

Royal Commission for the Exhibition of 1851

Report of the Board of Management
and Summarised Financial Statements

For the year ended 31 December 2021



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 2021 was 136

Contents

Chairman's Report	1-2
Secretary's Report	3
The Work of the 1851 Royal Commission	3-4
Public Benefit	4
Grant-making Policies	4-5
Achievements in 2021	6-10
COVID-19	11
Future Plans	12
Awards Granted in 2021	13-20
Awards Completed in 2021	21-38
Alumni Awards, Honours and Achievements	39-41
Report by the Chairman of the Finance Committee	42-44
Summarised Statement of Financial Activities	45
Summarised Balance Sheet	46
Note to the Summarised Financial Statements	47
Administrative Information	48-49
Commissioners, Committee Members and Staff	50-52
Professional Advisers	53

Chairman's Report

In common with the nation as a whole, we were greatly saddened by the news of the death of HRH The Duke of Edinburgh on 9 April. As our President for forty-four years, His Royal Highness played a leading role in modernising the Commission, and that it continues to thrive today is due in great measure to his influence and interest: he gave us so much of his time and continued to follow our fortunes and offer encouragement throughout his retirement. We look back with great fondness and respect for a most remarkable man, whose vision and determination shaped the Commission's purpose for more than a quarter of its existence in the same spirit as our founder, Prince Albert.

2021 began with continued restrictions on movement as a result of the COVID-19 pandemic, and the office did not reopen until the summer. Thus, for a second year the annual fellowship rounds were conducted entirely online, a process which ran very smoothly and produced an excellent result, with some truly exceptional new appointments. For the first time the Brunel Fellowship was run as a separate competition, attracting a strong field as a result, and it was very encouraging to see a record number of applications from industry for Industrial Fellowships, reflecting well on our Fellowship Programme Manager after her first full year in post.

Unable to meet in person, we held our annual Alumni Science Evening in February online for the first time. Although a poor substitute for a live event, it did enable those from further afield to take part and was well received by all who did so. While we intend to return to the live model next year, we are looking at options for live streaming it, thus extending its reach to our alumni around the world as well as those in the UK who are unable to come to London.

As life slowly resumed a semblance of normality from mid-May onwards, the Commissioners met together in person for a strategy day to consider whether our approach to the task of "increasing the means of industrial education and extending the influence of science and art upon productive industry" was still making best use of our resources. An open and far-reaching debate concluded that there was no need for a revolution, but it is clear that we could be doing more to promote good industrial design, more to encourage sustainability, both as an outcome of research and across the legacy estate, and more to encourage a greater exchange of ideas through our alumni network. We also had a good look at the impact of the many interventions we have funded to promote STEM to school children. We agree with the growing consensus that the best results are achieved by focussing on teachers, in particular on primary school teachers, many of whom have a limited science background. Work is now in hand to develop all these themes further. Overall, it was a very productive day and the first opportunity to bring together the four new commissioners who have joined us since the beginning of last year with those of longer standing. It was good to see them in person, contributing fresh ideas which suggest the Commission is in good hands going forward.

In July we were able to hold our annual 'Engineers' event with the BBC World Service. Last year it was entirely virtual, so it was good to be able to draw a small live audience to the Victoria and Albert Museum to join a worldwide virtual audience on-line. The subject this time was Clean Energy, with three excellent speakers. Henry Snaith, Head of the Photovoltaic Group at Oxford and Kristian Holmefjord, Project Director Fuel Cells at Corvus Energy, both appeared live with BBC presenter Kevin Fong, and were joined virtually by Danielle Merfeld, Chief Technology Officer with GE Renewable Energy in California, for a wide-ranging discussion and some probing questions from the audience. The programme was broadcast on the BBC World Service and also, for the first time, on BBC World News television, both attracting large audiences.

September saw the staff return to the office for at least part of the week and we held our first live event, the Industrial Fellowships Awards Ceremony in early October, when we welcomed two years' worth of new award holders to the 1851 family. That was swiftly followed by the first celebration of the Sir Misha Black Awards since taking them under our wing in early 2020. This is a community whose aims are a very close fit with the Commission's: the celebration and promotion of good industrial design. They are a very welcome addition to our stable.

In November we were delighted to welcome The Princess Royal to a Fellows' Reception at Fishmongers' Hall. This was the first time we had been able to bring together award holders from across all our programmes since December 2019 and it was heartening to witness the enthusiasm

with which they interacted with each other. These gatherings of exceptionally bright early career scientists, engineers and designers are often cited as one of the greatest benefits of our awards and from the lively conversations around the room it was clear that they had been much missed. Award holders presented work from across the whole spectrum of our work to the President, including displays from our newest category of award, the Technical Teaching Fellowship, which aims to improve the quality of teaching in the Further Education sector. It was a most stimulating evening, and we are immensely grateful to Her Royal Highness for her continued interest in our work.

November also saw the 1851 Group, comprising the Chairs and Chief Executives of the 1851 legacy institutions, come together for the first time in two years. As well as endorsing plans for the Great Exhibition Road Festival in 2022, we discussed one of the defining issues of our time: the climate emergency. Although each institution is already committed to decarbonising their own footprint and inspiring change, there was a genuine enthusiasm to do more, and do more together, to make Albertopolis an exemplar zero emission urban neighbourhood. Thus, the South Kensington Zero Emission Neighbourhood (SouthKenZEN) initiative launches in January 2022 with the Commission funding initial baselining work.

As the Royal Albert Hall celebrated its 150th anniversary, albeit in a more muted style than originally planned, it was good to see the completion of the public realm works around the north of the building, which the Commission has helped to fund. The improvement to the setting is spectacular, with more space around the north porch and a much easier crossing to the Albert Memorial. Phase 2 – more elegant barriers and a new surface – is eagerly awaited.

The last two years have seen a significant turnover of Commissioners with four reaching the end of their ten-year terms of office. I am very grateful for their support, and that of the whole Board of Management who give so generously of their time. We have some excellent new Commissioners to replace them who are already making their mark.

Our Secretary, Nigel Williams, retires in May 2022 after nearly twelve years in post. Nigel was due to retire in 2021, but very kindly agreed to stay on until we could recruit his successor in a more normal post pandemic world. He will be much missed – he has done a spectacularly good job and I could not have had a more thoughtful, engaged and hard-working colleague. His successor is John Lavery, and I am delighted that he has agreed to join us, and I look forward to working with him during my final year.

I too have completed my term of office and I retire in December 2022 so this will be my final Annual Report. I have been a Commissioner for more than eighteen years and it has been a great privilege to lead the Board of Management for the last ten years. I am immensely proud of what the Commission achieves. I have seen, during my time as a Commissioner, a five-fold increase in the level of our resources and a commensurate increase in the amount of work we are able to do to make a difference to all the members of our ‘1851 family’. I will hand on the Chairmanship to Lord Kakkar and I am confident that under his leadership and with a very strong and refreshed Board of Management, the Commission could not be in better hands.

I finish by thanking all who have been part of the Commission or helped us as advisers during my time as Chairman. I send a particular thank you to our dedicated staff and to all my fellow Commissioners. I have no doubt that ‘The 1851’ will continue to flourish in making a difference by meeting the task set 170 years ago by Prince Albert: to increase the means of industrial education.

Bernard Taylor CBE DL FRSC

Secretary's Report

As the Chairman has intimated above, my time as Secretary to 'The 1851' is almost up and by the time this report is published the post will be in the very capable hands of John Lavery. It has been an enormous privilege to lead the small team charged with the day to day running of this extraordinary, but little heard of organisation, and one of the greatest pleasures has been seeing the realisation dawn on peoples' faces when I explain why a Royal Commission set up to organise an Exhibition in 1851 is still so relevant today. Watching our eminent committee members selecting the most talented early career scientists, engineers, embryonic designers and entrepreneurs, then observing them flourish with the benefit of our support over the course of their awards and beyond, has been one of the most rewarding aspects of the job. The 1851 family is a remarkable body whose influence and contribution across the board continues to grow. Equally, being at the heart of the unique cultural community that is Albertopolis which, with the help of the 1851 Group and the broader Exhibition Road Cultural Group is doing more together than ever before, has been an unforgettable experience in which I have been immensely proud to have played a part. My only frustration is that, despite my best efforts, we are still relatively unheard of; I leave that challenge for my successor!

I am incredibly grateful for all the support I have received from the Commissioners, committee members, staff and award holders and my colleagues across the legacy estate and beyond over more than 11 years and I wish the Commission every success going forward.

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 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 six 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 £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 Commission ensures that its work is for the public benefit and takes full account of the published Charity Commission guidance. The 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 – usually around ten to fifteen – 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 to ten 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 has now been increased to six.

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.

In addition to the above schemes, the Commission also administers, in conjunction with the Sir Misha Black Awards Committee, two awards in the field of design education, for which nominations are sought each year. Full details are available on the Commission's website but in brief these are:

Sir Misha Black Medal for Distinguished Services to Design Education

Global in reach, the Medal acknowledges the important contribution of individuals to the teaching of design at all levels, from anywhere in the world – as designers, as champions, as mentors and as educators.

Sir Misha Black Awards for Innovation in Design Education

Salutes educators from across the United Kingdom and celebrates the innovative achievements of institutions and individuals. Recipients may receive a bursary of £10,000 to advance their work in innovative design education.

Together the Sir Misha Black Medal and Awards recognise those who by innovation, vision and contribution to theory or practice have measurably improved the education of designers and enhanced the profile of design education.

Achievements in 2021

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 13 to 20.

The true impact of the Commission's award holders will only emerge over time, but some evidence of the success of the various programmes can be gleaned from the achievements of those Fellows who completed their awards during the year and the positions they go on to secure. A representative sample of case studies is provided on pages 21 to 38.

Many completing Fellows comment quite explicitly on the importance of their Fellowship to their success:

The 1851 Fellowship was instrumental in giving me a platform to establish my own independent research, and I'm grateful to all involved for the support I received over the three years.

Dr Stephen Cox, Research Fellow 2017

I am extremely grateful to the Royal Commission for enabling me to pursue my research and for the doors this position has opened up for me. I am now continuing my research as a post-doc at the University of Oxford and am in the process of submitting grants to start up my own research group exploring research questions enabled by this Fellowship.

Dr Paul Holloway, Research Fellow 2017

The Industrial Fellowship was the principal enabler of this project. The support of the Fellowship allowed me to justify and validate the ambition of a far-reaching research project, and it helped open important doors in this path. It is a great honour to be a Fellow of the Commission, and a fact that I will carry with pride for the rest of my career.

Alexandre Raymond, Industrial Fellow 2018

For some, it is clear that without the award from the Commission, their project would not have gone ahead:

Without the support of the Royal Commission, it would not have been possible to undertake this project. The opportunity to study at Oxford University has accelerated my career progression immensely without the financial burden of leaving full time employment. Working within a world leading institution has not only improved my academic knowledge and skillset but granted me introductions to medical professionals collaborating with the university, offering me unique insights and opportunities within the medical device sector. This has enabled me to grow my professional network in spite of various obstacles during my graduate studies.

Jonathan Vince, Industrial Fellow 2018

It is gratifying that Fellows often comment on the ease of administration and quality of communication with the Commission:

I recently finished my 1851 Fellowship, and I just wanted to say a huge thank you to everyone on the Royal Commission team! The Fellowship has been an amazing experience and has been instrumental in my career. Everyone at the Royal Commission has always been extremely helpful and easy to communicate with, and I really appreciate this.

Dr Paul Knott, Research Fellow 2017

A sentiment that often persists long after a Fellowship has finished:

My memories of the Royal Commission are of a caring, generous and understanding organisation, which promoted research while respecting independence.

Professor Crispin Gardiner, Overseas Scholar 1965

Many Fellows have been impacted by the pandemic and have appreciated the Commission's flexibility and additional support:

I wish to take this opportunity to thank you for the endless opportunities that this fellowship has brought, and for the outstanding support during the pandemic (without the additional measures you've taken to facilitate working from home, I would have not been able to get to this point). A special thank you to Amahl, for the infinite patience with which he's dealt with my requests / questions.

Dr Davide Foffa, Research Fellow 2018

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

This is the fourth Industrial Fellowship that I have had the pleasure of supervising and in my experience, this is the best scheme I have come across for developing individuals within industry that have the potential to undertake research for a higher degree without them having to sacrifice their employment.

Professor Andrew Lewis, Queen Mary University of London

Based on my excellent experience, I will definitely recommend the Industrial Fellowship scheme to my colleagues – it worked very well, and I very much appreciated the limited amount of paperwork. Thank you very much to all members of the Royal Commission for the Exhibition of 1851 for the prompt and flawless support during this fellowship!

Dr Patrick Gruber, University of Surrey

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 39-41.

The real-world impact of the work done by our alumni should never be underestimated. To give one topical example:

I wanted to send a short update on my 2020/2021 role as the Lead Scientist on the NHS COVID-19 app, deployed in England and Wales, with over 23m downloads. The algorithms deployed as part of the risk calculation within the app were developed (in part) during my PhD, as part of my 1851 Commission Fellowship. The risk scoring algorithm in the NHS app is considered to be world leading. I advised Google and Apple on their roadmap, worked with nations around the world, and provided scientific evidence to government ministers during the peak of the crisis to inform decisions. I led the team that developed the scientific basis for the app, including ensuring that the app received MHRA approval. We recently published a paper in Nature showing that the app reduced the number of cases of COVID-19 by (median) 600,000 in its first three months of operation (<https://www.nature.com/articles/s41586-021-03606-z>), which translates into thousands of potential COVID-19 related deaths averted too. The success of the NHS COVID-19 app is a direct result of my 1851 Commission Fellowship.

