A refreshed Innovation Strategy for Scotland

Submission to the Call for Evidence by the Institute of Physics Scotland

June 2022

1. Introduction

1.1. We welcome the consultation on the Scottish innovation strategy and the opportunity to respond.

2. About us

2.1. The Institute of Physics ("IOP") is the learned society for physics and professional body for physicists across the UK and in Ireland. We seek to raise public awareness and understanding of physics, inspire people to develop their knowledge, understanding and enjoyment of physics and support the development of a diverse and inclusive physics community. Our mission as a charity is to ensure that physics delivers on its exceptional potential to benefit society.

3. Physics and innovation

3.1. Improvements in technology are the main drivers of innovation, alongside access to capital investment, a skilled workforce and efficiencies in business or organisational processes. Physics is indispensable to both economic growth and social progress as the foundation of many of the world's most impactful and successful innovations. From Newton's laws of motion, through to electrification after Faraday and the nuclear age during the last century, breakthroughs in physics have played an essential role in enabling new technologies to emerge, creating industries and shaping our lives.

3.2. Today, there are applications as varied as particle detectors, sensors and advanced satellite platforms to better understand and chart our universe, to new materials such as graphene and nanotechnology to drive engineering advances, develop new cancer diagnostics and treatments and so deliver improved outcomes for patients. There are transformative new technologies including quantum sensors, cryptography and computing, and zero-carbon energy generation using nuclear fusion, but also step-change improvements resulting from advances in, for example, laser-based photonic systems and next-generation multi-layer silicon devices.

3.3. Physics is also expected to drive many of the key innovations we expect in the coming decades such as advanced robotics and artificial intelligence, leading to a fourth industrial revolution.

3.4. Scotland has been the source of or contributed to developing many of these ideas – from Lord Kelvin's laws of thermodynamics, and James Clerk Maxwell's pioneering of electromagnetism, to John Leslie's work on heat. Scotland has also helped progress these ideas towards practical applications at scale and commercialised – such as Kelvin's electric telegraph, Maxwell's colour photography and Leslie's generation of ice and invention of thermometers.

3.5. Physics already **delivers substantial economic benefits**. In 2019, physics-based industries generated £28.4bn in gross value added (GVA), equivalent to 17% of Scottish GDP – or **one-sixth of the Scottish economy**. This is equivalent to more than the retail, construction and transport/storage sectors combined. These industries employed 220,000 full-time equivalent (FTE) employees – 10% of total Scottish employment – in productive, rewarding careers, with an average salary of £47,000 (half above the national average) and annual labour productivity of £129,000 per worker. If levels of public and private investment in research and development both in Scotland and across the UK reach the declared UK target of 2.4% of GDP, physics has even more potential to accelerate ever more success.

3.6. The IOP is currently developing **an R&D blueprint for physics**, which will set out how core elements of the R&D system can be strengthened, and the conditions and policy environment for R&D improved, so that we can create a thriving physics R&D ecosystem and realise the full societal and economic benefits of the new industrial era. This will centre on four pillars: scientific discovery; business; people and skills; and infrastructure. We would be happy to share the outputs of this work with the Scottish Government once available in the autumn.

4. Background to this submission

4.1. During 2021, the IOP commissioned CBI Economics to carry out a survey of the UK and Ireland physics community to understand the innovation activity which these businesses planned and how significant it was for their work, as well as challenges they face. The findings of that research, the largest such survey ever undertaken, were published in October 2021.[1] This submission draws substantially upon the responses of the 39 Scottish participants, who were spread broadly across different sectors of the economy.

4.2. The findings of the survey note a number of positives. Consistent with the historic role of physics in innovation noted above, physics skills and expertise contribute to high levels of innovation activity and interest. Most companies which do physics are innovating, and those doing the highest intensity of physics are innovating more. 93% of Scottish respondents saw innovation as central to their business purpose. And by a net balance of +50%, Scottish respondents are planning to raise their spending on R&D/innovation over the next five years (60% expect this to rise, 10% to fall).

1 *Paradigm Shift*: see www.iop.org/strategy/productivity-programme/innovation-survey.

4.3. However, the findings also note challenges in securing investment, accessing skills, and collaboration. This reflects the fact that physics innovation is seen as uniquely complex. Notably, it is felt that not all parts of the UK benefit equally from the most opportune conditions.

