airto
driving growth and innovation

More D!

A more DEVELOPMENT-focused strategy for paving the way to IMPACT:

Innovation that is Market Pulled, Applied, Commercially Translated!

March 2020

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Preface

Innovation is critical for our national and global survival and competitiveness, and must become the central pillar of our Industrial Strategy. Time is running out to reach 2.4% GDP for R&D by 2027! Efforts to boost R&D to this level over the last couple of decades have failed, despite repeated attempts of successive UK governments. Why? Because the 'technology push' approach has not worked. The strategy is skewed too heavily towards RESEARCH: all the *'eggs have been placed in one basket'!* Innovation is NOT always a linear process commencing in a laboratory. A fresh approach is needed to avert failure! The time has come to focus more on the 'DEVELOPMENT' aspects of R&D in our national strategic planning to complement our world-class research base.

If harnessed and resourced properly, the thriving Innovation, Research and Technology (IRT) sector can help underpin the UK's status as a world-class 'Science *and* Innovation Superpower'.

AIRTO is identifying the critical INTERVENTIONS necessary to achieve greater impact and translation of R&D into innovation by commercial enterprises and public services, by:

1. **Changing the mix to spread the risk: delineating between the 'R' and the 'D' to invest in more DEVELOPMENT.**
2. **Aiming for more MARKET PULL, as opposed to TECHNOLOGY PUSH.**
3. **Being more mission-led: driving more collaboration, and focusing less on competition at every step.**
4. **Creating urgency in doubling public R&D spend to gear in the private sector.**

March 2020

Executive summary

At the end of 2017, the UK government launched a new Industrial Strategy, a key part of which is to grow the level of investment in research and development (R&D), from 1.7% to 2.4% of Gross Domestic Product (GDP) by 2027. The call to grow R&D intensity in the UK has been made before - without success. An explicit call by the then Department for Business, Innovation and Skills (BIS) to lift R&D intensity from 1.9% to 2.5% of GDP by 2014, was made in 2004. **But why was this call not successful in driving change and stimulating innovation?** Throughout 2019, AIRTO has been examining this question, and exploring how the UK could benefit from **deploying more resources for development activities as part of a solution that will raise investment in R&D and unlock market opportunities for the UK, both at home and globally.**

In addition to consulting its membership across a broad range of sectors about the measures which they consider to be necessary, AIRTO has consulted extensively on this topic with stakeholders in government, industry and other representative organisations, through a series of roundtable discussions. **We have identified FOUR KEY LEVERS which must be applied, concluding that the approach to government stimulus and support for additional R&D investment must be...**

1. **Innovation-led... Innovation is critical for our national and global competitiveness. Our national strategy must shift in emphasis, such that user-driven innovation becomes the central pillar.** Only by prioritising innovation, is the UK going to be able to address the climate emergency, and to improve productivity, competitiveness and national prosperity. These kinds of mission-driven priorities are successfully approached by working from the identified user need to develop solutions and the underlying science and technology required for implementation. Such an approach places the requirements for practical innovation, and those organisations that can introduce and scale-up solutions, firmly in the driving seat.

2. **Market Pulled... To succeed, our innovation strategy should be based on a 'market pull' rather than a 'technology push' approach.** Overall UK R&D activity levels have stagnated over the past fifteen years, remaining stubbornly at only 1.7% of GDP! This lack of progress indicates a need to abandon the technology push approach that has been fostered by government for several decades; this presumes that public investment in underpinning research somehow leads to innovation in industry and economic prosperity – a strategy that has been proved to be singularly ineffective in most areas, and one which is akin to shoving 'square' packages of science into the 'round holes' of industrial problems and hoping for success! To raise the level of R&D investment from business and industry requires the central focus to be moved to addressing practical market needs. More appropriate use of public funding support for market-led innovation will gear in the larger scale industrial investment needed for the UK to reach its 2.4% target and, more importantly, for the UK to receive greater value and returns from public and private investment in R&D.