Dr Mark Briers, Industrial Fellow 2003

Moreover, the impact that our alumni go on to achieve is truly international. To take a couple of further examples almost at random:

In 2021, I designed and engineered an accessible all-in-one hand wash station to help improve hygiene in refugee camps and other areas of need around the globe.

The hand wash station delivers a complete and considered solution, whilst being very cheap to manufacture and fits perfectly in an air shipped palette, reducing overall costs. Thousands of the hand washing stations have been deployed by Oxfam to various refugee camps. Detailed feedback has shown them to be very effective, reliable and popular with users.

Matthew White, Industrial Design Student 1998

In 2021, one of the companies I set up at the end of my Fellowship, Omanos Analytics, worked in Kenya measuring the impact of geothermal plants on rural communities, connecting objective space data with the lived experience of those displaced by these large-scale complexes, and also worked in Indonesia allowing locals in the area to track the damage caused by tailing dams on their mobile phones through mixing geolocation, Earth imagery and local data collection.

Dr Stephen Greenland, Industrial Fellow 2013

Many of our alumni tell us that their Fellowship has made a decisive – and lasting – difference to their career:

The 1851 Studentship when I was at the Royal College of Art made a huge difference to me personally and without it, I do not think I would have been able to afford to do the Innovation Design Engineering masters and go on to found Concrete Canvas.

Peter Brewin, Industrial Design Student 2003

The 1851 Studentship had a huge impact on my career. The freedom it afforded meant that I had the resources to do an internship with YCombinator Research in Los Angeles over the summer in between the two years of my Master's, and to continue that work in my second year. The Principal Investigator I worked with gave me full freedom, and the work I completed on novel interfaces for music software eventually led to me moving to Los Angeles to work with Output to work on music creation tools used by hundreds of thousands of musicians, including some of the biggest names in pop music and film scoring. They hired me to lead the design of a new project – their most ambitious to date – based on the work during my time supported by the Fellowship. I am forever grateful.

Arthur Carabott, Industrial Design Student 2015

I was an Industrial Fellow from 1998-2001, when the Commission funded my PhD in artificial intelligence. At the time AI was so unfashionable that we played it down in our publications, but what we now call machine learning methods were key to the project's success. Through this, I co-developed AI-based software to measure the quality of phone calls, and in 2000 I co-founded a spin-out, Psytechnics, to commercialise it. The company was acquired in 2011 by one of its customers and still employs 59 people in the UK.

After 15 years in other industries, I have returned to AI and secured substantial seed investment in Lucida Medical in February 2021. Lucida Medical applies AI to find cancer in MRI scans, quickly and accurately. Our vision is to enable early detection of cancer and improve the outcomes of millions of cancer patients. The company has progressed quickly, achieving its first CE mark certification and completing a successful technology integration with GE Healthcare and the East Midlands Imaging Network (EMRAD). We are now raising investment again to put the technology into the hands of clinicians. It's a privilege to be drawing once more on a basis of research that the Commission made possible.

Dr Antony Rix, Industrial Fellow 1998

Even some of our more recent initiatives, such as the graduate Enterprise Fellowships run in conjunction with the Royal Academy of Engineering, are already having significant impact. Since its inception in 2016, awardees have raised just under £33m in external investments and grants and created over 200 jobs.

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 Royal Society of Chemistry to support its Steps into Science programme providing resources for primary science teachers; In2ScienceUK to produce an engineering research module to encourage disadvantaged secondary school students to consider a degree in engineering; Wellington Trust for its future maritime engineers project, exposing young people and, significantly, school

careers advisers to the breadth of STEM careers in the maritime sector; and EDT for its virtual STEM work experience project, providing secondary school students with exposure to real STEM workplaces even during the pandemic.

Most of these Special Awards are intended to have an impact over many years, but some initial successes are already evident. For example:

The aim of the Royal Society of Chemistry's (RSC's) Steps into Science is to solve the challenges of primary teachers lacking confidence and specialist knowledge in science, coupled with not knowing where to turn for 'trusted' resources, by developing a new primary science website bringing together in one place, for free, more than 160 new and existing high-quality teaching resources, including teacher notes, and support with accessing continuous professional development and funding.

The website went live in February 2021. Since then, it has had 47,000 visitors. Over 2500 teachers have signed up – on top of the 7500 previously registered with the RSC more broadly – giving them access to ongoing support. The first 11 primary science investigations – engaging experiments that link to the curriculum for 7 – 11-year-olds, including demonstration videos, classroom slides and detailed notes to support teachers – have been accessed more than 2750 times since being uploaded in July 2021.

The RSC continues to develop Steps into Science and is currently commissioning new careers resources to include on their Meet the Scientists page, along with plans for a set of cross-curricular resources linking science learning with numeracy and literacy. Resources translated into Welsh and Irish are also currently being user tested. All resources are developed in consultation with primary school teachers and many in collaboration with other organisations such as the Primary Science Teaching Trust and Primary Science Quality Mark. Feedback from users of the site has been very positive.

Or again:

EDT's Virtual Work Experience for 12-18- year-olds ran at the start of the Summer Break 2021. EDT ran a week of live interactive sessions allowing students to engage with over 30 STEM professionals from a variety of backgrounds including graduates and apprentices. Students were given an insight into the different careers and career pathways available to them, with speakers from Sky, Vodafone, Camwood, Profusion, Leidos and many more. The students took part in an industry led mini project at the end of each day. These included a future technologies creative project, an app design project and a virtual reality design project, which involved creating a solution to a problem within their local community, that can be controlled by an app. Students also completed a research project on one of the companies that featured during their week. At the end of their work experience students submitted their workbook which helped them reflect on the skills they had developed and the varied pathways they had heard about alongside employability skills activities to support the careers live sessions they took part in.

Of the 250 students that took part, over 50% were BAME and over 50% female, 16% were on free school meals, 4% said they are student carers while 7% declared they had a disability. 94% of the students reported greater awareness of key skills and confidence in their next steps after participation, 82% felt confident making career choices compared to just 52% pre-course and 84% indicated they would be pursuing a career in STEM.

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. A project from 2020 gives some feel for the numbers who can benefit:

Great British Minds is a series of audio programmes, broadcast on Fun Kids Radio and available as podcasts to listen and download, through which children can find out about 20 British inventors and technologists – who they are and what they achieved – providing inspiration for them to explore STEM topics. Each episode features one invention exhibited at the Great Exhibition and one from a contemporary inventor. Contemporary inventors featured include at least one 1851 alumnus. The

series also included information about the Great Exhibition itself, with tips on how children could organise their own Great Exhibition for family and friends. Fun Kids Radio also promoted the Great Exhibition at Home competition on air and online.

The initial broadcasts reached an audience of over 360,000 and the podcasts have been downloaded over 12,000 times. The associated webpages with further information have been viewed over 13,000 times. The materials are still available and still promoted.

As well as funding STEM outreach projects, the Commission also provides Special Awards to enhance its legacy estate in South Kensington and help the world leading institutions of Albertopolis to extend their reach. In 2021 these included support for the South Ken Green Trail and a new Empathetic Engineer website:

The South Ken Green Trail was designed to welcome people back to Albertopolis in Summer / Autumn 2021, while also promoting urban biodiversity with hubs for nature, and exploring inspiring ideas for a greener future.

A series of free-to-visit architectural installations were commissioned by the Exhibition Road Cultural Group from emerging and small architectural practices, working with London Festival of Architecture, the V&A, Goethe-Institut and Science Museum. By bringing together leading design and current research in biodiversity and sustainability and building connections with the work within institutions on the legacy estate, the installations epitomised the area's role in promoting debate and driving progress to address society's most pressing challenges.

The installations were seen by circa 1.5m visitors to Exhibition Road between 23 July and 20 October. Audience evaluation found that:

- *95% of visitors agreed or strongly agreed that the installations made Exhibition Road a more welcoming and enjoyable place to be*
- *85% of visitors agreed having things to see in Exhibition Road makes them more likely to visit South Kensington again.*

The Empathetic Engineer is a new website which provides online resources for engineering students, recent graduates and professional engineers to enable them to apply human centred design principles to their engineering practice. The Empathetic Engineer was developed by the Royal College of Art and the Engineering Design Centre at Cambridge University with input from the Dyson School of Design Engineering at Imperial College. It describes a highly structured process, provides online and downloadable tools, case studies and video content examining best practice. The design process and toolkit have been developed by Nick de Leon and John Clarkson from the RCA and Cambridge respectively and exploit a variety of existing tools and methods along with wholly new content including case studies and input from 1851 Industrial Design Student Alumni. The content is open source and freely available for any individual or university to use.

Needless to say, not all Special Awards proceed completely smoothly, and many recent awards are suffering significant delays in implementation as a result of the pandemic. Nevertheless, 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 and the Commission remains committed to doing what it can.

COVID-19

As made clear in the Chairman's Report, the Commission, like every other organisation, has been impacted by the pandemic; many events had to be cancelled and some programmes moved on-line. In terms of its core grant-making activity, however, the Commission has largely been able to continue as planned and Commissioners do not believe that any adjustments to the accounts are required.

As soon as the possibility of a pandemic became clear, the Finance Committee acted to ensure that there were sufficient cash or near cash assets in place to fund at least three years' expenditure in full. This gave confidence that the Commission would be able to ride out the immediate disruption and need not curtail any of its programmes. The Committee also met regularly with the investment managers to monitor the position. Investment markets have, to be sure, 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 value of the Commission's portfolio has risen over the year.

Similarly, 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. That is not to say of course that some of our legacy institutions have not been severely impacted.

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 and 2021 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.

All in all, Commissioners are confident that whatever the short-term disruptions, the pandemic should not have any material, long-term impact on the Commission's work.

Future Plans

As explained in the Chairman's report, the Commissioners held a Strategy Day during the year at which a number of themes were discussed including the need to do more to encourage sustainability, to promote good industrial design, and to encourage exchange of ideas through our alumni network.

Sustainability is a huge theme requiring action across investments, grant making and the estate. The Commission will be reviewing its investment strategy with an increased focus on ESG (Environmental, Social and Governance) considerations, including in particular the need to respond to the climate emergency. In 2022 the Commission is launching a new Fellowship in Regenerative Design, targeting ways in which not merely to lessen the harm of human development, but rather to put design and construction to work as positive forces that repair natural and human systems. Commissioners are also exploring ways in which the existing Fellowship programmes can be encouraged to address the challenges of climate change and biodiversity. Finally, the Commission is working with its legacy institutions on a new initiative, SouthKenZEN (South Kensington Zero Emission Neighbourhood), intended to identify ways in which the Albertopolis institutions can work together and learn from each other to accelerate the transition of South Kensington as an exemplar, world class, zero emission urban neighbourhood.

As regards industrial design, the Commission is currently engaging with the Royal Designers for Industry to see whether any joint initiatives are possible that might enhance the UK's industrial design capability. The Commission is also engaging with a number of UK universities to explore ways in which the Commission might encourage greater awareness of design amongst young scientists and engineers.

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, something it does primarily through its Special Award programme. The Commission is keen to more closely involve award holders and alumni in this work and is exploring with STEM Learning ways in which this might be done. The Commission is also working closely with the other Albertopolis institutions on the 2022 Great Exhibition Road Festival, which should provide another opportunity for award holders and alumni to engage with the public and promote the excitement and importance of STEM.

Awards Granted in 2021

Research Fellows

Dr Thomas Breithaupt

Subject: Redefining the relationship between crystal defects and mantle flow

University of Southampton

The prediction of viscosities in the Earth involves substantial extrapolation of laboratory-derived models. Extrapolation of a novel theory makes strikingly different predictions to traditional flow laws. This project will test the hypotheses laid out by this new theory, with potentially major implications for simulations involving flow of the Earth's interior.

Dr Gregory Chaplain

Subject: Novel development of elastic metamaterials

University of Exeter

This proposal aims to mathematically model, simulate and fabricate elastic metamaterial devices which can passively control vibration. This shall be achieved by taking inspiration from successes in analogous electromagnetic systems, enabling the design of structured, periodic elastic materials whose composite nature endows them with unexpected wave control phenomena.

Dr Amparo Güemes

Subject: Development of neurotechnology systems for improving glucose control

University of Cambridge

Existing therapies for diabetes suffer from shortcomings that hinder optimal glucose control. To overcome them, this project proposes a novel closed-loop platform that incorporates neurotechnology in traditional pharmaceutical-based devices. This multi-disciplinary research will generate novel hardware and algorithms that can be extended to other fields, further enhancing its great scientific significance.

Dr Tim Lamont

Subject: Ecological function on restored coral reefs

Lamcaster University

Coral reef restoration can regrow coral, but can it provide food, income and coastal protection for vulnerable communities, as natural reefs do? This project will evaluate the functional performance of restored coral reefs, in order to optimise goals and methods that provide meaningful benefit to people and nature worldwide.

Dr Monireh Kabirnezhad

Subject: A holistic approach to neutrino-nucleus interaction calculations for neutrino experiments

Imperial College London

The purpose of this project is to build the most precise model for neutrino-nucleus scattering by using modern statistical and computational methods. The research outcome from this proposal will not only produce essential results for existing neutrino oscillation experiments but will also provide the crucial input required for next-generation experiments.

