Royal Commission for the Exhibition of 1851

Report of the Board of Management
and Summarised Financial Statements

For the year ended 31 December 2019

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 Central 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 2019 was 154

Registered Charity No. 206123

Contents

Chairman's Report

Bernard Taylor, Chairman of the Board of Management

As our investment assets continued to grow – you will see that they reached £133 million at the end of 2019 – so too did the level and pace of our activities and it has been a busy and fruitful twelve months. The 200th anniversaries of Queen Victoria's and Prince Albert's births loomed large during the year and were the focus for the first ever Great Exhibition Road Festival at the end of June and, on a smaller scale, a celebration of Chemistry in Albertopolis in April. Both were a success, the Great Exhibition Road Festival, showcasing the 1851 legacy estate at its very best under the theme 'Explore the Extraordinary', spectacularly so, attracting some 60,000 visitors over two days.

With generous support from the City of Westminster and the Royal Borough of Kensington and Chelsea, Exhibition Road was closed to traffic on both days, allowing the free flow of pedestrians along its length and creating a large area with tents housing displays from all the institutions and a stage for live performance. These were complemented by over 60 talks on subjects as diverse as space exploration to dinosaurs and 150 live events across the site.

The 1851 Royal Commission tent featured a display about the Great Exhibition and the history of Albertopolis, with a large 3D printed model of the Crystal Palace centre stage. Royal Archives were also present, showcasing the Prince Albert Papers digitisation project, which the Commission is helping to fund. All visitors were offered '1851der' goggles which, with the aid of a smartphone and an app, enabled them to view original Victorian stereoscopic photographs of the interior of the Crystal Palace. On Saturday evening, in partnership with the BBC World Service, we staged the fourth of our annual series *The Engineers* in Imperial's Great Hall. The theme, Space Flight Engineering, attracted a capacity audience of 750 to hear presenter Kevin Fong in discussion with Adam Steltzner from NASA, David Parker from ESA and Anuradha TK, the first woman to become a satellite project director at the Indian Space Research Organisation. The programme was broadcast on the World Service in mid-July and was the most successful in the series to date, attracting excellent reviews from the critics.

The Festival would not have happened without the wholehearted efforts of the Imperial College team who generously subsumed their own annual festival into this whole-estate initiative and bore the brunt of the organisation and the costs. But it was very encouraging to see all the institutions throwing themselves into the Festival with an enthusiasm which bodes well for the future. It is safe to say that the 2019 Great Exhibition Road Festival surpassed all our expectations and was the perfect vehicle for celebrating the 200th anniversary of Prince Albert's birth. Although Covid-19 has disrupted plans for 2020, it is intended that the Festival will become an annual event thereafter and in 2021 will take place from 2-4 July, with the addition of a schools' day on the Friday.

We were delighted to welcome Her Royal Highness The Princess Royal to our biennial Presidential Dinner held at Fishmongers' Hall in March. As always this was a great opportunity to bring the 1851 'family' together to celebrate the Commission's activities, with Fellows and Industrial Design Students in their final year presenting displays of their work. There was a touch of Prince Albert here as well, with two of his Lieder performed by Royal College of Music students after dinner. These events, which present an excellent opportunity for Fellows to meet and exchange ideas are an important element of our awards; indeed, they are often quoted as the most valued aspect of a fellowship.

Continuing our initiative of making large Special Awards to institutions to which we are closely related (the Royal Horticultural Society and the Royal College of Music have both been recent beneficiaries) the Board of Management approved a grant of £227,000 to the Victoria and Albert Museum in July. This funded an extensive project on the Raphael Cartoons capturing 3D scans, infra-red and colour photography which will greatly enhance the visitors' experience when the Raphael Gallery reopens later this year, following major refurbishment. We have also supported the Open City Lab project at We The Curious, a science education centre in Bristol, and schools science initiatives in Rotherham and Skelmersdale as part of a conscious effort to spread our reach further.

As a further widening of activity, the Board of Management agreed in December that the Commission will take over the administration of the Sir Misha Black Awards from the Royal College of Art. The awards, for distinguished services to design education, are a perfect fit with our mission. Moreover, our former President, The Duke of Edinburgh, presided over the first awards in 1978 and was closely associated with them for many years so I am particularly delighted that we have been able to provide them with a new 'home' to enable them to continue to thrive.

In addition to these activities our fellowships and awards continue to grow. We receive several hundred applications for our postdoctoral Research Fellowships and whilst we would like to see more entries for our Industrial Fellowships and Industrial Design Studentships, the applications we do attract are of a very high standard, making for a healthy competition. Our Graduate Enterprise Fellowships, in partnership with the Royal Academy of Engineering, are on track to grow from three to six a year by 2021 and are producing some excellent results from some great entrepreneurs with a bright future ahead. Indeed, the achievements of all our award holders are truly impressive, as the summaries later in the report make clear.

The end of the year was marked by the retirement of our Senior Administrator, Jenifer Hewett, after 15 years with the Commission. The changes that she has introduced over that period have left us in excellent shape and we wish her a long and happy retirement. As the Secretary reports in more detail, we have made some changes to our staffing and I am delighted to welcome the new arrivals to the small team that keeps the Commission on track. I am grateful to them all, and for the strong support of Commissioners and Committee Members. Through their efforts the Commission is thriving and, with some excellent people joining the Board of Management and our committees this year, is in good shape for the future, despite the pandemic currently afflicting the world.

Bernard Taylor CBE DL FRSC

Secretary's Report

As the Chairman has mentioned, our Senior Administrator retired at the end of the year marking the first change in staff for nine years. Jenifer Hewett's role in 2019 was unrecognisable from that for which she was recruited in 2004 with the scale and pace of activity increasing with the growth of funds available for distribution. The job has therefore been split into two: an Office Manager/ Executive Assistant to look after the day to day administration and a Fellowship Programme Manager, working three days a week, to manage the awards programmes. This modest increase (of 0.4 people!) should make a real difference to the management of the business and I am delighted to welcome Helen Harris to the team as Fellowship Programme Manager and Kat O'Dea as Office Manager/Executive Assistant. We said farewell to Jenifer at the Annual Reception in December, when the Chairman paid tribute to all she had done to modernise the Commission during her time in post. She has left us in very good shape, and we owe her a great deal for her sustained efforts over fifteen years.

As the Chairman reports above, it has been a busy year, dominated by Prince Albert's bicentenary year and associated celebrations, including the outstandingly successful Great Exhibition Road Festival. But underlying the razzmatazz there is some truly inspirational work being done by our award holders and some equally impressive achievements by our alumni over the year. This shows the real impact of the '1851' and I hope you enjoy reading about it in the pages that follow.

Nigel Williams CEng

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 one or more Brunel Fellowships for engineering projects addressing the primary infrastructure needs of modern society. 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 Master's 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. Originally three fellowships a year were available, but this is being increased to six a year by 2021.

Great Exhibition Scholarships

The Commission's 5-year commitment to this scheme ended in 2018 when ten scholarships were awarded. These scholars will graduate in 2022. Awarded through The Institution of Engineering and Technology (IET), these scholarships were open to UK residents who achieved 3 A grades or above at 'A' level or equivalent joining an IET accredited undergraduate degree. Up to ten scholarships a year were available. Scholars receive an annual stipend. 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 2019

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 11 to 16.

The true impact of the Commission's award holders will only emerge over time, but many show ample indications of their future promise during their Fellowships. To take some examples at random:

- 2016 Industrial Fellow Tom Fleming has been appointed an SME Leaders Fellow by the Royal Academy of Engineering and raised £3.2m private investment for his start-up company, *Arctoris*
- 2018 Industrial Fellow Mariastefania De Vido has been awarded the Association of Industrial Laser Users (AILU) Young UK Laser Engineer's Prize;
- 2019 Industrial Fellow Alex O'Neill has been awarded the Engineering Integrity Society Peter Watson Prize and University of Surrey Ernest Littauer Prize;
- 2019 Industrial Design Student Beren Kayali has had her project on secure alternatives to passwords selected to be patented by InnovationRCA.

More evidence of the success of the various programmes can be gleaned from the achievements of those Fellows who completed their awards during the year and the positions they go on to secure. A representative sample of case studies is provided on pages 17 to 35. Many completing Fellows comment quite explicitly on the importance of their Fellowship to their success:

I would like to take this opportunity to thank the Commission for the Research Fellowship I was granted. It has had a huge impact on my career path. The Fellowship gave me the independence to establish the basis for research in my lab for years to come as well as an amazing support network.

Dr Florencia Iacaruso, Research Fellow 2016

I am indebted to 1851 for the flexibility of its Fellowship to investigate unorthodox project areas, the independence it gave me at an early career stage, and the friendliness of its community.

Dr Ben Pilgrim, Research Fellow 2016

Overall, being awarded the Fellowship has represented a huge stepping-stone in my scientific career, as it gave me the chance not only to pursue several high-profile research projects, but also to initiate many long-term productive collaborations and to grow the international consideration and reputation of my research profile.

Dr Andrea Cairoli, Research Fellow 2016

The independence this Fellowship provided has been instrumental in transitioning to the next step in my academic career and to profiling myself as a leading scientist in the field of active matter. The Fellowship has been very helpful in expanding my research horizons and establishing exciting collaborations with experimental biophysicists, zoologists, and chemists in the US, France, Spain, Japan, Denmark, and Singapore. Over and above this, the Fellowship was a life-changing experience for me. It came at a time when my plans for continuing my academic career and moving to the US were shattered by President Trump's travel ban against Iranian citizens in 2017. Receiving this Fellowship not only enabled me to continue my career in the UK, it also completely changed my life trajectory, for which I will always be grateful to the Royal Commission.

Dr Amin Doostmohammadi, Research Fellow 2017

The Fellowship has afforded me many opportunities to gain experience and expertise which has enabled me to do much more than just obtain a doctorate; crucially, it has allowed me to develop many skills which are pertinent to a career in industry focussed research. This enrichment of my time studying has had a very positive impact on my career, developing more skills than would have been possible just being in a purely academic environment, and I would recommend this Fellowship without hesitation to anyone considering following a similar path.

Dr Alex Ballisat, Industrial Fellow 2015

I have gained many new skills from this Fellowship, from increased confidence, research skills, presentation and communication skills, to time management capabilities from the continuous challenge of balancing commercial and research activities. Additionally, I have hugely valued the opportunities provided to interact with other award holders at Commission events. These were always stimulating and invigorating experiences which I returned from with fresh eyes and focus for my own research projects. I really appreciated being part of this family which made me feel less isolated and more part of the global research community.

Susanna Challinger, Industrial Fellow 2016

Academic and Industrial Supervisors are also very complimentary about the Commission's Fellowships:

I would highly recommend the Industrial Fellowship scheme to other companies as it provides the support necessary for Industrial Fellows to maximise the impact of their research, particularly through strengthening the path towards exploitation.

Dr David Hallam, DSTL, Industrial Supervisor

The 1851 Royal Commission scheme is excellent and rightly regarded as extremely prestigious. It enables students to go significantly above and beyond the work of their basic studentship. It affords students the opportunity to develop their international network through extended trips to internationally leading centres of excellence, providing significant international exposure to practitioners, far beyond what would be normally possible over the course of an EngD. I would not hesitate to recommend the scheme to other postgraduate students.

Professor Paul Wilcox, University of Bristol, Academic Supervisor

A more complete picture of the impact of the Commission's awards comes from the honours and awards bestowed on more senior alumni – some highlights are given on pages 36-37. Many of our alumni tell us that their Fellowship has made a decisive difference to their career:

For me there is no doubt that the fellowship was the one deciding moment that secured me a career in academia. It is always easy to bet on someone with a perfect track record, it is much more difficult to bet on young researchers fresh from their PhD with a lot yet to prove. The Royal Commission for the Exhibition of 1851 takes such risks by giving young researchers like I was a fellowship and the incredible intellectual freedom that comes with it. There is no doubt that any and all of my academic achievements are ultimately due to this risky bet that the Commission took on me. I strongly encourage the Commission to continue its wonderful work with young researchers and will be forever grateful for the fellowship I held.