3. **Applied... The ratio of public expenditure on initial scientific research and on more needs-driven applied development is suboptimal and needs rebalancing.** In the UK the ratio of 'R' to 'D' is approximately 85:15, in favour of Research activities. In competitor nations, such as Germany, the ratio is closer to 50:50. For the UK economy to benefit more from the national R&D portfolio, consideration must be given to achieving a more balanced mix of 'R' versus 'D'. There needs to be more applied development activity occurring rather than front loading the 'lion's share' of public resources into early stage research. However, this rebalancing must be achieved without diluting the world-leading research base that has been built up over the past century and which underpins the UK's stature as a science and innovation superpower. The currently promised increase in the level of public funding for R&D will mean these two objectives are not incompatible. This increase must be delivered if the strategy to reach the 2.4% target and the consequent benefits to the economy and society are not to founder.

4. **Commercially Translated... Two-thirds of all UK R&D is industry funded. To succeed in growing commercially funded R&D even further, we must all be better equipped to understand and fulfil the practical demands for assistance with development activities across different sectors.** The industrial strategy has to provide the conditions that will attract more businesses and private investors to grow their R&D. Consideration must be given to the absorptive capacity of the IRT sector to accommodate future growth in industrial development activities, since this will increase the demand for the demonstration/testing, training, analytical/measurement support and accreditation/certification services that the sector delivers to support the translation of innovations to fully functional products able safely and effectively to satisfy the requirements of the commercial market place. In addition, the sector provides significant 'trouble-shooting' capabilities to address industry's requirements to improve productivity.

AIRTO has consulted widely, and it is apparent that there is a strong appetite to work together to help the UK achieve growth in R&D. However, the sector is limited by constraints on capital infrastructure, especially for not-for-profit organisations that face challenges in responding to market demand due to restricted means for taking on conventional investment capital and under-investment from other sources that would not prejudice their independence.

We conclude that critical **INTERVENTIONS** are necessary to achieve greater impact and translation of R&D into innovation by commercial enterprises and public services, by:

1. **Changing the mix to spread the risk: delineating between the 'R' and the 'D' to invest in more DEVELOPMENT.**
2. **Aiming for MARKET PULL, not TECHNOLOGY PUSH.**
3. **Being more mission-led: driving more collaboration, and focusing less on competition at every step.**
4. **Creating urgency in doubling public R&D spend to gear in the private sector.**

This position statement is a synopsis of the findings from our consultations and sets out proposals calling for action from government.

Background

AIRTO – the Association of Innovation, Research & Technology Organisations - represents the **Innovation, Research & Technology (IRT) sector in the UK**, which **collectively employs 57,000 highly skilled people,** and impacts on the UK economy by contributing **over £32 billion of Gross Value Added** (GVA) per annum[1]. AIRTO's 60+ member organisations form a bridge between industry and academia, and therefore form a critical part of the national innovation eco-system[2].

Recognising the key role that UK's scientific and technological capabilities play in our economy, a key part of the government's plan for rolling out the Industrial Strategy is to grow the level of investment in research and development (R&D), from 1.7% to 2.4% of Gross Domestic Product (GDP) by 2027[3]. The objective is for the UK to be the "go to" place for R&D on a worldwide stage. This could mean around £80 billion of additional investment going into advanced technology in the coming decade, helping to transform whole sectors, create new industries, and support innovation across the country.

The UK's ambitions to increase productivity and prosperity, and the recent legislation to set into law the requirement to become a net zero carbon emitter by 2050, give impetus to the need to 'ramp up' innovation to create alternative technologies and to eradicate societal and economic reliance on fossil fuels in energy supplies, transport, food chains, telecommunications, healthcare and consumer goods. Public opinion is shifting, with a growing recognition of the need for the 'climate emergency' to be tackled as an urgent priority and a shift in public ethics around consumption; this further strengthens the urgency of the call for innovation.