4.4. One aspect of international collaboration is worth highlighting at this point. The UK Government secured associate membership of the Horizon Europe programme through the EU-UK Trade and Cooperation Agreement in December 2020. This would have allowed UK participants to apply for grants, and form and lead consortia with international partners, as with researchers from continuing EU Member States. Association included access to the European Research Council (ERC), the Marie Skłodowska-Curie Actions, the six Pillar II 'Global Challenges' clusters, the EU Missions, the Next Generation European Partnerships, the European Institute of Innovation and Technology, and others. Many of these relate to ambitions strongly reliant on physics, such as climate change and digitalisation. In September 2018, the Campaign for Science and Engineering (CaSE) and others identified several intangible, non-financial benefits from participation in EU programmes, including enhanced competition, greater diversity of the research base, access to advanced facilities, and attractiveness to research staff. The UK's focus on excellence over a fair distribution enabled its applicants to prosper and also helped shape the concentration of EU funding programmes; the absence of the UK since 2020 has enabled these programmes to shift away from the UK's comparatively advantageous position. The European Commission confirmed that this association could have been activated via a Protocol which was already agreed in principle, and which need not require additional negotiations. This gave encouragement to the physics research community that the prospects of this coming into effect were substantial. The lack of progress on this front is of considerable concern, as is the ongoing lack of detail about the replacement. There are assumptions that the full effects of Horizon Europe association will be very difficult to replicate through a domestic programme, and/or international agreements with non-EU countries. This has a disproportionate impact on the physics community in Scotland, where 38% of physics innovators here noting a reliance on EU funding compared with 19% across the UK as a whole.

4.5. The COVID-19 pandemic has notably disrupted physics-based R&D/innovation activity in Scotland, although a recovery is expected within the next five years. 41% of Scottish survey respondents felt that COVID-19 had an overall negative effect, although 27% said it had been positive – this could be accounted for by specific investment in physics applications to help us get through the pandemic, and/or greater public awareness of the potential for science to solve pressing social and economic challenges.

5. Responses to consultation questions – general

(a) How do we make Scotland one of the most innovative small economies in the world?

5.1. Scotland has several innovation-rich sub-sectors within the physics community, notably in photonics, space, quantum and energy (the latter being the most substantial portion of the

Scottish physics community). Support for these areas of strength would help to generate positive economic impact. These sectors also provide strong visual value, and can help to create and sustain a positive reputation for Scotland as an innovative, forward-looking destination for both skilled workers and investment.

5.2. Some of the concerns expressed by Scottish respondents to the innovation survey note that direct costs and risks inherent in the activities themselves are a barrier to undertaking R&D/innovation – there is comparatively little that government policy and action can do to mitigate this. Many physics installations are expensive and success is neither linear nor straightforward in any complex process of discovery. However, central resources such as the Higgs Centre for Innovation in Edinburgh, which makes facilities such as clean rooms available to smaller and newer enterprises, can over substantial benefits, especially since 93% of the 27,000 physics-based businesses in Scotland are microbusinesses.

5.3. We would caution against overloading support for the most easily commercialisable research at the expense of early-stage research, although it is tempting to do so. Physics is one of the most fundamental sciences, and it's not always possible to tell what the practical applications of discovery will be. When the structure of atoms and existence of electrons was discovered, no-one had any clue that a century later the world would be dominated by electronics. Nokia became a telecommunications giant within Finland after starting out in timber and pulp mills, after realising it could diversify into electric cabling through its work on telegraph poles and rubber as an insulator.

5.4. Since the onset of COVID-19, several different applications of physics helped our society cope with and progress beyond the pandemic. Fluid mechanics taught us about airborne transmission, which in turn informed rules on distancing and face coverings. GPS technology enabled contact tracing via smartphone devices. Semiconductors and microprocessors powered home working, home shopping and maintained virtual connections between friends and families. And x-ray spectroscopy revealed the virus structure, paving the way for the astonishing vaccination programme. None of these processes were designed with medicine in mind, let alone virology, yet all helped to preserve quality of life and significantly reduced the hit on our economy.

5.5. This essential uncertainty suggests that entirely planned and mission-driven innovation approaches risk missing out on organic development of technologies, and that a wise nation plays to its comparative strengths in research. Provided that movement of people remains relatively fluid, ambitious and creative researchers are likely to be attracted to where pioneering work is done, increasing the odds that intellectual energy and drive will spark new inventions and process refinements. Plus, a concerted focus only on late-stage research risks shrivelling the pipeline of discovery necessary for medium-term and longer-term success.