Dr Pierre-Louis Giscard, Research Fellow 2015

In 2019, thanks to a UKRI Future Leaders Fellowship, I secured a joint appointment to the School of Physics and Astronomy and the School of Mathematics at the University of Edinburgh. To me, this is literally the dream job: a position that will allow me to continue to pursue my research activities in stellar dynamics – a field at the interface between astronomy, applied mathematics and physics – and to share the opportunity for such an interdisciplinary dialogue with the next generation. Looking back, everything really started with my 1851 Fellowship. Italian, trained (in a mouldy basement) as a theoretical physicist, the fellowship allowed me to join the Applied and Computational Mathematics Group in Edinburgh (2012-2015) and to collaborate with one of its long-standing members – a true 'scientific hero' of mine. That experience truly shaped the subsequent evolution of my research vision and agenda. I decided to stay in Edinburgh for another three years (2015-2018) and to contribute to the tradition of collaboration with the local astrophysical community – so I moved to the Institute for Astronomy (thanks to a Marie Sklodowska-Curie Fellowship). Such a trajectory is reflected in the dual nature of my current appointment. And Edinburgh is now my scientific 'home' – I really cannot think of a better place to continue to grow, as a researcher and as a person. This may sound like hyperbole, but it is a factual truth: none of this would have happened without the 1851 Fellowship - and my gratitude cannot be overstated.

Dr Anna Lisa Varri, Research Fellow 2012

As I come to the end of my career, I can reflect how the award of the 1851 scholarship in 1955 changed my life. I was a physics Ph.D. student at University College Dublin when I discovered by chance interesting research going on in the Clarendon Laboratory in Oxford. Dr Brebis Bleaney, said he would be very happy to have me in Oxford provided I could find the money to come. I was fortunate to be awarded an 1851 Overseas Scholarship, having been nominated by the National University of Ireland. As I embarked on the journey to Oxford, I never imagined how that would open a new world to me.

After my arrival in Oxford I registered for a D.Phil. with Dr Bleaney, enabling me to be a member of St John's College. However, after two years I was offered a post at the Argonne National Laboratory in Chicago and I left Oxford imagining that my future would be spent in the US like that of many Irish citizens before me. But after a short time, Oxford summoned me back. I became a tutorial Fellow at St John's College and continued research and teaching in the Clarendon Laboratory. In my years in the department I supervised 55 D.Phil. students, published 422 papers and 3 books. I became Head of the Clarendon Laboratory in 1985. The Institute of Physics published a special issue of the Journal of Physics: Condensed Matter to celebrate my 70th birthday. I am still going into the laboratory on a daily basis.

But the story does not end there. At St John's I was asked to take over the Bursarship of the College and in 1987 I was elected as President of St John's College. Alas that meant I had to give up being Head of the Clarendon Laboratory, but I still kept a room there and continued my research. I was appointed a Pro-Vice Chancellor of the University in 1990 and that continued until I retired from the Presidency of St John's in 2001.

During my long career I have received Honorary Degrees from the National University of Ireland (University College Dublin) and Purdue University, Indiana USA, and Honorary Membership of the Royal Irish Academy. The award of the 1851 scholarship made all of the above possible.

Dr William Hayes, Overseas Scholar 1955

Many of our alumni also tell us about the impact their work is having in the world:

I held an industrial fellowship from 1999 to 2002, performing research on high performance networking at the University of Cambridge, supervised by Professor Andy Hopper [now a Commissioner!] and Dr Steve Pope. That research project lead to a start-up company (Cambridge Internetworking) founded by Steve Pope, Derek Roberts, David Clarke and myself, with Andy Hopper as chairman. The four of us initially worked in a garage, but over the next seventeen years grew to more than two hundred employees (with more than one hundred, mostly engineering, jobs in the UK) and became very successful in the market for high performance networking in electronic trading systems. In August 2019, and now called Solarflare, we were bought by Xilinx, and are now busy developing products that integrate their technology and ours.

Two other 1851 Industrial Fellows joined us at the end of their PhDs: Kieran Mansley has been with us ever since, and Tom Kelly was with us for a while in the early days.

David Riddoch, Industrial Fellow 1999

The Commission obviously aims to make its grants as impactful as possible. But in all its grant making, the Commission also aims for simplicity, flexibility and an absence of bureaucracy. It is gratifying that feedback suggests the benefits are appreciated:

I would definitely recommend the Industrial Fellowship scheme to colleagues who have industry-sponsored research. The scheme runs in an efficient manner and does not impose burdens on the awardee, his/her supervisor or the host department.

Professor Yiannis Andreopoulos, Academic Supervisor, UCL

As well as its core fellowships and studentships, the Commission also runs a very successful Special Awards programme, supporting individuals and institutions with similar aims to the Commission. As in previous years, many of the awards reflect the Commission's continuing commitment to raising the awareness of the young to the opportunities presented by science and engineering. They include awards to the WISE Campaign to train STEM ambassadors in the use of their My Skills, My Life tool that helps girls considering a career in STEM; to The Common Room of the Great North, established by the North of England Institute of Mining and Mechanical Engineers, to help them use their unique heritage to inspire the next generation of innovators; to RedR UK to support engineers starting in the humanitarian sector to improve their skills; and to the British Science Association to extend the reach of their CREST Awards programme, particularly amongst disadvantaged young people.

As the examples above illustrate, the Commission funds a wide range of innovative STEM initiatives 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 2018 the Commission gave a grant to Sheffield-based Bright Box, which aims to engage young people aged 7 to 11 in STEM by using mobile makerspaces in schools, libraries, museums and similar venues to provide hands-on problem-solving experiences for young people. The original intention was to use the funding to purchase and outfit a makerspace bus but it soon became clear it would be more effective to use indoor venues, so the bus concept was dropped in favour of more makerspace kit such as laptops, Raspberry Pis, micro:bits and Lego Robotics kits. The project has proved very successful: Bright Box engaged with 10,000 people in 2019 and has been nominated for two awards. It is working with more than 30 communities on a regular basis, has a team of 10 facilitators and has become part of the Prosper North programme to further grow its reach and capacity. The Commission's grant unlocked further funding and Bright Box is now seeking a five-year grant from the Big Lottery Fund of up to £0.5m to scale up further.

To take another example: in 2012 Fun Kids Radio approached the Commission for support to create a series of audio features entitled 'McSprocket's Everyday Items' exploring the inspiration, ingenuity and design of well-known items used every day at home and school. The series launched in March 2013 and was a great success, reaching over 350,000 listeners in just twelve months. Armed with this success, Fun Kids Radio was granted funding for a further series: 'How's That Made?' in 2017. This was broadcast over eight weeks, attracting more than 380,000 listeners with a further 7,250 downloading the podcast. Feedback suggests Fun Kids Radio is proving an effective way of inspiring young children's interest in exploring the science and ingenuity behind familiar items and thereby developing an interest in STEM. 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.

Not all Special Awards proceed completely smoothly. In 2018 the Commission launched a new design competition for undergraduates, known as The Great Competition, in partnership with the Design Museum. Some outstanding entries were received, but the scale and reach were disappointing, especially amongst the young scientists and engineers the Commission was most keen to target. Commissioners have agreed to fund the prize for at least one more year, but there is likely to be a delay while timing and profile are improved.

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, as mentioned in the Chairman's report, they included a major grant to support the V&A's refurbishment of the Raphael Court, with the Commission supporting a series of three-dimensional scans, infra-red and colour photographs which should improve public understanding and appreciation of Raphael's Cartoons for generations to come.

Finally, the Commission sometimes makes Special Awards to facilitate access to its own archives and in 2019 gave a grant to the University of Oxford to support the work of Dr Andrew Cusworth, who is seeking to enhance access to and understanding of material relating to Prince Albert's legacy, including the Great Exhibition.

Post balance sheet events – Covid-19

Like every other organisation, the Commission has been impacted by the coronavirus pandemic. The Commission has, however, largely been able to continue activities as planned and Commissioners do not believe that any adjustments to the accounts are required.

Investment markets have been much more volatile and the day to day value of the Commission's portfolio has inevitably reflected that. The Commission is a long-term investor, however, and Commissioners remain confident in the underlying strength of the portfolio; they see no evidence at this stage of any permanent loss of value. Indeed, the Commission's investment managers have ensured the Commission is well-placed to benefit from the recovery when it comes. Likewise, while some of the Commission's tenants have asked for and received temporary support with deferred rent demands and the like, there is not considered to be any risk to the long-term value of the estate. In anticipation of the volatility, Commissioners ensured that there were sufficient cash or near cash assets in place to fund at least three years' expenditure in full. The Commission should therefore be able to ride out the current disruption. For reference, as at 30 June 2020 the portfolio was valued at £130,755,467, compared to £133,797,945 at year-end.

The Commission had robust business continuity plans in place and Commissioners, Committee Members and staff have adapted relatively straightforwardly to the need for remote working. The 2020 award rounds for all the Commission's Fellowships and Studentships have gone ahead as planned with a full complement of awards made. A majority of existing award holders have been able to adapt their workflow patterns to fit the unusual circumstances imposed by lockdowns etc. Where this has not been possible, the Commission has granted extensions and provided the necessary financial support. Commissioners have also been pleased to provide 'paid sabbaticals' where award

holders' specialist skills have enabled them to support the fight against Covid-19, whether through testing, modelling or other means. Some events have had to be cancelled or postponed, but that should not have any material, long-term impact on the Commission's work.

Future Plans

The Commission has long recognised the need to ensure a future pipeline of applicants for its awards by raising awareness amongst the young of the excitement and importance of STEM. For many years it did this primarily through its Special Award programme. In recent years, this has been complemented by an increasing focus on its own educational initiatives, including in particular the inaugural Great Exhibition Road Festival, showcasing the extraordinary research being undertaken on its legacy estate in South Kensington. Commissioners are keen to build on this initiative. During 2019, Kat O'Dea joined the small staff team as Office Manager / Executive Assistant, bringing a wealth of experience in event management from her previous roles which she hopes to put to good use leading on the Commission's contribution to the next Great Exhibition Road Festival. The coronavirus pandemic has meant this has had to be put back to 2021, but that means there is plenty of time to plan something special.

Another ongoing priority for the Commission is to increase awareness of its award programmes and the opportunities they provide to the brightest and the best. In 2019 the post of Fellowship Programme Manager was created with Helen Harris recruited to the role. Once social distancing restrictions allow, Helen will be spending a significant proportion of her time getting out and about spreading the word about the Commission and encouraging applications. In the meantime, she will be working with our communication consultants, April Six, to produce promotional materials, including videos featuring Commissioners, award holders and alumni. Helen also hopes to establish a network of alumni at UK businesses and universities who are happy to be ambassadors for the Commission. The hope is that they will act as a first point of contact for potential applicants in their area who want somebody to talk to about the application process and the benefits an 1851 Fellowship can bring.

A third priority for the Commission is better articulating the value of its awards. Alumni will of course be well aware of the advantages of an 1851 Fellowship, and this report has many anecdotal examples. But this is not always as obvious to potential applicants, so the Commission is starting to explore other ways in which it can measure the impact of its awards, to better demonstrate their value. Alumni will no doubt be an important source of information as we try to work out some more quantitative measures.

Finally, as well as raising awareness of its awards, and their impact, the Commission will as always be reviewing ways in which they can be improved and made more attractive to potential applicants. Attention will focus on the Industrial Fellowships, where feedback has been sought from Fellows, Academic and Industrial Supervisors, and on potential schemes to complement the Industrial Design Studentships, where input is being sought from engineering and design faculties across the UK.

Awards Granted in 2019

Research Fellows

Dr Keith Andrews
Subject: Addressing diabetes: glucose recognition with a bespoke molecular glove
University of Oxford
Previous attempts at harnessing the molecular recognition and catalysis properties of enzymes have relied on editing approaches. This project combines recent advances in supra-molecular self-assembly with small molecule precision in order to develop enzyme mimics capable of sensing glucose molecules for diabetes technologies from the bottom up.

Dr Frances Dunn
Subject: The rise of animals: challenging Darwin's dilemma ***University of Oxford***
Since their emergence 540 million years ago, animals have come to rule the land, seas and skies, but their origins remain mysterious. Using state-of-the-art modelling techniques, this project will examine strange fossils from immediately before this time to gain an understanding of the origin and evolutionary rise of Kingdom Animalia.

Dr Timothy Haskett
Subject: Development of genetic tools for rhizosphere engineering ***University of Oxford***
Rhizopine-signalling is crucial for engineering plant-growth promoting bacteria, but currently lacks fine-tuned control and is functionally restricted to a few bacterial species. This project will refine rhizopine-signalling to gain the dynamic and conditional host-plant control over bacterial gene expression required to engineer complex plant-growth promoting traits in diverse bacteria.

Dr Amit Hazi
Subject: Diagram algebras via Soergel bimodules ***City, University of London***
The aim of this project is to unify the representation theory of classical diagram algebras under the modern machinery of diagrammatic Soergel bimodules, by establishing direct correspondences between the two. The project will apply this work towards calculating simple characters of algebraic groups in characteristic p via p-Kazhdan-Lusztig polynomials.