Introduction

At the start of a fresh decade, in 2020, from a science and technology perspective, the United Kingdom continues to be a notable towering presence on the world's stage, frequently topping the international university league tables and continuing to outperform competitor nations to scoop Nobel Prizes. The UK is arguably already a '*Science Superpower*' and has all the assets at its disposal to extend this position to that of a world-class '*Science and Innovation Superpower*'.

Our global standing for prestigious academic achievement must be maintained if the UK is to continue to lead the world in finding answers to some of our planet's most pressing and complex challenges. The United Nations (UN) currently lists eighteen such "Global Issues"[4], which include climate change, food security, health and ageing.

Research – *'the creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications'* (as defined in The Frascati Manual, 2015)[5], - provides an understanding of many of these global issues. Early stage research, which is largely conducted in universities, provides the scientific and technological understanding necessary to tackle the **'development'** work needed to create workable products, services and solutions for markets demanding **'innovation'** to alleviate the problems arising from these pressures on society – essentially new, improved ways of doing or achieving things. The processes of **research, development and innovation create solutions that make progress against seemingly insurmountable challenges possible.** Examples from history illustrate the key role that research and development can play in tackling global problems. For example, in the twentieth century the challenge of eradicating dangerous infectious diseases like polio in many countries would not have been surmountable without applied development to create a safe vaccine to interrupt transmission of the virus in the population, or without governments across the globe working together to act as customers and facilitators driving the adoption of the new technology. In 2020, the conquest of Covid 19 pandemic will rely on successful research and applied development to create a vaccine.

Achieving the UK's net zero carbon targets by 2050, is not going to be possible without enormous amounts of R&D, since we need to develop new technologies and services to, for example, repair our climate through carbon capture and remove our reliance on fossil fuels (in a phased manner to avoid triggering a global financial crisis). In short, the understanding is in place for most of the science and we now need to **develop** our way out of this mess!

Besides making technological progress towards tackling global challenges, there are other sound reasons for investing R&D to drive innovation, one of which is to **improve productivity. Many things impact on productivity including skills and infrastructure, but improving productivity also can be achieved through employing new products, processes and services… which require appropriately channeled R&D to create them**[6]**.**

The UK is recognised for having a well-supported and world-class research infrastructure. It "punches well above its weight" in terms of research output via our universities. However, it is important to understand that the **'development'** infrastructure is hugely fragmented in terms of where and how development activities are delivered, reflecting the varying requirements of different industries, past changes in how and where the government directs its funding and failure to produce or adhere to an industrial strategy over many years.

Development consists of the technical work that must be completed to **design, demonstrate and de-risk** new products, prototypes and services and put them into use. This can include, but is not limited to, the work needed to design and test prototypes, devise and refine manufacturing/production processes, prove the efficacy of solutions, perform safety testing and obtain the certification required to meet regulations, and develop novel delivery/packaging mechanisms for new technology – much of this has to be done in the field and at scale in order to establish traction and confidence with those pursuing innovation for their product or service based enterprises and operations. In the main, university laboratories are not generally equipped with the understanding of application, scale-up/test-bed facilities, skill sets or commercial focus to deliver all this. These activities more usually take place via Research & Technology Organisations (RTOs), including Catapult Centres, Contract Research Organisations, independent laboratories and some of our Public Sector Research Establishments, as well as within privately owned industrial facilities. These types of organisations comprise the UK's IRT sector.

It is important to understand that 'research' and 'development' phases of innovation are distinctly different activities, requiring different facilities, expertise and capabilities; this is often easily forgotten when the abbreviated term 'R&D' is used in shorthand in strategy and policy documents – and unintentionally an impression is created of a single amorphous activity. Also, it must be noted that 'R' work does not automatically move on to the 'D' stage, and sometimes 'R' reaches a natural conclusion or only finds application outside the UK and/or many years later. AIRTO asserts that, the time has come to delineate between the 'D' and 'R' of 'R&D' in our national strategic planning, and to consider what impact is to be gained from strategic investment in 'D' and in the subsequent translation to eventual end use of a technology as an innovative product or service.

