COUNCIL FOR SCIENCE AND TECHNOLOGY
10 Victoria Street
London SW1H 0NB

Rt Hon Kwasi Kwarteng MP
1 Victoria Street
London SW1H 0ET
Sent by email only

29 June 2021

Dear Secretary of State,

In March 2021, you met with the Council for Science and Technology and asked members for advice to help inform the Innovation Strategy.

In our recent letter to the Prime Minister, we offered some principles for improving our capacity to innovate, and scale up applications with commercial and societal value.

In the attached report, we offer detailed recommendations for how research and innovation policies and strategy can be combined to support economic growth across the United Kingdom, secure the future of our society and enhance our nation's contribution to the world.

In summary, the key elements are:

1. Businesses of all sizes must find and adopt innovative approaches to improve productivity in existing activities. Examples are the application of artificial intelligence (AI) to industrial control and distribution systems.

2. Experience shows that clustering early-stage activity into a few centres creates success. More must be done to grow the fruits of early stage venturing into flourishing enterprises. Examples are in battery manufacture, robotic application and zero emissions aviation.

3. This requires a more certain and clear set of incentives to adjust the balance of risk between the public and private sectors. Government should be prepared to take on more up-front risk both in applying technologies to existing activities and growing new ones to scale. This must be done within a set of "guard rails" which ensure that investments are made with appropriate due diligence and judgement. The risk taken must be compensated by back-end participation in profits.

4. This also equally requires enough diverse skilled people at all levels. Approaches to skills and education need coordination. Government has an important role in both removing barriers so as to encourage people to move permeably between government, academia, business and finance.

5. Enabling infrastructure (offices and laboratories for emerging growth companies, broadband, testing facilities and so on) must be made available. Next generation infrastructure needs to be developed in conjunction with the private sector (for example, connected digital twins).

6. The UK needs to know where its competitive advantage lies today and over the longer term. It needs to send clear signals to the market and encourage innovation in these advantaged sectors.

7. Government must use its own procurement to create appropriate demand from innovative enterprises, including being the "first customer".

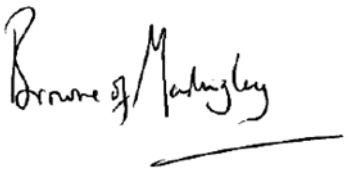
8. The UK needs to emphasise its commitment to innovation without lionising the innovators of the past. This is about the future.

We would be delighted to discuss this with you in more detail and to work with your officials to provide advice to support successful implementation of the Innovation Strategy.

We would like to thank members for giving their time and expertise to formulate this advice, with particular thanks to Paul Stein (Chief Technology Officer, Rolls Royce plc), Professor Fiona Murray (Associate Dean for Innovation and Professor, Massachusetts Institute of Technology, School of Management), Saul Klein (Executive Fellow of Management Science and Operations, Strategy and Entrepreneurship, London Business School), Suranga Chandratillake (General Partner, Balderton Capital) and Professor Julia Black (London School of Economics and Political Science).

We are copying this letter to the Chancellor of the Exchequer, the Secretary of State for Education, the Chief Secretary to the Treasury, the Minister of State for Universities, the Parliamentary Under Secretary for Science, Research and Innovation, the Cabinet Secretary, the Private Secretary to the Prime Minister and the Permanent Secretaries of HM Treasury, the Department for Business, Energy and Industrial Strategy, and the Department for Education.

Yours sincerely,



Sir Patrick Vallance
Co-Chair

Lord Browne of Madingley
Co-Chair

PRIME MINISTER'S COUNCIL FOR SCIENCE AND TECHNOLOGY

Advice on success factors for Innovation

What is innovation?

1. Innovation has several definitions but in a modern economy can usefully be defined as "the process of taking ideas from inception to impact"[1] whereby impact emphasizes creating value in terms of prosperity, social wellbeing, security, or other dimensions.

2. With ideas as its starting point, this perspective on innovation recognizes that ideas can originate from those with challenges and problems to solve or from those with solutions (which may be generated from fundamental research or adopted from other organisations, sectors, and locations).

3. The most successful innovation economies are those that combine strategic focus with a willingness to support multiple (at times competing) approaches and to accept risk in decision making and in investment. From this vantage point innovation is more effectively accomplished by a diverse range of individuals who bring different perspectives, skills, and knowledge (i.e., not simply the 'usual suspects').

4. Not the purview of a single organisation, the innovation journey requires engagement and collaboration across a wide range of organisations including start-ups, universities, large corporations, and the government at national, regional and local levels, each playing different, complementary roles.

Why promote innovation?

Businesses of all sizes must find and adopt innovative approaches to improve productivity in existing activities.

5. Successful innovation solves missions, challenges, and problems and in doing so raises productivity and living standards, expanding the range of goods and services available for individuals and society. It allows us to live longer, healthier, more fulfilled lives, providing resilience and security from the threats that arise in a complex world. Success requires that problems be effectively matched to solutions (generated and advanced from a range of sources) and subsequently translated and refined so they can be deployed at scale.

6. Strengthening our innovation system is central to being a science and technology superpower. If the United Kingdom can create, scale, and embed more such solutions into our domestic markets (including the government itself procuring innovative solutions) as well as internationally through exports, foreign investment, and partnerships, then we will have a globally competitive innovation economy and the national prosperity that comes with it.

[1] Budden, Phil, and Fiona Murray. "An MIT Approach to Innovation: eco/systems, capacities & stakeholders." *MIT Working Paper,* (2019).

How should we best foster innovation?

Experience shows that clustering early-stage activity into a few centres creates success. More must be done to grow the fruits of early stage venturing into flourishing enterprises.