(b) How can we better use innovation to help achieve Scotland's broader economic and societal ambitions?

5.6. Achieving economic growth through exploiting and consuming natural resources is a necessarily finite approach and, as seen through burning hydrocarbons, generates adverse consequences. Sustainable and inclusive growth in living standards for the long-term will only be possible through technologies which are carbon-neutral, carbon-free or indeed carbon-negative. The national ambition to achieve Net Zero by 2045 should be a significant push factor for technological innovation, provided it is backed by coherent planning, action and resources.

(c) How can we measure progress and what metrics and indicators should we use?

5.7. As a measure of economic activity, GNP is instructive because all value created is thought to generate income somewhere. However, it is comparatively less successful at recognising social value. Several alternative indicators have been suggested and formulated, but these are most likely to have broad impact when they are understood and recognised both by the private sector at home and by the research community internationally.

6. Theme 1 – World Leading Excellence and Expertise

(d) What sectors and sub-sectors should Scotland aim to be a world leader in?

6.1. See para 5.1 above. The Scottish Government has already identified ambitions to be a world-leader in some physics-based sectors, including space and hydrogen. It would make sense to recognise these in our innovation strategy too.

6.2. Paras 5.3 to 5.5 above also note the need to ensure a sufficiently broad approach which includes early as well as late-stage research.

(e) How do we ensure that our universities, and other research and innovation performing institutions, act as anchors for the economy, playing their fullest role in helping grow businesses at the cutting edge of innovation?

6.3. The main role for universities involves generating and sustaining a pipeline of talented workers able to perform high-end physics tasks both in research and industry. Skills shortages threaten to impede plans to invest in physics-based R&D/innovation, with half of Scottish innovators identifying this as a significant challenge. Scottish innovating physics-based businesses saw particular difficulties in filling roles with sufficient technical and commercial skills (58% of respondents), as well as specialist physics-related knowledge (45%). Skills shortages were particularly acute at the large-scale prototype and production/scaling-up stages of the "innovation funnel". 70% of Scottish innovators said these skills shortages caused R&D/innovation activity to be suspended or delayed during the previous five years, with 44% noting that such activity had to be sub-contracted or outsourced. However, it had led firms to invest more in staff training. We have shared these findings with the universities themselves, but this is also an argument for concerted efforts to ensure a sufficient number of study and research places within these institutions, and for filling the complement as far as possible. It also reinforces the need for co-ordination of this supply chain through specialist research pools such as the Scottish Universities Physics Alliance (SUPA), which has regrettably seen its funding from the Scottish Funding Council cut and will have to reduce its activities accordingly.

(f) How do we support and grow clusters of excellence to deliver on our vision for innovation?

6.4. No response

7. Theme 2 – Investing in Innovative Businesses

(g) What can we do to help businesses innovate today?

7.1. See para 6.3 in relation to investment in skills.

7.2. Access to public funding is a factor which would significantly assist. 81% of Scottish respondents to the IOP innovation survey identified this as vital for their innovation activity, compared with 70% for the UK as a whole. As well as being more reliant on public funding elements, Scottish innovators were more creative and flexible about sourcing, with 56% receiving funds from the UK Government, 38% from the EU, and 27% from devolved institutions. The most significant contribution this makes is to fill funding gaps, especially at the most basic or most applied research, where private finance is less readily available. Public funding also has a virtuous circle benefit, with 33% of respondents identifying this as a route to encouraging and securing private funding alongside it, allowing improvements to skills and equipment, but most importantly of all it fosters collaboration. Two-thirds of respondents identified greater direct funding for both early and late-stage development as factors which would increase their own spending over the next five years. Long-term funding in particular were seen as important by 81%, as half identified uncertainty as a significant barrier to investment. Two-fifths also suggested that easier access to existing support would make a difference, which is again higher than the equivalent UK response rate (29%).

7.3. Policy also plays a role. 44% of Scottish respondents identified government policy or regulation as a potential barrier, compared with 24% across the UK. One-third said that government procurement policies would be of benefit, and one-quarter called for better digital infrastructure. One-third called for an improved regulatory environment, with the administrative burdens of innovation protections seen as the most inhibiting element.