Dr Thomas Macdonald
Subject: Exploring nanostructured light absorbers: from optoelectronics to innovative photovoltaics ***Imperial College London***
This project will guide the development of efficient and stable photovoltaics by the incorporation of nanostructured light absorbers, perovskite nanocrystals. Novel experimental techniques will allow for the understanding of the physical processes occurring within the materials and interfaces, removing the barriers to the commercial application of perovskite-based photovoltaics.

Dr Konstantinos Meichanetzidis
Subject: Simulating compositional processes with tensor networks ***University of Oxford***
Process theory provides a compositional formalism describing complex systems. Examples are quantum many-body dynamics and computation, counting constraint satisfaction problems and statistical mechanics, neural networks and natural language processing. Through an admissible graphical language, such problems reduce to tensor networks. This paves the way for novel practical algorithms.

Dr Luke Rhodes
Subject: Emergent electronic properties of strain tuned superconducting materials
University of St Andrews
Strain in advanced quantum materials promises unprecedented levels of control over a material's properties and offers key insight for an understanding of these properties. This project will combine imaging of the electronic states in real and momentum space with in-situ strain tuning and modelling to revolutionise our understanding of superconducting materials.

Dr Farid Shahandeh
Subject: Constructing a unified resource-theoretic framework to characterise quantum computational processes ***Swansea University***
This project addresses a fundamental question in quantum computation by establishing a unique physical basis for characterisation of quantum computation algorithms. This framework will enable the reduction of costs of building quantum computers and offers new methods for identification of efficient quantum dynamics in complex systems.

Dr Benno Simmons
Subject: How invasive species transform a critical ecosytem function ***Univeristy of Exeter***
Invasive species significantly threaten pollination, an essential ecosystem service that supports crops and wild plant species globally. To date, methodological limitations have prevented the effects of invasive species on pollination being detected. Using novel techniques, this project will overcome these shortcomings to understand the current and future threat invasive species pose.

Dr Andy Kay Ping Tay
Subject: Magneto-mechanical biomedicine for pain modulation and immune-engineering
Imperial College London
Chronic pain affects one-third of the UK's population. Unfortunately, surgical, opioid and electrical treatments are ineffective. This project employs mechanical neuro-modulation for pain relief.
The current low T-cell transformation efficiency (<20%) hampers genetic engineering efforts for immunotherapy. This project will develop a gentle and efficient (up to 40%) technique for T-cell transformation.

Dr Tessa Young
Subject: Characterising the cobalt delivery pathway for vitamin B12 ***Durham University***
This research will solve the mystery of how cobalt is supplied to make vitamin B12 in bacterial cells. It will both provide fundamental understanding about how biological organisms safely use metal elements and enable the engineering of more efficient B12-producing microbes for sustainable and nutritious diets.

Industrial Fellows

Marie Dale
Subject: Automated identification and predicted translocation of marine hull invasive species
Sponsor: AkzoNobel ***University of Durham***
Invasive species, transported as biofouling on ships' hulls, are a major threat to the world's oceans. This project aims to develop an artificially intelligent inspection tool capable of rapidly processing video footage to automate the detection of invasive species on ships, supporting the management and prevention of invasive species translocation.

Veronica Glyn
Subject: Development of experimentally-integrated process models for adaptive CAR-T cell therapy manufacturing
Sponsor: Autolus ***University College London***
CAR-T cell therapy is a new generation of treatment and potential cure for certain aggressive cancers. Clinical trials have shown remarkable results, but production costs must be reduced to ensure therapies are accessible to every patient. This project focuses on providing a process development tool necessary to resolve these issues.

Alexander O'Neill
Subject: Predicting tyre behaviour on different road surfaces
Sponsor: Jaguar Land Rover ***University of Surrey***
The automotive industry is increasingly utilising virtual engineering for vehicle development. However, current understanding of the tyre-road interaction means that most tyre models represent driving on sandpaper. By studying the friction between tyres and various surfaces, this research aims to make the prediction of tyre behaviour on real surfaces possible.

Elisabeth Pickles
Subject: Applying quantitative image analysis to liver cancer
Sponsor: Perspectum Diagnostics ***University of Oxford***
The aim of this project is to explore the utility of quantitative MRI techniques for the diagnosis and characterisation of liver tumours, and for assessing the effects of chemotherapy and other therapies, as an alternative to qualitative contrast-enhanced MRI.

Bojidar Rangelov
Subject: Discovering CT imaging biomarkers of exacerbations of COPD
Sponsor: GSK ***University College London***
This project aims to build computational and machine learning tools which can discover novel imaging biomarkers of exacerbations of COPD. These biomarkers add value to GSK's drug development pipeline as a means of positively diagnosing exacerbations, drug effect quantification and patient phenotyping for clinical trial stratification.

Tatiana Rogova
Subject: Shining a new light on the synthesis of biologically-relevant tertiary amines
Sponsor: GSK ***University of Oxford***
In a collaborative effort between industry and academia, this project aims to devise a highly efficient, visible-light driven methodology for the synthesis of biologically-relevant tertiary amine structures in an industrial setting for applications in ongoing research into novel pharmaceutical agents.

Robert Rouse
Subject: Machine learning approaches to assessing future flood risk
Sponsor: Mott MacDonald ***University of Cambridge***
In the face of impending climate change, the need to understand the impact of extreme weather events is critical; through novel machine learning and probabilistic approaches, this project aims to enable the impact of extreme precipitation, tidal, and, consequentially, flooding events to be determined, allowing for the generation of accurate adaptive and mitigation strategies.

Shaun Smart
Subject: Determination of boundary conditions for occurrence of weld metal hydrogen cracking
Sponsor: TWI Ltd ***University of Leicester***
This project aims to assess the effect of parent material CE value, section thickness and the associated resulting residual stress and degree of alloy content of the weld metal in determining the boundary conditions for occurrence of weld metal hydrogen cracking using empirical research trials and finite element analysis.

Jack Sutro
Subject: Synthetic approaches to medically relevant *Euphorbia* diterpenes
Sponsor: UCB BioPharma ***University of Oxford***
This project aims to achieve a total synthesis of members of the jatrophane family of *Euphorbia* diterpenes which have been shown to inhibit P-glycoprotein. P-gp is an efflux pump responsible for multidrug resistance in certain cancers. The project aims to further understanding of P-gp, and develop a potent pre-clinical candidate to treat multidrug resistant cancers.

Enterprise Fellows

Surakat Kudehinbu
Company: RAB-Microfluidics
Early diagnosis of potential failure in heavy machinery is critical to operations across many industries. For this reason, in 2016 industrial businesses spent £2.01bn on state-of-the-art Oil Condition Monitoring (OCM) techniques. These techniques, however, are inefficient, expensive and environmentally unfriendly: in 2016 an additional £2.1bn was spent on breakdowns, repairs and costs associated with downtime losses.

RAB-Microfluidics has developed cutting edge microfluidic lab-on-a-chip technology to deliver real-time continuous testing and analysis of lubricating oil. The "lab-on-a-chip" technology delivers oil analysis 1000 times faster and 10 times cheaper than the current "send the sample to the laboratory" approach.

The company is currently focused on commercialising the technology, with pilot trials planned this year. Over the course of his Fellowship, Surakat will focus on achieving this through developing an understanding of the commercialisation requirements of the technology in target markets, with a specific focus on the wind sector.

Ben Lakey
Company: mitt Wearables
There are 70 million people who need prosthetic limbs around the world. Sadly, limb loss is up to 100 times more common in low-resource regions of the world. Current prostheses are rigid, uncomfortable, over-engineered and prohibitively expensive – as in 10s of £1000s per device. Because of this, 90% have no access to prostheses at all. mitt has developed easy-to-use, comfortable prosthetic limbs that are 100x more affordable than any other solutions. This allows users to interact with their environment, reaching their full potential within the community.

With an affordable price point, and a device that can be fitted by users themselves without medical intervention, mitt can provide direct to the users and communities that need them, no matter how isolated from medical infrastructure. Removing barriers and empowering individuals to take control over their own disability.

mitt's ambition is to open up opportunities to people around the world by giving them the power over their own limbs.

Rowan Minkley
Company: Chip[s] Board
Sustainability is the core principle Chip[s] Board was founded on. The company's vision is to create a truly circular bioplastic, using abundant waste as a feed source. Currently partnered with McCain, the largest global potato processing company in the world, the company has developed a process to transform their waste into Parblex bio-plastics used in Chip[s] Board composites.

Chip[s] Board currently offers two ranges of composites: natural-fibre reinforced melt blends for applications such as furniture, fashion and consumer electronics; and aligned-fibre composite panels for engineering materials in the automotive and aeronautical industries.

By combining Parblex bio-plastics with natural fibres the company creates completely bio-based composites to replace traditional reinforced plastics. This means at the end of a product's life it can be disposed of sustainably via composting, anaerobic digestion or in-house recycling.

Chip[s] Board is also building a network of food and drink manufacturers to identify other viable feed-stocks to create bio-plastics from their waste.

Built Environment Fellow

David Rudlin (with Dr Lucy Montague and Vicky Payne)
Subject: What is the high street for?
Mentor: Steven Bee, Academy of Urbanism
What do we mean by the crisis on the high street? We know that scores of retailers have disappeared and thousands of shops closed. But is this dire scene the whole picture? Do we understand why some places are doing well while others have been devastated? Why initiatives in one place work while the same strategy elsewhere has no effect? Is it because some retailers have failed to adapt or is the high street itself the problem?

There is no shortage of suggestions about what we might do: environmental works, traffic calming, environmental improvements, better promotion and animation, pop-up retailers have all been set out in good practice guides. But before we prescribe the medicine we should take a little more time to make sure we have the right diagnosis. The high street is not a homogeneous place and the aim of this research will be to understand it a little better.

We will do this by studying one hundred high streets, including big cities, smaller cities, large towns, small towns and suburban centres as well as out-of-town centres and online retailers. In doing so we will analyse data to understand the cold, hard facts, but will also look for the stories – the people who have made a difference and the initiatives that have worked.

Many of these stories go beyond what can be captured in best practice guides. You can't write a policy that will magic into existence an extraordinary community activist or a creative entrepreneur. But their stories can inspire and show that change is possible and that there is a future for our high streets. Our aim is to do this by narrating the tales of a hundred high streets.

Industrial Design Students

Cameron Brookhouse	Innovation Design Engineering	Royal College of Art
Jeffrey Chow	Innovation Design Engineering	Royal College of Art
Sandeep Hoonjan	Innovation Design Engineering	Royal College of Art
Beren Kayali	Innovation Design Engineering	Royal College of Art
Aimee-Elisabeth Kyffin	Innovation Design Engineering	Royal College of Art
Maximillian Medhurst	Innovation Design Engineering	Royal College of Art
Tom Pais	Innovation Design Engineering	Royal College of Art
Lorenzo Spreafico	Innovation Design Engineering	Royal College of Art
Kristof van der Fluit	Service Design	Royal College of Art

Special Awards Granted

STEM education and outreach

Foundation for Science and Technology – Debate sponsorship
Smallpeice Trust – Space Engineering course
Joseph Leng – Travel bursary
County Upper School – Junior Cospace Robotics Competition
Matthew Elsmore – British Society of Rheology Poster Prize
Armourers' & Brasiers' Company – Cambridge Forum
Design Museum – the Great Competition
STEM Learning – ENTHUSE Partnership
WISE Campaign – My Skills, My Life
The Common Room – Children of the Revolution
RedR UK – Affiliate Scheme
Smallpeice Trust – Arkwright scholarships
Foundation for Science and Technology – Future Leaders programme
Design and Technology Association – Designing your Future
The PTI – Subject Leadership CPD Programme
British Science Association – CREST Awards for disadvantaged students
Serpentine Trust – Digital Knowledge and Skills Sharing workshops
UK Electronics Skills Foundation – Electronics Everywhere

Support for legacy estate

Victoria and Albert Museum – Raphael Cartoons
Exhibition Road Cultural Group – Day of Design

Archives and Alumni Relations

University of Oxford – Digitising Albert Research Fellowship
English Heritage Trust – Victoria and Albert at Osborne

Awards completed in 2019

Research Fellows

Dr Obinna Abah
Project: Quantum information machines in ion-trap systems ***Queen's University Belfast***

Recent research exploits quantum effects, measurement and many-particle exotic phenomenon to engineer energy-efficient thermodynamic information machines. However, the current challenge is to design energy efficient thermal machines that deliver more output for the same input, without sacrificing power. Such devices would reduce both energy consumption and energy costs, thereby providing novel efficient cooling and heat-management solutions. One of the most promising ways to achieve this goal is known as shortcuts-to-adiabaticity (STA), in which fast nonadiabatic processes mimic the evolution of an infinitely slow adiabatic process.