The UK needs to emphasise its commitment to innovation without lionising the innovators of the past. This is about the future.

7. An effective Innovation Strategy will strengthen the UK's position as a science superpower, level up prosperity across the country, support our net zero ambitions, and position us to address the emerging challenges of the future. It must:

    a. reinforce the UK's successful clusters of research and innovation, enabling them to compete globally while maintaining a broad base of fundamental R&D provides the knowledge and expertise to fuel innovation;

    b. encourage investment in the development of the fruits of innovation across the whole of the UK, from focussed investment in specialized facilities for testing, experimentation and scaling solutions in strategically important arenas, to enhancing the ability of local leaders to link research and education providers, business and finance, to create opportunities for local economic growth;

    c. focus resources in areas of present or potential competitive advantage, through explicit targeted incentives and a clear understanding of the balance of risks to be absorbed by government and the private sector;

    d. encourage and incentivize collaboration. Innovation requires engagement and collaboration across a wide range of organisations including public and private finance, start-ups, universities, large corporations, and government (in its role as a grant maker and as a purchaser) at national, regional and local levels. A coherent integrated approach is needed through deployment of clear policies and improved coordination in strategically important areas;

    e. enable the private sector to invest with greater certainty. The role of government is to influence the balance of risks facing innovators, so that their decisions reflect, as much as possible, the desired national priorities [2]. Policy based on a framework of incentives and related regulations that are transparent, consistent and stable over time will galvanise action to achieve the goals the nation cares about;

    f. demonstrate a willingness to take informed risks, an acceptance of some level of failure and the agility to redeploy resources from one project to another. This will require action from the National Audit Office (NAO) and Public Accounts Committee (PAC).

    g. develop a skilled and diverse workforce. Innovation is more effectively accomplished by a diverse range of individuals who bring different perspectives, skills, and knowledge. Growing a cadre of diverse innovators will be important and their flow across business, government and academia must be catalysed.

[2] Innovation: Managing risk not avoiding it, Government Office for Science, (2014): https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/381906/14-1190b-innovation-managing-risk-evidence.pdf

8. Across the innovation system there are some critical factors where government action can shape how resources are deployed towards innovation. The challenge is to harness the potential of the entire ecosystem, coordinate public and private support, and bring together and include the whole of society in this effort. These critical success factors can be simplified into several key pillars:

    i. People
    ii. Finance
    iii. Infrastructure
    iv. Demand

9. We expand on these below and offer recommendations for where the government's Innovation Strategy should focus.

People

Innovation requires enough diverse skilled people at all levels. Approaches to skills and education need coordination. Government has an important role in both removing barriers so as to encourage people to move permeably between government, academia, business and finance.

A nation of innovators

10. We need more people contributing to innovation. Successful innovation requires entrepreneurial talent that comes together with scientists, engineers, financiers, designers, marketers, and operations experts, to name but a few. Having access to the right people, who are open-minded, curious, and creative can spark innovative ideas and inspire the entrepreneur to action.

11. The UK will need many such people to undertake the activity involved in meeting the Government's 2.4% R&D target. This increase from 1.7% has been estimated to need as many as 150,000 additional individuals engaged in Research and Development, each with appropriate skills[3]. These goals are significant - meeting them will require drawing individuals from talents pools beyond historic ones.

Skills gap

12. The UK has a long-standing skills shortage in STEM[4]. While more young people are taking STEM subjects than before[5], most of the engineers and technicians who will be practising in 2030 have already left education. There is a need for strategic workforce planning across government to fully understand where future skills needs will be across the economy (the specific skills, industries and places) and, working with business and education providers, how these skills will be developed. Close working with business to "co-create" the approach will be essential among people of all ages and backgrounds.

[3] Kingman, K., 'The 2.4% challenge: where will our researchers come from?' speech at the Research culture: Changing expectations conference, The Royal Society, (2018).
[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277090/bis-14-544-insights-from-international-benchmarking-of-the-UK-science-and-innovation-system-bis-analysis-paper-03.pdf
[5] https://dfemedia.blog.gov.uk/2021/02/09/more-young-people-are-taking-stem-subjects-than-ever-before/

13. International evidence shows the power of combining technical input with creative skills[6]. As the National Data Strategy highlights, the data revolution has implications not only for experts with advanced analytical skills, but also for the entire UK workforce. It is important to encourage data and digital skills training for all students at all stages, no matter what specialisms they end up pursuing. Businesses using SHAPE skills in technical industries grow three times as fast and are more likely to innovate[7].

14. The opportunity to contribute towards innovation can occur in all careers and disciplines. Scaling up innovation requires a range of skills to smooth the path from invention to implementation: from understanding people, design, sales, marketing, professional skills in negotiation, management and finance, and delivery systems as well as technical skills[8]. World class abilities in technical and professional skills are in short supply, with the lack of qualified personnel a barrier to innovation[9,10]. Our previous advice on diffusion of technologies for productivity[11] focusses on:

    a. improving the infrastructure of business support for skills upgrading that in turn leads to technology diffusion; and
    b. ways to address deficiencies in skills and training that limit the UK's technological capability.

Diverse people in inclusive environments innovate better

15. Inventing solutions and matching them to critical problems could be accomplished by people anywhere in society; industry, academia, local and national government, small enterprises, and individuals. There is evidence to suggest individuals from under-represented groups innovate at a higher rate[12] and that diversity, combined with inclusion, accelerates innovation through a multiplier that comes from mixing people of different experiences, disciplines, geographies, backgrounds, age, and genders[13]. Companies with higher-than-average total diversity have 19% higher innovation revenue[14], whereas monolithic cultures are less able to innovate and suffer from 'group think'.