Dr Jasmine Lee

Subject: Mapping conservation actions for Antarctic biodiversity facing rapid global change

British Antarctic Survey

Climate change is set to intensify already growing pressures on Antarctica and its unique species. Yet we have limited knowledge of which conservation actions to take or where to implement them. This project will determine how we can best conserve Antarctic species by mapping threats and actions across time and space.

Dr Benjamin Walker

Subject: Multifilament methods on the microscale

University College London

This research will consider the fluid-structure interactions of slender elastic filaments in a viscous fluid, aiming to realise computational methods that are simultaneously efficient and accurate. User-friendly and open-source implementations will facilitate a new generation of cross-disciplinary investigations into the rich dynamics of microfilaments, spanning biology, mathematics and engineering sciences.

Dr Matthew Westaway

Subject: Simple representations of modular Lie algebras

University of Birmingham

The goal of this research is to understand the simple representation theory of Lie algebras over fields of positive characteristic. This shall be done by using category theory to compute the number of appearances of each simple module in the composition series of certain nice modules, called baby Verma modules.

Dr Philip Wijesinghe

Subject: Revealing cell mechanics with light-sheet microscopy

University of St Andrews

The role of mechanics in biology can be as important as chemistry and genetics in development and disease. This project proposes a light-sheet microscope with an unprecedented capacity to rapidly quantify mechanics at cellular resolutions and over large volumes. Revealing mechanics at this scale can improve therapies and disease detection.

Brunel Fellow

Saikumar Reddy Yeddula

Subject: Dynamics of the shock wave in supersonic air-intake systems

Imperial College London

With the increased interest in high-speed aircraft and zero-to-low carbon emission engines, this project will develop simplified lower-order models to predict the shock response and improve engine air-intake performance and then apply these models to the air-intake of the industrial hydrogen-powered engine under development by Reaction Engines to ensure stability, efficiency.

Industrial Fellows

Daniya Aynetdinova

Subject: Cationic cyclisation cascades mediated by carbon-electrophiles for the formation of novel polycyclic products

Sponsor: Vertex Pharmaceuticals

University of Oxford

This project aims to develop a biomimetic cyclisation methodology to expand the existing compound libraries in drug discovery by stereoselective formation of new carbon-carbon bonds in a divergent single step procedure. This would enable medicinal chemists to rapidly construct structurally diverse natural product-like scaffolds to access their pharmacological properties.

Augusto Bartolome Diaz de Budalles

Subject: Development of a hierarchical nanocoating technology for enhanced electrode efficiency of commercial alkaline electrolyzers

Sponsor: Oxford nanoSystems

University College London

This project will develop a nanostructured hierarchical coating, easily and cheaply applicable on the electrodes to significantly improve their efficiency for green hydrogen production; the larger pores will promote rapid mass transport whilst the smaller ones will dramatically increase the surface area with more active catalytic sites for reactions.

Kyle Bowman

Subject: Accelerating the commercial implementation of electromethanogenic reactors

Sponsor: WASE

University of Westminster

Electro-methanogenesis (EM) is a process where methane is produced by microbial conversion of electrical current, hydrogen and carbon dioxide to methane. EM improves upon anaerobic digestion, improving treatment times and efficiency. Further research is needed to fully understand and optimise EM, so that it can be of benefit to society.

Shefali Bhumbra

Subject: Developing a medicine designed to modulate cancer patients' immune systems to selectively eliminate cancerous cells

Sponsor: Adaptate Biotherapeutics

Imperial College London

This project will contribute to the development of novel antibody-based cancer medicines designed to target V δ 1 T-cells, a specific immune-cell subset, to eradicate a patient's cancerous tumour. The project involves characterization of V δ 1-specific antibodies to rank the medicines' effectiveness as cancer therapeutics ahead of potential clinical development.

Liam Bussey

Subject: A quantum optical receiver for ultra-sensitive wireless digital communications

Sponsor: BT

University of Birmingham

The non-linear quantum-optical effect of electromagnetically-induced-transparency (EIT) in an atomic vapour provides an ultra-sensitive SI-traceable electric-field sensor at radio frequencies (RF). This can be used as an all-optical electrically passive receiver for analogue and digital RF communications. This project studies the use of the EIT effect in RF communication systems.

Thomas Corner

Subject: Development of potent AspH inhibitors as novel small-molecule anti-cancer therapeutics

Sponsor: GSK

University of Oxford

Aspartate/asparagine- β -hydroxylase (AspH), a 2-oxoglutarate-dependant oxygenase, is overexpressed in several cancer cell types. Inhibition of AspH catalysis is proposed as a successful mode of action for a novel, small molecule anti-cancer therapeutic. The project will focus on the design of efficient AspH inhibitors, targeting both its 2-oxoglutarate and substrate binding pockets.

Isobel Gordon

Subject: Quantitative MRI of the breast parenchyma to improve detection and diagnosis of breast cancer

Sponsor: Perspectum

University of Oxford

Mammography is not effective for pre-menopausal women and misses half of all tumours in 'dense' breasts. This project will develop quantitative, non-contrast MRI methodologies which will be applied to the breast parenchyma. This will enable earlier detection of breast cancer with higher specificity, remove operator variability and improve patient comfort.

Amelia Markfort

Subject: AI technologies for the next generation of quantum imaging

Sponsor: Photek

University of Leicester

This project will explain why modern large-scale Artificial Intelligence (AI) is broadly successful, focusing on applications in quantum imaging. Bridging the gap between existing knowledge, which demands huge volumes of data for guaranteed learning, and vast empirical evidence showing that such learning occurs on smaller datasets.

Daire O'Dubhthaigh

Subject: Smart green manufacturing for mass customisation in the textile industry

Sponsor: Interface UK Manufacturing

Queen's University Belfast

Interface are a global commercial flooring company that manufacture carpet tiles and resilient flooring. The aim of this project is to evaluate and implement leading technology to transform Interface's manufacturing processes, allowing them to meet the evolving customer needs of customisable, complex and smaller batch size products.

Parijat Patel

Subject: Artificial intelligence to improve cardiometabolic risk evaluation using CT (ACRE-CT)

Sponsor: Caristo Diagnostics

University of Oxford

This project will improve early detection of diabetes, pre-diabetes and identification of individuals at risk of future diabetes and its cardiovascular conditions from routine CT scans using AI and deep learning methods. It will aid in preventing future heart attacks and strokes, making a profound impact on global health welfare.

Daniel Pybus

Subject: Alternative production methodologies for formation of complex-geometry graphite components from recovered graphite powder

Sponsor: Mersen UK Teesside

Teesside University

To develop new, inorganic binding materials to 3D print high-concentration graphite components as an alternative to traditional machining. Material is sourced from recovered graphite powder, segregated to remove trace metals and resins. A digital decision-making tool will be developed to advise the most efficient manufacturing method according to experimental results.

Andrei-Claudiu Roibu

Subject: Mapping brain network activity from structural connectivity using deep learning

Sponsor: F. Hoffmann-LaRoche

University of Oxford

By using the latest advances in neuroimaging and artificial intelligence, this project seeks to address one of the major goals in neuroscience, which is understanding the structure-function relationship of the central nervous systems, by creating a deep learning model capable of predicting an individual's functional connectivity from their structural connectivity.

Elliott Smyth

Subject: Discovery of novel small molecules for the treatment of human coronaviruses

Sponsor: LifeArc

University of Leeds

This project will aim to develop novel anti-viral therapeutics to treat human coronaviruses, addressing the urgent unmet medical need for current and future pandemics. Three deadly zoonotic coronaviruses have emerged in the last 20-years and to date no specific anti-viral drugs for the treatment of coronavirus infections have been developed.

Enterprise Fellows

Brendan Digney

Company: Machine Eye Technology [Financially supported by the ERA Foundation]

Machine Eye Technology uses computer vision, underpinned by AI algorithms, to accurately sense the environment around the machine, and understand the presence of any risks (at the moment, humans). Being able to give sight to a machine in this manner increases accuracy, eliminating a lot of the errors and challenges encountered by traditional sensing systems such as radar systems, which struggle with the variability and environmental conditions on farms and industrial sites. It means the system can identify a person, determine if they are at risk, and take appropriate action to warn, or intervene, both the operator and at-risk person.

Alexander Macdonald

Company: HindSight Technologies

HindSight have designed rear vision cycling glasses which allow competitive cyclists and urban commuters to achieve vastly improved awareness of their surroundings, enabling them to make better, safer decisions in less time and with more information. A scientifically designed rear-view mirror is integrated into a pair of specialised, stylish, professional cycling glasses, via lenses which allow rearward viewing without impeding the user's forward vision.

Harish Pesala

Company: Balkerne

Balkerne offers an easy-to-use risk and early warning system to property owners as an add-on service to an existing insurance policy. The platform captures data from over 35 different sources including IoT, geospatial modelling, news and social media, recognising factors such as chronology, context and geo-spatial relevance to build location intelligence. The key differentiator is that the data captured is granular, real-time, and trusted. This is achieved through using machine intelligence techniques such as computer vision on satellite imagery and natural language processing on news and social media feeds of trusted feeds from local emergency services, local authorities.

Reka Tron

Company: Multus Biotechnology

Multus create true animal-free serum replacements that support high-performance growth across multiple cell lines. With a statistically driven approach, Multus screen thousands of different combinations of ingredients to find the optimum composition for each step of the production process. Their machine learning based protein optimisation platform is used to enhance the performance characteristics of key protein ingredients within their growth media to make them suitable for large scale cultivated meat production. With a focus on the cultivated meat industry, they use vegan, food-safe ingredients that can be produced at scale to meet demand.

Rebecca Donaldson

Company: Blue Tap

Blue Tap is a social enterprise that has designed a chlorine doser which inserts the correct amount of chlorine into a piped water system, making it safe to drink according to WHO guidelines. The system is designed specifically for community water supplies, and other locations where larger volumes of water are treated, where chlorination is the most cost-effective purification solution.

Natalie Kerres

Company: SCALED

SCALED is a custom-fit protective wearable, inspired by the natural world. It uses a parametric algorithm to design an interlocking geometry of scales. This engineering innovation allows flexibility in specific directions, with protection and support in others. It calculates each individual scale's geometry to control the structure's properties.

Naomi McGregor

Company: Movetru [Financially supported by the ERA Foundation]

Movetru has designed wearable technology that provides the user with information to correct their alignment and improve mobility between physiotherapy sessions while creating a long-term medical history with a numerical analysis of the user.

Tom Simpson

Company: Ratio Technology

Ratio Technology has designed a 16-speed bicycle drivetrain. The inverted teeth of these chains meet the sprockets at low contact velocities, transferring load over large contact areas. As a result, they are quiet, efficient and highly wear resistant.

Design Fellow

Tijana Blanus

Subject: Restoring nature in the city

Mentor: Dr Ross Cameron, University of Sheffield

Urban hedges are a simple, space-saving, cost-effective green intervention with the potential to alleviate a number of local environmental problems (localised flooding, poor air quality, excessive noise to name just a few).

Focusing solely on the benefits of singular plant varieties could however generate a homogenised cityscape with negative implications for biodiversity and pest and disease resistance. There are also practical barriers to wider uptake (e.g., in school settings in urban areas where they could bring considerable benefits) due to concerns around the safety, cost and time inputs into plant management.

Two key components of this project will be 1. Research into the required plant structural and functional traits for the delivery of multiple environmental benefits of mixed hedging and 2. A school ‘case study’ testing a science-driven solution in practice, in order to capture the environmental and social benefits of diverse planting, whilst addressing the practical concerns in implementation and maintenance.

The project will further link the research and school case-study through a ‘living lab’-type demonstration at RHS Garden Wisley, where the engaging, publicly accessible interpretation will showcase examples of best practice which passed both the research and practical criteria. It is hoped that a planned strong and varied programme of dissemination (with the support of the RHS media and RHS education networks, with links to thousands of schools nationally) should facilitate popularisation and uptake of the tested solutions.

Sir Misha Black Medal for Distinguished Services to Design Education

Professor Don Norman

Director of the Design Lab

University of California San Diego

Professor Norman is widely regarded for his expertise in the fields of design, usability engineering, and cognitive science and a pioneer of user centred design that has influenced designers all over the world. Many of his books, especially *The Design of Everyday Things*, have been part of the core reading list for design students for decades.