During his fellowship, Obinna developed the general framework for finite-time thermodynamics of quantum thermal machines (heat engines and refrigerators) that are driven by shortcut-to-adiabaticity protocols. He showed that higher efficiency and higher power may be achieved simultaneously, even when the energetic cost of the STA driving is included. He derived the generic fundamental limits imposed by quantum mechanics on performance of driving machines. He further successfully established the hierarchy of different quantum control processes based on their energetic cost. Furthermore, he investigated the implication of information backflow from system to environment (non-Markovian dynamics) on measurement-driven machines. He found regimes in which non-Markovianity could enhance the performance of information thermodynamic machines. Obinna used the insights from STA, measurement and spin-boson interaction to propose a robust framework for generating nonclassical states.

Obinna remains at Queen's University Belfast as a postdoctoral research fellow.

Dr Felicity Allen
Project: Powerful CRISPR/Cas9 screens via computational prediction of DNA repair profiles ***Wellcome Sanger Institute***

CRISPR/Cas9 is a transformative new DNA editing technology. It uses a short guide RNA (gRNA) with a sequence matching the target DNA as an addressing system to recruit a Cas9 protein to that target. The Cas9 protein cuts DNA at that location, and when the DNA is repaired by the cell, small insertions or deletions can occur. When these insertions or deletions occur within a gene, they can prevent that gene from functioning. This enables genome-wide CRISPR/Cas9 screens to be conducted on human cells (in dishes in the lab), in which every gene in the human genome can be intentionally knocked out to assess its impact.

Felicity's work demonstrated that the particular insertions and deletions that occur after a cell repairs Cas9-induced cuts to DNA are predictable from the DNA sequences of the target. This is important as it allows scientists to select targets more carefully knowing the most likely outcome. This research, which was joint work with colleagues at the Wellcome Sanger Institute, was published this year in *Nature Biotechology*. Felicity and colleagues conducted a high-throughput measurement of Cas9-induced mutations in targeted DNA, and compiled the largest, most comprehensive dataset available for these mutations to date. Felicity used this data, combined with machine learning methods, to build a highly accurate computational predictor of the profile of mutations for a particular targeted DNA sequence. It is freely available as a web service at https://partslab.sanger.ac.uk/FORECasT and is in regular use by researchers all over the world.

In addition to this work, Felicity developed a statistical method for processing data from genome-wide CRISPR/Cas9 screens, which was published in *Genome Research*, and is also freely available.

Felicity is now a Principal Scientist at biotech company Genomics Plc, based in Cambridge.

Dr Sinan Açikgöz
Project: Novel assessment of tunnelling-induced damage for heritage masonry structures
University of Cambridge and University of Oxford

In the United Kingdom, and throughout the world, underground construction in urban environments is necessary to meet growing infrastructure demands. However, underground construction activities, such as tunnelling, can place buildings at risk due to potential ground movements. This risk is significant for heritage masonry buildings, where small differential ground movements can lead to unsightly cracking and irreversible damage. To safeguard sensitive heritage structures, an improved understanding of their response to ground settlements is required. In this project, two Grade-I listed historic buildings in London undergoing settlements from tunnelling were investigated. New insight into the structural response of these buildings was obtained from a first of its kind application of distributed fibre optic strain sensing and laser scan displacement monitoring. This research work (conducted in collaboration with Transport for London and Geocisa UK) helped preserve the historic assets and enabled significant cost savings. This was recognised with industrial awards at the NewTechFest and Tunnelling Festivals in 2018. The new monitoring data also revealed the limitations in our ability to predict and assess tunnelling-induced damage in masonry assets. This led to the development of new finite element-based modelling procedures that capture the salient aspects of the complex interaction mechanisms between the tunnel, soil and the buildings in a computationally efficient manner. Sinan was awarded the 'Outstanding Young Engineer Contribution Award' in 2019 by the International Association for Bridge and Structural Engineering.

Sinan is continuing his research at the University of Oxford, where he is an Associate Professor.

Dr Jack Alexander-Webber
Project: A graphene-organic platform for spin-engineered optoelectronics
University of Cambridge

Semiconductors lie at the heart of computers, renewable energy generation, displays, lighting, and imaging sensors, to name but a few. If we reduce the size of these materials to atomic dimensions, squeezing electrons into the atomic scale, this dramatically changes how they interact with other materials and how they react to external stimuli such as light, heat or magnetic fields.

The aim of Jack's research is to explore fundamental physics in these new nanostructured material systems and translate this understanding into electronic and optoelectronic devices with enhanced or novel functionality. The large surface-area-to-volume ratio in these materials results in an extreme sensitivity to the local electronic environment. As such, for any device applications passivation and encapsulation techniques are essential. Jack has developed techniques to protect ferromagnetic electrodes from oxidation using graphene for energy efficient organic LEDs. He has developed processes to interface graphene with metal-oxides to achieve high-performance, reproducible graphene transistors. This has formed the basis of an industry funded project to incorporate graphene into mobile devices for signal processing. His research has been extended to control the properties of semiconductor nanowires for photo-responsive memory devices as well as the demonstration of an ultra-miniaturised visible light spectrometer based on an individual nanowire, recently published in *Science*.

Jack is continuing his research career as a Royal Society Dorothy Hodgkin Research Fellow at the University of Cambridge.

Dr Andrea Cairoli

Project: Active Lévy matter – emergence and universality ***Imperial College London***

Spontaneous collective behaviour, typically manifest as collective motion or phase separation, is widely observed in systems out of equilibrium, particularly in biological systems such as bird flocks, insect swarms and tissue under dynamic re-organization.

These phenomena are typically modelled under the active fluid formalism, which relies on underlying microscopic models of self-propelled interacting particles (with constant velocity) typically subjected to rotational diffusion. However, anomalous diffusive dynamics is also widespread in biology. Therefore, situations where anomalous single-particle dynamics and interparticle interactions that can generate collective behaviour are present simultaneously may be advantageous; and indeed they have been recently observed in experiments. Nevertheless, the emergence of collective motion in systems displaying such anomalous diffusive behaviour has not yet been investigated and requires the formulation of a more general framework than that of active fluids.

During his Fellowship, Andrea researched how anomalous diffusion affects the emergence of collective phenomena in many-body interacting systems. His main achievement in this context is the formulation of a system of active particles performing Lévy flights, i.e., a random walk with power-law distributed jump lengths, and subjected to polar alignment interactions, and the derivation of its hydrodynamic equations, which he employed to investigate the properties of the order-disorder phase transition. Remarkably, Andrea found that, differently from ordinary active fluids, this phase transition becomes critical and does not belong to any previously known universality class. The methodology that Andrea developed in this project will potentially be applicable to understand the effects of anomalous single-particle diffusion on several other types of collective phenomena, such as active turbulence or motility-induced phase separation, which he is planning to study in the future.

Andrea is now a postdoctoral training fellow at the Francis Crick Institute.

Dr Amin Doostmohammadi

Project: Living colloidal metamaterials ***University of Oxford***

Over the past decade there has been a growing list of biological materials that continuously take energy from their environment to produce motion. Striking examples include fibroblast cells, bacterial suspensions, and mixtures of sub-cellular filaments and motor-proteins. These are all composed of elongated elements and show salient features of liquid-crystals, particularly the emergence of orientational-order and topological defects. They are classified as a new type of matter, termed active liquid-crystals. While ordinary liquids only passively flow when pushed on, active fluids spontaneously flow on their own because they carry along some internal fuel.

Amin's research has focused on understanding how activity may be harnessed in order to generate mechanical work on the microscopic level: for instance, by the actuation of a small rotor or transport of a passive colloid. He has shown that when dense active matter is confined, the interplay of the active and the confining length scales, together with the possible creation of motile topological defects, can lead to surprisingly complex behaviour and stabilization of active fluids to coherent structures. Investigating this is relevant to understanding finite active systems, such as cells or organoids, and to possible uses of active matter to power microscale devices.

Amin is now an Assistant Professor at the Niels Bohr Institute at the University of Copenhagen and has also been appointed as a Specially Appointed Assistant Professor of Bioengineering at Osaka University in Japan.

Dr Florencia Iacaruso

Project: How midbrain circuits integrate sensory information during target selection

University of Oxford and Francis Crick Institute

In order to generate appropriate responses to external events, living organisms often need to combine sensory information from multiple sensory modalities with motivational and contextual information. Specific brain areas weigh and combine this information to instigate optimised behavioural outputs. The superior colliculus (SC) is a prominent site of convergence for sensory inputs from multiple modalities as well as non-sensory information, which is integrated locally and employed to trigger fast motor responses. This evolutionary conserved structure, present in all vertebrates, is involved in orienting and escape behaviours and has been implicated in spatial attention and target selection.

Florencia's project aimed to understand how functional microcircuits within the SC integrate and assess the relevance of sensory information from different modalities in order to generate appropriate responses. Florencia conducted electrophysiological recordings from hundreds of neurons using Neuropixels probes to characterise visual and auditory responses in the SC of behaving mice; set up behavioural experiments to study multisensory target localisation and developed analysis tools for these experiments; and established optotagging experiments to identify specific subpopulations of neurons. In addition to gaining insights into the mechanisms underlying multisensory integration for target selection, this work has established the foundations for further research in Florencia's own lab at the Francis Crick Institute.

Florencia also started a second project during her fellowship studying multisensory processing in the primary visual cortex (V1). Preliminary results show that sound can enhance the responses to natural visual stimuli, especially at low contrast, and there are neurons in the primary visual cortex that are mainly driven by naturalistic sounds. Florencia is currently collaborating with Dr Aleksander Domanski from Bristol University, a computational neuroscientist who is applying multidimentionality reduction techniques as well as multi-neuronal pattern analysis to the data she collected during her fellowship. They are currently studying how the introduction of auditory input affects the correlation structure, dimensionality and strength of information readout of V1 neurons and ensembles during low contrast scene viewing.

During her fellowship, Florencia was an invited lecturer for the Cold Spring Harbor Laboratory school on Imaging Structure and Function in the Nervous System; an invited speaker for a workshop at the Bernstein Conference and at the Society for Neuroscience annual meeting. She has also been appointed as an honorary supervisor at University College London and at King's College London.

Florencia is now a Group Leader at the Francis Crick Institute in London. This position comes with start-up funding for equipment (~ £250,000), and additional funding for two postdocs, two PhD students and one research scientist.

Dr Beth Mortimer

Project: Vibrational communication in animals ***University of Bristol and University of Oxford***

Vibrations that propagate along surfaces or through materials are a ubiquitous form of information utilised by hundreds of thousands of diverse animals. Beth has used her 1851 Research Fellowship to explore how a diverse set of animals use these vibrations as an information source, using an interdisciplinary approach bridging animal behaviour and sensory ecology with biomechanics and seismology.

Beth has shown how orb weaving spiders can control vibration propagation in their web, and how they can use this information to locate prey items. Whereas spiders make their own material to control vibration propagation, this is not the case for most other animals. Beth has shown how we can eavesdrop on the seismic vibrations generated by elephants to monitor them. At the other end of the size spectrum, she has found vibration sensitivity in soft-bodied nematode worms and unpicked how small planthopper bugs, which are serious pest species, generate vibrations using an efficient elastic recoil mechanism. All these projects have expanded our appreciation of this enigmatic information transfer mode and the inherent links between animals, their mechanics and their external environment, shaped by natural selection and physical laws.

During the fellowship, Beth has raised over £830k of research funding and has received numerous invitations to speak at international conferences on various aspects of her work, including a talk at the TEDWomen 2018 conference.

Beth is now a Royal Society University Research Fellow at the University of Oxford where she will continue her research on sensing surface vibrations, hoping to apply the biological insights gained to develop bioinspired technologies for use in robotics.

Dr Ben Pilgrim

Project: Stimuli-responsive molecular containers for biomimetic catalysis

University of Cambridge

Nanometre-sized molecular boxes 10,000 times smaller than a human hair can be constructed in a variety of different shapes, with each shape giving rise to distinct behaviour. By changing the structures of these boxes, we can alter their functions.

Ben's project established new methods to make such molecular capsules stimuli-responsive to different signals (such as a chemical trigger molecule, heat or light). This was accomplished by embedding a reactive panel called a tetrazine into the edges of their structural framework which could then be altered by the application of different chemical triggers. Excitingly, studies have confirmed these 'nanoboxes' bind catalysts for reactions of interest, and that catalyst release and recapture can also be modulated in response to different networks of chemical signals.