16. The UK, however, has a well-documented gap of representation in STEM education and STEM careers[15,16] as well as among entrepreneurs[17], which means we are not harnessing the full potential across the nation.

17. Exposure to innovation in childhood makes a critical difference shaping inventive potential but under 1.5% of the UK's school population is currently reached by schemes

[6] https://www.researchgate.net/publication/339748692_Hipsters_vs_geeks_Creative_workers_STEM_and_innovation_in_US_cities
[7] https://www.thebritishacademy.ac.uk/programmes/research-innovation/understanding-rd-in-the-arts-humanities-social-sciences/
[8] https://www.oecd.org/cfe/leed/Cooney_entrepreneurship_skills_HGF.pdf
[9] UK Innovation Survey 2019: Headline findings covering the survey period 2016–2018, BEIS (2020)
[10] Deloitte, Soft Skills for Business Success (2017)
[11] https://www.gov.uk/government/publications/diffusion-of-technology-for-productivity
[12] The Diversity-Innovation Paradox in Science, Bas Hofstra et al, PNAS (2020)
[13] Hewlett SA, Marshall M, Sherbin L.' How diversity can drive innovation'. Harvard business review. 2013 Dec 1;91(12):30 (viewed on 19th May 2021)
[14] How and where diversity drives financial performance, Harvard Business Review, (2018)
[15]. https://royalsociety.org/topics-policy/publications/2021/trends-ethnic-minorities-stem/
[16] Royal Academy of Engineering: 7.8% of engineering professionals were from BAME backgrounds, compared to 12% of the UK working age population: https://www.raeng.org.uk/diversity-in-engineering/business-benefits-key-facts
[17] https://www.british-business-bank.co.uk/research-alone-together/

focused on getting children interested in inventing[18]. The same is true for entrepreneurship and for STEM activities.

18. Our innovation industries should have an explicit focus on increasing diversity and attracting people who do not think of themselves as 'innovators' or who leave the STEM pipeline at critical junctures. We have plenty of evidence of the problem of representation – the focus should be on identifying, testing and scaling up practical approaches to address systemic STEM and diversity challenges. This could be an important part of the levelling up agenda and would greatly benefit our national capacity for innovation.

Recommendation 1: Government should provide clearer departmental ownership of skills, to improve the quality of education and training, and to help employers understand where they can access relevant talent. Government should produce a breakdown of the number and variety of skills it will require to meet its ambitions in innovation and to strengthen the UK's role as a global science superpower. This assessment should be used to define targets and monitor progress. Working with business and with providers of further education and higher education, the goal should be to address the impending skills shortage and create more flexible systems that can cope with rapid change in jobs and skills, with a greater emphasis on reskilling. We should be using the data to showcase number of existing jobs in science & technology, as well as areas (skills, sectors and places) of projected demand, to give clearer pathways for developing talent.

Recommendation 2: Government should invest in testing and scale up of initiatives to address broadening participation in the innovation economy to include individuals who have traditionally been underrepresented. Successful businesses should be encouraged to participate, building on models such as the 'This is Engineering' campaign for STEM.

<u>Developing entrepreneurial skills</u>

19. Entrepreneurial aspirations are widespread, but successful entrepreneurs are rare. Entrepreneurs may be drawn from many sectors of the economy: some may be inventors, others will have had long careers in industry or academia, and some have just completed or may still be in education. Creating the environment for entrepreneurs to develop critical skills and to thrive is key to any innovation strategy. On top of this we should look to develop the leaders who can bring together the skilled individuals to create an innovative environment.

20. Having more graduates with skills in entrepreneurship could encourage the growth of successful innovative enterprises. In our previous advice on this topic, we offered six recommendations on how to develop high quality entrepreneurship skills in our previous letter "Improving entrepreneurship education"[19]. Evidence shows that training programs for scientists and engineers centred on developing commercial and entrepreneurial skills are effective at increasing start-up activities and leveraging private capital. A national entrepreneurial fellowship could provide talented researchers and engineers with a defined period support as they strive to commercialize their research. This could build on

[18] Nesta, Opportunity lost report (2018): https://www.nesta.org.uk/report/opportunity-lost-how-inventive-potential-squandered-and-what-do-about-it/
[19] https://www.gov.uk/government/publications/improving-entrepreneurship-education

models such as existing UKRI Fellowship schemes, the Royal Academy of Engineering (RAEng) Enterprise Fellowships[20] or the US National Science Foundation's (NSF) I-Corps programme[21]. The fellowship would provide postdoctoral scientists and engineers with access to labs and other technical resources; entrepreneurship training, education, and professional support; and connections to experts across government, industry, and finance.

Recommendation 3: The UK should develop programmes that build entrepreneurship and skills for innovation leadership. UKRI's ICURe programme is based on I-Corps and should be scaled up in ways that are appropriate to support more academics commercialising their research outputs across a wider range of disciplinary and technical domains, and help them access finance. Other models that could be scaled include Zinc and Entrepreneur First. This could contribute to boosting the number of Unicorns which emerge from UK HEIs, and the wider economy[22].

Recommendation 4: Government should work with universities to improve the wider training available in innovation leadership for those doing STEM masters and PhDs, who are particularly well placed to take innovative ideas from lab to market. We envisage a large-scale national innovation leadership programme to provide a clear path for scientists and engineers to take their skills and knowledge from the lab to the "real world" with a focus on developing market-ready solutions for critical challenges.

Foster and incentivise mobility

21. Movement of people between industry (from start-ups or large corporations), academia, government, and finance, improves skills, helps break down barriers and links people who understand needs/problems with those with deep expertise in particular solutions[23]. Mobility provides innovative firms with a continuous flow of knowledge, skills, and networks, crucial to managing risks and maintaining competitiveness; university researchers with previous work in industry have a greater focus on applied research[24]. Compared to those in other countries, including Sweden and Denmark, UK academic researchers are less likely to change sector[25]. The UK is particularly 'stove piped' in individuals' careers, and these barriers are rarely crossed, which is a significant inhibitor to innovation[26].

