opportunities they provide to the brightest and the best. Following the successful completion of two major internal projects to modernise our application system and alumni platform, plans are now taking shape for a new dedicated resource within the Commission focused on raising awareness of the awards, including engaging our alumni network to help in this endeavour. Watch this space for further details.

Awards Granted in 2018

Research Fellows

Dr Davide Foffa

Subject: Elgin reptiles: the origins of the modern terrestrial fauna *National Museum of Scotland*
This project will use microCT-scanning techniques to study the anatomy of the enigmatic Late Triassic 'Elgin reptiles' from Scotland, to shed light on the origins, relationships, and early evolution of lizards, turtles, dinosaurs and crocodylians and investigate the palaeoecology of one of the first (200+ million-year-old) modern terrestrial ecosystems.

Dr Aden Forrow

Subject: Modelling and inference in single-cell RNA sequencing *University of Oxford*
Recent advances in single-cell RNA sequencing promise important discoveries in biology and medicine, from identification of cell types to individualized cancer therapies. By mathematically understanding and optimizing experimental procedures and developing widely-applicable analysis methods designed for RNA-seq data, this project aims to ensure the technology reaches its potential.

Dr Jake Iles-Smith

Subject: Quantum control through photonic engineering *University of Sheffield*
The difficulty in describing light-matter interactions in solid-state devices remains a key barrier for developing quantum technologies. This project constructs a novel theory of quantum optics for solid-state emitters valid in regimes inaccessible to current methods. This will form the basis for the development of novel, scalable photonic quantum devices.

Dr Emilio Martinez-Pañeda

Subject: Micromechanical modelling of rock fracture: towards energy-efficient mining *University of Cambridge*
This project aims to develop a constitutive model for anisotropic cracking of heterogeneous rocks. Motivated by micromechanical considerations and enhanced by critical experiments and advanced numerical simulations, the model will be used to determine the sequence of loading that gives rise to low-energy mineral liberation.

Dr Guillaume Nataf

Subject: Colossal barocaloric effects in liquid crystals *University of Cambridge*
State-of-the-art high-pressure calorimetry, thermometry and Raman spectroscopy will be used to understand and optimise liquid crystals with colossal barocaloric properties that outperform those observed in barocaloric solids. The insight gained from the project should provide the foundation for a completely new cooling technology, easily transferable to industry.

Dr Christoph Schnedermann

Subject: Investigation and optimisation of highly efficient next-generation photo-electrochemical devices *University of Cambridge*
Solar energy is the key to a sustainable energy infrastructure, requiring a deep understanding of light harvesting and corresponding catalytic transformations to generate 'solar fuels'. This project addresses current challenges in this field and aims to study and optimise next-generation photo-electrochemical devices to achieve highly efficient solar energy storage.

Dr Ryan Schwamm

Subject: Activation of nitrogen using alkaline earth metals *University of Bath*
The efficient utilisation of dinitrogen (N₂) as an abundant and sustainable feedstock remains one of the great challenges in synthetic chemistry. This project will focus on the activation and reduction of nitrogen using cooperative transition metal/alkaline earth metal systems.

Dr Susannah Bourne-Worster

Subject: New design principles for biomimetic photosynthesis *University of Bristol*
This project aims to use theoretical and computational models to derive design principles for biomimetic photosynthetic devices. Using these criteria, it will explore the possibility of altering the protein environment of photosynthetic pigments, or replacing it with cheap, synthetic materials, to optimise selected aspects of photosynthesis without compromising natural efficiency.

Industrial Fellows

Ben Barnes

Subject: Process development for recovery and purification of exosomes for regenerative therapy
Sponsor: ReNeuron *University College London*
Exosomes are vesicles containing bioactive molecules and offer great potential as regenerative medicines. This project aims to develop novel technology to purify exosomes and generate two distinct exosome products at ReNeuron. The additional funding will support investigation of affinity-based technology and facilitate access to specialist flow cytometry equipment.

Jasmine Bone

Subject: Durability assessment and lifetime prediction of polymer composites under harsh marine environments
Sponsor: National Physical Laboratory *University of Surrey*
Polymer composite materials are increasingly being put to use in applications where durability is a required benefit. This project aims to explore possible methods for identifying and quantifying the degradation occurring in a marine environment, with the long term aim of developing a model for predicting life.

Mariastefania De Vido

Subject: Advanced gain materials for high energy, high average power laser systems
Sponsor: STFC Rutherford *Heriott Watt University*
This project will focus on the study and development of novel laser gain materials and of advanced techniques for their manufacture. Research outcomes will enable the realisation and commercialisation of a new generation of high-energy, high average power laser systems required for a wide range of industrial and medical applications.

Marta Ferran Marqués

Subject: Luminescent coatings for ultrahigh temperature measurements
Sponsor: Sensor Coating Systems *Cranfield University*
This project will develop thermal history coatings to sense temperatures at ultra-high temperatures up to 1500°C through characterisation of the physical mechanisms undergone by the material. The technology is capable of relaying stored temperature information through laser-induced luminescence, and has vast applications in industries including automotive, power generation and aerospace.

Adam Hornsby

Subject: A computational model of consumer preference formation and decision making
Sponsor: Dunnhumby *University College London*
This project will develop a new computational model of consumer decision-making that integrates decades of research in cognitive and data science. This unique algorithm will be used in over 50 countries to drive revenue for dunnhumby and their clients. It will help to better predict consumers' actions and encourage healthier purchase habits.

Carlos Julià

Subject: Development of an automated bioreactor for suspension and adherent cell expansion for cell therapy manufacture

Sponsor: Aglaris Ltd

University College London

Current cell cultivation and manufacturing methods are not commercially viable since they are mostly manual, have contamination risks, are expensive, and lack consistency and control for quality and good manufacturing practice requirements. This project will address the problem through the development of an automated perfusion bioreactor system for the consistent, cost-effective and scalable manufacture of cells for patient specific applications.

Aleksandr Kovaltsuk

Subject: Using antibody next generation sequencing data to aid antibody engineering

Sponsor: UCB Pharma

University of Oxford

Antibodies are products of immune systems that bind pathogens with high specificity, thus making them the most successful class of biopharmaceuticals. Successful exploitation of antibodies relies on our ability to interrogate their diversity. This project is focused on investigation of antibody next-generation sequencing data to inform rational antibody engineering.

Christopher Magazzeni

Subject: Ultrasonic testing for jet engines

Sponsor: Rolls-Royce plc

University of Oxford

Rolls-Royce plc developments in linear friction welding and additive manufacturing lie at the forefront of innovation in safety and efficiency of jet engines. Fatigue, however, limits the lifetime of these materials. This project will explore the science in long term fatigue, observing the behaviour of micron-sized individual grains.

Adam McKenzie

Subject: Photonic and electronic convergence: epitaxial growth on silicon

Sponsor: Compound Semiconductor Technologies Global Ltd

University of Glasgow

Integration of traditional III-V semiconductor based photonics with the existing silicon framework of electrical components is crucial for next generation opto-electronic devices. The purpose of this project is to develop a direct III-V/Si epitaxial process with the aim of producing a commercial 1550 nm indium phosphide distributed feedback laser diode.

Alexandre Raymond

Subject: Equipping autonomous surface vehicles with intelligent interaction capabilities

Sponsor: ASV Global

University of Cambridge

This project aims to develop the first autonomous boat capable of interacting and negotiating with other vehicles via existing media (e.g. radio speech).

Jonathan Vince

Subject: Using ultrasound to enhance targeted radiotherapy

Sponsor: BTG Biocompatibles

University of Oxford

This project will investigate the use of ultrasound and microbubbles to both deliver and detect radioactive microspheres for the targeted treatment of liver cancer. The key aims will be optimising microsphere distribution within tumours and providing real-time treatment monitoring. Therapeutic enhancement using oxygen-loaded microbubbles will also be explored.

Euan Ward

Subject: Nonlinearity in the RF sensing chain: single and multiple channel signal processing solutions

Sponsor: Leonardo UK

University of Edinburgh

Radars are becoming increasingly popular sensors as driverless cars and UAVs adopt them.

This increased use exposes them to unprecedented levels of interference which degrades system performance. This project aims to develop a signal processing solution that will allow modern radars to operate in environments crowded with radio frequency energy.