Ben has also started to investigate how systems of multiple nanoboxes can respond to different types of signals and hence control multiple catalysts. This will become the major focus of Ben's work going forward, as it is crucial that chemists develop innovative approaches that allow multiple catalysts to work in tandem, and permit their isolation and recovery, to secure a sustainable future for the global chemical industry.

During Ben's Fellowship he published multiple high impact papers and gave numerous selected and invited talks and poster presentations. Ben was also heavily involved in outreach and public engagement. Ben is currently the Head Mentor for the UK Chemistry Olympiad team and was elected onto the International Steering Committee for this competition in 2017. He has given many demonstration lectures all around the UK and helped launch a 'STEM for Women' summer masterclass event for sixth form students.

The preliminary ideas generated in this Fellowship formed the basis of a successful application for a competitive Nottingham Research Fellowship in the Green Chemicals Beacon of Excellence for a project entitled 'Tandem Multi-catalytic Nanoboxes', as well as the basis for several other grants currently under review. Ben has now moved to the University of Nottingham to set up his independent research group.

Dr Nicole Reindl

Project: Probing the nature of dark matter using hot white dwarfs ***University of Leiceter***

Nicole's project aimed to obtain information about the nature of dark matter, by deriving the Galactic distribution of the hottest white dwarfs and the hot end of the white dwarf luminosity function. For this she initially carried out a visual inspection of about 2000 spectroscopic observations form the Sloan Digital Sky Survey and classified them according to their chemical compositions. She also computed large model grids of synthetic spectra using a state-of-the-art non-local thermal equilibrium model atmosphere code. Developing an efficient fitting routine, she was able to derive the atmospheric parameters of about a thousand hot white dwarfs. A quality control has been established and results were checked against previous results which relied on simplified models. Nicole also started using data from the Gaia data release 2 in order to determine in combination with the spectroscopic information the Galactic population memberships of the hot white dwarfs.

In addition, Nicole investigated a particularly baffling phenomenon that affects several of the hottest white dwarfs, namely the occurrence of ultra-high excitation absorption lines. While this was thought to affect mainly hydrogen-deficient white dwarfs, her discovery of two new white dwarfs also showing these obscure features demonstrates that the phenomenon affects a significant fraction of all stars in the universe at the beginning of the white dwarf cooling sequence. An important consequence of this is that without knowledge of the mechanism responsible for creating these lines, it will not be possible to derive the hot end of the white dwarf luminosity function accurately. Nicole's discovery of both a photometric and spectroscopic variable white dwarf showing ultra-high excitation absorption lines lead her to the interpretation that these lines stem from a shock-heated, co-rotating magnetosphere, which would solve a decades long mystery.

Nicole now holds an Open Topic Postdoctoral Fellowship at the University of Potsdam. She will continue her research on hot white dwarfs from large sky surveys and deepen her studies on the class of white dwarfs which show ultra-high excitation absorption lines as well as close binary systems.

Dr Mehdi Saravani

Project: Nonlinear evolution and causality beyond general relativity ***University of Nottingham***

For the past 100 years, General Relativity has been our most successful theory of gravitational interactions. Although it is a simple theory which has been consistent with all observations, many alternatives have been proposed with motivations ranging from quantum gravity, cosmology and resolving dark matter/energy to testing Lorentz violation.

The recent discoveries of gravitational waves produced by mergers of black holes and neutron stars have provided a new avenue of testing alternative gravitational theories in a new regime. The simultaneous detection of gravitational and electromagnetic waves of a binary neutron star merger has put a severe bound on the speed of gravitational waves. Mehdi has studied the consequences of this discovery for Horava gravity, a proposed alternative theory of gravity.

Additionally, the detection of gravitational waves from binary black hole mergers has helped us better understand the structure of black holes. That is why a comprehensive study of black holes in modified gravity theories is vital. During the Fellowship, Mehdi studied the black hole horizon structure at the extremal limit in theories that allow superluminal signal propagation. In addition, he investigated the causal structure of black holes in Horndeski theory, a well-known class of modified gravity theories. Both works help us better understand black holes in a wider class of gravitational theories.

Following these studies, Mehdi has introduced a classification of Horndeski theories based on their black hole structures and identified a specific sub-class with very interesting properties. This classification could play an important role in future studies of Horndeski theories.

Mehdi is now a corporate treasury strategist at Goldman Sachs.

Industrial Fellows

Alex Ballisat
Project: Model assisted qualification of non-destructive testing methods
Sponsor: STL Porton Down and CFMS Services Ltd ***University of Bristol***

A cornerstone of assuring structural integrity across many industries is the use of non-destructive inspections to probe the internal state of an object without causing further damage. These inspections require qualification to demonstrate reliable detection of defects prior to their use in service. Traditionally, this has been achieved using expensive and time-consuming experimental trials. Within the Ministry of Defence this problem is exacerbated by a scarcity of defect specimens and the short time scales in which inspections have to be developed, qualified and deployed.

Alex's project developed and demonstrated a methodology which allows the vast majority of these experimental trials to be replaced with the results of computer simulations of the inspection. This methodology also provides optimisation information and sensitivity analysis as a by-product, informing operators how to perform the best possible inspections. This has significantly reduced the time and cost of introducing novel inspections into service.

The success of this work has allowed the project to continue following the completion of the doctorate with Alex taking a research position at the Centre for Modelling and Simulation (CFMS). Alex's work at CFMS has focused on applying this methodology to the inspection of pipelines, optimising and validating permanently installed sensor technology to detect and monitor corrosion degradation of pipes, an inspection challenge faced across a broad range of industries. This is allowing the methodology to be further refined, demonstrated and presented to a wider audience.

Alex is now continuing in his role as a Senior Research Engineer at CFMS, applying these tools and techniques to a broad range of sectors and simulation challenges.

Arnau Garriga Casanovas
Project: Robotic deployment of NDE probes inside aircraft engines for in situ inspection
Sponsor: Rolls-Royce plc ***Imperial College London***
Arnau's project proposed a new robot concept to perform inspections of jet engines while the engine is on-wing. The device resembles a "snake-robot", and consists of two main parts: a gross-positioner, to reach the engine region of interest, and a fine-positioner, which is mounted at the tip of the gross-positioner, and which can accurately deploy a probe mounted at its end.

The proposed gross-positioner belongs to the category of robots known as concentric-tube robots, while the proposed fine-positioner belongs to the category of soft robots. Arnau conducted research on both devices. The overall robot concept proposed and work conducted is also applicable to perform minimally invasive surgery (MIS).

In terms of gross-positioner, Arnau discovered the complete set of trajectories that concentric tube robots can follow in a stable manner using a type of motion known as follow-the-leader. Unfortunately, the trajectories are excessively short to be used in jet engines. However, they show potential in MIS.

In terms of fine-positioner, Arnau proposed a new robot design, which offers higher force than equivalent robots of its kind. The design was patented. Arnau also made advancements to the control of the robot that enable robust and accurate positioning of the tip of the robot. An important part of the work on control was done in collaboration with Dr Enrico Franco. This work is expected to lead to a miniature snake-robot that can be controlled accurately to position its tip to any position and orientation in 3D space in the near future.

Lastly, Arnau worked on the fabrication of prototypes of the different parts of the full robot concept and successfully validated their performance.

The work completed in this project laid the foundation for a new "snake-robot" capable of performing on-wing inspections of jet engines, and led to an early prototype of its main parts. The "snake-robot" has the potential of significantly reducing inspection costs for the sponsoring company while ensuring safety. The work also involved a general analysis and review of solutions for on-wing inspections, which can be a useful reference for the development of new technology for the company.

Arnau is now conducting post-doctoral research at Imperial College London.

Aaron Chadha
Project: High-speed analysis of big video data
Sponsor: BAFTA ***University College London***
Aaron's project focused on making visual similarity and action recognition in video practically applicable in low-resource computing systems.

This project originated before the Fellowship commenced, but the Fellowship award strengthened Aaron's participation in the project, which in turn accelerated developments and results for the final prototype.

BAFTA are now considering applications and commercial trials of this technology in a number of media production and distribution contexts, such as detection of unauthorised online distribution of content, corporate logo detection, content de-duplication for very large video databases in the creative industries sector, etc.

Aaron is now a postdoctoral research fellow at UCL working on deep neural networks for computer vision.

Susanna Challinger
Project: Work function study of materials including fingerprint recovery by electronic imaging
Sponsor: KP Technology Ltd ***University of St Andrews***
Susanna's research focussed on measuring the energy levels of materials. Knowledge of the energetic structure of semiconductors and electronic materials is critical for the efficient operation of the devices that underpin our modern world. KP Technology's combined ambient pressure photoemission and Kelvin probe system was adapted for use in vacuum and nitrogen blanket/ controlled humidity environments which allowed changes in the energy level characteristics due to atmospheric conditions to be investigated.

Energy level research was conducted across a broad range of materials with particular focus on solar cell materials, including perovskite and organic semiconductors, and diamond, an excellent high temperature semiconductor. Additionally, the use of the scanning Kelvin probe for fingerprint recovery was explored. This non-contact, non-destructive technique provided high quality, identifiable fingerprint images from invisible prints on a variety of metals including iron and brass. The study was conducted across a range of flat and cylindrical surfaces including fired cartridges, in collaboration with Police Scotland and the National Crime Agency.

Susanna represented KP Technology at a range of international conferences winning three poster prizes: two in diamond research and one in forensics. The research undertaken during this fellowship has resulted in seven peer-reviewed publications to-date, with five as first author. Further work from the research projects will be submitted for publication in the short to medium term future.

Susanna has now accepted a position within the Hydrology Department at the Scottish Environmental Protection Agency (SEPA).

Joshua Elliott
Project: Integrated ultrasonic imaging for the inspection of near-surface defects in safety-critical components
Sponsor: Rolls-Royce plc ***Imperial College London***
Josh's project developed and assessed the performance of super resolution ultrasonic array algorithms for use in the Non-Destructive Evaluation (NDE) of nuclear power plant components. These algorithms have the potential to accurately size small defects far better than conventional techniques used within the industry.

Josh has recently published a peer-reviewed journal article outlining a computational study he completed which investigated the performance of the super resolution algorithms against the widely studied total focussing method in sizing small embedded planar defects. The defects investigated had a range of sizes, orientations and magnitude of surface roughness. This paper can be found via its Digital Object Identifier 10.1109/TUFFC.2019.2925974. This work was presented at the international QNDE conference and the UK BINDT conference.

Josh is also currently completing experimental work where the super resolution algorithms will be used to characterise manufacturing style defects within hard to inspect components (austenitic stainless steel welds). Conventional techniques often struggle within components of this type so if the super resolution methods are successful, it could lead to significant improvements of manufacturing NDE inspections within the company. This marks the first time to his knowledge that these methods have been experimentally applied to components of this type. Once this work is completed, an industrial journal paper will be written.

Josh's work forms the foundation for a research task within the business which looks to investigate the potential application of these advanced imaging methods to future manufacturing inspections. The research he has conducted has driven plans for future research programmes, which Josh will be a part of having become a full-time employee of Rolls-Royce Submarines.

Rachel Fort
Project: A molecular modelling tool for predicting hydrocarbon properties
Sponsor: BP ***King's College London***
Molecular dynamics modelling is a valuable tool that can be used to evaluate molecules and systems without running costly or hazardous synthesis and physical testing. Rachel's project investigated the application of molecular modelling techniques, using commercially available software, to the challenges of predicting hydrocarbon properties at the extreme conditions found within internal combustion engines.

The aim was to discover whether the viscosity characteristics of the base oils used in lubricants could be accurately calculated and compared to experimental results in ambient conditions, and then progress to higher temperatures and pressures at which experimental data is not available. Rachel was also looking at ways to simplify the simulation process using modelling software recently purchased by BP in order to make modelling more accessible for technologists across the business.

Over the course of her Fellowship, Rachel learnt a lot about molecular modelling and the capabilities of the system and has been able to share this within the research community at BP. Although the main aim of the project was not ultimately fully successful, progress has been made in understanding the systems of interest and how to model them.

During her Fellowship Rachel progressed within BP, working in different roles across Product Development and Research. She has now started a new role in Technology Deployment, turning BP's lubricant formulations from test results and a 'recipe' into products in the market.

Adam Funnell
Project: Dynamic photonic networks for UHD production services
Sponsor: BBC Research and Development ***University College London***
The future of live broadcast production requires high quality video and audio streams for immersive and interactive personalised content, resulting in an enormous increase in the data rates required. Uncompressed media sources can reach 200 Gbit/s, and although the broadcast production industry is transforming to use commodity IT hardware, current data centre network connectivity cannot meet the strict timing and traffic requirements of live media creation.