(h) How can we maximise the funding and investment available to businesses that innovate?

7.4. See paras 7.2 and 7.3 above.

8. Theme 3 – Adoption and Diffusion of Technology

(i) How can we become one of the best places in Europe for the adoption and diffusion of technology?

8.1. See previous answers in relation to both skills and digital infrastructure.

(j) How can we better support businesses to improve their ways of working and be adaptive and responsive to changing markets?

8.2. Greater science capital and public knowledge about the potential of scientific research, especially physics, to transform lives could help businesses see market opportunities and also increase demand.

9. Theme 4 – Role of the public sector and procurement

(k) What levers do we have in terms of public sector procurement which would encourage greater innovation within key sectors?

9.1. One-third of Scottish respondents to our innovation survey cited improved government procurement of innovation as a factor which would allow them to undertake more R&D or innovation activity within the next five years. This is notably more than the equivalent response rates across the UK as a whole (21%) or the Republic of Ireland (9%). This suggests either a greater reliance upon government's financial muscle in Scotland than elsewhere, or a recognition that difficulties remain in generating demand from alternative, commercial sources.

10. Theme 5 – innovation infrastructure and architecture

(l) Do we have the infrastructure and architecture in place to become a world leading innovation ecosystem?

10.1. The presence and work of Interface and the Innovation Centres seem to be well-respected and well-received. Ensuring that they are sufficiently connected to Scottish Government ambitions to become a world-leader in certain industries (including space and hydrogen, for example) should help to upskill and refocus in these areas.

(m) What opportunities are there for greater co-ordination and collaboration across the ecosystem?

10.2. Connection and collaboration were cited as one of the most valuable aspects of public support by Scottish innovators. Given the comparative reliance upon public sources of finance and difficulties in obtaining private finance, promoting collaboration opportunities could be made a strategic objective for the innovation support ecosystem. Most physics-based innovations do not conform to the stereotype of a lone actor, but instead rely on substantial collaboration involving many moving parts.

11. Case study: AAC Clydespace

To emphasise both the general points and the answers to specific questions made above, we include here a case study of a blue-chip physics-based Scottish business, who were winners of the Queen's Award for Enterprise in the innovation category in 2017.[2] This case study, commissioned from the IOP by CBI Economics, appeared in the IOP's *Paradigm Shift* report documenting the innovation survey of physics businesses, and describes the relevance of innovation to AAC Clydespace's work, its plans and the context in which it operates.

About the organisation

AAC Clyde Space specialises in small-satellite technologies and services that enable commercial, government and educational organisations to access high-quality, timely data from space. Our company has over 150 employees and more than 15 years of experience in subsystems, advanced sensors and data delivery and operates in Sweden, the UK, the Netherlands, and the US.

What are the physics-based technologies that you are developing in your business?

- Space data as a service: we offer a range of satellite solutions and services. Timely, high-quality satellite data or communications delivered directly to our clients enables applications such as weather forecasting and ship tracking;
- space missions: fully assembled micro and nano satellite platforms (1-50kg) and mission services including support for launch and spacecraft operations; and
- space products and components: a full range of off-the-shelf and tailor-made subsystems for cube and small satellites (up to 500kg). This includes power (such as batteries and solar arrays), command and data handling (including on-board computers and data-storage systems), communications, attitude and orbit-control systems, and structures.

What was your innovation journey like?

At AAC Clyde Space, innovation is a core value. We are continuously moving forward, anticipating market needs and pioneering new ideas. In 2017, we won the Queen's Award for Enterprise in the innovation category. It's an exciting time in the industry, with fast innovation cycles and a rapidly expanding range of space applications.

An unprecedented number of companies are eager to tap into this lucrative space-based, data-driven market. Collaboration is critical to innovation, so we have worked successfully with clients, partners, and suppliers with support from shareholders, customers, economic development agencies, and space agencies to support continued growth of the industry.

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[2] See https://queensawards.blog.gov.uk/2017/07/21/2017-queens-award-winners-in-innovation-clydespace-reach-the-final-frontier/

As demand for data from small satellites continues to grow, the industry is already working to deliver the next generation of constellation satellites and services. For example, projects such as the Scottish Enterprise Grant, to design a highly integrated core avionics system, and xSPANCION, which will develop an innovative satellite constellation service, including the manufacture of 10 spacecrafts.