Enterprise Fellows

Tara Massoudi

Company: Zyba Ltd

Zyba is a clean-tech company that transforms the energy in ocean waves to rapidly grow artificial coral reefs. These reefs not only enrich marine ecosystems, they also provide much needed coastal protection and boost economies through tourism. Zyba's core technology is an ultra-light-weight wave energy converter called CCell, which moves with the waves to generate electricity. A portion of this energy is used locally to run a low-voltage, safe electrolytic process, which results in mineral accretion around a steel structure. This process, known as BioRock, was pioneered by Zyba's partners at the Global Coral Reef Alliance (GCRA) and enables the growth of reefs in any shape or size from natural seawater minerals. In tropical waters, the process can enhance coral growth rates by 5 to 8 times compared to nature. These reefs grow to provide long-term coastal protection, acting as dynamic breakwaters with self-healing characteristics.

In a single solution, Zyba and the GCRA offer coastal communities and remote islands coastal protection, coral reefs for tourism and marine renewable energy.

Jack Pearson (ERA Foundation Fellow)

Company: EngX Ltd

As manufacturing advances there is a requirement for fully automated end to end production processes. Currently, wiring and assembly are extremely challenging to automate due to the complexity of modern products and limitations in current technologies. As customer demand grows for custom and niche products this is no longer acceptable.

After interviewing more than 30 companies on the challenges of producing custom products, EngX has developed a hybrid production process that automates 3D printing, assembly and wiring on one platform. With only a digital file, manufacturers can automate the production of custom electromechanical products. This reduces labour costs, error rates, injuries and opens up a new world of previously impossible products! Initially it will be applied to solve the challenges in producing custom robotics.

EngX has developed the prototype while working at the world's top hardware accelerator in China. They are in the process of gearing up for pilots with a major UK robotics company.

Atif Syed

Company: Wootzano Ltd

Currently, robots lack the ability to feel objects in the same way as humans do, which makes them unable to handle delicate objects or tell their consistencies. Although robots rely on various sensors to sense their surroundings and the objects they interact with, none are able to measure pressure/force as precisely as human skin. Skin is an immensely complex organ, but the ability to sense touch comes from its nerve endings, which are extremely sensitive and numerous.

So far attempts to create a commercial electronic skin (e-skin) that would give robots a human-like sense of 'touch' have been unsuccessful. Wootzano Ltd has invented a novel piezoelectric nanocomposite sensing material called Nanflx. This is being used to create a highly sensitive, flexible, and mass-producible e-skin called Nanskin to address this problem.

One market where this will be especially useful is online grocery retail, where robots are not able to distinguish between ripe and unripe fruits and vegetables yet. Wootzano's first commercial project will be integrating Nanskin into the robots used by the world's largest and most high-tech online grocer.

Hsin-Hua (Sheana) Yu

Company: Aergo Ltd

Proper seating posture is vital to digestion, breathing and communication, but the ability to sit comfortably is a daily struggle for over 1 million wheelchair users in the UK. Finding the right postural support for young wheelchair users is especially challenging as their bodies and needs change so quickly. Improper seating can exacerbate spinal deformities and leads to pressure sores that can devastate lives and costs the NHS over £3 billion a year.

Aergo is the world's most adaptable postural support system. It uses a network of patent-pending air cells to support individuals of all shapes and sizes. The remote-controlled system provides customisable support for a range of physical conditions and is the first device of its kind to grow with the user through its expandable frame. The user can initiate air cycling between pockets to relieve pressure and prevent the development of pressure ulcers.

Aergo's product vision includes a software platform that can monitor and adjust posture dynamically instead of fixing users into a static posture throughout the day. Artificial Intelligence algorithms will allow Aergo to promote comfort and protect skin integrity in every individual by adapting to positional changes automatically and effortlessly.

Design Fellow

Jennifer George

Subject: The Shelter Schema: Designing for Displacement

Mentor: Dr John Orr

With predictions of displacement reaching the several hundreds of millions, wide spread shelter project success is becoming a key requirement of emergency response. Prescriptive shelter solutions have been tried before but often differing climates and cultural contexts can leave these projects falling short. A solution is needed that does not prescribe a “one-size-fits-all” approach to organisations but instead recognises the fluid and dynamic nature of emergency work and enables organisations to substantially improve on the work that is already being nobly conducted across the world. Providing a tool in which material selection recommendations, reference to local design, and consideration of cultural context are offered, without the need to conduct weeks’ or months’ worth of research, could have a substantial impact on the success of shelter projects.

The vision of the Shelter Schema is to provide a software-based tool which can significantly improve emergency shelter provision and consequently improve the living conditions of millions of people forcibly displaced by natural disaster or conflict every year. The Shelter Schema will provide a fast and efficient way to disrupt questionable information in humanitarian aid, provide verification for the basis of emergency shelter design, and use harvested data to direct decisions and instruct improvements in design. Distinctively, this tool will include not only conventional architecture and engineering recommendations, but also suggestions based on the attitudes, expectations, wishes and hopes of the affected people.

Industrial Design Students

Ewan Alston	Design Products	Royal College of Art
George Anderson	Industrial Systems, Manufacture and Management	University of Cambridge
Harry Barber	Innovation Design Engineering	Royal College of Art
Nadia Bassiri	Innovation Design Engineering	Royal College of Art
Douglas Brion	Innovation Design Engineering	Royal College of Art
Thomas Hartley	Global Innovation Design	Royal College of Art
Sean Irving	Innovation Design Engineering	Royal College of Art
Harvey Jones	Innovation Design Engineering	Royal College of Art
Claudia Maw	Innovation Design Engineering	Royal College of Art
Hugo Richardson	Innovation Design Engineering	Royal College of Art
Ravi Woods	Innovation Design Engineering	Royal College of Art

Great Exhibition Scholars

Christy Chan	Imperial College London
Lois Conway	University of Cambridge
Richard Gooch	University of Cambridge
Shonak Joshi	University of Cambridge
Nikita Kamath	University of Cambridge
Hana Khan	University of Cambridge
Chloe Parker	University of Oxford
Zeena Patel	Imperial College London
Nikita Sarker	Imperial College London
Mark Wallace	University of Bristol

Special Awards Granted

STEM education and outreach

Smallpeice Trust – Humanitarian Engineering
Prince Philip Maritime Collections Centre – Science Behind Conservation
Maths on Toast – Child Maths Advocates
Armourers' & Brasiers' Company – Cambridge Forum
County Upper School – Junior Cospace Robotic Competition
Bright Box – Mobile Makerspace
Paul Holberton Publishing – Britain Can Make It
National Life Stories – Britain Building the World
Engineers Without Borders UK – Role model videos
Design Museum – the Great Competition
Kids Invent Stuff – Rube Goldberg Challenge
Foundation for Science and Technology – Debate sponsorship
South Downs National Park Trust – Dark Night Skies Festival
We the Curious / IRIS – Open City Lab
National Space Centre – Extended Reality for New Audiences
Well North Enterprises – Summer Science School

Support for legacy estate

Royal College of Art – Future States: Science and Design for Sustainability
Royal College of Music – More Music
Royal Horticultural Society – Herbarium

Awards completed in 2018

Research Fellows

Dr Alyssa-Jennifer Avestro

Project: Hierarchical assembly of one-dimensional bio(opto)electronic nanomaterials

University of Durham

Controlling the precise organisation of functional aromatic molecules represents a long-standing fundamental interest and challenge for the fields of supramolecular chemistry, synthetic biology and materials science. For instance, the development of new nanotechnologies and materials for energy applications relies on the efficient assembly of functional π -surfaces into well-defined face-to-face configurations. However, these interaction geometries are not normally the energetically most favourable. Alyssa's projects have taken advantage of the non-covalent bonding motifs utilised commonly in natural biological structures to control the assembly and order of electrochemically and photochemically active aromatic molecules with high efficiency and fidelity into desirable π -configurations for conductive and energy storage materials. Excitingly, her research direction has also evolved into using these same electrochemical and photochemical stimuli to likewise dictate the shape and dimension of biomimetic structures, of which few examples currently exist.

During her fellowship, Alyssa has published as an independent corresponding author and has amassed over £750k in independent research funding from the EPSRC, Royal Society, British Council Newton Fund, UK Department for Business, Energy & Industrial Strategy, Universities UK International, Rutherford Fund, and the Global Challenges Research Fund through collaborations with Indian, Malaysian and Mexican colleagues. She has developed a considerable portfolio of plenary speaker invitations and early career accolades, which include a Japan Society for the Promotion of Science International Collaboration Prize (2016), Durham Energy Institute Early Career Fellowship (2016-18), L'Oréal For Women in Science Highly Commended Award (2017), and most recently a Royal Society Dorothy Hodgkin Fellowship (2018-23). Alyssa is now carrying out her Royal Society Fellowship as an Honorary Lecturer in Synthetic Molecular Materials in the Department of Chemistry at the University of York, where she plans to spearhead the development of multi-dimensionally conjugated energy materials. She has also been appointed as a Visiting Academic in the Department of Chemistry at Durham University and an Associate Fellow at the Durham Energy Institute.