Are we an innovation nation?

The UK consistently ranks highly in the Global Innovation Index (ranking fifth in 2019)[7]. However, this is largely due to the way that the UK frequently punches above its weight on certain educational and academic components of the Index; it is not so strong on some of the other components such as market sophistication e.g. obtaining investment/credit. This may explain why despite the strong ranking, the UK is frequently cited as being poor at commercial development and exploitation of its research, with preventable innovation failures estimated in 2015 to cost UK organisations up to £64.7 billion per year[8]. This failure to gain significant levels of benefit from the research is recognised as a national weakness, particularly when the UK is compared with competitor nations.

One reason proposed for this under-exploitation is the relatively modest public investment apportioned to applied development to support industrial uptake of outputs from well-funded fundamental research programmes. In an era of increased public investment in R&D, there is the opportunity to increase the public investment in applied development activities to boost industrial innovation, while maintaining existing levels of funding for academic and very early Technology Readiness Level (TRL) stage research, thereby addressing the imbalance between research and development without any detriment to the former.

The UK's current imbalance of public funding for 'R' versus 'D' is in marked contrast to proportions of public expenditure made by competitor nations, where there is more emphasis on supporting the exploitation of basic research by investing a commensurate amount in 'D'. AIRTO has previously called for 'more D' in the R&D mix through its discussion paper presented as input for the 2019 Comprehensive Spending Review[9]. Relatively lower levels of public funding support for 'D' arguably reduce the catalytic effect of the funding on gearing-in industrial support and private investment for R&D.

A further proposed reason for the UK's poor exploitation of research relates to how the research output is used by industry: the linear model of public funding of research, that then leads to development and demonstration to innovation and exploitation is suboptimal for much of industry. Market pull rather than technology push drives the innovation needs of the majority of industry. A linear 'conveyor belt' model of innovation risks creating a misassumption that more input (and hence funding) at the research 'end' will lead to more exploitation of research at the industry/innovation 'end'. Whereas, in reality, industry is starting from the innovation 'end' and seeks access only to the knowledge that is required to meet its market-driven needs, rather than access to research outputs for the sake of it. Underpinning research provides the knowledge resource that industry can exploit, often in collaboration with IRT organisations, to solve their focused development opportunities and problems. **We propose that policy makers adopt a fresh paradigm for strategic planning regarding innovation funding, to take account of this more realistic fit of applied R&D within the innovation ecosystem, as well as to begin rebalancing the actual level of funding deployed to development capabilities in the UK.**

Of course, for policy makers seeking to optimise/maximise the level of innovation in the UK, different industrial sectors present different challenges. For example, in certain sub-sectors of clean energy e.g. tidal, wave and nuclear power generation, the engineering challenges, market uncertainties and financial risks are often considered too high by many investors (both public and private). Whereas, the digital sector, for example, does not have such major issues with financing the commercialisation of innovations *per se* and the sector's clustering around London arguably makes the necessary financial investment more accessible, especially for start-ups. However, the sector does face considerable challenges in seeing technologies adopted and businesses scaling-up, a problem exacerbated by skills shortages.