Industrial Design Students

Solomija Bogusz	Architectural Design	University College London
Erin Carr	Earthquake Engineering and Infrastructure Resilience	University of Bristol
Luisa Charles	Global Innovation Design	Royal College of Art and Imperial College London
Jahan Daya	Global Innovation Design	Royal College of Art and Imperial College London
Hemal Dias	Innovation Design Engineering	Royal College of Art and Imperial College London
Alasdair Grant	Global Innovation Design	Royal College of Art and Imperial College London
Daniel Hale	Innovation Design Engineering	Royal College of Art and Imperial College London
Eden Harrison	Innovation Design Engineering	Royal College of Art and Imperial College London
Samuel Jones	Design Products	Royal College of Art and Imperial College London
Georgia Mackenzie	Innovation Design Engineering	Royal College of Art and Imperial College London
Annie Tang	Global Innovation Design	Royal College of Art and Imperial College London

Special Awards Granted

STEM education and outreach

EDT – Virtual STEM work experience

Royal Society of Chemistry – Steps into science

In2ScienceUK – Engineering research module

National Literacy Trust – Linking literacy and STEM careers

Education and Training Foundation – Technical teaching fellowships

Wellington Trust – Future maritime engineers project

Kids Invent Stuff – Mini YouTube musical

All Party Parliamentary Engineering Group – Meeting sponsorship

STEM Learning – Involving fellows in primary STEM outreach

Support for legacy estate

Royal College of Art – The empathetic engineer

Royal Geographical Society – Upgrading 1 Kensington Gore

Exhibition Road Cultural Group – South Kensington green trail

Awards completed in 2021

Research Fellows

Dr Stephen Cox

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

University of Cambridge

Interfaces between solids and electrolyte solutions (e.g., salt water) are of great fundamental and technological importance across a variety of fields. Examples include batteries, fuel cells, biological membranes, and colloids (e.g., paint).

Steve's project focused on advancing the latest techniques in molecular simulation to improve our understanding of solid/electrolyte interfaces, providing insight that is difficult to obtain experimentally. Steve showed how previously used "standard" methods give qualitatively incorrect results, and how a new theoretical framework can be used to correctly model these important systems. He also provided theoretical insight into how systems with short-ranged interactions respond to electric fields, which will be important for the application of machine learning approaches to describe intermolecular interactions more accurately. Steve now intends to use the advances made during his Fellowship to predict the surface structures of crystals in complex environments.

Steve published many high-profile papers during his Fellowship, including a single author contribution in *Proceedings of the National Academy of Sciences* and an experimental collaboration in *Physical Review Letters* as corresponding author. Steve was also awarded 2020 Best Paper by an Emerging Investigator by *Journal of Chemical Physics* for his article 'Macroscopic surface charges from microscopic simulations'. He is now a Royal Society University Research Fellow at the University of Cambridge.

Dr Paul Holloway

Project: A microfluidic model of the neurovascular unit for stroke research *University of Oxford*

This project aimed to develop a novel cellular model of the brain using 'Organ on chip' technologies to provide new investigational tools for stroke research. Protecting the brain following stroke has been a major therapeutic goal but despite over a thousand prospective neuro-protective treatments tested, none of these have been approved for clinical use. Methods to test drugs in human cells are, however, extremely limited and often rely on cells grown in a flat plastic dish, which fails to replicate brain form and function.

During his Fellowship, Paul set out to use 'Organ on Chip' techniques to develop a human cell culture system that mimics key elements of brain structure and function (from neuronal circuits to brain blood vessels) and can recreate the conditions of a stroke, to provide new methods to test drugs and understand disease mechanisms. During this project, Paul was able to develop two distinct models that are now being used to explore potential new therapies. One model guides cellular self-assembly in a 3D gel, to provide brain blood vessel mimics that can be blocked using micro-clots to explore the responses of the "neuro-vascular unit" in stroke, while the other creates living neuronal circuits that can be used to explore how cell damage can spread between connected regions of the brain following stroke.

During his Fellowship, Paul secured over £200k of research funding, became a member of the leadership team for the UK Organ on Chip Technology Network and Topic Editor at *Micromachines*, and published his work in *Lab on Chip* (2019 & 2020), *Cellular and Molecular Bioengineering* (2021) and a review in *The Journal of Neuroscience Research* (2021).

Paul is now utilising the technologies developed during his Fellowship to explore a new therapeutic approach as a post-doc at the University of Oxford in collaboration with the University of Cambridge and an Oxford-based biotech company.

Dr Davide Foffa

Project: Elgin reptiles: the origins of the modern terrestrial fauna *National Museums Scotland*
Davide's research focused on the Triassic 'Elgin Reptile' fauna, a series of understudied fossils closely related to the earliest ancestors of dinosaurs, pterosaurs, lizards, turtles and crocodilians. During his Fellowship, he adopted a digital approach (using computed tomography (CT) data) to circumvent destructive preparation of the specimens and reveal never-before-seen details of the skeletons of these animals. Davide created accurate digital reconstructions of these fossils which he used to study clues about their in-life behaviour and their positions in the reptile family tree. The results were pivotal to contributing to shedding light on long-standing questions in palaeontology (e.g., the origins of pterosaurs and the anatomy, biology and relationships of *Scleromochlus* and *Erpetosuchus*). Results of his research were published and more will be in due course.

This approach ultimately showed that the richness of the Elgin deposits may be greater than previously thought. For this reason, this project will survive the end of the Fellowship: unprocessed data will provide materials for training students and supervision experience for Davide's future career. A series of projects on the Permian 'Elgin Reptiles' has been started. Finally, the concluding outreach project will provide freely available learning materials and activities for schools worldwide.

Following the Fellowship, Davide has been awarded a Marie Skłodowska-Curie – Individual Fellowship – Global Fellowship to research the ecological effects of the Permian-Triassic mass extinction on terrestrial ecosystems. This post, which stemmed from fruitful collaborations during his project, will be based at the University of Birmingham with two years as a visiting researcher at Virginia Tech (USA).

Dr Jake Iles-Smith

Project: Quantum control through photonic engineering
University of Sheffield and University of Manchester

Describing light-matter interactions in solid-state systems is a key barrier to developing photonic quantum technologies. Strong interactions between the electronic degrees of freedom of a solid-state emitter (SSE) and the vibrational modes of its host material, lead to complex dynamical and optical properties, and typically degrade an emitter's performance as a quantum technology. Standard theoretical methods in quantum optics assume an emitter is only weakly influenced by its environment and thus may be treated as a perturbation – a treatment that rapidly breaks down when used to describe SSEs. Therefore, in order for SSEs to reach their potential as a quantum technology, it is crucial that we have a versatile formalism capable of capturing emitter-environment interactions in the strong coupling regime.

During his fellowship, Jake developed techniques to describe the emission properties of SSE valid in regimes intractable to standard quantum optics methods. Two examples include: the collective coordinate approach, in which important environmental degrees of freedom are identified and incorporated into a new augmented system, effectively redrawing the boundary between the 'system' and 'environment'; and a numerically exact approach, which efficiently encodes system-environment correlations in a tensor network representation. These methods have been applied directly to realistic quantum emitters such as quantum dots and organic molecules, providing new insights into electron-phonon interactions in SSEs and how the optical properties of these emitters might be controlled through photonic structures. Furthermore, using the formalism as a basis, Jake has proposed quantum technologies that are robust against noise induced by environmental interactions, and even utilise this coupling to enhance their operation.

Jake is now a Presidential Fellow at the University of Manchester.

Dr Paul Knott

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

University of Nottingham

A requirement of any experiment involving quantum mechanics is that the quantum state of the system is engineered (i.e., designed, prepared and manipulated) with extreme precision and control. But the counter-intuitive nature of the quantum world, whilst enabling disruptive new technologies, also makes it particularly challenging to design quantum experiments that can engineer useful states – our usual intuitions can fail us here.

To overcome this, Paul pioneered an automated technique, the quantum state engineering algorithm, which in essence uses computer algorithms to design quantum experiments. This technique – which utilises methods from both genetic algorithms and machine learning – found numerous solutions that surpass the previous results in the literature whilst involving surprising experimental arrangements quite different from the human designs.

During the latter half of the Fellowship, Paul's future plans for the project became more ambitious. He now plans to develop an intelligent virtual laboratory, which will contain at its core a learning agent that learns from experience, utilises powerful search algorithms, can be trained by human experts, and can respond to human interaction and feedback in real time, ensuring the output satisfies the specific requirements of the user. This will have applications from quantum-enhanced precision metrology and quantum computing to quantum simulation and fundamental experimental tests. To develop the machine-learning expertise to enable him to complete this ambitious project, during his Fellowship Paul worked as a Visiting Scholar at the world-leading Berkeley Artificial Intelligence Research Lab. This experience gave him expertise in deep reinforcement learning and resulted in a publication on evaluating and improving the robustness of collaborative deep reinforcement learning agents.

Paul is now at the Centre on Long Term Risk where he researches the long-term risks associated with artificial intelligence.

Dr Emilio Martínez-Pañeda

Project: Micromechanical modelling of rock fracture: towards energy-efficient mining

University of Cambridge and Imperial College London

Emilio's Fellowship aimed at developing a new generation of physically based models for rock fracture to optimise energy-intensive mining and construction technologies. Emilio worked on shedding new light into our understanding of rock fracture and also developed new bio-inspired techniques to manufacture rock-like materials with unique mechanical properties. He also worked on developing new mathematical methods that enabled simulating the nucleation and growth of multiple cracks for the first time. This allowed him to present pioneering models not only for rock fracture but also for predicting the failure of embrittled metals, advanced composites, and smart materials, as well as opening a new path for computational modelling of corrosion. Several of these fundamental models are now being used by industry to conduct "Virtual Testing" in applications and sectors where computer simulations had not been employed previously.

The Fellowship also provided a remarkable boost to Emilio's academic career. He went from being a postdoctoral research fellow at the University of Cambridge (2018) to a Lecturer (2019) and Senior Lecturer (2021) at Imperial College London. By the end of the Fellowship, Emilio led a group of five postdoctoral researchers and seven PhD students tackling mechanics of materials challenges that are the key to understanding physical phenomena such as corrosion or iceberg calving and are at the core of technologies such as Li-Ion batteries, offshore wind energy, and hydrogen storage.

Emilio has recently been awarded an UKRI Future Leaders Fellowship, which will support him and his team for seven years to continue tackling exciting material degradation challenges at the interface between mechanics and chemistry.

Dr Konstantinos Meichanetzidis

Project: Simulating compositional processes with tensor networks

University of Oxford

Konstantinos maintains that being awarded the Fellowship has been one of the most significant events, not only for his academic career but also for his personal development.

Having the Fellowship hosted by the Department of Computer Science at Oxford University with a three-year research horizon provided him with the priceless opportunity to independently and deeply think about his research interests while being surrounded by a variety of interesting and gifted researchers. Such breathing space allowed him to collaborate widely and connect seemingly disparate fields of study from formal graphical languages and complexity theory to quantum computing and artificial intelligence.

Following the Fellowship, he is joining a key player in the quantum computing industry, Cambridge Quantum, as a Senior Research Scientist, where he will be part of a diverse and interdisciplinary team envisioning applications of quantum computers to artificial intelligence.

Dr Zahid Padamsey

Project: Speed or precision? Dynamics of information flow in the brain

University of Edinburgh

Information processing in the brain is energetically expensive. Indeed, the brain consumes approximately 20% of our calorie intake despite comprising only 2% of our bodyweight. Much of this energy is spent on fuelling the rapid and precise transmission of information between neurons. Given the prohibitive costs of neuronal communication, how might information transmission change if caloric intake is reduced? One hypothesis is that the speed and/or precision of information transmission would decrease in order to save energy.

During his Fellowship, Zahid explored how information processing in the brain is impacted by a reduction in food intake in laboratory mice. He recorded neuronal activity in a region of the mouse brain responsible for vision. When food intake was reduced by 30%, he discovered that the precision with which neurons transmitted information was reduced. In effect, neurons were no longer transmitting precise details of the visual world, making it more difficult for mice to see clearly. However, whilst neurons were less apt at transmitting information, Zahid found that they were also using 30% less energy. These findings are the first to establish that the precision of information transmission is reduced in the mammalian brain to save energy when food availability is limited. This work has important implications for understanding how diet impacts cognition in humans.

Following his Fellowship, Zahid has been awarded a research grant by the Biotechnology and Biological Sciences Research Council (UK) to continue his line of work at the University of Edinburgh. He is now looking at the underlying molecular and genetic mechanisms that control how much energy neurons spend on information processing.

Dr Matthew Pusey

Project: Notions of non-classicality as sources of quantum advantages

University of Oxford

Quantum computation and quantum cryptography aim to exploit the unique features of quantum mechanics to achieve faster speeds and better security than is possible with current technology. But exactly which quantum features are responsible for each quantum advantage can be surprisingly difficult to pin down. A promising approach to these questions is via rigorous notions of non-classicality, the most important of which are quantum contextuality and quantum nonlocality. Because these notions provide a precise characterization of what makes quantum mechanics unusual, they offer the possibility to identify exactly what powers quantum advantages in computation and cryptography.

Matthew developed the theory of quantum contextuality, with a particular focus on making demonstrations of it more robust to various experimental imperfections. Since all experiments are imperfect, such robustness is important for doing convincing foundational experiments. This robustness is also important for any cryptographic applications where such imperfections could lead to security loopholes, and to make solid connections with quantum computation which always has to contend with noise. In particular, Matthew ensured the robustness of the connections between contextuality and another useful form of non-classicality known as “anomalous weak values”.

Matthew also worked on a structure theorem that makes it easier to identify and study contextuality by considering transformations alongside preparations and measurements. Most recently, he applied this theorem to give a full characterization of the contextuality of the “stabilizer subtheory”, which plays a key role in quantum computation. This characterization provides a very direct link between contextuality and certain forms of quantum computation.

Matthew is now a Lecturer in Quantum Information in the department of Mathematics at the University of York. His research is still in broadly the same areas: connections between quantum information and quantum foundations.