Dr Richard Bowman

Project: Open source hardware for globally accessible science and healthcare

University of Cambridge / University of Bath

The high tech, computerised laboratory instruments that underpin experimental science and medical diagnostics often rely on expensive manufacturing methods and are difficult to maintain or customise. Richard's research uses 3D printing and mass-produced electronic parts to create precise, highly automated instruments that can be replicated anywhere. One important application of this is in malaria diagnostics, where automated microscopy can improve the quality of diagnosis and enable more patients to be diagnosed per day. The ability to produce, maintain, and repair these instruments locally removes the need to send them back to manufacturers based in richer countries, which is often a barrier to the use of donated or discounted technology. Using local entrepreneurs to produce these items also builds skills and creates opportunities for high-tech innovation in regions where the huge benefits of computerised equipment are not yet available.

Richard's microscope design is now in use by a number of research labs and educational organisations around the world, and has been produced using locally recycled plastic bottles in Nairobi for a project in local schools. Richard is starting a project together with colleagues in Ifakara Health Institute, Tanzania and the University of Cambridge to use the microscope in malaria diagnostics, including the use of computer vision to assist in diagnosis.

Richard says: ‘I am grateful to the Commission for allowing me the flexibility to follow this project, which was initially a small side project that outgrew my original fellowship project on reconfigurable waveguides. This work is now supported by two EPSRC grants as part of the Global Challenges Research Fund, and forms the basis of my research group in Bath. For the next five years I will be supported by a Royal Society University Research Fellowship, focusing on robotic microscopy and open hardware development.’

Richard was awarded the 2018 Institute of Physics Clifford Paterson medal and prize and the early career Prize for Industrially Relevant Physics. This was awarded for *contributions to optical microscopy, in particular to experiment automation and the creation of globally accessible, open-source hardware.*

Dr Timothy Craig

Project: Investigating seismicity and deformation within shallow subducting slabs

University of Leeds

The majority of large earthquakes occur at the boundaries between tectonic plates, particularly in subduction zones. However, an important secondary class of earthquakes occurs in the interiors of plates as they deform internally – these are particularly common during the initial stages of subduction, as the downgoing plate changes geometry repeatedly as part of its initial descent into the Earth interior. It is these earthquakes that have formed the focus of Tim’s fellowship. In the initial stages of his fellowship, Tim undertook a range of technical studies aimed at improving techniques for the location of these earthquakes. The latter years have then been focused on the application of these new techniques to provide unprecedented images of the seismicity occurring within the subducting plates, focusing on two regional studies of particularly active intraplate seismicity – western Indonesia and northern Chile. In the case of western Indonesia, in particular, this work highlighted a unique tectonic process, whereby the internal deformation and associated seismicity of the Indian Ocean plate beneath Sumatra is driven by the recent ‘unbending’ of the plate, as the overlying material spreads out into the Indian Ocean. In addition to the main focus of his fellowship, Tim has also been involved in the response to the 2016 Central Italy earthquake sequence, as part of his ongoing work looking at the temporal evolution of earthquake sequences.

Following his fellowship, Tim is continuing his research at the University of Leeds, now supported by a Royal Society University Research Fellowship. As well as continuing the research themes developed during his Royal Commission Fellowship, he is now looking at the time-varying response of fault systems and seismicity to short-term external forcing, both from the natural environment and from anthropogenic sources.

Dr Robert Edkins

Project: Photosensitizer-lanthanide dyads for cancer diagnosis and photodynamic therapy

University of Oxford

Photodynamic therapy is a non-invasive treatment of cancer in which light is used to stimulate a photosensitizer, generating reactive oxygen species that cause cell death. By developing systems in which an active form of the photosensitizer is produced from a non-reactive precursor in specific cells, it was proposed that this technique could be made more specific and reduce side effects. Bob has been working on a class of compounds called phthalocyanines that are particularly promising photosensitizers. Prior to starting this work, it was very difficult to control their synthesis, with a mixture of different forms (isomers) usually being produced. During his fellowship, Bob has developed a versatile route to making these photosensitizers in a controlled and selective way that will ultimately allow us to make bespoke photodynamic therapy agents in a single form.

The freedom provided by the fellowship has also allowed Bob to diversify into other related areas. In particular, he has been developing an understanding of diffusion in a type of gel material that he wishes to use to deliver his photosensitizers, and he has begun collaborative projects to develop fluorescent imaging agents that can be used to study cells at super-resolution.

Building on the results generated during the fellowship, Bob will continue to explore the design of photosensitizers for photodynamic and photothermal therapies as well as fluorescence imaging agents at the University of Strathclyde, where he has recently started as a Lecturer and Strathclyde Chancellor’s Fellow.

Dr Pierre-Louis Giscard

Project: A theory of walks for computer vision

University of York

Networks of interacting entities, such as people or proteins, are now ubiquitously used as a representation of the many complex systems that surround us. The difficulty in understanding the dynamics exhibited by these systems is compounded with their ever-increasing size: protein-interactions networks now routinely have tens of thousands of nodes; social ones, more than a billion. It has thus become crucial to train computers to 'see' through this mass of information, helping us distinguish network patterns and analyse the systems' dynamics. Ultimately, this is always achieved by walking on the networks. Pierre-Louis's project has shown that such walks are constrained by deep mathematical structures: they obey the non-commutative extension of number theory, complete with its fundamental functions (zeta, Möbius, etc.) and extensions of the time-honoured results of this field. Exploiting this breakthrough, Pierre-Louis has produced the best algorithm for counting certain patterns in graphs; established procedures for detecting dominant feedback mechanisms in complex systems and for classifying their dynamical behaviours from their sole network-representations. In turn, with these tools he increased by 25% the state-of-the-art model for protein-targeting by pathogens in plants; showed that sociologists were right to conjecture that certain patterns of conflicts disappear from social networks over time and more. On the mathematical front, he obtained several novel formulae for counting graph cycles and described their algebraic environment. Recently, he started to use number-theoretic sieves to attempt asymptotically counting self-avoiding cycles and discovered a hitherto unknown type of algebraic structure common to walks, continued fractions and systems of differential equations.

Pierre-Louis is now a Lecturer in Algebraic Combinatorics at the Université Littoral Côte d'Opale, Calais, France. He will continue to develop the extension of number theory obeyed by walks on graphs and seek its applications in computer science and elsewhere. He is currently focusing on the equivalent of the prime number theorem which, in this context, asks for the number of self-avoiding polygons on lattices. It turns out that this is an old and famous open problem of combinatorics, at the heart of many phenomena in statistical physics.

Dr George Knee

Project: Foundations and implementations of quantum technology

University of Warwick

Quantum mechanics predicts that particles must be described by a kind of exponentially-complex probability wave that collapses upon measurement. There is a raft of technologies that promise to leverage quantum effects for enhanced performance: be that in a precision sensor or in a quantum computer.

George authored computer code which designs new experiments to help us understand the fundamental nature of the quantum state. Can quantum states be thought of as epistemic? As existing only as a state of knowledge about the physical world, rather than as a proper part of physical reality? George's algorithm found new ways of addressing this question in the laboratory that are far more effective and robust than previous, human-found strategies.

In the course of his fellowship George has contributed to a theoretical proposal for testing the quantum or classical question with a particular emphasis on testing for the most macroscopic quantum states. He collaborated with experimental colleagues to develop and test new and more effective 'quantum witnesses': protocols whose data can serve as a smoking gun for the existence of quantum coherence. This has developed into a comprehensive treatment of witnessing coherence in open quantum systems, where the usual assumptions cannot be made and previously unknown loopholes arise.

Naturally occurring light harvesting systems are suspected to exploit coherence for efficient transport of energy across molecular networks on the nanoscale. George investigated the relative efficiency of a natural light harvester versus a large set of alternate molecular networks created from the first via geometrical perturbations. He found that nature's version is strikingly efficient, but gets much of this advantage merely from being geometrically compact and having well aligned chromophore molecules.