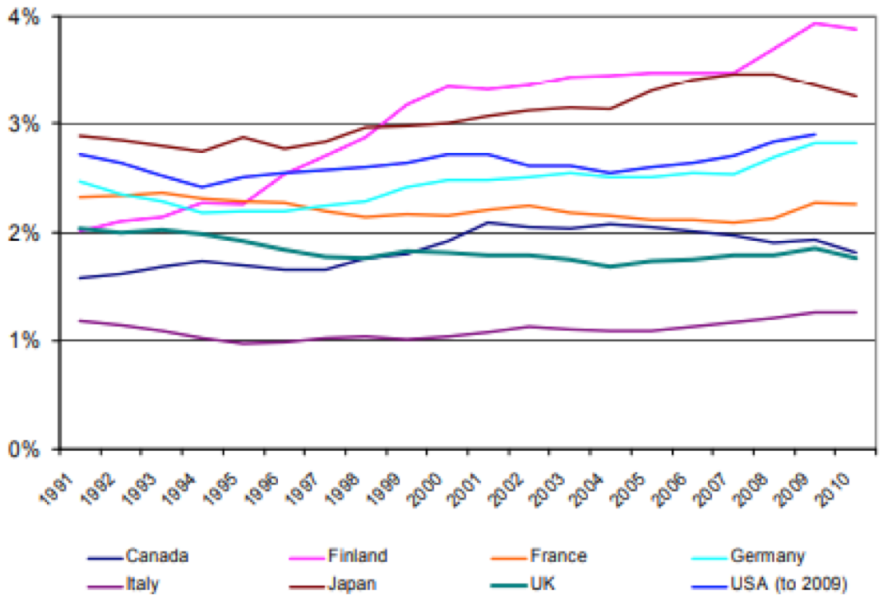
Throughout 2019, AIRTO has been exploring why, and how the UK could benefit from **deploying more applied R&D resources as an important part of the solution required to unlock further R&D investment and market opportunities in the UK and globally.**

In addition to consulting members across a broad range of sectors about the measures which they think are necessary, AIRTO has consulted extensively with stakeholders in government, industry and representative organisations on this topic through a series of roundtable discussions to determine **how best we can exploit the UK's R&D capabilities. We have been considering:**

- **The enablers, opportunities and barriers to the development ('D') phases of innovation.**
- **What the UK can do to stimulate commercial exploitation of applied R&D for the benefit of our economy and communities.**
- **How we can identify more effective mechanisms for deploying recent and promised increases in public funding for applied R&D; this is desirable, if funding invested is to achieve its aim of greatly increasing innovation in industry.**

The call to grow R&D intensity in the UK has been made before - without success. An explicit call by the then Department for Business, Innovation and Skills (BIS) to lift R&D intensity from 1.9% to 2.5% of GDP by 2014, was made in 2004[10]. However, Figure 1 shows that R&D intensity in this period did not grow[11].

Figure 1: Gross expenditure on R&D as a percentage of GDP



Source: OECD, Main Science and Technology Indicators (MSTI), August 2012

Why have the government's plans not been successful in driving change and stimulating innovation over the past decade? As noted in the introduction, these plans perpetuated a disproportionate emphasis on investing in fundamental research and the approach was not sufficiently well matched to the market-driven needs of much of industry. Arguably, ensuring support for development activities was not a key part of the strategy and it was not seen as part of a consistent and wider, long-term industrial strategy.

Findings from consultations with members and stakeholders

AIRTO's consultations with members and stakeholders identified some key areas where innovation policy in the UK could be improved, or needs to change. The findings from our consultations are reflected upon herein.

Innovation is not a linear process; translation from an idea to an outcome is a complex interaction of people and organisations as an innovation matures towards the customer. The stages of the maturity of an innovation are often referred to as Technology Readiness Levels (TRLs), a framework developed in the space sector[12]. Whereas the TRL scale is a useful "shorthand" for describing the state of development of a new invention/innovation/technique, it does perpetuate the notion and narrative of a linear process. To be realised, an innovation also needs to become manufacturing and market ready and, the drive and direction for the innovation may come from the end-user rather than the underpinning research. The process involves not just basic research which underpins an invention, but also the development stages involved in design, prototyping, testing, certification, verification by customers/end users, regulatory compliance, manufacturing process development and product training. All these components of the translational pathway to adoption and diffusion of an innovation are as critical as the fundamental research which underpins a concept for a new product or service. Many of these later stage development activities in the UK are conducted by experts residing in specialist IRT sector organisations, with strong links into the supply chains in the industry sectors that they operate to serve. It is important to recognise that there is often a "disconnect" between underpinning research and innovation.