Industrial Fellows

Jasmine Bone

Project: Durability assessment and lifetime prediction of polymer composites under harsh marine environments

Sponsor: National Physical Laboratory

University of Surrey

Jasmine's research project focussed on the effects of accelerated ageing and moisture absorption in polymer composite materials. These materials are increasingly being used in marine and offshore environments where it is essential to understand the effects of the environment on degradation and material performance over time. The aim of this research was to use methods of accelerated ageing (increased severity test conditions) to correlate the absorption of water in the composites to reductions in material properties such as strength and stiffness.

Over the course of the Fellowship, Jasmine developed test methods to accelerate moisture uptake in the materials and vary exposure conditions with temperature, pressure and applied mechanical load. Different techniques were used to characterise the degradation occurring and diffusion modelling used to assist the understanding. This work provided the foundation for a capability to test and understand the degradation of composite materials due to moisture uptake and identified a relationship between the degree of water absorption and its location in the material to the degradation of material properties.

After completion of the EngD, Jasmine was employed full time by NPL in order to investigate the validity of the test work to industrial case study materials.

Jasmine is now a Research Fellow at the joint AWE and University of Surrey Centre of Excellence in Materials Ageing, Performance and Life Prediction.

Laurence Devesse

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

Sponsor: Verogen

King's College London

Laurence's project was born out of a Knowledge Transfer Partnership between Verogen (the forensic genetics group at Illumina at the time of the award) and King's College London. As a new company, Verogen benefitted from the support of the forensic genetics community, and the partnership with King's Forensics helped establish the Verogen MiSeq FGx technology as a gold standard for massively parallel sequencing in forensic DNA typing. Laurence's research has proven that this technology is fully concordant with what forensic laboratories have been doing for the past 20 years and can be applied to forensic cases previously too complex to solve with less informative techniques. The results and databases made available through multiple publications during the Fellowship have facilitated uptake and implementation of the MiSeq FGx in laboratories world-wide, and already form part of the "Verogen story". Laurence's academic output is often utilised by the company, and her knowledge of the processes she applied and developed during her Fellowship is shared with Verogen customers on a regular basis.

Laurence remains a field application scientist with Verogen.

Mariastefania De Vido

Project: Advanced gain materials for high energy, high average power laser systems

Sponsor: STFC Rutherford Appleton Laboratory

Heriot-Watt University

Stefania's Fellowship focussed on advancing DiPOLE, a world-leading high energy, high repetition rate nanosecond diode-pumped solid state laser amplifier architecture developed at the Central Laser Facility (CLF), part of the STFC Rutherford Appleton Laboratory.

She conducted wide-ranging experimental and numerical studies to address performance issues in existing systems and to open up routes to future increases in pulse energy and average power. Activities carried out during the Fellowship have yielded three first-author papers (with three more papers in preparation) and one patent application.

Stefania's contribution has allowed DiPOLE to remain a record holder in several categories, such as output energy, average power and system efficiency and facilitated the commissioning of a new DiPOLE system for the European Free Electron Laser (X-FEL) in Hamburg (Germany). This allowed CLF to remain at the forefront in the high energy high repetition rate laser field.

DiPOLE technology has been chosen to be at the heart of a new UK facility, the Extreme Photonics Applications Centre (EPAC), an £82m research centre currently under development at the CLF which will focus on the development and application of novel, laser-based accelerators and particle sources for sensing, medical and security applications. Stefania's research will contribute in making DiPOLE fit for purpose in terms of energy, efficiency and reliability performance.

Stefania's work allowed the development of next generation DiPOLE systems operating at 100 Hz repetition rate, 10 times the repetition rate of current DiPOLE lasers. Commissioning of a DiPOLE 100 Hz laser will open up new avenues in industrial applications of high energy, high repetition rate lasers and may be the first step towards the development of new high repetition rate facilities and the upgrade of existing ones.

Stefania continues to work at the CLF on the development of DiPOLE technology and on the development and commissioning of EPAC.

Christopher Magazzeni

Project: Ultrasonic testing for jet engines

Sponsor: Rolls-Royce plc

University of Oxford

Aviation has become safer and more efficient, with every iteration of high-performing jet engine contributing to this change. A major source of improvement has come from a change in the way we manufacture the precise components in the engine: from shaping and cutting uniform blocks to friction-welding or 3D printing complex shapes. These new tools enable an enormous range of designs with significant performance benefits, from reducing the number of individual parts needed to bio-mimetic geometries.

However, these new tools also completely change the material structure, often at a micro-scale. In order to understand this, new tools for studying and qualifying these materials at a similar scale are needed: having refined our focus in the material with smaller and smaller features, we similarly need to downscale our testing methods.

Christopher's project delivered two novel methods to answer questions on material behaviour of these parts. The methods – applicable to any material, rich in data, and fast – have been developed on the case study of a friction weld in Rolls Royce plc jet engines. Exploring the weld-line, a region with higher strength, allowed for understanding the material behaviour of each individual link in the chain instead of just finding the weakest one. By combining new testing machines with advanced data analytics, these methods will cut down on the development cycle for the new manufacturing methods. The tools have been shared with the scientific community across the disciplines of aerospace, geology, and plastics, and have been incorporated in Rolls Royce's toolbox.

Christopher is now a Research Fellow with the European Space Agency.

Shaun Mansfield

Project: Manufacturing process for clinically relevant cord blood haematopoietic stem cells

Sponsor: Biovault Technical

University College London

Umbilical cord blood (UCB) is a source of haematopoietic stem and progenitor cells (HSPC) that have a proven clinical track record for the treatment of over 80 conditions. However, the finite number of cells within one unit, which limits the overall cellular dose available, ultimately limits its potential as a therapeutic, restricting the use of UCB to children and adolescents or requiring multiple units be transplanted in adults. To overcome this, expansion strategies to increase the overall number of HSPCs have been adopted. These strategies largely focus on the use of supplementation to promote proliferation whilst limiting differentiation. However, they rely on dated technologies, which are manual, laborious, inconsistent and lack the ability to scale.

For these expansion technologies to realise their full potential, manufacturing strategies are required that improve scalability and consistency whilst reducing overall cost and manual processing steps. The main aim of Shaun's project was to investigate the use of a bioreactor system for the expansion of HSPCs, which can address many of these challenges. Within the project it was demonstrated that agitating HSPC cultures improved the overall yield of cells, cell viability and their potency compared to a static control. In addition, specific process parameters were investigated, the dissolved oxygen concentration, cell seeding density and culture media pH. Investigating the design space for these parameters highlighted optimal operational parameters, which when applied to multiple donors, resulted in a further significant improvement in final cell yield, viability, and potency, whilst also decreasing the time required for manufacturing.

Biovault will be able to utilise the output from the research as a tool to secure more customers for their Umbilical Cord Blood storage service as well as new overseas partners. In addition, the research can be used to promote future collaborations between Biovault, academic institutions and other industry partners, building upon the outputs from this project either internally or with future collaborations.

Shaun is now working as a Research Scientist at Ori Biotech.

Marta Ferran Marqués

Project: Luminescent coatings for ultrahigh temperature measurements

Sponsor: Sensor Coating Systems

Cranfield University

Temperature is one of the most critical properties of thermal systems in power generation and aerospace. The extreme inlet temperatures influence the efficiency, reliability, and lifetime of an engine system. This demands accurate data concerning the thermal load on components. Current temperature sensors exhibit some limitations. Thermocouples and thermal crystals only provide point measurements making it difficult to reveal temperature gradients. Pyrometers require optical access and can be influenced by emissivity changes. Thermal paints deliver surface coverage, but they also present some challenges such as toxic chemicals, poor resolution, wide temperature data gaps, and poor durability.

To overcome some of these challenges, Sensor Coating Systems (SCS) has developed Thermal History Coating (THC) technology, able to measure temperature profiles in the 900 – 1600 °C range post-operation. THCs are phosphor thermometers synthesised via co-precipitation methods and deposited to form a coating via Atmospheric Plasma Spray (APS). This new offline temperature profiling technique uses optically active ions in a ceramic host material that phosphoresce once excited by light. After being exposed to high temperatures the host material irreversibly changes at the atomic level affecting the phosphorescence properties which are then related to temperature through calibration. The technique records the past maximum exposure temperature so that it can be determined once the component has already cooled down.

The data obtained during Marta's Fellowship has helped develop a more robust and reliable THC system for the 900 to 1600 °C temperature range. Firstly, a study on how the spray deposition parameters influence the microstructure, and thus the luminescence of the material, was carried out. The optimised and selected spray parameters are now used for all industrial projects at SCS. Secondly, several materials characterisation techniques, such as, X-ray diffraction, Raman spectroscopy and optical spectra, were used to reveal the different phase changes undergone by the THC material when exposed to high temperatures, providing a new calibration method. An in-depth characterisation of the decay kinetics undergone by the material was carried out, providing a better understanding of the underlying physics of the material. Lastly, engine and lab exposed samples were compared for the first time, revealing differences at the microstructure level and providing valuable results to SCS.

The findings throughout Marta's Fellowship will not only benefit design engineers in their race to achieve higher firing temperatures but will also help SCS in growing as a company and broaden its temperature range capabilities.

Marta continues to work at SCS.

Elsa Noaks

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

Sponsor: Autolus

University College London

Chimeric antigen receptor (CAR) T-cell processing is a rapidly developing cancer therapy that can offer treatment for patients where traditional therapies have failed. Concerns regarding host rejection have resulted in the majority of CAR T-cell therapies using a patient's own cells, collected through a process called leukapheresis, and so manufacturing success is inextricably linked to starting material composition and quality.

Establishing the relationship between donor material composition and the success of CAR T processing stages is critical. The ability to predict how patient material will behave from its composition would allow manufacturers to adapt their processes, helping to prevent production of an ineffective product or failure to meet dosage. Reducing the chances of processing failure is especially important for CAR T-cell therapies, as their application is almost exclusively in refractory cancer patients who may not be able to wait for additional manufacturing cycles. Elsa's work found that depletion of specific cell groups from donor cells could significantly enhance the performance of key CAR T-cell production manufacturing steps.

Although widely implemented, replacing leukapheresis with an alternative starting material could be beneficial. The simplicity of blood collection makes it cheaper and more widely accessible to patients, which could be vital for those who may be too unwell to travel long distances to a specialist centre or undergo the procedure. However, much like leukapheresis, white blood cells (WBC) from whole blood also contain disruptive cell populations, such as monocytes, as well as a higher level of red blood cells. To examine the potential of using whole blood collections, Elsa's project reviewed how the CAR T-cell process cycle was affected by changing the WBC collection method.

Elsa has now taken up a position at Autolus as a Research Scientist.

Alex O'Neill

Project: Predicting tyre behaviour on different road surfaces

Sponsor: Jaguar Land Rover

University of Surrey

Alex's work has provided a solution to a long-standing, industry-wide problem that will directly benefit Jaguar Land Rover (JLR) by improving its tyre modelling capabilities. JLR aims to undertake a significant amount of its new vehicle development virtually. By using full-vehicle simulations to refine products as much as possible, the considerable costs associated with building expensive physical prototypes can be reduced substantially. The quality of simulations rests on the quality of the constituent models. Currently, tyre models often represent driving on sandpaper, diminishing correlation with physical tests conducted on asphalt and reducing the efficacy of the virtual engineering process.

Alex's work has successfully developed a process where tyre models can be reliably transferred from one surface to another (e.g., from sandpaper to asphalt). To do so, the complex frictional interaction that occurs between tyre rubber and different surfaces was captured experimentally. Then, the obtained frictional characteristics were used as an input to a tyre model. Results showed that changing the frictional characteristics in the model mirrored the changes seen in measured tyre forces on the different surfaces. Fundamentally, the results show the importance of capturing the frictional behaviour of the rubber.

Going forward, experimental tyre data obtained on sandpaper can now be 'scaled' to that of asphalt, in a reliable and physically meaningful way. Consequently, JLR's tyre models are more representative of reality, and, thus, the company's virtual engineering capability is improved. This allows more work to be done on the 'virtual' car and speeds up the process of bringing new products to market.

Following the Fellowship, Alex has secured a dream role with Siemens' tyre research group, who are industry-leading in their modelling capabilities.

Alexandre Raymond

Project: Equipping autonomous surface vehicles with intelligent interaction capabilities

Sponsor: L3Harris ASV

University of Cambridge

During his Fellowship, Alex conducted a deep investigation into the open challenges of explaining the behaviour of autonomous vehicles. His research sets out a new paradigm of developing autonomous vehicles that are ‘explainable by design.’ These vehicles of the future can reason about their current state and justify their intentions to operators and other vehicles alike (manned or unmanned). As a result, he hopes to increase trust and speed up the regulatory hurdles in the indispensable adoption of this technology.

More specifically, Alex extended the concept of explanations not only for humans, but for other robots as well. He provided concrete answers to representative questions such as: how to explain intent according to the rules of the sea? How to optimise explanations and minimise potential conflicts of interest between vehicles? Can those explanations be used to improve the performance of AI algorithms?

For L3Harris ASV, Alex’s work represents a competitive advantage in the form of a clear roadmap for designing technology that not only complies to regulations but can also exhibit awareness by explicitly reasoning about existing norms. The first player in the market who can demonstrate that their vehicles can coexist with humans will lead the way with the technology.

Following the Fellowship, Alex hopes to take on a technology leadership position in the autonomy domain at L3Harris ASV.