In the pursuit of applying quantum systems to gain a precision advantage in sensing, George helped overhaul a well-known two-photon interferometry protocol to boost its performance. A successful experimental test showed sensitivity to optical path length changes at nanometre resolution.

George has helped adapt machine learning algorithms to the problem of estimating quantum states and processes from experimental data. This enabled impressive speed-ups and improvements in accuracy, as well as eliminating the chance of producing an unphysical estimate.

George's hope is that the contributions he has made will lead to a better understanding of the fundamental aspects, as well as more effective technological exploitations of quantum mechanics.

Following his fellowship, George has joined Magmo, a company conducting research and development into blockchain technology and cryptosystems.

Dr KC Sivaramakrishnan

Project: Rigorous functional engineering for loosely-coupled massively scalable systems

University of Cambridge

Modern computer systems are highly concurrent. Heterogeneous multicore platforms are the norm everywhere from mobile phones to cloud computing systems. Distributed databases provide the substrate over which web applications such as email and social networking provide always-on, world-wide access despite partial node and network failures. We have come to depend on modern hardware and application services for our daily lives. Nevertheless, the languages and tools for programming and reasoning about concurrent systems continue to merely be simple extensions of sequential counterparts. This has resulted in an unfortunate situation where it has become increasingly difficult to write and reason about the correctness of programs as the scale and ubiquity of concurrent systems increases.

KC's research focusses on developing programming language abstractions to make it easier for non-expert developers to write correct concurrent programs. To this end, KC leads the development of Multicore OCaml, a concurrent and parallel extension of the industrial strength OCaml programming language. KC has developed and incorporated a well-behaved and composable concurrency abstraction called Algebraic Effect Handlers into Multicore OCaml, which generalises many ad-hoc concurrency abstractions found in other languages. While several prototype languages incorporating effect handlers exist, Multicore OCaml is the first industrial strength language to have it.

Parallel programming languages running on modern multicore hardware are said to exhibit surprising "weak memory" effects where memory accesses appear to be reordered due to the combination of compiler optimisations and low-level hardware optimisations. Providing understandable program semantics while retaining performance is an important open problem. KC has developed a memory model for Multicore OCaml that balances comprehensibility and efficiency. This work has opened up exciting possibilities in understandable memory models for high-level programming languages. Inspired by techniques to reason about weak memory, KC has also developed verification and program synthesis techniques for declarative concurrent programs running on distributed databases.

During the course of the fellowship, KC was appointed as a Research Fellow at Darwin College, Cambridge and has now taken up an Assistant Professorship in Computer Science and Engineering at the Indian Institute of Technology, Madras (IITM) where he will continue to explore themes related to concurrent programming and distributed systems.

Dr Dong Liu

Project: Multi-scale analysis and modelling of energy materials in extreme environments

University of Oxford

For efficient production of energy for domestic use or industrial processes, structural materials with improved properties are desired. These materials often have to work under extreme conditions such as high temperature in an aero-engine and neutron irradiation in a nuclear fission reactor, and they often have complex multiple length-scale structures spanning from nano- to macro-size for optimized properties with combined strength and toughness.

Dong's research uses unique experimental techniques to obtain the microstructure and mechanical properties of these materials over the full range of the length-scales (from nanometre to centimetre/ metre) and links them to the real-time fracture pattern imaged in 3D, under load at high temperature and/or after neutron irradiation. One of the primary materials studied was nuclear graphite used in the core of UK Advanced Gas-Cooled Reactors, and Dong's research has visualized the 3D cracks formed in this material at 1000°C for the first time. This research was published in *Nature Communications* and has caught the attention of both the nuclear and aerospace industries because such techniques are exactly what are needed to understand how those high temperature materials fail during service.

During the project, Dong has established strong national and international collaborations (e.g. with EdF Energy, UK National Nuclear Lab, UKAEA Culham, US Idaho National Lab, US Lawrence Berkeley National Lab, Germany Aerospace Centre, Element Six and so on). With their support, Dong was able to extend her expertise to a much wider range of materials including graphite/carbon for use in next generation fission/fusion reactors, ceramic-matrix composites with applications in aerospace and nuclear areas, and novel diamond composites designed for ultra-high power electronics in satellites and radars. While the research project focused on the development of fundamental mechanistically-based experimental and predictive capability, high-level engineering design rules will be distilled to enhance the impact of the project on relevant industries.

Dong is now a Lecturer in the School of Physics at the University of Bristol.

Dr Philipp Thomas

Project: Stochastic reaction kinetics in growing cells

Imperial College London

Modern experiments allow us to study reaction kinetics inside living cells with unprecedented detail. The outcomes of these experiments are often difficult to interpret because they vary drastically from cell to cell, even between identical cells under the same conditions. The sources of this variability lie within the random nature of intracellular reactions. Since these reactions are involved in almost all cellular functions, mathematical models are needed to understand the complex dynamics of living systems.

Philipp investigated how and why populations of seemingly identical cells can become so heterogeneous. He developed stochastic models to study how, starting from a single cell, cells diversify through cell divisions and growth. He found that fluctuations in these processes have a profound impact on the frequency at which reactions occur in living cells and that these effects depend on the experimental device used to grow the cells.

The theory explains why cell growth shapes the kinetics of intracellular reactions inside cells and how this coupling results in the heterogeneity we observe in experiments.

The theory further predicts that randomness in reactions carrying out essential cell functions themselves are sources of growth fluctuations. Philipp used these insights to investigate how an intracellular biochemical oscillator, called the circadian clock, affects the decision of cells to divide, and how the drug response of antibiotic-resistant bacteria varies between cells. His findings may help researchers to understand single cell responses and to develop more effective drug treatments in the future.

Philipp is now a Lecturer in Biomathematics at Imperial College London.

Industrial Fellows

Harry Cronin

Subject: Investigation of novel inorganic materials for printable photovoltaics

Sponsor: DZP Technologies Ltd

University of Surrey

Printable solar cells represent a flexible, lightweight and low-cost energy conversion technology which may soon be approaching commercial deployment. Harry's fellowship investigated manufacturing techniques for an emerging class of material, known as halide perovskites, which are used to form the light-absorbing layer of the cells. Additionally, the project made advances in the post-processing of conductive materials used for the electrodes. The sponsoring company, DZP Technologies Ltd., specialises in the development and application of printable electronic materials.

During the fellowship Harry was able to demonstrate marked improvements in the performance of DZP's conductive inks through the implementation of photonic curing technology, a post-processing technique. This work led to a high impact journal paper, which served as great publicity for the sponsoring company. The work also eventually helped to enrich the company's product offering; opening up new market sectors for their materials, especially in power electronics.

Within the fellowship Harry also investigated processing-property relationships in halide perovskites, working closely with collaborators at the University of Surrey. This work progressed to the point where high performing cells could be produced consistently at lab scale, and led to a journal publication. Finally, a novel perovskite ink was developed, which has shown great promise in applications beyond solar cells.

In the final year of the fellowship Harry began working full time with the sponsoring company as Research and Development Manager, and will continue in this role following the fellowship.

Mathew Holloway

Subject: Robotics for the insulation of buildings

Sponsor: Q-Bot Ltd

Imperial College London

In the UK there are more than 8m older, 'hard to treat' homes which have cold, draughty suspended floors. Current options to insulate them are impractical and cost prohibitive. To meet this opportunity Q-Bot has successfully commercialised a unique solution that uses a robotic device to apply insulation in situ, to the underside of floorboards. Q-Bot's solution is quicker, cheaper, performs better and has none of the hassle of traditional methods. The technology is proven, fully accredited and ready to be deployed at scale.

Since the award was made, Q-Bot has: secured approximately £5m in government grants from the EU Commission and UK Government, £2m in private investment and £3m in sales; developed and proven an innovative technology platform; filed 35 patents with the first 8 granted in the UK and overseas; secured accreditation and approvals including BBA, PAS2030 and CE Mark; and won a number of competitions and awards including the 2018 Ashden Sustainable Cities Award and the CIBSE 2018 Innovation Award.

The Industrial Fellowship has directly contributed to these successes by helping Mathew put in place a framework for the development of complex, multi-disciplinary systems. This has improved the communication across the team, reduced the time to deliver, improved the quality of the resulting outputs, and helped select the right commercialisation route. The fellowship has also created a number of indirect benefits, including a number of ongoing collaborative research projects with industry and academia, as well as increasing visibility and credibility, which has also contributed to the hiring of new staff.