Dynamic optical networks are a promising technology for media production. Fibre optic links can easily accommodate the required data rates, and Adam's project explored the use of rapidly reconfigurable optical data transmitters and receivers for use across optical star networks. The developed network designs have ideal properties for media production networks, such as the efficient broadcast of input media signals to multiple outputs simultaneously, and nanosecond scale network reconfiguration times.

During the Fellowship, a dynamic optical network which precisely meets the needs of media production was designed and simulated, using network data and plans from real BBC production centres. Simulations showed that the developed network design would consume 41% less power and cost 35% less than existing comparable network prototypes.

Experimental demonstrations were performed of key network subsystems including fast tunable lasers and novel receiver topologies. These innovations will inform future media production centre designs and have resulted in several academic journal and conference publications.

Adam is now a University Teacher at the University of Sheffield. He leads the Computing, Control and Electronic Engineering team in the Department of Multidisciplinary Engineering Education, developing a revolutionary approach to the practical, hands-on training of undergraduate and postgraduate engineers.

Jordan Homan
Project: Influence of acoustic mixing on energetic materials
Sponsor: QinetiQ ***Imperial College London***
Jordan's project aimed to determine the impact of resonant acoustic mixing on energetic materials, or explosives. Resonant acoustic mixing is a novel mixing technique that has the potential to dramatically reduce mixing times, as well as produce novel materials that may not be able to be currently processed. The research conducted focused on polymer-based composites and proved that the mixing method did not impact the materials' behaviour. The study did highlight that new mixing methodology needs to be developed to effectively use the technique and that applying the current methodology leads to an inhomogeneous sample with varying degrees of curing.

The primary result of this research is that QinetiQ now has a scientifically based increase in confidence and has developed the ability to mix a range of explosives with this technique. As a direct result of this research, QinetiQ have acquired the next generation of the mixer: one specifically designed for explosive compositions. This will enable QinetiQ to produce new and novel bespoke charges with greater ease.

Jordan continues to work at QinetiQ in the energetic analysis group.

Chao Jiang
Project: Epigenetic re-activation of aged mesenchymal stem cells to proliferate and differentiate into the osteoblast lineage
Sponsor: UCB Celltech ***University of Oxford***
Ageing is associated with a significant decline in the proliferative and osteogenic potential of mesenchymal stem cells (MSCs), which results in a decreased bone mass and bone strength, leading to an increased risk of age-related fragility fractures. However, the cause of the age-related impairment of MSC functions remains unclear.

Chao's research revealed novel transcriptional and epigenetic mechanisms of MSC ageing. This better understanding of the mechanism of MSCs revealed novel candidates for bone anabolic, which UCB is strongly interested in. In particular, Chao has demonstrated for the first time that restoring the canonical WNT signalling activity in aged MSC restored their impaired osteogenic potential. More importantly, this study demonstrated the validity of the concept that a multi-omics approach can be used to gain insight towards the mechanisms of MSC ageing and to identify promising candidates to restore MSC functions in the elderly. There is a wealth of information within the data generated in this project that needs to be followed up within the company and may lead to additional therapeutic candidates for replenishing MSC and osteoblast numbers in individuals with age-related bone loss.

Chao is now doing a graduate course in medicine and surgery at the University of Cambridge, after which he plans to apply for posts in academic medicine in order to combine both clinical work and research.

Jennifer Longyear

Project: Developing remote sensing tools for quantifying ship-borne marine fouling biofilms

Sponsor: International Paint Ltd ***University of Southampton***

Fouling control coatings are increasingly sophisticated as the industry chases down the challenge of marine slime, which causes frictional drag and so incurs globally relevant emissions penalties across the marine fleet. As such, coating performance assessment tools that give insight as to both coating efficacy and mode of action are required to rapidly progress technology design.

Jennifer's project developed novel imaging techniques that quantify and map photosynthetic biofilm biomass from spectral reflectance, a step change from the previous categorical standards of Low, Medium and High fouling. Biomass estimation tools Jennifer has built are now routinely used in International Paint's fouling control research and development projects, and the next phase of research includes both how to effectively deploy the imaging tools for in-dock fouling assessments and avenues for commercial exploitation. These approaches are an industry-first.

Additionally, Jennifer has created spatial and spectral heterogeneity analysis techniques that will be immediately useful in examining biological underpinnings of biofilm-induced drag. Analogous approaches might have a much wider application across the business to quantify coating properties, defects, and performance, and Jennifer will be running an internal hyperspectral imaging and analysis consultancy for her colleagues to broaden the impact of her work.

Jennifer is continuing as Technical Lead of the Marine Biofouling project at International Paint, maintaining an active collaboration with the University of Southampton.

Sheun Oshinbolu

Project: Analysis of critical quality attributes in monoclonal antibody for biopharmaceutical process development

Sponsor: GlaxoSmithKline ***University College London***

Aggregation is the self-association of protein molecules which can affect the safety, function and efficacy of a medicinal drug. To aid better decision-making for selecting cell lines and candidate molecules, there was a need to measure protein aggregation earlier in the process development. Hence, the aim of Sheun's project was to develop an assay to measure aggregation of antibodies without prior purification of cell cultures.

Fluorescence Resonance Energy Transfer (FRET) was used to design an assay to measure aggregation based on the distance of two fluorophores. The FRET assay was initially designed to measure monoclonal antibodies aggregation, but they were found to put the two fluorophores outside the detectable distance for FRET to work. However, the FRET assay had success in measuring aggregates of a smaller protein (lectin (38kDa)) in cell culture medium, down to 5% aggregation with strong linearity. Therefore, the assay has the potential to work with smaller proteins that enable the two fluorophores to come within the detectable distance.

Overall, the characteristics of proteins suitable for the FRET assay were identified and the methodology for developing a FRET assay could be applied in designing and understanding other FRET assays with donor and acceptors free in solution. The research has also been presented at an international conference.

Sheun is currently writing up her thesis.

Pratyay Poddar

Project: Low cost quantum information processing using Si based surface acoustic wave quantum computation

Sponsor: Hitachi Europe Ltd ***University of Cambridge***

Quantum computers offer a great opportunity to spur the development of new breakthroughs in science and improve medication to save lives. In addition, machine learning methods to diagnose illnesses sooner, materials to make more efficient devices and structures, financial strategies to live well in retirement, and algorithms to direct resources more efficiently.

There are a few different ways to create a qubit – the fundamental unit of quantum information processing. During his industrial PhD, Pratyay focused on a novel method of quantum information processing in silicon. Using Surface Acoustic Waves (SAW) in silicon, this project was devoted to developing affordable and scaleable quantum computing with an easily adaptable and well-established silicon technology.

Since the award was made, Hitachi Europe Ltd and the University of Cambridge started a new collaboration to develop SAW-based quantum computing in silicon. Over the course of this project, further collaborations were formed with the Central Research Laboratory, Kokobunji, and JAIST, Kanazawa (both in Japan), Purdue University (US) and the University of Glasgow (UK). Pratyay represented Hitachi and the University of Cambridge at multiple international conferences in the UK and overseas, including in Japan, India and New Zealand, and won a number of competitions and awards including the highest scientific achievement award in Hitachi Ltd in Japan – the Kenkai Award in 2016 for "Transferring spin data with surface acoustic waves".

The Industrial Fellowship has directly contributed to these successes by helping Pratyay put in place a framework for the development of complex, multi-disciplinary systems. This has improved 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 two interns.

Following his PhD, Pratyay founded a MedTech company, *perfexia Health Technologies Ltd*, based in Cambridge, in which he serves as CEO. His immediate goals are to apply the technical and commercialisation skills that he has developed during his industrial fellowship to make *perfexia* a viable business.

Tim Sudmeier

Project: Electrochemical ammonia production in molten salt systems for energy storage applications

Sponsor: Siemens Corporate Technology ***University of Oxford***

Electrochemical ammonia synthesis provides the tantalising possibility of CO_2-free long-term energy storage for renewable power sources and a way to produce fertilisers in a sustainable fashion. Working with Siemens, Tim investigated two different approaches to electrochemically form ammonia from air and water, using water- and molten salt-based media.

In the molten salts, Tim was able to elucidate the mechanism of ammonia formation showing previous literature reports to be flawed. Using these mechanistic insights, Tim devised a novel strategy to conclusively show ammonia synthesis in such systems and was able to produce ammonia at one of the highest rates recorded to date. This led to a patent application by Siemens for a molten salt strategy to electrochemically form ammonia. Additionally, Tim designed novel metal nitride-based catalysts which exhibit interesting ammonia synthesis activities in the molten salt opening up a potential avenue to further improve rates in the future to bring electrochemical ammonia synthesis closer to application.

In water-based media, Tim screened a library of novel catalysts and took significant steps towards understanding the main competing reaction of ammonia synthesis.

Throughout this project Tim provided Siemens with a detailed overview of the state-of-the-art in electrochemical ammonia production, outlined the many challenges in the area and potential strategies to overcome these, supporting Siemens in their strategic planning to commercialise ammonia as an energy store and green fertiliser.

Tim continues to work in the Tsang lab at Oxford, writing up publications and training colleagues in the use of the customised equipment enabling them to carry out further work on electrochemical ammonia synthesis in molten salt systems.

Louisa Waine

Project: Network design for low energy curing

Sponsor: AkzoNobel ***University of Sheffield***

Louisa's project aimed to modify and optimise technologies used within coatings to achieve the required ultimate film performance whilst using significantly less energy to deliver these targets. It was anticipated that in better understanding the structure, reactivity and general polymer design criteria to deliver high film performance, this knowledge could be applied to design and synthesise an optimal technology combination to allow performance criteria to be achieved at lower film formation temperatures.

To gain initial insight into the chemistry used, work was carried out to understand the side reactions which could occur, the prevention of these side reactions and to give greater understanding on optimum processing conditions.

Once processing conditions were confirmed, controlled polymers were produced. These types of polymers have never been used in coatings before and have very interesting possibilities due to how they can be easily modified to modify properties.

Relationships with the changes in polymer vs coatings properties have been reported and further work is to follow.

If relationships discovered from this project give an insight into understanding lower film formation temperature coatings, this will most importantly save a large amount of energy in heating large ovens.

Louisa is now continuing her research as a full-time employee at AkzoNobel.

Industrial Design Students

Ewan Alston
Course: Design Products ***Royal College of Art***
Ewan graduated with two projects that present alternative production models for cities looking to move towards circularity and sustainability.

The first, *GoodWaste*, proposed furniture and fittings for a specific housing development made from the surrounding area's abundant and diverse waste streams; waste that includes offcuts of high-quality materials like marble, Corian and metals, due to the area hosting the largest industrial site in London, Park Royal. Designed in collaboration with two classmates, *GoodWaste* represents a new model of highly local, highly circular manufacturing where cities make use of the materials and resources around them in order to reduce their environmental impact and help local communities thrive.

Ewan's personal project, *Resource/React*, aims to build on this by using maturing technologies like machine vision, generative design and additive manufacturing to make the concept more scalable. The project proposes a system in which offcuts are scanned and identified as the material is cut, allowing manufacturers to keep a digital inventory of their stock and enabling a platform that automatically generates designs for objects based on whatever offcuts are available locally. For an initial test, a lamp was chosen as the exemplar object and standard metal profiles were the chosen offcut. At the RCA Show, Ewan presented 7 variations of one lamp, all based on the same design that was automatically adapted for a variety of real offcuts sourced in London. The joining parts were designed parametrically so that they could auto-update for the selected offcuts before being 3D printed.

Since graduating, Ewan and his collaborators have joined the InnovationRCA incubator and started *GoodWaste* as a business. Their first project involved a range of homeware products made from waste materials, commissioned by Selfridges for sale online and in their flagship Oxford Street store. Upcoming projects will incorporate aspects of *Resource/React* and include public realm work with The Mayor's Office as well as collaborations with various global brands keen to bring the approach to their products or interiors.

George Anderson

Course: Industrial Systems, Manufacture and Management ***University of Cambridge***

Over the course of his Master's degree, George completed four commercial projects with a range of companies, from well-known multinationals to early-stage start-ups. He also participated in an overseas study tour, exploring themes from the course in an international context, and undertook a technically focused research project.

Working with a small, London-based mathematics education start-up called NumberFit, George developed a series of designs for products to be used within the company's games that use physical activity to teach maths to children. Going through the entire design process, George worked with teachers to design innovate concept systems with the goal of making the games more intuitive for the children. He then developed and tested the designs before creating a full manufacturing and rollout plan and working with manufacturers to commission the final products.