Jonathan Vince

Project: Using ultrasound to enhance targeted radiotherapy

Sponsor: BTG Biocompatibles / Boston Scientific

University of Oxford

Jonathan’s Fellowship has supported the development of a new method for delivering targeted radiotherapy to cancer patients using ultrasound and microbubbles. The technology has been specifically explored in the context of brain tumour treatment (glioblastoma multiforme), but also has the potential to treat other solid tumours with poor vascular access.

The use of ultrasound induced cavitation of commercially approved microbubble contrast agents, drastically extends the potential of selective internal radiation therapy (SIRT) as a modality for treatment of various cancers. It enables radioactive microspheres to be delivered into various tissues which do not have existing vasculature for intra-arterial microcatheter delivery and offers a new and exciting way to distribute selective internal radiotherapy within the body. The discoveries made possible by the Fellowship may pave the way to an improved standard of care for glioblastoma multiforme and transform the lives of patients suffering from this highly aggressive form of cancer.

A patent has been submitted between Oxford University Innovations and Boston Scientific with respect to the findings of this research and their commercially available radioactive product TheraSphere®. It is hoped that this new technology platform will improve the existing treatment of currently approved cancer indications and enable the use of radioactive microspheres for other indications. Two academic paper submissions are currently being written up summarising the findings and development of ultrasound mediated delivery of radioembolic microspheres.

Jonathan is now a Project Manager at Airfinity.

Fergus Watson

Project: The prevalence and relevance of hospital biofilms and their inactivation by H₂O₂ vapour technology

Sponsor: Bioquell UK

University of Southampton

The aim of Fergus's Fellowship was to expand upon our understanding of the microbiome on dry surfaces within a hospital environment and utilise this to model the microbial challenge for in vitro efficacy testing of common disinfectants.

Environmental surfaces play a key role in the transmission of hospital-acquired infections (HAIs) and are believed to act as a reservoir to HAI-associated pathogens. Fergus's analysis of the clinical environment was able to support the limited literature for the presence of biofilm contamination on dry surfaces. Moreover, from his data he has been amongst the first to define the true levels of microbiome on dry surfaces using microbiologic culture techniques. He found the surface bioburden for hand-touch sites in patient wards was 10,000x higher than the current limits for cleanliness (5 CFU/cm²). Furthermore, by categorising his dataset into different types of surfaces he has been able to show which surfaces pose a greater risk to patients than others. Clinical equipment can often be missed during routine hospital cleaning yet was seen to harbour more clinically relevant pathogens such as *Acinetobacter* spp., whilst surfaces in closer proximity to the patient (e.g., bed rails, tables etc) were more abundant in environmental flora which are arguably less harmful yet are more frequently cleaned.

From this work Fergus has developed a novel in vitro model for emulating hospital microbiomes. There is a distinct lack of understanding of how biofilms grow on dry surfaces and Fergus postulates that patient bodily fluids transmitted through touch, such as sweat, are key contributors. Therefore, he developed his model to emulate the formation of dry surface biofilms via contact between a patient's 'hand' and clinical surfaces supplemented with a unique artificial sweat growth media. The resultant biofilms have been used for downstream efficacy testing of common disinfectants and will provide valuable information for clinicians when choosing Infection Prevention and Control (IPC) measures.

The information obtained during Fergus's Fellowship will be used to advance Bioquell's position within the healthcare industry and provide a comprehensive hygiene solution with multifaceted approaches to bioburden control. The techniques devised should enable Bioquell's clients to tailor their IPC approach to unique situations or facilities.

Following the Fellowship, Fergus has moved into a leadership role within the supply chain (production) division of Bioquell. He continues to provide input to on-going development work on Bioquell's biological products. He is also looking at areas within the global parent company, Ecolab, where his research and expertise can be utilised.

Industrial Design Students

Alex Dallman-Porter

Course: Innovation Design Engineering

Royal College of Art / Imperial College London

During his second year of IDE, Alex completed a group project with three peers, and a solo project. The former was concerned with the little known but significant environmental issues of clothes washing, which uses large volumes of fresh water, requires high energy input for heating and drying, and is overkill for how dirty most clothes are, which results in their frequent damage. Alex and his collaborators came up with a gentle waterless alternative that leaves clothes bacteria-free and smelling fresh.

Alex's solo project was originally inspired by rowing, and the feelings of calm many experience whilst out on the water. Through a lengthy development process, this resulted in his creation of a novel approach to mindfulness at home that incorporated gentle exercise, nature therapy and movement-responsive audio.

After graduation Alex has gone full time at the ex-IDE startup he'd been helping out with part time during his studies, Charco Neurotech. He works on a range of areas including product development, manufacturing and community support. Charco Neurotech recently launched their product the CUE1, a non-invasive wearable that alleviates the movement symptoms of Parkinson's.

David Harris

Course: Global Innovation Design

Royal College of Art / Imperial College London

During his Studentship, David was driven by his desire to apply his background in product innovation and venture building to ideas with social impact. A central theme of his work was designing platforms, services and experiences that facilitate wellbeing and human connections.

During GID David spent a year living in Tokyo, where the widespread presence of daily rituals in Japanese culture inspired a research project into ritual design. The final concept presented was *Ritually*, a digital assistant for personal ritual creation that enables people to playfully establish new patterns of behaviour, for instance by designing ritual objects.

Whilst taking remote classes at Brooklyn's Pratt Institute, David explored the epidemic of urban loneliness and social isolation. In collaboration with residents of New York, he designed *Pal*, a fresh spin on traditional pen pal schemes aimed at building more meaningful human connections and cohesive communities in local neighbourhoods of large metropolitan areas.

David's final year project *NEXT* showcased a digital platform that connects people transitioning into retirement and enables them to find a new purpose in life by starting impactful community projects with others. *NEXT* followed a human-centred design approach, involving over 20 participant interviews, and built on the expressed needs for meaningful activity in retirement and opportunities to expand social connections.

David is now leading the product innovation team at a London-based software start-up where he works in partnership with the NHS and community organisations to address social determinants of health. His primary focus is on developing a digital ecosystem of wellbeing support and exploring the future of self-care pathways for citizens. He is part of the DigitalHealth.London accelerator programme for digital innovation in health and care.

Ella Hetherington

Course: Bio-integrated Design

University College London

Ella's research focused on passive bioremediation of water using melanin, a natural pigment found in all biological kingdoms. In nature, melanin's function is often for protection from harmful environmental stresses. Melanin is capable of binding and absorbing many harmful pollutants such as heavy metals. Heavy metal pollutants are one of the most challenging substances to remove from our environment as they are bio accumulative. They can be costly and time consuming to remove using current physical and chemical methods.

Melanin is produced in-situ by bacteria that can express the pigment extracellularly. The bacteria are grown inside tiles of a hydrogel material made from seaweed that is both highly absorbent and biocompatible. Creating robotically printed lattices of these hydrogels maximises surface area for absorbance. The melanin can both permanently bind the metal or act as a reservoir which poses exciting prospects for the recovery and recycling of these metals.

Following her Studentship, Ella is continuing with the development of her project as a researcher at UCL with the aim of making a prototype for installation on a site. She is also a research assistant on a new project exploring the automation of construction of Cob (a sustainable natural building material made from sub soil, water and a fibrous aggregate like straw) with industrial robotics.

Sandeep Hoonjan

Course: Innovation Design Engineering

Royal College of Art / Imperial College London

During his studentship, Sandeep focused on computational solutions to sustainable eating, physical communication, and longevity of electronics.

Sandeep's final group project, *Meal Engine*, was a system for generating customised food recipes in a way that fostered more sustainable and healthier practices for both the consumer and producer. The basis of this was a visual programming language Sandeep devised called EGlang, which condensed the complex act of cooking into simple classes. Sandeep and his team members devised methods for incorporating such a system into existing food systems now and far into the future.

His final solo project, *Computational Heirlooms*, created a manifesto for computational hardware that could last multiple human lifetimes. Sandeep took a hybrid approach of speculative design and physical prototype generation to create a vision of the future where our computational devices are cherished and enjoyed as life partners, rather than disposable tools.

One of his most notable first-year projects was entitled "Feel the Conversation", created in collaboration with Xianzhi Zhang. It consisted of a set of communication devices that translated multilingual conversations into a simple haptic movement. The project received global press and was included in a year-long exhibition at the Stedelijk Museum Amsterdam.

Since graduating, Sandeep has begun work as a designer and creative technologist, where much of his work focuses on future developments in digital communication.

Daniel Karaj

Course: Global Innovation Design

Royal College of Art / Imperial College London

During his Studentship Daniel focused on the relationship between digital and physical media, from exhibiting at a physical pixel art show in Japan, exploring the effect of technology on the future of music to more extensive projects focused on the application of technology to aid in physical and mental health care.

Developed in consultation with London based cellular agriculture start-up Hoxton Farms, Daniel's final project *Eggriculture* is a proposal in which cultured meat is incubated using household chickens in a consumer's garden. Unfertilised eggs are given transformation factors to induce pluripotent stem cells and then growth factors to guide the cells into producing a portion of steak, bacon or other meat following a three-week incubation period underneath a brooding hen. The proposal had three aims: humanising lab grown meat, reducing some of the economical concerns by leveraging experience design principles and aligning lab grown meat with the home-grown movement.

While on exchange in Japan, Daniel worked at the University of Tokyo with the DLX Design Lab on capillaroscopy research. Since graduation he has continued to take on software engineering and design projects including work with Nesta and the Scottish Government on the future of healthcare data and further collaborations with the DLX Design Lab, primarily focused on the future of autonomous transport.

Roumyana Kotopanova

Course: Manufacture and Commercialisation of Stem Cell and Gene Therapies

University College London

During her Master's year, Roumyana worked on a research project focussed on CAR-T cell therapy, one of the main advanced therapies for leukaemia based on genetically modified patient immune cells. The main limitation of CAR-T therapy is its high manufacturing cost of over £300,000 per patient, which is why her project explored different methods for cell activation. Activation is one of the steps of the production process that is a major cost driver, hence, she compared the use of four different activation methods and how each of them affects the quality of patient cells. Additionally, she explored the performance in three different donors, showing the significant difference that donor material makes for therapy production. She then produced a final report discussing the data she had generated and compared the four activation methods based on cost-efficiency. Roumyana's project highlighted the potential of some of the reagents to improve process efficiency and reduce production cost. It also brought to light the need for further research in the matter of cell activation as well as further innovation in the advanced therapy field.

Following her graduation, Roumyana is currently a cell and gene therapy scientist at GlaxoSmithKline as part of their Future Leaders Programme, a graduate programme consisting of three rotations within the Cell and Gene Therapy team in Stevenage. There she works on developing novel cell therapies in the oncology field and eventually bringing them to the commercial market, the main focus being improving patient quality of life.

Max Medhurst

Course: Innovation Design Engineering

Royal College of Art / Imperial College London

The IDE course gave Max the skills and experience to apply his existing mechanical engineering knowledge to the field of design and innovation, working on a range of projects from novel injection-mould making techniques for recycled plastics to bio-photovoltaic algae cultures that could one day provide electricity for settlements on Mars. These diverse projects enabled Max to explore his design practices, teaching him to combine technical knowledge with creative thinking, alongside learning to thrive in multi-disciplinary design teams.

After graduating from the course, Max started working as a freelance prototyping consultant, helping clients turn provisional ideas into working prototypes, minimum viable products, and proof-of-concept models. His clients have already included a cutting-edge sports technology start-up and Brompton Bicycles, the world-leading folding bicycle company. Through the skills he developed during the Studentship, he has been able to develop both the technical and user sides of these early concepts, experimenting through rapid prototyping to bring seemingly impossible ideas to life.

Hugo Richardson

Course: Innovation Design Engineering

Royal College of Art / Imperial College London

Throughout his Master's degree, Hugo's roots in engineering and passion for design led him to take an interdisciplinary approach to the complex and nuanced challenges we face.

Today, over a million tons of tyre wear particles are produced annually across Europe. It is the second largest microplastic pollutant in our oceans, toxic to marine life, and a major contributor to airborne PM2.5. Hugo's final year group project, *The Tyre Collective*, developed the first retrofittable device to capture tyre wear at source, to prevent these harmful particles from entering our environment.

Thanks to the support of the Royal Commission, *The Tyre Collective* has gone from university project to fully fledged start up. They had the honour of winning the UK National James Dyson Award, Mayor's Entrepreneur Environment Award as well as Forbes 30U30 Honourees. This success, alongside a recent exhibition at the Design Museum, has helped to increase public awareness of tyre wear and prompt important conversations around the topic with policy makers and industry leaders.

Last September, Hugo and his team completed their first on-vehicle test alongside CEVT and Volvo. Over a period of 7 weeks, 3000km driven, the device successfully captured tyre wear and validated their core technology.

Without tackling tyre wear, transport will never be net-zero. Hugo and his colleagues are now exploring ways of reusing this captured material to create a closed loop system. Hugo wishes to thank the Commission for their ongoing support, without which this entire journey would not have been possible. Together, let's save our air from tyre wear!

Joy Zhang

Course: Innovation Design Engineering

Royal College of Art / Imperial College London

As a student self-financing her master's education, Joy had considerable difficulty juggling the cost of living while also fielding the cost of course materials. This meant she took on part time jobs as she studied at the Royal College of Art and Imperial College London. When she received the Industrial Design Studentship in her second year, the newfound financial security gave her the opportunity to more freely invest in her final thesis project. Without the support of the Industrial Design Studentship, she feels she might not have had the courage to pursue a thesis topic in Web 3.0, which is a field far removed from her undergraduate mechanical engineering degree. Since then, her final thesis project has featured in the 2021 Global Graduate Show, has gathered advisors and collaborators, and is on its journey to becoming a funded start-up. Joy says: "I can't express how grateful I am to be pursuing work I love and believe in".