Mathew plans to continue to lead the company as CEO. His immediate goals are to scale up the under-floor insulation service across the UK, and then overseas.

Daniela Ledwoch

Subject: New directions in electrode design for electrochemical energy storage

Sponsor: Sharp Laboratories of Europe Ltd / Johnson Matthey plc *University College London*

Daniela's time as an Industrial Fellow can be divided into two main phases. When the fellowship was first awarded, she was working as a Research Scientist at Sharp Laboratories of Europe Ltd. During her time working at Sharp one patent was published (20180287134, Composite electrode including composite slurry and methods of manufacturing) and another one is awaiting publication.

Following the closure of her section, Daniela transferred with her Industrial Supervisor to Johnson Matthey PLC, where she gained a deeper understanding of electrode characterisation methods which she transferred through to different groups across different sites within the UK and Germany. The knowledge she gained in sample preparation and analysis based on physical characterisation using X-ray computed tomography has also proved very useful to the analytical department of Johnson Matthey in Sonning Common, not least in reducing setup and installation time for new equipment.

Following the fellowship, Daniela will remain at Johnson Matthey working on different projects that utilise her experience and allow her to develop a deeper understanding within the areas she has worked on so far.

Devesh Mistry

Subject: Liquid crystal based ophthalmic devices with switchable focusing for correction of the ageing eye

Sponsor: UltraVision CLPL

University of Leeds

This project sought to use liquid crystalline materials to develop novel treatments for the ageing eye and make reading glasses a thing of the past. During the fellowship Devesh made strides towards this aim in demonstrating the feasibility of devices and developing novel device concepts which continue to be pursued with the aim of developing patentable technologies. Alongside developing the initial target technologies Devesh discovered the molecular auxetic nature of liquid crystal elastomers. Based on this discovery a patent has been filed and a publication has been accepted by *Nature Communications*. Looking forward, the University of Leeds and UltraVision CLPL are looking for additional industrial partners and licensing opportunities which will take advantage of the unique technology Devesh has helped develop.

Devesh has now been awarded a Lindemann Trust Fellowship from the English Speaking Union to support a one year position in the Smart Materials and Biomechanics group at the University of Colorado, Denver. Longer term Devesh intends to continue to pursue an academic career in soft matter science and technology.

Fiona Muirhead

Subject: Airborne radar signal processing for environmental monitoring

Sponsor: Leonardo UK

University of Edinburgh

Synthetic Aperture Radar (SAR) creates high resolution images of the Earth. It does so by synthesising a large effective antenna using a smaller one, which is moving along a flight path. SAR Interferometry (InSAR) is a technique that uses multiple SAR images to measure heights on the Earth's surface, enabling high-resolution digital elevation models (DEMs) to be produced. DEMs give accurate height measurements and are very useful for geoscience applications such as topographic mapping and monitoring environmental phenomena. In areas of dense vegetation the DEMs do not give an accurate representation of the ground height but instead give the height of the tree canopy.

Fiona's project focused on developing techniques to help overcome the vegetation issue by utilising exciting new signal processing methods using airborne data that could later be applied to satellite systems, allowing heights of objects under the canopy to be measured. Techniques were applied to Leonardo's PicoSAR system. PicoSAR is a low cost, compact, lightweight, X-band, airborne SAR system that can be placed on fixed wing aircrafts, helicopters and UAVs, giving PicoSAR an excellent advantage to larger systems. By overcoming the vegetation bias the DEMs produced will become more reliable for end users and can be used for a wider range of applications.

Fiona is now working as a senior systems engineer at Leonardo where she continues her work on radar.

Adam Polak

Subject: Intelligent mid-infrared active laser-based hyperspectral imaging

Sponsor: Fraunhofer UK

University of Strathclyde

Although Adam's project was initially called 'Intelligent mid-infrared active laser-based hyperspectral imaging', this does not adequately reflect the breadth of work he performed over the course of the fellowship. Adam's activities were aligned with research projects lead by either the Fraunhofer Centre for Applied Photonics or the Centre for Signal and Image Processing at the University of Strathclyde. During the first year of the fellowship, his work followed the initial plan, such that, while exploring two application based projects, the main focus was placed on the Firefly IR Imager – the laser-based, mid-infrared hyperspectral imager. However, during this phase, it was observed that the extent of the integration achievable between hardware and software – the initial goal of Adam's fellowship – was severely limited by the technological solution driving the device. Accordingly, and with the main focus being on the application in art forgery detection (where developed technology was demonstrated to successfully detect anachronistic paints), extensive work was done on both hardware improvements and analysis of the data produced by the device.

In the latter part of the fellowship, the scope of Adam's activities broadened and reached beyond hyperspectral imaging (HSI). Thanks to the set of skills developed during the initial work with HSI, Adam has subsequently been involved in other spectroscopy projects, where both his hardware and software developments capabilities have been put to use. Adam's activities in this field have been focused on exploration of two photo-thermal spectroscopic techniques: photo-acoustic spectroscopy and phase fluctuation optical heterodyne spectroscopy. In each case, Adam's work focussed on development of ultra-sensitive spectroscopic techniques with applications in explosives detection in mind. In both cases the initial work demonstrated sensitivity of single parts-per-billion, and Adam's current work progresses to further move these limits to lower concentrations.

Following completion of the fellowship Adam was employed by his sponsoring company and currently holds a researcher position at the Fraunhofer Centre for Applied Photonics.

George Roberts

Subject: Optical injection locking applied to quantum key distribution

Sponsor: Toshiba Research Ltd

University of Cambridge

George's project focused on quantum key distribution, a technology that enables two parties to communicate with absolute security. The idea was proposed in 1984, but it was not until recently that it became practical, with laboratories demonstrating shared encryption keys over distances of 400 km of optical fibre, and at rates of over 10 Mbit/s. It has also been shown over deployed fibre in real-world networks to secure confidential data transfers. The development of this field has been rapid, leading to many different methods of sharing the keys, with each method requiring different hardware. This is an issue because the future could hopefully see quantum key distribution networks, where all parties are able to communicate securely with one another.

To remedy this, George has built and tested a single transmitter that can be used to share keys with any receiver hardware on a network. This has been successful, with error rates shown that are comparable to hardware dedicated to a single method. The transmitter is also power efficient and compact, with the possibility of implementation on a centimetre-scale chip. The favourable properties of the transmitter mean that it has a strong potential to be the standard transmitter for future quantum communication networks.

Following the fellowship, George has accepted a position as a machine learning engineer for a start-up company based in Cambridge called Informatix.

Industrial Design Students

Shankho Chaudhuri

Course: Global Innovation Design

Royal College of Art

Shankho's body of work examined the intersection of technology with the performing arts, exploring the 'future of storytelling' and the creation of new media.

His first major project along these lines was the creation of a musical experience whilst studying abroad at Keio Media Design in Tokyo. Initially experimenting with music visualisation in Processing, he created a 3-D concept using Unity which visualised the individual tracks that constitute a produced music song, turning the experience of the song into a spatial landscape which one could explore in Virtual Reality. Whilst studying at the Pratt Institute in New York, he entered the MIT Media Lab's Hacking Arts competition with a project exploring the use of motion capture technology to build a new graphical language around different styles of dance. He led his team to a top 10 finish, eventually winning the runners-up prize in a sponsor category.

His final major project, a collaboration with Helen van Baal, was a speculative design concept exploring the possibilities of augmented reality in theatre. Building on a research foundation examining new media, video games and immersive theatre, he created a room-sized installation in which audiences could have the set respond to their interaction with specific objects. Depending on what they touched, they would activate different narratives within the space that were delivered with a mixture of lighting, sound and projection.

Alongside his major body of work, Shankho also spent a great deal of time exploring issues of cultural narratives, identity politics and racial hegemony through a design lens. He researched the evolution of hip hop, the erasure of people of colour in media and the parallels of storytelling to design thinking. He eventually seeks to pursue further research into the power relationship between design pedagogy and vulnerable or underrepresented groups.

Shankho is now working as a designer for theatre and new media. He was shortlisted for the Old Vic 12, invited to join a cohort of creatives working in collaboration with the Royal Shakespeare Company and Magic Leap, and is currently working on two shows for London's VAULT theatre festival. He is also designing for Poltergeist Theatre, whose upcoming Edinburgh Fringe show was recently selected for the Untapped Award, presented by Underbelly and New Diorama Theatre. He seeks to build theatrical work that challenges the relationship to the audience, finds exciting new ways to integrate technology, and tells more stories representing minority voices.