These projects will improve the ability to offer more affordable cutting-edge satellites for constellations and involve a significant expansion of AAC Clyde Space's delivery capability.

xSPANCION is one example of a collaborative development project, funded by the European Space Agency (ESA) with support from the UK Space Agency. Partners include Bright Ascension Ltd., the University of Strathclyde, D-Orbit UK, Alden Legal UK and the Satellite Applications Catapult.

> ***"Increased provision to medium-sized enterprises to support growth to large multinationals is key."***
>
> **Pamela Anderson, head of institutional engagement, AAC Clyde Space**

What is your approach to achieving physics-based innovation?

At AAC Clyde Space innovation is informed and driven by market demand and customer needs.

We work with fast-paced innovation cycles to meet the increasing demand for the reliable, timely delivery of data from constellations of small satellites and aim to improve our ability to deliver innovative solutions at scale by:

- increasing production capacity of satellites through more efficient manufacturing and assembly;
- using standardised and integrated platform design to reduce costs while maintaining high performance, quality, and reliability; and
- developing new types of sensors where we provide Space Data as a Service.

The timelines associated with the 'new space' industry and the fast-paced innovation cycles are often at odds with traditional approaches to space and often do not align well with innovation support timelines.

Flexible, responsive support from institutional bodies is required to enhance commercial innovation and enable companies to respond to global opportunities.

How have you gained the skills and knowledge to drive out innovation?

Our highly skilled team combines expertise from the aerospace, defence, and commercial industries to deliver market-leading solutions and services. We pride ourselves on cultivating an inclusive working environment where talented people want to work and where innovation can thrive.

This is essential to building our long-term competitive edge as we continue to expand our team in line with our strategy to become a world leader in commercial small satellites and services from space – both through direct hires and by acquisition.

We aim to create challenging roles and development opportunities to attract and retain talent. We are committed to improving gender equality in the space industry and strive for equality across the group.

We want to inspire the next generation of budding scientists, engineers, and mathematicians, and in particular to encourage more females to consider a future in space. Our strategy calls for continued growth of the hardware product lines and for significant expansion of the services business. To support this, we are hiring more engineers and technicians.

> ***"Through commercialisation of physics-based innovation, we are changing the way we use and benefit from space technology."***
>
> **Pamela Anderson, head of institutional engagement, AAC Clyde Space**

What has the result of your journey been?

At AAC Clyde Space we are thrilled to bring the benefits of space to Earth, and we have made great strides in positioning ourselves as the partner of choice for commercial, government and educational organisations.

We want to ensure that space technology works to benefit the Earth and the space environment and contributes towards accelerating sustainable development – for example delivery of Mauritius' first satellite to tackle three issues of national priority (ocean surveillance, road traffic congestion, natural disaster mitigation).

We have 29 satellites designed and launched to-date, including for earth observation, for applications such as ocean colour monitoring and wildfire detection, and communications, for services such as ship tracking and the internet of things. Testament to the level of innovation and product quality, AAC Clyde Space technology is present on 30-40% of more than 1,000 nanosatellites launched to the end of 2020.

What tips would you give to businesses developing commercial services underpinned by physics and requiring innovation?

We've learned a lot over the course of our innovation journey, our top tips are:

- invest in R&D and innovation, they are hugely valuable;
- work collaboratively and with partners to fulfil any gaps in your own technical and business competencies; and
- innovate to meet market demand, fully understand the benefits of the innovation, and listen carefully to customer needs.

Be ready to encounter some barriers:

- access to skills and a diverse workforce is challenging. More must be done to attract greater diversity in the space industry in particular and in physics-based businesses in general;
- poor access to demonstration flight or validation opportunities to demonstrate new technical capability and gain in-orbit heritage, which is so critical to commercialisation of innovation in the space sector; and
- the support for scaling-up and commercialising innovations can be limited. It is therefore important to maximise the utility of funding and support to deliver greatest impact.

12. Final details

This response is submitted on behalf of the Institute of Physics ("IOP"), a charity incorporated in 1920, governed by Royal Charter and registered in both Scotland and in England and Wales. Details of the IOP's charter, bylaws and governance appear here: www.iop.org/about/governance.

We are content for this response to be published, and for the Scottish Government to contact us again in relation to this consultation exercise. We confirm that we have read the privacy policy and consent to the data we have provided being used as set out in the policy.

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