In taking a fresh approach to boosting R&D over the coming decade, we advocate that to capitalise on increased public investment in R&D, government actions should include working with businesses, industry and the IRT sector to design additional assistance to support market-driven innovation priorities, to complement and balance the existing emphasis on research activity. Technology-driven innovation grant support mechanisms must be industry-friendly, and accessible and flexible to meet SME (Small and Medium Enterprise) needs. Mechanisms for anticipating future barriers to the adoption of new technologies (e.g. regulatory barriers) must be put in place. New approaches to cultivating innovation-focused skill sets are also going to be essential to improve the capacity for exploiting and commercialising technologies.

We have identified FOUR KEY LEVERS which we contend that the UK's Industrial Strategy must apply...

KEY LEVER 1: Innovation-led...

Innovation – finding and adopting new ways of doing things - is critical for our national and global prosperity. Our national strategy must shift in emphasis, such that innovation becomes the central pillar complementing and exploiting our research excellence. Although the Industrial Strategy does encompass the role of innovation, it is only through prioritising innovation that the UK is going to face down the big challenges facing our global society, such as the climate emergency and maintenance of a productive economy. This challenge is now an existential battle. Without the innovation needed to adapt existing technologies and create new ones to heat our homes, power our businesses and transport our population, we will continue to be reliant on fossil fuels for all that we need to live well and trade. But the national push required to abandon our dependence on carbon has the potential to transform our economy and presents unparalleled opportunities for the UK to shine as a '*Science and Innovation Superpower*'. This will be achieved by extracting value from our knowledge and expertise to transform communities and, in turn, create new career paths helping the next generation of young people with talent to thrive in work and prosper.

Adopting an innovation-led Industrial Strategy is not simply about creating the conditions to encourage invention to thrive; it is also about stimulating process innovation in identified mission-critical areas and ensuring that knowledge originating in the UK is harnessed by the market for the benefit of UK plc. Innovating processes and infrastructure represent a big opportunity to improve productivity. There is a central role of the UK's IRT sector in finding solutions by changing the processes already in place to deliver our utilities and helping to overhaul our national infrastructure. An example of an opportunity requiring such a 'process innovation' approach is the national challenge we have for finding new ways of powering automotive vehicles, the bulk of which still rely on petrol and diesel. By encouraging and incentivising alignment of key performance indicators for many of our IRT sector organisations, it may be possible to fast-track solutions for innovation by encouraging more collaboration, having removed two key barriers – the fear of going first and competition at every step! Blue-prints exist for tried and tested models of innovation that should be replicated, such as the FARADAY CHALLENGE – as described in CASE STUDY 1. It is important to note in areas of emerging technology that by investing in demonstration and design through public procurement channels, the government has a critical role to play by acting as a customer/early adopter, and also by anticipating the necessary future regulations and standards. Hence the government can help to improve investor and insurer confidence by supporting the creation of new markets and associated regulatory frameworks, helping to break new ground both technologically and economically. When the government is prepared to invest in this sort of pioneering activity, it is actually investing in the development process for new markets, creating more favourable conditions for foreign direct investment by large businesses, and creating supply chain ecosystems in key sectors where SMEs have the opportunities to thrive. However, schemes such as the Faraday Challenge, must remain nimble to succeed. They must not be allowed to be encumbered by onerous administrative oversight. Conversely, regulatory frameworks may represent a huge barrier to business in the current climate with the UK facing the implications of Brexit. For example, in the chemical, pharmaceutical, aerospace, automotive and food & drink sectors there is the looming challenge of regulatory divergence, which poses a potential risk to manufacturing competitiveness in the UK[13]. Failure to maintain regulatory alignment with the EU will result in 'regulatory divergence' which will act as a barrier to innovative products and materials being manufactured here and exported from the UK. This issue has recently been raised with government by senior industry representatives[13].