22. Mechanistic, practical, and cultural barriers to necessary movement of people must be addressed. There is a need for radical change to break down siloes, enabling cross-pollination of experience and ideas between the interfaces of academia, industry, and the public sector.

23. There are models of good practice for encouraging mobility across sectors. The American Association for the Advancement of Science (AAAS) Science and Technology

[20] https://www.raeng.org.uk/grants-prizes/grants/enterprise-hub-support-for-entrepreneurs/enterprise-fellowships
[21] https://www.nsf.gov/news/special_reports/i-corps/
[22] https://www.ft.com/content/fd038300-f09a-4afc-9f7d-c0e3d6965243
[23] NCUB, The Exchange of Early Career Researchers between Universities and Businesses in the UK, (2015)
[24] Robert Tijssen, Wout Lamers and Alfredo Yegros, UK universities interacting with industry: patterns of research collaboration and inter-sectoral mobility of academic researchers, (2017)
[25] https://cdn1.euraxess.org/sites/default/files/policy_library/survey_on_researchers_in_european_higher_education_institutions.pdf
[26] https://royalsociety.org/topics-policy/industry-innovation/case-studies/pushing-the-revolving-door/)

Policy Fellowship (STP Fellowship) is one such example, as is the Kauffman Fellowship that places STEM PhDs into the venture capital sector.

Recommendation 5: The government should review how policies and funding practices limit or encourage mobility of individuals across different sector boundaries. This should focus on where Government policies shape the culture: for example, how public sector funding such as the Research Excellence Framework (REF) shapes career pathways and mobility between academia, industry or government, and how hiring practices within the Senior Civil Service encourage or limit industry/government interchange. Government should review the success of recent programs (including the new No.10 Innovation Fellowships) and scale those that are successful.

24. Actions to address these issues could include:

a. Universities may need to modify their incentives and arrangements for staff – including recruitment and promotion criteria – to encourage career paths that value innovation, whether deeper collaboration with industry or founding a new company to develop an invention. Stronger incentives are needed to encourage cross-sector mobility, allowing researchers time to develop their ideas and ensure achievements beyond publications can be recognized. Government should explore more effective ways to reward universities for supporting staff engaged in knowledge exchange or development of invention into commercial applications, building on the impact elements of REF as an important lever.

b. Challenge-led research funding schemes should include provision for mobility of researchers at all career stages, including PhDs and post-docs, to ensure a pipeline of researchers equipped for problem solving on national priorities. Relevant centres for doctoral training could be aligned with key national and global challenges and allow for mobility and interaction among academia and industry, in important sectors including service sector and creative industries. This is the approach taken, for example, in Singapore.

c. Improve interchange between business and academia at all career stages by designing and implementing programmes to facilitate sabbaticals and exchanges with business. The national academies and learned societies have an important role to play in creating prestigious mid-career fellowships spanning industry and academia, such as the RAEng industrial fellowships.

d. Government should expand opportunities to bring many more senior and mid-career industry and academic expertise into relevant civil service positions, removing barriers that may disincentivize their willingness to move and creating pathways for them to return. We welcome focus on this as part of the recent declaration on government reform and look forward to the expansion of practical measures to increase porosity of government to people and ideas to build a more innovation-literate cadre of officials. We welcome initiatives like UK Government Investment (UKGI) Insight Secondment and the No.10 Fellowship Programme. Government should evaluate and build upon this experience to scale-up access to talented individuals to address specialist government requirements.

e. Establish and encourage the development of co-creation centres e.g. in public sector laboratories, Catapults and other government facilities, that bring expertise from

industry, academia and government into specific locations to enable the flow of knowledge, as demonstrated by the GCHQ Innovation Co-lab at The Landing in Manchester.

Finance (including Government Grants and Loans)

The role of government is to influence the balance of risks facing innovators, so that their decisions reflect, as much as possible, the desired national priorities. A more certain and clear set of incentives is required to adjust the balance of risk between the public and private sectors. Government should be prepared to take on more up-front risk both in applying technologies to existing activities and growing new ones to scale. This must be done within a set of "guard rails" which ensure that investments are made with appropriate due diligence and judgement. The risk taken must be compensated by back-end participation in profits.

25. Finance, together with ideas and people, is the fuel of the innovation engine. The journey from idea to impact can be short (such as a mobile phone application) or long (such as a new drug, battery storage, airplane, or advanced nuclear power plant), but is rarely linear and differs greatly for companies of different sizes, sectors, and maturity levels[27]. The longer the innovation journey, the greater the uncertainty around the value to the business or resulting economic and social benefits, so the more Government may need to support maturation of the long term 'big bets'.

26. One of the main levers to drive investment is Government research and innovation funding. Government plays an important role in financing basic research and development. UK's research base with its strong international connections is a rich resource for understanding challenges and developing solutions[28]. Government support for applied research and experimental development of technologies is also critical to explore their potential and support scale up. Its role ranges from carrying out this work directly (in its own labs and public sector research establishments) to funding (or co-funding) external actors including universities and the private sector. Government also has a role shaping the development of technology in areas of national priority where the private sector is unwilling or unable to undertake the capital expenditures and bear the uncertainties and risks.

Change the gearing

27. To reach the 2.4% of GDP in R&D expenditure, every £1 invested by government needs to be matched with £2 from the private sector if we are to maintain the present balance between public and private capital. Every country that has achieved the level of increase that the UK aspires to has done so through a higher ratio of private to public spend on R&D. This represents a major increase in private investment.