In his second project, George developed a number of "blue-sky" innovations for use within the supply chain for the Danish toy company LEGO. Focusing on harnessing new technologies, George explored known problems within the existing supply chain and developed solutions to create further efficiencies across the network.

In his third and fourth projects, George worked with two recent spin-out companies from the Department of Engineering at Cambridge University called Sorex Sensors and NeWT. The former had developed an innovative sensor technology and the latter had created the first wireless neo-natal monitoring system. For each of these companies, George developed a series of market analyses to explore suitable markets to enter the companies' technologies and then created business development roadmaps for the companies to efficiently develop their product for the chosen markets.

Before starting his research project, George embarked on a two-week international study tour of South Africa. Here, George explored some key themes of the course, such as the effects of national politics and culture on manufacturing and industry in an international context.

In his research project, George used 3D printing to create an ear plug that selectively blocks loud noises through a physical mechanism that uses no electronics and still allows the user to hear quiet sounds. This type of "smart" meta-material mechanism design exploits aspects of material structure and geometry to enable precise behaviours in systems – in this case the mechanism was tuned to expand within the user's ear canal, sealing it upon a sound in excess of 130 dB to protect the user's ear drum from damage. After the loud noise has subsided the mechanism contracts to allow the user to hear normally again.

George is currently working as a product manager for Amazon in London. Here, he aims to apply the principles that he learned in his Master's degree and develop a range of experience through the broad remit of his role.

James Fraser

Course: Innovation Design Engineering ***Royal College of Art***

James's second year group project involved the development of a new composite material: *re:flex*. *re :flex* is a shape memory material that can be programmed to change its form in response to heat. Despite over three decades of research into shape memory materials, they have still yet to be widely adopted and are largely invisible in our everyday lives. They are prohibitively expensive, difficult to obtain and even more difficult to process. Inspired by natural structures where the material is the machine, James and his team developed *re:flex* as a low cost, widely available and more sustainable shape memory material that can be manufactured at low temperatures on a large scale. *re:flex* was exhibited at the London Design Festival and Dutch Design Week in 2019, and the *re:flex* team are now looking for investment to take the project further.

James's graduation project, *solace*, was an award-winning interior lighting system powered by the energy of the sun. Each object in the series uses luminescence to concentrate light onto solar cells, increasing the power available from indoor natural light. This gathered energy is then used to power a series of LEDs, which give the light back to the user in the evenings when it is needed. Combining fluorescence and optics gives *solace* a unique aesthetic, drawing the eye away from the solar cell and into the narrative of light. For the user, the object works within the rituals that already exist in the home environment, and fits with interior design languages, making it possible to bring renewable energy directly and seamlessly into daily life. This project was awarded first prize in the KI Award in 2019 and was exhibited at the London Design Festival and the Furniture Maker's Exhibition in London.

Building on his successful solo project in sustainable design, James is now a Design and Engineering Associate at Sustainable Ventures in London. Sustainable Ventures' vision is to tackle climate change and resource scarcity through developing commercial solutions and innovative technologies. So far, he has consulted on several projects in a variety of sectors including the circular economy, electric vehicle transport, smart waste management and smart home thermal control.

Harvey Jones

Course: Innovation Design Engineering ***Royal College of Art***

For Harvey's final project, he created an augmented reality games console, AR_CADE. The combination of a cardboard arcade machine, cardboard toys and corresponding AR mobile software allows players to physically interact and pick up digital elements in a game with their hands. Utilising the user's smart-phone as the gaming headset in combination with the AR_CADE kit, the product provides an inexpensive gateway to an interactive mixed-reality world.

Combining his Physics undergraduate degree and Innovation Design Engineering Master's, Harvey has been able to fulfil a number of contracts since graduating including AR development, educational toys, and research and development for robotics education for children, alongside maths and computing tuition. Bringing design to education, Harvey is now Head of Education at Blueshift Coding – a robotics and coding education provider for ages 5 to 16.

Amos (Timi) Oyedeji
Course: Innovation Design Engineering ***Royal College of Art***
Throughout his Master's degree, Timi placed considerable focus on exploring how we might interact with hardware products in the future. Using prototyping and visual storytelling, Timi's projects invite people to take a peek into the future of various product sectors in a way that is relatable and meaningful.

In his final year, Timi explored the future of online music education, specifically drumming. This project, in which he collaborated with the Royal College of Music, brought real-time feedback to digital drumming experiences, a trend that is set to continue growing over the next few decades. By using a motion-tracking camera and highly reflective drumstick tips, Timi developed a cheap and effective system that would directly compare the drumming dynamics of drum students to that of their favourite online music tutors in real-time. In addition to this, Timi envisioned a future in which a drum teacher's arm movements could be recorded in one location and replicated by retrofitted robotic drumming arms in the student's location – literally bringing the presence of digital tutors into your room.

Upon graduating, Timi began freelancing for a variety of start-ups across London where he was facilitating design workshops with corporate bodies, developing branding guidelines for skin care companies and developing testing rigs for the next generation of wetsuits. Timi also spent time exhibiting his final year group project, *Cellul-air*, at both London Design Festival 2019 and Dutch Design Week 2019.

After taking time to travel and refine his body of work, Timi joined SPACE10, Ikea's research and design lab based in Copenhagen. Timi will be leading design research into emotional detection and recognition technology and investigating how this technology may one day change the way that we interact with products and furniture in the home.

Enterprise Fellows

Tara Massoudi
Technology: Transforming ocean wave energy into artificial coral reefs ***Zyba Ltd***
Tara was Lead Structural and Geotechnical Engineer and Head of Business Development for Zyba Ltd, which developed the world's first ecological coastal protection that grows an active breakwater and generates renewable electricity. Alongside reducing coastline erosion, the added benefits include creating or repairing coral reefs, providing new custom designed dive spots, restoring fisheries and enhancing beaches.

During Tara's Fellowship, Zyba's C-Cell wave powered generator was tested in Mexico, a delivery partner was found, potential customers engaged and initial funding raised towards a pilot installation.

Tara left Zyba in October 2019 to join Revolut as an Executive Assistant.

Jack Pearson
Technology: Automated 3D printing ***EngX Ltd***
Jack is Commercial Director of EngX Ltd which had developed a hybrid production process that automates 3D printing, assembly and wiring on one platform. During the Fellowship, Jack has moved on from seeking to establish this platform and is instead focusing on providing training and integration services for manufacturing with robots. EngX are revenue generating, having worked with DHL, Petronas and the Manufacturing Technology Centre. They have two more projects about to start and are liaising with the Royal Academy of Engineering to identify further links in their network. In addition, Jack is currently exploring how the skills he has learnt can be passed on through an internship or apprenticeship programme providing positions at start-ups for recent graduates.

Atif Syed

Technology: e-skin ***WootZano Ltd***

Atif is Chief Executive and Co-founder of WootZano Ltd, whose main product, Wootzkin, is a piezoelectric nanocomposite sensing material, especially useful in online grocery retail, where robots are not yet able to distinguish between ripe and unripe fruits and vegetables – WootZano's biggest customer to date is Ocado, the world's largest online grocer.

During the Fellowship, Atif secured two InnovateUK grants totalling £1.2m to continue the development of Wootzkin. Atif comments that "The Enterprise Fellowship has had an extraordinary effect on my business. The mentorship and support I had access to was amazing, especially at a time when one feels very isolated. We are now a team of 10 and rapidly growing. Just last year, we were only able to make 10 sensors a week. Our production capacity has now increased to 180 sensors a day with 99% yield. This is beyond belief but possible only because of extreme hard work by the entire Team WootZano. We are also going to start our first export to China in early 2020 and also plan on releasing our development kits to the general population as a taster for our technology. We will shortly be starting a crowd funding campaign to raise £500k and a further growth investment of £1 million into the business."

Hsin-Hua (Sheana) Yu

Technology: Postural support system ***Aergo Ltd***

Sheana is Founder and CEO of Aergo Ltd, which has designed the world's most adaptable postural support system. 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. Artificial Intelligence algorithms allow Aergo to promote comfort and protect skin integrity in every individual by adapting to positional changes automatically and effortlessly.

During the Fellowship Sheana was able to complete the development of Aergo's MVP (minimum viable product) with support from the mentorship program provided by the Royal Academy of Engineering. This milestone enabled Aergo to successfully complete CE marking in compliance with the Medical Device Directive, which means Sheana is now able to advance conversations with potential distributors in the industry. Sheana also raised £100k impact angel investment to fund pre-production and post market surveillance with early adopters and was awarded Women in Innovation by Innovate UK with £50k grant funding and a plaque installed to commemorate Aergo's achievement in innovating for disability. Sheana comments that "it's been extremely inspiring to be part of the 1851 Royal Commission community, meeting founders and leaders in various industries who have shared their experiences and knowledge with me".

Alumni Awards, Honours and Achievements

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

Overseas Scholars

Professor Wilfred Jefferies (1982-1985)
– Elected Fellow of the National Academy of Inventors

Professor Jennifer Martin AC FAA (1986-1989)
– Appointed Deputy Vice-Chancellor (Research and Innovation) at the University of Wollongong

Research Fellows

Dr Jo Ashbourn (2002-2004)
– Organised conferences on *A History of the Small* and *Paradigm Shifts Across the Ages* at the St Cross Centre for the History and Philosophy of Physics

Dr Owen Davies (2007-2009)
– Awarded a Wellcome Senior Research Fellowship to be held at the University of Edinburgh

Dr Thomas Montenegro-Johnson (2014-2017)
– Awarded Leverhulme Research Leadership Award
– Microbots exhibition, Thinktank Birmingham Science Museum

Professor Genevieve Langdon (2004-2006)
– Elected a member of the Academy of Sciences of South Africa

Professor Apala Majumdar (2006-2008)
– Appointed Professor in Applied Mathematics, University of Strathclyde
– Awarded FDM Everywoman in Technology Academic Leader Award
– Appointed to the Global Challenges Research Funding Strategic Advisory Group

Professor Elizabeth New (2009-2011)
– Awarded Prime Minister's Prizes for Science, Malcolm Macintosh Prize for Physical Scientist of the Year
– Awarded Le Fèvre Medal, Australian Academy of Science and Royal Australian Chemical Institute
– Awarded Outstanding Achievements of Young Alumni Award, University of Sydney
– Awarded Senior Fellowship of the Higher Education Academy
– Appointed to Sargeson Lectureship, Royal Australian Chemical Institute Inorganic Division
– Finalist (top 5 worldwide) for Universal Scientific Education and Research Network Prize, physical sciences category

Dr Anna Lisa Varri (2012-2015)
– Awarded Caroline Herschel Prize Lectureship, William Herschel Society and Royal Astronomical Society
– Awarded Future Leaders Fellowship, UK Research Innovation
– Awarded JSPS International Fellowship, Japan Society for the Promotion of Science and The Royal Society

Professor André Xuereb (2011-2014)
– Appointed Head of the Department of Physics, University of Malta
– Appointed Associate Editor of the *New Journal of Physics*

Industrial Fellows

Dr Matthew Harwood (2011-2014)
– Appointed Principal Scientist, Certara UK Ltd, Simcyp Division

Dr Steve Greenland (2013-2016)
– Awarded Enterprise Fellowship, Royal Society of Edinburgh
– Awarded EO for Society contract from the European Space Agency to support advocacy groups in data deprived areas through social enterprise Omanos Analytics
– Awarded UK Space Agency mission for in-orbit demonstration of quantum-secure telecommunications through start-up Craft Prospect Ltd

Dr Ruth Tunnell (2011-2014)
– Appointed Senior Principal Scientist – Energetics, QinetiQ

Dr Edward Williamson (2017-2019)
– Appointed Senior Materials Engineer, MBDA

Enterprise Fellows

Henrik Hagemann (2016-2017)
– Awarded West London Business Award's Technology Business of the Year (for CustoMem)
– Selected for the European Forbes' 30 under 30 list under the Manufacturing & Industry category (for CustoMem)

Victoria Hamilton (2017-2018)
– Granted US patent for Recoil Kneepads

Built Environment Fellows

Michael Hebbert (1998-2000)
– Published 'The Long After-Life of Christopher Wren's Short-Lived London Plan of 1666' *Planning Perspectives 2018*

Rome Scholars

Anne Desmet (1989)
– Miniature print, 'Manhattan', awarded first prize at World Art Print International, Sofia and Mini Print International, New York

Alumni Pledges and Donations

On occasion, the Commission is fortunate to receive donations and bequests from alumni. In 2019, the Commission received a bequest from the estate of Lady Rooke. Sir Denis Rooke OM CBE FREng FRS was Chairman of Commissioners from 1987 to 2001. The bequest is for the general charitable purposes of the Commission. The Commission extends its grateful thanks to the Rooke family and 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 2019 stood at £128m compared with £111m at 31 December 2018. The total expenditure on charitable activities during 2019 was £4.3m, compared to £4.1m the previous year. For the last eight 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 8.3% 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 2019 met two times. I would like to thank all members of the Committee for their sterling work in overseeing the Commission's finances.