Enterprise Fellows

Alex Murdock

Company: Thermulon

Technology: Affordable nanoporous building insulation that is energy-efficient, fireproof and sustainable

Thermulon's nanoporous building insulation materials are engineered to tackle climate change and designed to make buildings energy efficient without compromising safety.

Aerogels are the most insulating materials in existence, but current production costs have made thermally efficient and fire safety-compliant products cost prohibitive for the construction sector.

Thermulon has developed an innovative production process utilising new continuous chemical pathways to produce an affordable aerogel without compromising on fire-safety or thermal performance.

The company is now aiming to scale up production to capitalise on its innovation as the global thermal insulation market is set to boom. The growth is being driven by net-zero targets mandating better home insulation to reduce CO2 emissions and safety factors including the need to replace cladding on many residential buildings across the UK following the Grenfell fire tragedy in 2017.

The company will initially target the UK retrofit market of solid-wall properties, which account for 25% of property building stock which equates to an estimated eight million dwellings. The UK high-rise building market, where combustible materials are banned, will become another key market focus and, longer term, Thermulon aims to extend its offering to the global thermal insulation market.

To date, Thermulon has attracted 878 investors. It has received a £750,000 grant from Innovate UK and recently raised £650,000 on CrowdCube.

Matt Escott

Company: Protolaunch

Technology: Rocket engines that use a novel thermodynamic cycle to enable truly dedicated launch of Small Satellites

Protolaunch is a chemical propulsion company changing the way rocket engines are designed to enable future small launch vehicles.

Satellites are getting smaller while the rockets that launch them have not. A new generation of microlauncher vehicle is on the horizon targeting <1000kg payloads. Smaller rockets need smaller engines. Reducing the size of engines intended for much larger vehicles results in spiralling complexity and cost. Protolaunch is taking a different approach.

Protolaunch has taken a bottom-up design philosophy to propulsion development, designing specifically for small payloads from the outset. Their technology leverages a new thermodynamic cycle and system-level optimisations. This eliminates the need for complex pumps and turbomachinery, reducing manufacturing complexity and producing vehicle weight savings.

Positioned as an engine supplier, Protolaunch works with launch partners to bespoke standard propulsion units for particular customer use cases.

Protolaunch was recently awarded the Enabling Innovation award at Advanced Engineering.

Bella-Trang Ngo

Company: Brarista

Technology: AI-driven virtual bra fitting service

Brarista is working to democratise professional bra fitting. Their vision: a world where you can get fitted professionally from home using your phone's camera. Brarista brings together a team of professional bra fitters and computer vision scientists to solve one of the biggest problems of female well-being.

Brarista promotes convenience, accuracy and inclusivity, eliminating discomfort, saving time and reducing waste.

Brarista was recently awarded a development grant by Future Fashion Factory, an initiative funded by UKRI.

Varun Sarwal

Company: Hammer Missions

Technology: Versatile mission planning and data analysis for commercial drones

Hammer Missions helps clients collect and analyze quality drone data for asset mapping and inspection.

Their app allows clients to create automated flight plans, upload, annotate and share captured data with all stakeholders, all in 3D, and automatically upload and digitally maintain flight logs to ensure operations are efficient and compliant.

Hammer recently deployed with a reforestation business using drones to plant trees.

Joseph Sherwood

Company: FLIT

Technology: Lightweight folding e-bikes for urban commuters

Folding e-bikes open up the market to new customers as they can be easily stored or used with public transport. By developing a folding e-bike from scratch, and integrating the electrical system into the frame, FLIT's first product, the FLIT-16, is 30% lighter and smaller than a typical folding e-bike. FLIT-16s are available for purchase on-line.

FLIT is working on new models and hopes to trial a leasing scheme. In 2022 it hopes to expand into international markets in Europe and North America.

Joseph parted company with FLIT in 2021 and is now a Research and Development Engineer at Robert Bion & Co Ltd, an independent, UK-based metal and plastic perforating company.

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 Dawn Bazely (1984-1987)

- Awarded Minister’s Teaching Excellence Award, Ontario Ministry of Colleges and Universities (for Future Proofing Students during the pandemic)

Professor John Boothroyd (1976-1979)

- Elected to the Governing Council of the U.S. National Academy of Sciences
- Winner, Alice and C.C. Wang Award in Molecular Parasitology, American Society of Biochemistry and Molecular Biology

Professor Crispin Gardiner (1965-1968)

- Published *Elements of Stochastic Methods*

Professor Shahina Ghazanfar (1977-1981)

- Became the first Pakistani and the first woman in Asia to be awarded the Linnean Medal in the field of Botany since the award was instituted in 1888

Research Fellows

Dr Jo Ashbourn (2002-2004)

- Organised discussion panels on *Space Travel Across the Decades and Beyond* and *Searching for Extra-terrestrial Intelligence Across a Century*, and lectures by Professor Carlo Rovelli on *Scientific Thinking Across the Centuries and the Foundations of Physics* and by NASA’s Chief Scientist on *The Martian – Science Fiction and Science Fact* at the St Cross Centre for the History and Philosophy of Physics

Dr Chris Bowman-Scargill (2013-2016)

- Awarded EPSRC Early Career Research Fellowship (£1.1m to work on *Tensor and wreath products of symmetric groups*)

Professor Byron Byrne (1999-2001)

- Elected Fellow of the Royal Academy of Engineering for developing new design methods for the foundations of offshore wind turbines, leading to the substantial cost savings that are now enabling the expansion of this green energy technology

Professor Amin Doostmohammadi (2017-2019)

- Awarded ERC Starting Grant (€1.5m to work on *Physics of collective cell decision-making*)
- Awarded New Exploratory Research & Discovery (NERD) Grant from Novo Nordisk Foundation (€1.5m to work on *Topography-mediated cellular sensing & communication*)
- Awarded Young Scientist Prize and Medal in Biophysics, The International Union of Pure and Applied Physics
- Awarded Lars Kann-Rasmussen Prize, Denmark

Dr Andrew Humphris (2002-2004)

- Appointed Honorary Professor, School of Physics, University of Bristol

Professor Apala Majumdar (2006-2008)

- Appointed Visiting Professor, Indian Institute of Technology, Bombay
- Appointed invited foreign expert, Institute of Responsive Soft Matter, Indian Institute of Technology, Madras
- Elected to the Executive Committee of the International Society for the Interaction of Mechanics and Mathematics
- Appointed to the Editorial Board of *Partial Differential Equations and their Applications*

Dr Alan W. McConnachie (2006-2008)

- Elected to the College of New Scholars, Artists and Scientists of the Royal Society of Canada

Dr Muhammad Nangrejo (2001-2003)

- Awarded Chartered Engineer status

Professor Edward Tate (1999-2001)

- Awarded CRUK Programme Grant (£1.9m to work on discovering and validating new drug targets in cancer)

Professor André Xuereb (2011-2013)

- Appointed Ambassador for Digital Affairs, Malta

Industrial Fellows

Dr Andrew Anderson (2017-2020)

- Appointed Lead Research and Development Engineer at Plasma App Ltd

Professor Michael Clinch (1996-1999)

- Elected Vice-President, Institute of Materials, Minerals and Mining
- Appointed Visiting Professor, Materials Innovation and Sustainability, Loughborough University
- Awarded Chartered Engineer status

Dr Silvia Araguas Rodriguez (2014-2017)

- Appointed Technical Director, Sensor Coating Systems

Dr Ruth Sanderson (2009-2012)

- Founder of Full Matrix Ltd, which in 2021 was awarded a contract with UKAEA to study the feasibility of guided wave inspection for supply pipes in fusion reactors

Industrial Design Students

Arthur Carabott (2015-2017)

- Winner, Core77 Design Education Initiative Award for *Intentional Interactions*, a module taught to students on the Global Innovation Design course at the Royal College of Art / Imperial College London

James Fraser (2017-2019) and James Wright (2012-2013)

- Launched *Sustainable Ventures Design*, a design studio offering services in new product development, design engineering and graphic design, exclusively for impact-led founders and organisations
- Successfully completed Project NEMO with the Royal College of Art, working on a custom marine observation camera fitted to Extreme E's vessel *St Helena* to monitor the surface of the world's oceans, providing data for scientists investigating environmental sustainability, plastic pollution, loss of marine habitats and new ocean economies

Yusuf Muhammad (2006-2008)

- Plumis won Active / Passive Fire Project of the Year, Security and Fire Excellence Awards
- Featured in Lord Winston's book *Inventors*

Enterprise Fellows

Guillem Buxarrais (2017)

- Neurofenix was one of only 50 companies worldwide selected to participate in MedTech Innovator's Showcase and Accelerator Programme

Henrik Hagemann (2016)

- Puraffinity awarded a grant of £174,000 to successfully optimise a suite of adsorbent materials to treat broad spectrum Per and polyfluoroalkyl substances that can be adapted to a range of point of use systems

Ming Kong (2016)

- TGO secured a deal with French automotive supplier Novares for its smart 3D sensing material

Surakat Kudehinbu (2019)

- RAB-Microfluidics secured £1.2m investment
- Appointed Investment Executive, Green Angel Syndicate
- Appointed to Enterprise Fellowships Selection Panel

Ben Lakey (2019)

- Syndi Health launched integrated digital mental health platform with UNiDAYS, the world's largest student discount platform

Yang Lu (2016)

- Vivacity Labs secured a contract from the City of Port Philip, Australia, to install sensors to measure bike, pedestrian and motor vehicle movements, and to help the local council reduce congestion and increase sustainable transport

Rowan Minkley (2019)

- Secured £1m investment, allowing Chip[s]Board to relocate to Yorkshire and establish a pilot plant
- Secured contracts with Cubitts eyewear and bespoke button manufacture

Dr Atif Syed (2018)

- Secured £300m deal for WootZano with one of the country's leading pack-house conglomerates
- WootZano delivered first tomato packing robot
- WootZano received Made in the North East Award: Digital Engineering / Technology

George Wright (2017)

- Vochlea named one of TechRound's top 28 UK Music and Audio Tech companies

Rome Scholars

Anne Desmet (1989)

- Designed the £5 coin launched by the Royal Mint in March 2021 to mark the 150th Anniversary of the Royal Albert Hall
- Curated and wrote the exhibition catalogue for the touring exhibition *Scene through Wood: A Century of Modern Wood Engraving* celebrating the centenary of the Society of Wood Engravers

Professor Mark Jones (1982)

- Elected Chair, Traditional Architecture Group
- Appointed Output Assessor for UK REF 2021

Report by the Chairman of the Finance Committee

Executive summary

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. Sir William Castell stepped down as a Commissioner and the Chairman of the Finance Committee in July. Over his tenure he reshaped the finances of the Commission and built an exceptional group of Committee members. He leaves the Commission's finances in excellent condition. I would like to thank all members of the Committee for their support as I transitioned into the role of Chair and for their ongoing valuable contribution in overseeing the Commission's finances.

During 2021 there were two formal meetings of the Committee. In the spring meeting we reviewed the annual accounts and met with the Commission's auditors. We also heard presentations from the investments managers. In the autumn meeting the Committee focused on reviewing the long-term investment objective and investment strategy for the Commission, recognising that the return of inflation and a less accommodative monetary environment would be challenging for markets. In view of the derecognition of RPI as a national statistic, the Committee recommended to the Commissioners that the investment objective be revised from 4% after RPI to 4% after CPI. Historically, CPI has tended to be somewhat lower than RPI, which should mean that this change has the advantage of making the investment objective more realistic in the new environment. During the year the Commissioners also appointed and onboarded a new property advisor, Daniel Watney LLP.

Highlights for the calendar year to 31 December 2021

The Commission's income and gains derive primarily from its investment portfolio. For the 12-month period the investment portfolio generated combined income and gains of £17,086,913 (2020: £15,593,069). The total funds as of 31 December 2021 were £150,029,559 (2020: £138,125,545).

Expenditure on core Fellowships and Studentships increased from £3,245,516 to £3,839,642. Total expenditure on charitable activities of £4,538,642 was £640,019 less than the previous year. This primarily reflects an exceptional Special Award in 2020 of £1.2m for public realm improvements at the northern end of the Commission's estate.

Expenditure on raising funds – which primarily comprises investment and property management fees – decreased from £740,364 in 2020 to £643,883 in 2021.

Investment Policy

Over the long term, the Commission aims to disburse 4% per annum of the trailing three-year average value of the portfolio. However, the Commission has few if any fixed liabilities and annual budgets include an allowance for Special Awards that can be adjusted without detriment to other programmes so this can vary from year to year depending on grant making opportunities and investment returns.

The investment objective is to generate a return of at least inflation plus 4% per annum over the long term, after expenses. This should allow the Commission to at least maintain and ideally grow the real value of the assets, whilst generating a stable and sustainable return to fund annual expenditure as set out above. The Finance Committee has determined that the inflation measure most relevant to the Commission's expenditure is the Consumer Price Index.

The Finance Committee is charged with agreeing a high-level asset allocation strategy with the investment managers, which is set so as to achieve the overall Commission investment objective. The Finance Committee will revisit the strategic asset allocation, and consider the need for tactical deviations from it, on at least an annual basis. The Finance Committee is responsible for identifying and monitoring investment managers and investment vehicles for the Commission.