28. As the R&D roadmap highlighted, the UK has a low proportion of R&D spend on experimental development compared to highly innovative nations. Addressing this would

[27] https://www.thebritishacademy.ac.uk/publications/research-innovation-evidence-synthesis-conditions-translate-research-drive-innovation/

[28] This was demonstrated during the Covid-19 outbreak where countries with a diverse research base responded with a rapid and comprehensive range of innovative research – but most specialist countries did not: 2021 ISI Global Research report: Subject diversity in research portfolios

require additional public funding into later stages of R&D than at present, with appropriate incentives for private investment. Increased funding for late-stage R&D should not be at the expense of existing R&D spend. The Council's letter on investing in R&D[29] provides six recommendations to Government on ways to address this.

29. A key structural and cultural dimension to enabling innovation is tolerance of failure. High risk, high payoff innovative ideas will occasionally fail. Indeed, some degree of measured failure is an indicator of the overall success of an innovation strategy. The issue is who bears the risk of failure, and how is risk allocated to the public and private sector at different stages in the innovation and development cycle. During the early, high risk stages of innovation, it is the responsibility of Government to take on risk to attract private investments.

30. To shape the risk tolerance on areas that are also areas of national interest, the new Cabinet Committee on science and technology will need to identify priorities and signal action in a way that government will take an appropriate share of the risk and that provides innovators and investors with confidence their involvement will pay off in the long term. The Committee must consider the technology maturity level and the ability of the private sector to take on risk of investment. What is the balance between early venture, late-stage venture, and emerging growth investments, each of which has a different risk profile? Where will government need to take on some of the investment risk and what is the best mechanism to do this?

31. The Committee can also enable more open discussion across government about risks, mitigating risks, and definitions of successes, and learning from failures which would be part of a shift towards more effective decision-making on how to support innovation.

32. The Advanced Research and Invention Agency (ARIA) should offer an opportunity to exploit the benefits that transformational ideas can offer through catalysing emerging technology development pathways, nurturing R&D networks, and supporting in areas of uncertainty.[30] ARIA should focus on encouraging all forms of innovation including radical approaches and work alongside industry, UKRI and other parts of the UK research and innovation ecosystem to de-risk technologies and support the transition to market.

<u>Unlocking finance for scale up</u>

33. State institutions and policies can provide the patient, long-term finance needed for the demonstration and early commercialization stages of innovation. For example, Innovate UK and the British Business Bank provide loans to smaller businesses that can support innovation, bring innovation to market, or in areas where markets do not work well. They need to do so in a way that is consistent with national priorities as well as the balance of public versus private risk taking. Government should front-load public sector investment and set an ambitious goal for R&D expenditure which will give businesses the confidence to make long-term investment plans.

34. Businesses are the main funders and performers of research and innovation in the UK. It is therefore essential that government understands the current barriers to industry

[29] CST letter on investing in research and development, (2019): https://www.gov.uk/government/publications/investing-in-research-and-development
[30] Written evidence submitted by Dr Eoin O'Sullivan to the HoC Select Committee Enquiry: A new UK research funding agency https://committees.parliament.uk/writtenevidence/9584/pdf/

increasing its investment in R&D and develops policies which are internationally competitive and that crowd-in private sector finance, with a view to establishing sustainable market-led arrangements. Appropriate finance and growth capital are central elements for businesses to develop and translate knowledge and ideas into impact. There is a widening growth capital gap for all companies in the UK[31] but there are specific issues for technology and innovation, which affect business investment in innovation:

a. **Address the gap in support for late-stage R&D** – Given that outcomes and duration of late-stage R&D activities can be uncertain, conducting late-stage R&D carries a financial risk. There is a compelling case for Government sharing some of the burden of the financial risk, given the spill over benefits to the economy and society. Companies finance late-stage R&D in different ways including seeking finance from innovation bodies. Current investment options are narrow, overly complex, and targeted at a limited range of sectors which can be dominated by large organisations. Despite companies having the ability and willingness to commercialise research, the inconsistency in the public sector support available is a limiting factor. New mechanisms are needed to support innovative companies to manage the risk associated with investing in late-stage R&D.

b. **Rigid/siloed support mechanisms** - The gaps in access to capital for development of ideas and invention, or for scale up and growth of innovative firms vary depending on the sector. One of the biggest issues in the UK is the lack of investment in young, agile companies outside of R&D intensive sectors. Current public sector support options for R&D and commercialisation are often targeted at a limited range of sectors which can be dominated by large organisations. Once an innovative technology or application has left the lab, government taking a more activist approach to encouraging development of strategic technologies means understanding the availability of private sector finance.

c. **Lack of recognition of the full range of R&D and weak understanding of the value of intangible assets** - Innovation and value creation in the modern economy relies on intangible assets such as Intellectual Property (IP), software, data and network capital (goodwill, users, brand recognition). This is particularly the case in some of the fastest growing areas of the economy: the creative industries and high value services sectors. Some of these assets can be the basis for further innovation and value creation. With the expansion of the digital economy and new tech-driven business models, investment in intangibles has increased significantly in advanced economies[32]. However, the UK does not use the Frascati definition of R&D in measuring R&D, and focuses only on STEM-based R&D, skewing policy and under-counting existing levels of R&D investment[33]. Further, the specific nature of intangible assets makes them less easy to use as collateral, which may result in suboptimal investment. This is an issue for the UK: in the service sector, which now makes up over 80% of the UK economy, where intangible assets are particularly important. Digital-centric sectors, such as internet, software and tech/IT, are heavily reliant on intangible assets. Innovative companies with a high ratio of intangible assets have challenges getting access to funding in the UK. In addition to existing approaches, the UK should learn from other countries such as Japan, South Korea and Singapore who have introduced state-backed schemes to educate banks and commercial

[31] Scale Up Institute: Scale up Annual Review (2020): https://www.scaleupinstitute.org.uk/scaleup-review-2020/introduction/
[32] ECB Economic Bulletin, Issue 7/2018
[33] Business R&D in the arts, humanities and social sciences, Nesta, (2021): https://www.pec.ac.uk/policy-briefings/business-r-d-in-the-arts-humanities-and-social-sciences

lenders on IP value and rights, allowing them in turn to better support innovative businesses[34].

d. **Lack of specialist investors with deep sector knowledge** is a key weakness in the UK system.