Sources of Funding

The Commission's income and gains derive primarily from its investment portfolio. In 2019, property (the Commission's estate) made up 16%, stock market investments and bonds 83% and cash 1% of the capital assets (for 2018 the corresponding restated figures were 17%, 83% and less than 1% respectively).

Reserves Policy

The total funds at the balance sheet date were £128,403,095 (2018 (restated): £111,081,240).

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 Commissioners believe that they can best 'make a difference' by maximising the financial return from the investment portfolio and using that return to fund fellowships, studentships and other charitable grants. The Commissioners' investment objective is therefore to achieve sufficient total returns to fund the existing award programmes whilst also protecting the capital value of the portfolio for future beneficiaries. Superior performance will be used to sustainably expand the programme of activities. The Commission reviews its asset allocation and manager selection on a regular basis with these objectives in mind.

Commissioners have 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 over the long term. In order to ensure sufficient liquidity so 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 £66.7m managed by Schroders (C.I.) Ltd; a portfolio of exchange traded funds of approximately £39.2m actively managed by Charles Stanley & Co. Ltd and an investment of approximately £6.6m in a strategic bond fund managed by JP Morgan Asset Management Ltd. The Commission also owns the freehold of various properties on its legacy estate in South Kensington valued at £21.4m.

The overall portfolio targets an absolute return over the economic cycle 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 recognises that its investments have wider impacts and seeks to align its investment strategy with its aims, reflecting the views of its stakeholders and taking into account broader public benefit. The Commission expects its investment managers to integrate Environmental, Social and Governance (ESG) considerations into the normal investment process and to fulfil the requirements of the UK Stewardship Code, actively engaging with the companies in which they invest to promote best practice corporate behaviour and sustainable business practices. Given its limited staff resources, it is not practical for the Commission to engage directly with individual companies, but it does expect its investment managers to report annually on their engagement activities and results.

The Commission expects its investment managers to apply ESG considerations to both segregated holdings and pooled holdings, taking account of the extent to which suitable alternative investment vehicles are available and bearing in mind de minimis considerations. The Commission will only appoint managers who are signatories to the UN Principles of Responsible Investment (UN PRI) and will take into account the ranking assigned to those managers by the UN PRI.

The Commission may exclude certain stocks or sectors where these are seen to be in direct conflict with its objects and activities. Equally, where consistent with the financial objectives, the Commission seeks to invest in areas with positive environmental and / or social impact, such as clean energy and various areas of new technology.

The Commission recognises that climate change is a key challenge for the next decade and that limiting global temperature rises will require significant change in business, investment, technology development and fossil fuel use. The Commission monitors the carbon emissions of its main equity investment portfolio and through its investment managers seeks to reduce these emissions over time. As at the balance sheet date, the Commission's main segregated equity portfolio had scope 1 and 2 carbon emissions that were 67% less than the MSCI World index.

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

In 2019, the portfolio generated returns of £22,144,755 (2018 (restated): negative returns of £1,095,957). After allowing for donations and other income of £24,792 (2018: £7,798), total expenditure of £4,924,544 (2018: £4,773,804) and actuarial gains of £76,852 (2018: losses of £6,053) this resulted in a net increase in funds available to finance future grants of £17,321,855 (2018 (restated): net decrease in funds of £5,868,017).

The total return comprises income and gains / losses. The annual income generated in 2019 by the Commission's assets was £2,728,598 or approximately 2.5% of opening portfolio value, the yield being broadly consistent with the previous year (2018: £3,180,400, 2.6%). 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 2019, the Commission's liquid investment portfolio enjoyed gains of £17,229,216 (2018: loses of £6,068,767) further boosted by revaluation gains on directly held property of £2,186,940 (2018 (restated): gains of £1,792,410).

Expenditure on raising funds – which primarily comprises investment and property management fees – decreased from £683,840 to £658,343. This decrease primarily reflects the fact that in the previous year substantial fees were incurred in respect of a commercial rent review.

Total expenditure on charitable activities of £4,266,201 was £176,236 more than the previous year. This primarily reflects increased direct charitable expenditure on networking and educational events, including in particular the inaugural Great Exhibition Road Festival, a flagship STEM outreach event for the general public bringing together all the Commission's legacy institutions in South Kensington, but also including outreach activity in connection with the associated *Engineers* event held in conjunction with the BBC World Service; ChemFest 2019, celebrating 150 years of the periodic table; and an enhanced Annual Reception for the Commission's current award holders.

Overview

2019 was a good year for equity investors.

The Commission manages its assets on a total return basis. Overall the Commission achieved a total return net of fees of approximately 18%, considerably in excess of the RPI + 4% target for the year of 6.2% and the LIBOR rate of 0.67%. This return was comfortably ahead of peer group indices such as the ARC Equity Risk Charity Index (17.4%), although somewhat below stock market indices such as the MSCI AC World (21.7%) and the IA Global Equity Index (22.1%). In 2018 the Commission achieved a total return of approximately -1.5%, compared to a target of 6.7%, an MSCI AC World Index return of -3.9%, an IA Global Equity Index return of -5.6%, ARC Equity Risk Charity Index return of -6.1% and LIBOR rate of 0.45%.

Looking at the last eight years together, since the current investment policy was established, the real return on the portfolio net of fees has averaged 8.5% 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 charitable expenditure during the year increased slightly in absolute terms, it fell marginally as a percentage of the trailing three-year average closing capital value of the portfolio from 3.7% in 2018 to 3.6% in 2019; in both years it remained slightly below the target of 4.0%. Commissioners will consider the scope in coming years 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 to make additional Special Awards. Commissioners also remain mindful of the desirability of maintaining disbursements through periods of inferior market return.

The Commission's Auditors

In 2008, Moore 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 2019

	2019 £	As restated 2018 £
Income		
Donations	20,000	3,850
Investments	2,728,598	3,180,400
Other	4,792	3,948
Total income	2,753,390	3,188,198
Gains and losses		
Gains on property	2,186,941	1,792,410
Gains / (losses) on investments	17,229,216	(6,068,767)
Actuarial gains / (losses) on defined benefit pension scheme	76,852	(6,053)
Total gains and losses	19,493,009	(4,282,410)
Total resources available	22,246,399	(1,094,212)
Expenditure		
Raising funds	658,343	683,840
Charitable activities	4,266,201	4,089,965
Total expenditure	4,924,544	4,773,805
Net movement in funds	17,321,855	(5,868,017)
Reconciliation of funds		
Total funds brought forward	111,081,240	116,949,257
Total funds carried forward	128,403,095	111,081,240

Royal Commission for the Exhibition of 1851

Summarised Balance Sheet
as at 31 December 2019

	2019 £	As restated 2018 £
Fixed asset investments		
Investment properties	21,370,300	19,903,865
Listed investments	110,771,099	96,856,625
Cash held as part of the investment portfolio	1,656,546	161,847
	133,797,945	116,922,337
Current assets		
Debtors	272,882	346,157
Cash at bank and in hand	950,898	651,176
	1,223,780	997,333
Liabilities		
Creditors: Amounts falling due within one year	(3,867,120)	(3,645,674)
Net current liabilities	(2,643,340)	(2,648,341)
Total assets less current liabilities	131,154,605	114,273,996
Creditors: Amounts falling due after more than one year	(2,324,510)	(2,663,756)
Net assets excluding pension liability	128,830,095	111,610,240
Defined benefit pension scheme liability	(427,000)	(529,000)
Net assets	128,403,095	111,081,240
The funds of the Charity:		
Capital Funds		
Balance as at 1 January	111,081,240	116,949,257
Movement in year	(17,321,855)	(5,868,017)
Balance as at 31 December	128,403,095	111,081,240

Royal Commission for the Exhibition of 1851

Note to the Summarised Financial Statements for the Year Ended 31 December 2019

1. CHARITABLE ACTIVITIES

	2019 £	2018 £
Grants	3,617,560	3,598,461
Direct costs	335,329	213,127
Support costs	313,312	278,377
	4,266,201	4,089,965

Analysis of grants and awards committed in the year:

	2019 No.	2019 £	2018 No.	2018 £
Research Fellowships	11	1,743,614	9	1,134,058
Industrial Fellowships	9	509,607	12	718,575
Industrial Design Studentships	9	354,850	11	496,260
Built Environment Fellowship	1	100,000	–	–
Design Fellowship	–	–	1	100,000
Enterprise Fellowships	3	187,762	3	187,500
Great Exhibition Scholarships	–	–	10	57,000
Special Awards	18	721,727	19	905,068
Total fellowships and studentships	51	3,617,560	65	3,598,461

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 46 to 48. Details of the Commission's professional advisers are provided on page 49.

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 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 also benefit from a Group Income Protection policy that will cover basic salary and pension contributions if they are 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. All of the above benefits are available to all employees, including key management personnel. 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*
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 Dame Lynn Gladden DBE 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 Chris Wise RDI FREng FICE MIStructE HonFRIBA FRSA

Professor Chris Wise was appointed to the Board on 17 April 2019
Professor Sir Richard Brook retired from the Board on 1 January 2019

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 retired from the Committee on 22 September 2019

Science and Engineering Fellowships Committee

Professor Dame Kay Davies DBE FRS FMedSci *Chairman*
Professor Gillian Bates FRS FMedSci
Professor Andrew Briggs
Professor Neil Champness FRSC FLSW
Professor Anne Dell CBE FRS FMedSci
Professor John Dewey 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 CBE FRS
Professor Stephen Muggleton FREng
Professor Rachel O'Reilly FRSC
Professor Sheena Radford FRS FMedSci
Professor Maurice Skolnick FRS
Professor Trevor Stuart FIC FRS
Professor John Wood CBE FREng

Professor Sheena Radford was appointed to the Committee on 18 January 2019
Professor Maurice Skolnick was appointed to the Committee on 5 June 2019
Professor Rachel O'Reilly was appointed to the Committee on 21 August 2019
Professor Sir Richard Brook retired from the Committee on 1 January 2019
Professor Christopher Dobson retired from the Committee on 1 January 2019

Industry and Engineering Committee

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

Naomi Climer was appointed to the Committee on 2 June 2019
Professor John Clarkson was appointed to the Committee on 27 November 2019
Professor Dame Lynn Gladden retired from the Committee on 1 January 2019

Built Environment and Design Fellowships Committee

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

Staff

Mr Nigel Williams CEng	Secretary
Mr Amahl Smith ACA	Finance Director
Mrs Helen Harris	Fellowship Programme Manager
Mrs Angela Kenny RMARA	Archivist and Alumni Relations
Ms Kat O'Dea	Office Manager / Executive Assistant

Mrs Jenifer Hewett, Senior Administrator, retired on 31 December 2019

Professional Advisers

Bankers

The Royal Bank of Scotland plc
South Kensington Branch
29 Old Brompton Road
London SW7 3JE

Investment Managers

Schroders (C.I.) Limited
Regency Court
Glategny Esplanade
St Peter Port
Guernsey GY1 3UF

Surveyors

Cluttons LLP
Portman House
2 Portman Street
London W1H 6DU

Charles Stanley & Co. Ltd
55 Bishopsgate
London EC2N 3AS

Strategic Property Advisors

Cushman & Wakefield LLP
125 Old Broad Street
London EC2N 1AR

JP Morgan Asset Management (UK) Ltd
20 Finsbury Street
London EC2Y 9AQ

Auditors

Moore Kingston Smith LLP
Devonshire House
60 Goswell Road
London EC1M 7AD

Legal Advisers

Farrer & Co LLP
66 Lincoln's Inn Fields
London WC2A 3LH

Actuaries

XPS Pensions
Albion
Fishponds Road
Wokingham RG41 2QE

Insurance Brokers

Aston Lark Ltd
9th Floor, Colman House
King Street
Maidstone
Kent ME14 1DN

Royal Commission for the Exhibition of 1851

453 Sherfield Building
Imperial College
London SW7 2AZ
Telephone: 020 7594 8790
Fax: 020 7594 8794
e-mail: royalcom1851@imperial.ac.uk
website: www.royalcommission1851.org
alumni: https://rc1851.hivebrite.com
LinkedIn: https://linkedin.com/company/royalcom1851
twitter: https://twitter.com/royalcom1851
instagram: https://instagram.com/royalcom1851