The Commission adopts a total return approach to investment, generating the investment return from income and capital gains or losses. Recognising the likely volatility of the capital, the Commission will typically aim to generate an overall income return of between 2% and 3% per annum to reduce the risk that losses will need to be crystallised to fund commitments.

The Commission recognizes that long term investment is subject to market, political, economic, counterparty and other risks, with financial instability in particular being a key risk. The Commission also recognizes inflation as a significant risk to the long-term sustainability of its activities and one that the investment policy should mitigate against.

The trustees are able to tolerate volatility of the capital value, as long as the Commission is able to meet its short-term grant making commitments through either income or liquid capital assets. To allow for volatility of capital values, the trustees wish to maintain at least £5m in cash or lower risk fixed income investments. Bearing in mind income generated by the portfolio and the flexibility to curtail Special Awards, this should allow three years' worth of Fellowships to be funded without needing to sell risk assets.

Ethical Investment Policy

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.

Investment Performance 2021

2021 was another challenging year for investors. Key themes over the year included the emergence of the Omicron variant, ongoing supply chain disruptions, high inflation readouts and expectations for tightening monetary policy in the US and Europe. Despite this equity markets had a strong 2021 in aggregate, with the MSCI ACWI Index returning 19.6% across the year. Beneath this, however, there was a high degree of dispersion in returns across sectors and regions, with a significant amount of global equity performance driven by a small number of US technology stocks. Credit markets were weak in aggregate in 2021, particularly long duration bonds, in part linked to higher inflation and expectations of interest rate rises in a number of regions. The Bloomberg Barclays Global Aggregate Index was down -1.7% for the calendar year. Against this backdrop the Commission achieved a total return net of fees of approximately 10.2% (2020: 11.0%). CPI + 4% was 9.4% (2020: 4.6%).

The Commission's portfolio is invested by three investment managers: Schroder & Co. Ltd; Charles Stanley & Co. Ltd and JP Morgan Asset Management (UK) Ltd. The Commission also has direct property holdings on its legacy estate in South Kensington. The asset allocation of the combined portfolio as at 31 December was 75.4% in global equities, 3.1% in listed alternative assets, 8.8% in cash and bonds and 12.7% in the legacy estate (at the end of 2020 the proportions were 69.0%, 2.9%, 11.9% and 16.2% respectively).

Schroder & Co. Ltd and Charles Stanley invest globally, predominately in equities and returned 11.8% and 11.7% respectively (2020: 12.8% and 12.7% respectively). JP Morgan Asset Management (UK) Ltd manage a short duration bond account and returned 0.8% (2020: 6.2%). The directly held property returned 7.6% (2020: 11.6%) enjoying (predominantly unrealised revaluation) gains of £1,213,607 (2020: £1,975,082), the majority of the gains reflecting decreasing lease terms and the increasing impact of reversionary values. Income from property over the 12 months was £594,269 (2020: £1,300,782 including back rent of £665,000).

As at the balance sheet date, the Commission's main segregated equity portfolio had scope 1 and 2 carbon emissions that were 82% less than the MSCI World index (2020: 81% less than the MSCI World index). The carbon intensity of the Commission's combined equity portfolio (direct and indirect holdings), measured in tonnes of CO₂ emissions per million dollars of sales was a little over half that of the MSCI World index, broadly in line with the position the previous year.

Long term performance vs investment objective

The value of the investment portfolio – and the grant making it funds – has grown significantly in real terms over the last 10 years. The annualised real return achieved has been 8.0% for 10 years, 6.5% for 5 years and 9.3% for 3 years.

The Commission recognises this has been against a backdrop of high equity returns and central bank easing. As we move into a period of higher inflation and tightening monetary policy, the Commission recognises the “excess” real return enjoyed over the last decade is likely to reduce and so remains flexible in its disbursement policy.

Reserves Policy

The Commission's 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 above 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.

The Commission's Auditor

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

Ms Sandra Robertson

Royal Commission for the Exhibition of 1851

Summarised Statement of Financial Activities for the Year Ended 31 December 2021

	2021 £	2020 £
Income		
Donations	3,000	71,107
Investments	2,256,608	2,715,229
Other	58	925
Total income	<u>2,259,666</u>	<u>2,787,261</u>
Gains and losses		
Gains on property	1,213,607	1,975,082
Gains on investments	13,616,698	10,902,758
Actuarial losses on defined benefit pension Scheme	(3,432)	(23,626)
Total gains and losses	<u>14,826,873</u>	<u>12,854,214</u>
Total resources available	17,086,539	15,641,475
Expenditure		
Raising funds	643,883	740,364
Charitable activities	4,538,642	5,178,661
Total expenditure	<u>5,182,525</u>	<u>5,919,025</u>
Net movement in funds	<u>11,904,014</u>	<u>9,722,450</u>
Reconciliation of funds		
Total funds brought forward	<u>138,125,545</u>	<u>128,403,095</u>
Total funds carried forward	<u><u>150,029,559</u></u>	<u><u>138,125,545</u></u>

Royal Commission for the Exhibition of 1851

Summarised Balance Sheet as at 31 December 2021

	2021 £	2020 £
Fixed asset investments		
Investment properties	20,940,350	23,345,382
Listed investments	133,023,295	119,307,960
Cash held as part of the investment portfolio	1,501,182	1,017,499
	<u>155,464,827</u>	<u>143,670,841</u>
Current assets		
Debtors	404,829	1,140,855
Cash at bank and in hand	1,577,788	1,103,335
	<u>1,982,617</u>	<u>2,244,190</u>
Liabilities		
Creditors: Amounts falling due within one year	(4,070,791)	(4,580,884)
Net current liabilities	<u>(2,088,174)</u>	<u>(2,336,694)</u>
Total assets less current liabilities	153,376,653	141,334,147
Creditors: Amounts falling due after more than one year	(2,948,094)	(2,783,602)
Net assets excluding pension liability	<u>150,428,559</u>	<u>138,550,545</u>
Defined benefit pension scheme liability	(399,000)	(425,000)
Net assets	<u>150,029,559</u>	<u>138,125,545</u>
The funds of the Charity:		
Capital Funds		
Balance as at 1 January	138,125,545	128,403,095
Movement in year	11,904,014	9,722,450
Balance as at 31 December	<u>150,029,559</u>	<u>138,125,545</u>

Royal Commission for the Exhibition of 1851

Note to the Summarised Financial Statements for the Year Ended 31 December 2021

1. CHARITABLE ACTIVITIES

	2021 £	2020 £
Grants	3,948,787	4,647,379
Direct costs	249,505	210,543
Support costs	340,350	320,739
	<u>4,538,642</u>	<u>5,178,661</u>

Analysis of grants and awards committed in the year:

	2021 No.	2021 £	2020 No.	2020 £
Research Fellowships	10	1,490,400	10	1,707,647
Industrial Fellowships	13	1,165,435	10	494,982
Industrial Design Studentships	11	466,506	10	412,192
Built Environment Fellowship	1	100,000	–	–
Design Fellowship	–	–	1	90,000
Enterprise Fellowships	6	312,500	5	312,500
Great Exhibition Scholarships	–	–	–	(9,000)
Sir Misha Black Award Bursaries	2	20,000	–	–
Special Awards	12	393,946	14	1,639,058
	<u>55</u>	<u>3,948,787</u>	<u>50</u>	<u>4,647,379</u>
Total awards				

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 50 to 52. Details of the Commission's professional advisers are provided on page 53.

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 role 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 are summarised below. Actions taken to mitigate the impact of COVID-19 are described on page 11 above.

Investments: security, performance, liquidity

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

Grant making: applications, assessment, administration

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

Legacy estate: character, experience, relevance

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

Commissioners and Committee Members

President

HRH The Princess Royal

Commissioners (and Board of Management)

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

Professor Jim Al-Khalili CBE FRS FInstP

Professor Dame Kay Davies DBE FRS FMedSci

Professor Dame Ann Dowling OM DBE FREng FRS

Mr Jim Eyre OBE

Professor Sir Andrew Hopper CBE FRS FREng FIET

Professor Lord Mair CBE HonDSc FREng FICE FRS

Dame Alison Nimmo DBE MRTPI FRICS HonFRIBA FICE

Ms Sandra Robertson

Professor Dame Carol Robinson DBE FRS FRSC FMedSci

Professor Chris Wise RDI FREng FICE MIStructE HonFRIBA FRSA

Professor Jim Al-Khalili was appointed to the Board on 8 December 2021

Professor Dame Carol Robinson was appointed to the Board on 7 July 2021

Sir William Castell retired from the Board on 7 July 2021

Mr Stuart Corbyn retired from the Board on 7 July 2021

Sir John O'Reilly retired from the Board on 8 December 2021

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

Ms Sandra Robertson *Chairman*

Ms Sarah Arkle

Professor Sir Andrew Hopper CBE FRS FREng FIET

Mr Nicholas Moakes CFA

Dame Alison Nimmo DBE MRTPI FRICS HonFRIBA FICE

Sir William Castell retired from the Committee on 7 July 2021

Mr Stuart Corbyn retired from the Committee on 7 July 2021

Science and Engineering Fellowships Committee

Professor Dame Kay Davies DBE FRS FMedSci *Chairman*
Professor Jim Al-Khalili CBE FRS FInstP
Professor Gillian Bates FRS FMedSci
Professor Mike Benton FRS FRSE
Professor Martin Bridson FRS
Professor Andrew Briggs
Professor Neil Champness FRSC FLSW
Professor Anne Dell CBE FRS FMedSci
Professor John Dewey FRS
Professor Cyril Hilsum CBE FREng FRS
Professor Patrick Keogh FREng
Professor Jane Langdale CBE FRS
Professor Stephen Muggleton FREng
Professor Rachel O'Reilly FRSC
Professor Sheena Radford OBE FRS FMedSci
Professor Dame Carol Robinson DBE FRS FRSC FMedSci
Dr Dame Frances Saunders DBE CB FREng FInstP
Professor Trevor Stuart FIC FRS
Professor Christopher Tout
Professor Stuart West
Professor John Wood CBE FREng

Professor Jim Al-Khalili was appointed to the Committee on 8 December 2021
Professor Patrick Keogh was appointed to the Committee on 30 April 2021
Professor Dame Carol Robinson was appointed to the Committee on 7 July 2021
Dr Dame Frances Saunders was appointed to the Committee on 21 July 2021
Professor Christopher Tout was appointed to the Committee 25 June 2021
Professor Stuart West was appointed to the Committee on 28 April 2021
Professor David Ewins retired from the Committee on 27 April 2021
Professor James Feast retired from the Committee on 1 January 2021
Professor Douglas Gough retired from the Committee on 27 April 2021
Professor Maurice Skolnick retired from the Committee on 27 April 2021

Brunel Fellowships Sub-Committee

Professor Dame Kay Davies DBE FRS FMedSci *Chairman*
Professor Dame Anne Dowling OM DBE FREng FRS
Professor David Ewins DSc FREng FRS
Professor William Powrie FREng FICE
Professor John Wood CBE FREng

Industry and Engineering Committee

Professor Dame Ann Dowling OM DBE FRS FREng *Chairman*
Professor John Clarkson FREng
Ms Naomi Climer CBE FREng FIET
Dr Nicholas de León
Professor Lord Mair CBE HonDSc FREng FICE FRS
Professor Ron Pethig
Dr Malcolm Skingle CBE DSc
Professor Eleanor Stride OBE

Sir John O'Reilly retired from the Committee on 8 December 2021

Built Environment and Design Fellowships Committee

Mr Jim Eyre OBE *Chairman*
Professor Rachel Cooper OBE
Dame Alison Nimmo DBE MRTPI FRICS HonFRIBA FICE
Dr Andrea Siodmok EMPP FRSA HonDCL
Professor Chris Wise RDI FREng FICE MStructE HonFRIBA FRSA

Mr Robin Levien retired from the Committee on 1 January 2021

Sir Misha Black Awards Committee

Ms Mary Mullin *Chairman*
Professor Chris Wise RDI FREng FICE MStructE HonFRIBA FRSA
Professor Peter Childs
Dr Nicholas de León
Professor Sir Christopher Frayling FCSD FRSA FRIBA
Professor Malcolm Garrett MBE RDI FISTD
Professor Geoff Kirk RDI FREng

Staff

Mr Nigel Williams LVO CEng	Secretary (to 25 May 2022)
Mr John Lavery	Secretary (from 25 May 2022)
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

Professional Advisers

Bankers

The Royal Bank of Scotland plc
London Drummonds (B) Branch
49 Charing Cross
London SW1A 2DX

Investment Managers

Schroder & Co. Limited
1 London Wall Place
London EC2Y 5AU

Surveyors

Daniel Watney LLP
165 Fleet Street
London EC4A 2DW

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

Auditor

Moore Kingston Smith LLP
9 Appold Street
London EC2A 2AP

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

Actuaries

XPS Pensions
Albion
Fishponds Road
Wokingham RG41 2QE

Insurance Brokers

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

Legal Advisers

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

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
<http://alumni.royalcommission1851.org>
LinkedIn: <https://linkedin.com/company/royalcom1851>
twitter: <https://twitter.com/royalcom1851>
instagram: <https://instagram.com/royalcom1851>