35. Financial markets have an important role to play in managing and sharing the risks of innovation but tend to favour short-term investments. We welcome the reforms suggested in the Government's 'Plan for Growth' to address disincentives for pension funds to invest in high growth companies and provide continued government support for start-ups and scale ups through programmes such as British Patient Capital.

36. We welcome the current work being undertaken by the Bank of England's Productive Finance working group to explore the role of pension funds and other asset managers as levers for investment into research and innovation, and as actors who could stimulate a specialist analysts' investor base whilst offering regional incentives. The goal should be to engage with a broad range of market participants and discover practical solutions to the barriers to investing in longer-term and less liquid assets – which will allow greater investment in UK 'productive finance', including venture capital, private equity, and infrastructure. Developing a cadre of specialist investors in the UK would be an important part of stimulating innovation and scale up.

37. The portfolio of financial sources from Government (UKRI, ARIA, MoD S&T, government procurement) must be viewed as a complement to private sources of finance (personal wealth, company R&D funds, VC funds, PE, creative fund constructions such as SPACs, etc) and together can be set against the disincentives (in taxation and private finance 'short termism') to determine whether changes are required to ensure innovation can be supported through all stages of research, development and scaled deployment. The aim should be to create multiple, effective and agile pathways and tools for supporting development of ideas and scale-up for commercial application, with priority placed on addressing gaps rather than avoiding duplication. The ability to make investment (funding) decisions at a pace appropriate for the needs of teams at each stage of the innovation process is critical.

Recommendation 6: Review the UK's innovation support mechanisms, from the perspective of innovators, including 'unusual suspects'. Government should ensure there is a diversity of opportunity available across all stages of innovation, but these should be clear and easily navigated. Government should use this information to coordinate and accelerate the pace of initiatives and make it easy for innovators to find the most appropriate support for their needs. The goal should be helping firms to innovate and widen access to capital to innovators from all backgrounds.

Recommendation 7: We endorse the recommendation from the Royal Academy of Engineering that BEIS, Innovate UK and the British Business Bank (BBB) should work together to **review availability of capital to ensure innovative companies have access to funding across all stages of technology development.**

We suggest a review should consider:

a. Are new public sector support mechanisms needed to provide continuity of support in strategically important areas? For example, Ron Khalifa's Review of Fintech has made a

[34] https://www.oecd-ilibrary.org/economics/fostering-the-use-of-intangibles-to-strengthen-sme-access-to-finance_729bf864-en;jsessionid=gBROSdw21H9E_EBlz0anamMT.ip-10-240-5-126

pitch for a specific fund to support technology for the financial services sector. Another example is the Dementia Discovery Fund, a venture capital fund investing in, and creating, biotech companies pursuing transformational therapeutic approaches for dementia. The UKRI/Innovate UK Catalyst funds helped to de-risk innovative science and commercialise ideas arising out of academia and industry which assisted UK SMEs to develop into competitive and sustainable organisations, accelerating the progress of novel products to market and facilitating onward investment.

b. The future fund established during the coronavirus outbreak and its recent incarnation -- Future Fund Breakthrough -- provides a model for crowding-in private sector capital by aligning government capacity with professional investors. The future opportunities fund proposed by the Scale-up Institute offers an approach to taking measured and recognised risks, as well as facilitating the mobilisation of private sector capital into key emerging global industries that are of strategic importance to the UK.

c. What incentives are needed to supercharge private investment to create the patient capital needed for long cycle businesses? Overall tax relief for private equity investment is considered to work well, but a review could explore how existing tax incentives to encourage investment (such as the Seed Enterprise Investment Scheme and Entrepreneur Investment Scheme) can be extended.

d. How to generate a strong cadre of specialist investors with a focus on areas of key national interest backed by significant funds?

    i. Targeted engagement with the investment community about Government initiatives can help attract more investors into strategically important sectors, building on experience from the Green Finance Initiative.
    ii. A key challenge is how to mobilise UK pension funds, endowments and others to invest in emerging UK science and tech companies? An unlocking of pension funds would itself help create specialist investors. In addition to redoubling efforts to implement the findings of the Patient Capital Review, we note that schemes in the USA to mobilise institutional investors have a strong element of investor capacity development. In the UK, the Newton Venture Programme is a rare example of training the next generation of investing professionals which aims to increase diversity of venture investors and finding better ways of developing the UK's scientific research and innovation.

e. How to better measure business R&D and innovation across all sectors to build a clearer picture of strengths and weaknesses.

Recommendation 8: To strengthen investment in intangible assets, **HMT, the British Business Bank (BBB), and the Intellectual Property Office (IPO) should work together to explore how Government can support and educate asset managers, banks, commercial lenders and others to build consideration of IP and intangible assets into their credit risk models to unlock lending for companies offering digital-led innovation.**

Infrastructure

Enabling infrastructure (offices and laboratories for emerging growth companies, broadband, testing facilities and so on) must be made available. Next generation infrastructure needs to be developed in conjunction with the private sector (for example, connected digital twins).