Nick Hooton

Course: Innovation Design Engineering

Royal College of Art

Nick's final year group project, *Pluvo*, developed with fellow alumnus Lewis Hornby (see below) is a cost neutral solution to urban air pollution. Despite efforts to tackle air quality, deaths due to pollution are set to double from 3 million to over 6 million by 2050. *Pluvo* recognises that councils aren't cash rich, but they do own the land in pollution hotspots, and this land, due to high footfall, is of high value to advertisers. *Pluvo* is based on the highly efficient industrial air cleaning technology, wet scrubbing. It uses a mist of water particles to absorb pollutants from the air, whilst simultaneously using this mist to augment images to create a holographic like advertising medium. *Pluvo* was awarded the Braun Design Prize and was featured in the Evening Standard. The company is now thriving and Nick has recently signed a deal with the world's largest out of home advertiser.

Nick's final year solo project, *Peer2*, exists to release academics from the hells of publishing. Scientific research saves more lives than any other activity. Not only this, but it is instrumental in the discovery and development of technologies that we use on a daily basis. Unfortunately, the scholarly publishing model, a relic from times of periodic paper publications, is stifling scientific discovery. It promotes short-term 'sexy' science, rewards results before rigour and locks outputs behind paywalls. For researchers, this antiquated system manifests as an institutional labyrinth, blocking the path to the advancement of human knowledge. *Peer2* streamlines an antiquated system by enabling peer review to take place before submission to journals.

Nick is currently CEO of *Jelly Drops*, Lewis Hornby's graduating project described further below.

Lewis Hornby

Course: Innovation Design Engineering

Royal College of Art

Lewis's first solo project drew on his civil engineering undergraduate knowledge to create a cheap replacement for steel reinforcement. Building collapse is the leading cause of death during earthquakes in developing countries, and is often caused by concrete buildings not containing the necessary reinforcement. *Ropebar* uses simple processes that can be carried out by hand to make reinforcement from locally sourced rope and recycled plastic bottles. A bar of *Ropebar* is 10% the cost, and 20% the weight of its steel counterpart. The technology was patented with the support of Innovation RCA.

Lewis's second year group project, *Pluvo*, aimed to tackle urban air pollution, was developed in collaboration with fellow alumnus Nick Hooton and is described further above.

Lewis's graduation project was in response to his grandmother's struggle with dehydration. Dehydration is at least partially responsible for a third of deaths of people with dementia, itself the biggest killer in the UK. Developed after a month of living in his grandmother's care home, *Jelly Drops* are brightly coloured hydrating treats that attract and excite people with dementia. The project was awarded the Helen Hamlyn Snowdon Award for Disability, the Dyson School DESIRE Award for Social Impact, the Student Meaning-Centered Design Award, a Huawei New Working Order Bursary and was runner up at the Dubai Global Grad Show. After videos received over 100 million views online Lewis was interviewed on the BBC and Sky and recently spoke at a TEDx event in California. *Jelly Drops* is the inaugural project in the Alzheimer's Society's accelerator, a partnership that will help Lewis and his colleagues (Nick Hooton, above, and fellow RCA alumna Claudia Arnold) bring the product to market.

Jelly Drops has a waiting list of over 1,000 care homes and 5,000 individuals ready to purchase.

Merlin Kafka

Course: Industrial Systems, Manufacture and Management

University of Cambridge

During his year in Cambridge, Merlin completed four commercial three-week projects with start-ups and multinationals, participated in an overseas study tour and completed a research project at the intersection of consumer neuroscience and new technologies.

Working with chemical and paint manufacturer AkzoNobel, Merlin was able to offer solutions reducing the production time of the top 20 most recurring paints by more than 8% per batch, resulting in an annual time-saving beyond 800 hours. He achieved this by developing a set of new analytics solutions to examine the available large-scale manufacturing data and identify inefficiencies in the system.

In his second project, Merlin worked with the early-stage London-based 3D-printing start-up Additive Flow and developed a toolbox to assist the innovator in the system optimisation process of the machine prototype.

Merlin's third project included work with the Oxford-based start-up Bockatech aiming to develop a sustainable solution to the problem of disposable coffee cups. Merlin's work was instrumental in understanding customer needs and user behaviour and consisted of a 1-week study with 30+ users and more than 50+ consumer interviews. The outputs of Merlin's work allowed the entrepreneurs to identify the most viable use-case for their reusable coffee cup scheme and presented them with a set of nudging strategies to inspire users to return their cups.

His final project tasked him with the delivery of an automation strategy for Herman Miller, known for manufacturing high-end furniture such as the Eames Lounge chair. Facing a labour shortage in the region, Merlin provided actionable recommendations and implementation blueprints for new automation and digitalisation technologies for the firm's highest-output manufacturing lines to help regain flexibility. Today, the firm has committed to investing in three of Merlin's recommendations, including collaborative robots and automated tooling.

Before starting his research project, Merlin spent two weeks in Taiwan and South Korea as part of an excursion with his cohort to learn about manufacturing industries in highly developed Asian countries. The tour focused on industrial sustainability, Industry 4.0 and marketing and covered a broad spectrum of industries, from artisanal paper craft producers to world-leading semiconductor manufacturers.

Merlin used his research project as an opportunity to explore a field previously unfamiliar to him – consumer neuroscience and artificial intelligence. The research involved the development of an emotion-based customer experience analytics technique to automatically detect moments of truth during experiences, i.e. moments in which the consumer invests a high amount of emotional energy in an interaction.

Merlin is currently working as a Product Manager for a Cambridge-based start-up to build his career within the technology field and leverage his multidisciplinary skill-set. His goal is to start his own venture in the near future.

David Leonard

Course: Innovation Design Engineering

Royal College of Art

Throughout his Master's Degree, David focused on acquiring industrial design skills to complement his background in mechanical engineering. He completed a range of projects to maximise his exposure to different design disciplines and techniques. By his second year, David had developed a keen interest in sustainable design and an aspiration to solve modern environmental problems.

During his final year project, David aimed to understand the complex reasoning behind the rapid decline of insect pollinators, to design interventions to aide their survival. His efforts resulted in a modern bee hive, called *Beeosphere*, for native bumble bees, as opposed to conventional bee hives for the non-native honey bee. *Beeosphere* is a maintenance free hive that arrives in the post with a starter colony of bees already living inside it. It is easily stuck to the outside of a window so the user can watch the activity of a growing bumble bee colony throughout the summer months. Once the bumble bee colony reaches the end of its lifecycle in the autumn, and the queen deserts the hive to hibernate over winter, the entire hive can be thrown onto a compost heap to biodegrade. The *Beeosphere* hive is designed to allow anyone with an interest in bees to be able to keep them at home and learn about the roles they play in maintaining our ecosystem. David also designed a school pack and curriculum to implement *Beeosphere* hives in primary schools.

Following a summer job surf instructing in South West France, David is now working full time as an Innovation Designer at Dyson's headquarters in Malmesbury.

Douglas Mann

Course: Innovation Design Engineering

Royal College of Art

Dougie's final year projects revolved around human computer interaction. His first project, *Voice Blox*, was the first language learning tool to embody pronunciation as a simple physical form, allowing users to explore their accent with their hands. Mandarin speakers teach tones with small finger gestures that mimic the 4 fundamental tones. Dougie's team found a way to teach everyone this intuitive tonal language using simple shapes to guide a learner's hand – making tones easy. *Voice Blox* deconstructs and tracks your vocal frequencies using Fourier analysis. The master surface shows the ideal pronunciation, while the mirror block moves to match how you sound. You can run your finger along the surfaces to hear and feel how you sound in comparison.

Dougie's final year solo project, *TypeCase*, is a gestural keyboard that uses 'chords' of button presses, built right into your phone case. Heavily driven by inclusive design principles, *TypeCase* reintroduces tactility and feedback to phones, allowing users to operate their smart devices without even looking and with just one hand. Although initially designed for amputees and hemiplegics, this concept extends to the blind by providing them with a novel physical typing mechanism, using just five buttons. Reversing this interaction, one can even read by touch using miniature haptic motors. This concept also has the power to reduce repetitive strain injuries, speed up text input, and rethink how we control our devices.

Upon graduating, Dougie left for San Francisco to work at N.A.S.A Ames Research Centre in the Human Factors Division. He successfully developed a new way to measure refresh rate latencies of touch screens, and a patent has been filed to protect the design. In November, he exhibited his graduate project in Dubai for the Global Grad Show at Dubai Design Week, alongside his RCA colleagues.

Now back in London, Dougie hopes to push his interest in human-centred design and human-computer interaction, and design the future of consumer electronics.

Hamza Oza

Course: Innovation Design Engineering

Royal College of Art

Hamza's work focused on how design and engineering can tackle complex problems at scale. His solo major project, *Rehber*, looked at helping families find each other during the pilgrimage to Mecca. Every year more than 2 million perform the pilgrimage with an estimated 10,000 people getting lost, 40% of whom are children.

Hamza worked with stakeholders to develop the electronics, form, materials and system to develop a solution that can help families locate each other using a wearable device and supporting service without using sim cards, mobile networks or smartphones. Each device has a range of up to 5 km making it easy for children and the elderly to operate. The project was awarded a distinction upon graduation.

Since graduating, Hamza has turned *Rehber* into a startup. He was invited to exhibit his work at Dubai Design Week and Saudi Startup Forum, winning 3rd place as best new startup. The project was also featured in international publications such as Arab News, Gulf News and Dezeen.

Hamza has also taken a position as a Research Associate at the Helen Hamlyn Centre for Design working to deliver a physical and virtual exhibition for his client, University of York. The exhibition is exploring the relationship between antimicrobial resistance and architecture within the context of cystic fibrosis clinics. As such, he is delivering a system using projection mapping and WebVR to allow clinicians, patients, designers, architects and other stakeholders to come together and facilitate knowledge exchange of the research outputs and enable further co-design of what new clinics may look like in a post-antibiotic age. The project is co-funded by the Wellcome Trust and University of York.

Robert Turner

Course: Innovation Design Engineering

Royal College of Art

Robert's work looks at how technology can be applied in a creative way to improve elements of our day to day life.

His final project looked at applying the Internet of Things to help people reduce food waste in the home. The device allows users to easily track food in the home and suggests recipes that utilise ingredients before they go out of date.

Whilst continuing to work on his own projects, since graduating Robert has worked as a freelance designer and engineer on projects at Imperial College and Altherr / Weiss (a Zurich based design studio), and is currently working at the art and design studio Random International.

Enterprise Fellows

Guillem Singla Buxarris

Technology: Neurological rehabilitation through gaming

Neurofenix

Neurofenix has developed the NeuroBall, a low-cost hand training device connected wirelessly to a mobile application allowing stroke survivors to play games that make rehabilitation exercises entertaining and allows them to track and share their progress. During 2018, Neurofenix launched the product to market; published a research paper in *BMJ Open* together with their academic partner, Brunel University London; reached the finals of The Institution of Engineering and Technology Awards 2018; and won UK Best Invention 2018, appearing on Sky news. NeuroBall is currently being trialled in over 20 NHS centres and has received brilliant testimonials.

George Wright

Technology: Audio controlled interfaces for music production

Vochlea Music

Vochlea Music is a music technology company with a focus on audio controlled interfaces for music production. 2018 was a great year for the company, which won the SXSW pitch competition in entertainment and content; raised its first equity funding round and grew the team from 1 to 4 full-time personnel. In spring 2019 Vochlear Music will be launching its first product, the Dubler Studio Kit, providing live vocal MIDI control.

Victoria Hamilton

Technology: Recoil knee pad

VH Innovation Ltd

VH Innovation's launch product is the Recoil Omniflex 1.0 knee pad. During 2018 the product was featured on Channel 4's Buy it Now TV show. As a result the company received fantastic buy in from the audience and an order from retailer Clas Ohlson

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

Dr Rajendra Kumar Bhandari (1967-1970)

- Lifetime Contribution Award of the Indian National Academy of Engineering
- Lifetime Achievement Award of the Indian Building Congress

Professor Hans Gottlieb (1968-1971)

- Appointed Honorary Professor in the School of Environment and Science, Griffith University, Brisbane

Professor Jennifer Martin (1986-1989)

- Appointed Deputy Vice Chancellor (Research and Innovation), University of Wollongong
- Awarded Suffrage Science prize, MRC London Institute of Medical Sciences

Research Fellows

Professor Byron Byrne (1999-2001)

- Appointed Ørsted / Royal Academy of Engineering Research Chair in Advanced Geotechnical Design, University of Oxford

Professor Alan Drew (2004-2006)

- Appointed Professor of Physics, Queen Mary University of London
- Appointed Interim Director, Materials Research Institute, Queen Mary University of London

Professor Haley Gomez (2004-2006)

- Appointed MBE

Dr Elizabeth New (2009-2011)

- Awarded Australian Museum Eureka Prize for Emerging Leader in Science

Dr Deepak Parashar (2002-2004)

- Appointed Turing Fellow, Alan Turing Institute for Data Science and Artificial Intelligence

Professor Daljit Singh Virk (1976-1978)

- Appointed OBE

Professor Sir Stephen Sparks (1974-1976)

- Awarded Royal Medal for the physical sciences by the Royal Society

Professor André Xuereb (2011-2014)

- Appointed Associate Professor, Department of Physics, University of Malta

Industrial Fellows

Dr Rob Deaves (1994 -1997)

– Elected a Fellow of the Institution of Engineering and Technology

Dr Alex Mahon (1995-1998)

– Appointed Chief Executive Officer, Channel 4

Dr Chris Town (2001-2004)

– Appointed Affiliated Lecturer, Department of Computer Science and Technology, University of Cambridge

Dr Ruth Tunnell (2011-2014)

– Appointed QinetiQ Senior Fellow

Industrial Design Students

Arthur Carabott (2015-2017)

– Invited to run interactive session on sound design for ‘Today at Apple’ event at Apple Store, Covent Garden

Edward Murfitt (2008-2009)

– Appointed Designer in Residence, Tsinghua University, Beijing

Robert Rouse (2015-2017)

– Awarded Hawley Medal, Worshipful Company of Engineers

Built Environment Fellows

Professor Michael Hebbert (1998-2000)

– Published ‘The long after-life of Christopher Wren’s short-lived London plan of 1666’, *Planning Perspectives*

Alumni Pledges and Donations

On occasion, the Commission is fortunate to receive donations and bequests from alumni. In 2018, the Commission received donations from Professor Mario Onyszchuk (Overseas Scholar, 1954-1956) and Dr Evert Ditzel (Overseas Scholar, 1981-1984). 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 at 31 December 2018 stood at £110m compared with just under £116m at 31 December 2017. The total expenditure on charitable activities during 2018 was £4.1m, compared to £4.2m the previous year. For the last seven 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. Notwithstanding recent volatility, this policy has aligned itself with the value expansion in equity markets with the result that the nominal value of the Commission's portfolio has grown at an average annual rate of approximately 7.3% after all fees and disbursements.

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 2018 met two times. On 4 July 2018, Professor Andrew Hopper, an expert in computer science, serial entrepreneur and Treasurer of the Royal Society, joined the Committee, adding greatly to its breadth of expertise. On 13 November 2018, Mr John Manser retired from the Committee after ten years' service; I would like to pay tribute to his insight and wisdom over that period. I would also 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 2018, property (the Commission's estate) made up 16%, and stock market investments and bonds 84% of the capital assets with cash holdings of less than 1% (for 2017 the corresponding figures were 14%, 85% and 1% respectively).

Reserves Policy

The total funds at the balance sheet date were £110,043,440 (2017: £115,964,957).

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 £56.8m managed by Schroders (C.I.) Ltd; a portfolio of exchange traded funds of approximately £32.6m actively managed by Charles Stanley Pan-Asset and an investment of approximately £7.8m 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 £18.9m.

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 2018, the portfolio generated negative returns of £1,149,457 (2017: positive returns of £15,814,369). After allowing for donations and other income of £7,798 (2017: £21,508), total expenditure of £4,773,804 (2017: £4,804,679) and actuarial losses of £6,053 (2017: £10,715) this resulted in a net decrease in funds available to finance future grants of £5,921,916 (2017: net increase in funds of £11,020,483).

The total return comprises income and gains / losses. The annual income generated in 2018 by the Commission’s assets was £3,180,400 or approximately 2.6% of opening portfolio value, slightly higher than the previous year (2017: £2,422,621, 2.2%). 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 should even out over an economic cycle with gains outweighing losses. In 2018, the Commission’s liquid investment portfolio suffered losses of £6,068,767 (2017: gains of £12,206,038) ameliorated to a limited extent by revaluation gains on directly held property of £1,738,910 (2017: gains of £1,185,710).