38. Some innovations need little or no specialized infrastructure: a rapid internet connection may be enough to deploy an App, created on a laptop, at scale. In other cases, specialized innovation infrastructure for testing, experimentation and scaling is essential, including large-scale scientific equipment, specialized testbeds, measurement and testing capabilities.

39. The UK already boasts a significant number of successful innovation initiatives, institutions and infrastructures that could be scaled and learnt from. Similarly, the United States has used their extensive National Laboratory infrastructure as the basis for a range of activities to support their innovation economy including training, collaboration across stakeholders and access to infrastructure. Within the UK, examples include:

    a. The National Nuclear Laboratory (NNL) in Cumbria is a UK public sector research establishment (PSRE) with significant sector expertise essential for the net zero agenda. NNL is increasingly focussed on benefits for the wider UK economy, working closely with large companies, start-ups, regional LEPs.

    b. The UK's High Value Manufacturing Catapult, which works closely with companies to enable the translation of research and to progress innovations towards commercialisation. The Catapult's Centre for Process Innovation (CPI) has engaged with over 900 unique SMEs and led and partnered on R&D projects worth over £332 million. Analysis of CPI's investment model shows SME partners go on to raise up to three times more private investment[35].

    c. Industry-led joint ventures with government such as the Advanced Propulsion Centre (APC) and the Aerospace Technology Institute (ATI) which provides funding and drives collaborations between multiple companies to solve national challenges in the transition to low-carbon and electric transport.[36] Such approaches encourage risk sharing and bring sectors together towards a common goal and could be developed in other sectors.

<u>From lab to market</u>

40. Business incubators and accelerators provide a different type of innovation infrastructure (often with a focus on business support, training and community building in a specific technology, sector or challenge area) but with some access to infrastructure which has a positive effect on the success of innovative SMEs. Evidence shows that while such programmes can vary significantly, companies which participate in some accelerator programmes have experienced significant company growth and have increased

[35] Innovation, Public Funding and Private Investment*: a CPI perspective*
[36] *Late-Stage R&D: business perspectives*, Royal Academy of Engineering, 2021

fundraising by almost 80%[37]. Accelerators supported by government (such as JHub and Octo supported by the UK MoD) have positive spill-over effects by linking government challenge-owners and business customers for tech applications with the wider community of SMEs and innovators. They can also draw in VC investment and leading to VC spill-overs to other start-ups in the local area.

41. Once scaled, many innovative solutions must be deployed into existing physical infrastructure such as the electricity grid, into complex supply chains, or challenging user environments. The government can play an important role in catalysing provision of real-world testing infrastructure, taking account of sector-specific needs and complexities. For example, the Connected Place Catapult testbed programmes help to connect businesses and innovators with local leaders to address challenges such as homes for healthy aging.

42. Regulators should be viewed as innovation enablers, providing opportunities for testing and demonstration can help understand the innovations from an early stage, test solutions to areas of market failure and explore what regulatory environment is appropriate for emerging technologies. Regulatory sandboxes can provide safeguards for supply chains and consumers while innovators have space to explore.

43. Innovation infrastructure can also play an important role in convening communities, enabling networking to create partnerships, share advice on navigating the R&D systems and developing skills, with important spill-over benefits for businesses in the local economy[38].

44. With appropriate support, PSREs could play a stronger role in the UK's research and innovation system, de-risking the early stages of innovation, providing key scientific and technical resources and engaging business to promote innovation and economic growth.

Recommendation 9: To enable business (start-ups, scale-ups and established businesses) access to relevant physical, digital and data infrastructure and enable planning future investment, we recommend Innovate UK commissions or **develops a map of infrastructure supporting innovation across the UK to enable businesses to easily locate facilities and expertise relevant to their needs**. Examples may include High Performance Computing, advanced manufacturing capability centres, sensing, analytical and measurement facilities (such as Diamond Light source or National Physical Laboratory (NPL)) or wind tunnels, or Living Labs providing real world test environments to de-risk and scale innovation for markets. This could build on the UKRI infrastructure roadmap[39] but should include PSREs or university facilities. Drawing together the UK's existing infrastructure in a single catalogue will help improve visibility to businesses and identify gaps and overlaps to inform planning for future investment.

Recommendation 10: Government departments should encourage PSREs and other government funded bodies with significant infrastructure that supports innovation to make their infrastructure available to external partners. As part of their role supporting government with research and expertise to solve major challenges, they can serve as

[37] *The Impact of Business Accelerators and Incubators in the UK* (BEIS Research Paper Number 2019/0009)

[38] https://hvm.catapult.org.uk/annual-review-2020/anchoring-regional-investment/

[39] UKRI (2019) The UK's research and innovation infrastructure: opportunities to grow our capability. Accessed [02/06/2021]. Available from: https://www.ukri.org/wp-content/uploads/2020/10/UKRI-201020-UKinfrastructure-opportunities-to-grow-our-capacity-FINAL.pdf

network hubs, bringing together talented individuals and organizations. The success in the US of organisations such as the Lawrence Berkeley National Laboratory and their Cyclotron Road Program, Battelle, and the Lincoln Laboratory for National Security, show how national infrastructure can be used to shape regional excellence. Examples in the UK may include NPL or the Met Office as well as other potential co-creation centres.

Demand

Government must use its own procurement to create appropriate demand from innovative enterprises, including being the "first customer".

45. Government shapes demand for innovation through public procurement, fiscal policy, regulations, standards, and fostering new social norms/values. For example, regulation can be effective in bringing innovation through to market to address challenges of value to society (faster banking payments, development of alternatives to the internal combustion engine).