Expenditure on raising funds – which primarily comprises investment and property management fees – increased from £559,396 to £683,840. This increase primarily reflects one-off adviser fees arising from the transfer of the old Post Office site (the first freehold acquisition since 1853), a complicated rent review finalised during the year and researching various issues pertaining to leasehold enfranchisement claims.

Total expenditure on charitable activities of £4,089,964 was £155,319 less than the previous year. This primarily reflects the late withdrawal of one research fellow.

Overview

2018 was a difficult year for equity investors, with interest rate normalisation and tightening liquidity, especially in the US, deterioration in Sino-US trade relations, Italy-EU budget tensions and the political uncertainties of Brexit all weighing on markets.

Overall the Commission achieved a total return net of fees of approximately -1.5%, with returns on the liquid portfolio of -3.9% partially mitigated by gains on the property portfolio. Although some way short of the RPI + 4% target for the year of 6.7%, and even some way below LIBOR (0.45%), the liquid portfolio performed significantly better than peer group indices such as the ARC Equity Risk Charity Index (-6.1%), in line with some stock market indices such as the MSCI AC World (-3.9%) and somewhat better than others such as the IA Global Equity Index (-5.6%). In 2017 the Commission achieved a total return of approximately 13.5%, compared to a target of 8.3%, an MSCI AC World return of 13.1%, an IA Global Equity Index return of 13.8%, ARC Equity Risk Charity Index of 11.5% and LIBOR rate of 0.26%.

It is obviously disappointing that investment returns were not higher. However, looking at the last seven years together, since the current investment policy was established, the real return on the portfolio net of fees has averaged 7.5% pa, more than sufficient to fund the target 4% disbursement. 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 inevitably affect short term performance, the portfolio is well positioned to capture returns over the long term.

Although disbursements during the year decreased slightly to 4.1% (2017: 4.3%) of the trailing three year average closing capital value of the portfolio they remained slightly above the target of 4.0%. This reflects active decisions to award additional fellowships, recognising that some fellows will be so successful they withdraw early; to allow fewer awards in one area to be balanced by additional awards in another; and the identification of major Special Awards worthy of support, especially as regards the legacy institutions. The cumulative underspend remaining of approximately £1.5m will be carried forward for future use, with Commissioners remaining mindful of the scope to maintain disbursements through periods of inferior market return.

The Commission's Auditors

In 2008, Kingston Smith LLP was appointed the Commission's auditors 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 2018

	2018 £	2017 £
Income		
Donations	3,850	16,450
Investments	3,180,400	2,422,621
Other	3,948	5,058
Total income	<u>3,188,198</u>	<u>2,444,129</u>
Gains and losses		
Gains on property	1,738,910	1,185,710
Gains / (losses) on investments	(6,068,767)	12,206,038
Actuarial losses on defined benefit pension scheme	(6,053)	(10,715)
Total gains and losses	<u>(4,335,910)</u>	<u>13,381,033</u>
Total resources available	(1,147,712)	15,825,162
Expenditure		
Raising funds	683,840	559,396
Charitable activities	4,089,965	4,245,283
Total expenditure	<u>4,773,805</u>	<u>4,804,679</u>
Net movement in funds	<u>(5,921,517)</u>	<u>11,020,483</u>
Reconciliation of funds		
Total funds brought forward	<u>115,964,957</u>	<u>104,944,474</u>
Total funds carried forward	<u><u>110,043,440</u></u>	<u><u>115,964,957</u></u>

Royal Commission for the Exhibition of 1851

Summarised Balance Sheet as at 31 December 2018

	2018 £	2017 £
Fixed asset investments		
Investment properties	18,866,065	17,127,155
Listed investments	96,856,625	102,564,327
Cash held as part of the investment portfolio	161,847	1,014,555
	<u>115,884,537</u>	<u>120,706,037</u>
Current assets		
Debtors	346,157	589,480
Cash at bank and in hand	651,176	614,854
	<u>997,333</u>	<u>1,204,334</u>
Liabilities		
Creditors: Amounts falling due within one year	(3,645,674)	(3,154,946)
Net current liabilities	<u>(2,648,341)</u>	<u>(1,950,612)</u>
Total assets less current liabilities	113,236,196	118,755,425
Creditors: Amounts falling due after more than one year	(2,663,756)	(2,242,468)
Net assets excluding pension liability	<u>110,572,440</u>	<u>116,512,957</u>
Defined benefit pension scheme liability	(529,000)	(548,000)
Net assets	<u><u>110,043,440</u></u>	<u><u>115,964,957</u></u>
The funds of the Charity:		
Capital Funds		
Balance as at 1 January	115,964,957	104,944,474
Movement in year	(5,921,517)	11,020,483
Balance as at 31 December	<u><u>110,043,440</u></u>	<u><u>115,964,957</u></u>

Royal Commission for the Exhibition of 1851

Note to the Summarised Financial Statements for the Year Ended 31 December 2018

1. CHARITABLE ACTIVITIES

	2018 (note 9) £	2017 £
Grants	3,598,461	3,772,108
Direct costs	213,127	189,693
Support costs	278,377	283,482
	<u>4,089,965</u>	<u>4,245,283</u>

Analysis of grants and awards committed in the year:

	2018 No.	2018 £	2017 No.	2017 £
Research Fellowships	9	1,134,058	10	1,360,410
Industrial Fellowships	12	718,575	14	1,111,869
Industrial Design Studentships	11	496,260	7	236,614
Built Environment Fellowship	–	–	1	100,000
Design Fellowship	1	100,000	–	–
Enterprise Fellowships	3	187,500	3	187,795
Great Exhibition Scholarships	10	57,000	10	43,500
Special Awards	19	905,068	19	731,920
	<u>65</u>	<u>3,598,461</u>	<u>64</u>	<u>3,772,108</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 40-41. 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. All employees benefit from a Group Income Protection policy which covers basic salary and pension contributions for staff unable to work due to long-term illness. 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)

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

Professor Sir Richard Brook OBE FREng

Mr Stuart Corbyn FRICS

Sir William Castell LVO

Professor Dame Kay Davies DBE FRS FMedSci

Mr Jim Eyre OBE

Professor Sir Christopher Frayling FCSD FRSA FRIBA

Professor Lynn Gladden CBE FREng FRS

Professor Andrew Hopper CBE FRS FREng FIET

Professor Lord Mair CBE HonDSc FREng FICE FRS

Sir John O'Reilly DSc FREng FLSW

Professor Andrew Hopper was appointed to the Board on 4 July 2018

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*

Ms Sarah Arkle

Mr Stuart Corbyn FRICS

Professor Andrew Hopper CBE FRS FREng FIET

Mr Nicholas Moakes CFA

Mr Adam Taylor-Smith

Ms Jane Tufnell

Professor Andrew Hopper was appointed to the Committee on 4 July 2018

Mr John Manser retired from the Committee on 13 November 2018

Science and Engineering Fellowships Committee

Professor Sir Richard Brook OBE FREng *Chairman*
Professor Gillian Bates FRS FMedSci
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 Christopher Dobson FRS
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
Professor Stephen Muggleton FREng
Professor Trevor Stuart FIC FRS
Professor John Wood CBE FREng

Professor Gillian Bates was appointed to the Committee on 10 September 2018

Industry and Engineering Committee

Professor Lynn Gladden CBE FREng FRS *Chairman*
Dr Nicholas de Leon
Professor Lord Mair CBE HonDSc FREng FICE FRS
Sir John O'Reilly DSc FREng FLSW
Professor Ron Pethig
Dr Malcolm Skingle CBE DSc
Professor Eleanor Stride FREng

Professor Muffy Calder retired from the Committee on 19 July 2018

Built Environment and Design Fellowships Committee

Professor Sir Christopher Frayling FCSD FRSA FRIBA *Chairman*
Professor Rachel Cooper OBE
Professor Chris Wise RDI FREng HonFRIBA FRSA
Mr Jim Eyre OBE

Staff

Mr Nigel Williams CEng	Secretary
Mr Amahl Smith ACA	Finance Director
Mrs Jenifer Hewett	Senior Administrator
Mrs Angela Kenny RMARA	Archivist and Alumni Relations

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South Kensington Branch
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London SW7 3JE

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Guernsey GY1 3UF

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London EC2N 1AR

JP Morgan Asset Management (UK) Ltd
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