46. These policy levers can either inhibit or drive innovation, and it is Government's role to ensure they remain agile, proportionate and do not create undue barriers to innovators and investors.

47. We welcome the White paper on regulation for the fourth industrial revolution to improve the regulatory environment for innovation. We believe the government should focus on more effective use of procurement to stimulate demand for innovation – both to encourage innovation generally and to accelerate innovation in strategically import areas.

<u>Procurement</u>

48. Public sector procurement is an important feature of effective innovation economies: from early-stage challenges and prizes to large-scale but agile procurement. This is particularly important in sectors where the Government is one of the largest customers, such as health, infrastructure, and defence. The power of a long-term strategy is to send a demand signal that drives businesses and investors' confidence to invest. It can also be used as a method to boost innovation by bringing SME contractors into the market.

49. Approaches to increase access and benefit from innovative SMEs can be seen in pockets of government, including through Innovate UK's SBRI process, DSTL's Defence and Security Accelerator, and innovation tithes used by Department for Transport (DfT) on large projects. While the Cabinet Office proposes establishing a new unit to oversee public procurement across government, the practical aspects of government procurement still appear to block innovation.

50. Through its use of procurement as a lever, government is an "unusual customer" with the capability of using the scale and breadth of its procurement power to shape future markets. Procurement should be used imaginatively to crowd in solutions to address challenges including achieving net zero, levelling up, and health. This should take a whole-systems approach, recognising value to communities, businesses, academia, investors and government and the importance of supply chains and delivery systems.

We welcome recent action to guide how procurement can be used to deliver social benefits.

Recommendation 11: As part of the current review of procurement, Government should **explore measures that broaden outcomes-based approaches to procurement that encompass the need to build UK capability in specific areas.** Government departments need credible in-house expertise and a portfolio approach that tolerates failure. Priorities should be:

a. Improving technical expertise for procurement: Different departments will need relevant specialist expertise in-house to procure effectively, both to make sure that what is procured is fit for purpose (due diligence on technical standards) and to be able to assess alternative approaches. The success of the Vaccines Task Force was in part based on the ability to bring in people from outside government with relevant expertise (manufacturing of vaccines, R&D) and credibility across industry, and then deliver in the NHS.

b. Using different modes of procurement and pre-procurement practices to building UK capacity and stimulate innovation in specific areas. Government has some pockets of good practice such as the RAF Rapid Capability Office which uses procurement to enable relevant technologies to mature and build supplier capability for future need.[40] Introducing mechanisms to engage multiple suppliers and explore multiple solutions using the 'fail fast' concept for iteration and learning can give public sector procurers space and opportunity to explore ambitious and challenging options. Where appropriate a specific requirement for innovation.

c. Strengthening the use of public procurement to deliver national missions. The US's DARPA programme shows the value of this approach in building domestic capability and driving demand and pull through of technology.

d. Helping UK companies to build and retain Intellectual Property (IP) for growth by enabling SMEs to protect and retain IP when participating in public procurement, as proposed by the Innovation Expert Group.

e. Culture change to enable procurement from 'unusual suspects' particularly SMEs which may be more innovative but less experienced. Allowing for appropriate levels of risk can support innovation where the private sector fears to tread, creating a lead market for new technologies and solutions or by providing a testing ground for innovative products. Cabinet Office should work with the National Audit Office (NAO) and Public Accounts Committee (PAC) to develop a broader definition of outcomes and value for money. The goal should be to provide scope for risks to be taken and failure to be accepted, within a wider portfolio of work.

f. Where government has strategic priorities, including technology areas it wants to support, the value of innovation should be considered during appraisal processes. In the 2020 update to the HMT Green Book, additional value was given to analysis by 'place' helping to support the levelling up agenda. A similar approach could be taken to support the government's innovation agenda, with guidance on valuing innovation added to the Book.

g. Building an expectation to support innovation into procurement metrics, and developing specialist procurement units to enable interactions with SMEs.

[40] https://brite.nridigital.com/brite_autumn19/royal_air_force_rapid_capabilities_office_defence_innovation

Government could also consider the addition of specific requirements for innovation as an objective of government procurement guidance.

Where should we focus?

The UK needs to know where its competitive advantage lies today and over the longer term. The government needs to send clear signals to the market and encourage innovation in these areas.

51. In our recent letter to the Prime Minister on "Strengthening the UK's position as a science and technology superpower", we offer advice on the governance, values and approach needed to enable informed decision making. In addition, we have previously written detailed advice on principles that government should use for selecting specific missions and science and technology moon-shots[41] which we commend for use in support of the Innovation Strategy.

52. Government will need to align some aspects of innovation support with a compelling national vision on priority areas (such as achieving net zero by 2050). It must be prepared to commit to fostering innovation in those areas over the long-term to provide direction, targets and certainty for innovators and investors. Clear challenges and missions need to be chosen that will generate defined research and innovation questions. Demand for resulting products and processes could be stimulated by establishing enabling and innovation friendly regulations[42], by fostering new social behaviours and through government procurement. Our advice on taking a systems approach to net zero offered some examples of the options available to government[43].

53. We should pursue international collaborations and partnerships which draw on complementary efforts and strengths of key allies rather than try to duplicate established success in other nations. Government should use the Own-Collaborate-Access approach (as set out in the Integrated Review) to guide development of action on strategically important technologies, including where international partnerships may need to be strengthened or limited.

END

[41] https://www.gov.uk/government/publications/principles-for-science-and-technology-moon-shots
[42] https://www.gov.uk/government/publications/reforming-the-governance-of-technological-innovation
[43] https://www.gov.uk/government/publications/achieving-net-zero-carbon-emissions-through-a-whole-systems-approach