The government should also continually strive to review the way innovation activities of UK Research & Innovation (UKRI) / Innovate UK are being managed, to ensure they are accessible to the needs of industry, especially to those of SMEs. It is well known that some SMEs struggle with the processes of accessing funding, which are heavily geared towards organisations with prior experience of the 'art' of winning grants. SMEs are sometimes concerned about the way Innovate UK funded projects are costed, with hourly rates assigned for collaboration projects being cited as being too low. Certain SMEs have published analyses of their failed attempts at engaging with the grant application process[14], highlighting the difficulties in being able to navigate UKRI's mechanisms for deploying innovation funding (which are well designed for the capacity of universities to engage with). Of course, the nature of grant funding is competitive, and there will always be some organisations whose bids are unsuccessful, for sound reasons. Nevertheless, such an example highlights the need for public grant mechanisms to demonstrate a good understanding of their target market. The level of funding deployed to some projects also needs to be better matched to the development activity in question. RTOs have recently been concerned, on occasions, about the assigned overhead rates to grant funding being too low, and consequently leaving consortia because the funding supplied is insufficient to cover the full costs of projects.

FARADAY CHALLENGE

CASE STUDY 1

The Faraday Battery Challenge is part of the government's Industrial Strategy Challenge Fund which brings together leading research and business to tackle the big societal and industrial challenges today. This scheme is the government's challenge to industry and research to develop the next generation of batteries for vehicles and other applications. There is growing demand for batteries for electrification, with the market estimated to be worth £5 billion to the UK and £50 billion to Europe by 2025. In the UK, this is driven in part by government's plan to ban new conventional petrol and diesel vehicles by 2040 to be replaced by electric and zero emissions vehicles. Through this challenge, the government will invest in research and innovation projects and new facilities to scale-up and advance the production, use and recycling of batteries. It will lower carbon emissions and air pollution in the UK, while creating new opportunities and industries. While the government investment will focus on the automotive sector initially to meet its commitment and the growing global demand for electric vehicles, this will also help advance battery development for other applications for an electrified economy. The government has pledged up to £246 million to develop batteries that are cost-effective, high-quality, durable, safe, low-weight and recyclable. Funding will be deployed via collaborative research and development projects; UK businesses can obtain grants for feasibility studies and collaborative research and innovation projects that develop new and improved battery technologies that are more cost effective. The High Value Manufacturing Catapult Centre partner, Warwick Manufacturing Group, played a critical role bringing this programme together, working with the Local Enterprise Partnership and the local city council to realise the UK Battery Industrialisation Centre. Funding of this sort for scale-up of R&D to progress industrialisation is hugely important. Projects funded so far include improving battery lifespan and range and the reuse, remanufacture and recycle of batteries at their end-of-life. To maintain the pace of 'development' in the battery challenge, it is important that the committed funds flow easily and accessibly to industry partners.

Coupled to the investment in R&D, the UK is also making the necessary legislative and regulatory changes to enable deployment of new technology for electric and Ultra Low Emission vehicles.

For more detail see: **https://www.ukri.org/innovation/industrial-strategy-challenge-fund/faraday-battery-challenge/**

Electric Car Charging. Credit: Innovate UK, 2019

CALL TO ACTION

The UK must become more innovation-led in its national strategy, adopting a smarter approach in the use of public funding that will gear in industrial funding of R&D by:

- **Removing barriers to collaboration and the fear of 'going first' and competition at every step, by helping different organisations to align Performance Indicators.**
- **Using tried and tested models like the Faraday Challenge, acting with pace.**
- **Harnessing public procurement to drive process innovation in mission-critical areas, which in turn will gear in more private investment.**

HOW COULD IT WORK BETTER?

Harness public procurement in mission critical areas:

A potential solution to utilising public procurement contracts to support technology/application demonstrators whilst encouraging industrial investment in development activities.

To solve the problem of complying with state aid rules with government acting as a client whilst partnering with industrial suppliers, the newly proposed Advanced Research Projects Agency (ARPA) style funding agency might be able to achieve this with the following competition style process - as successfully used in the US, to stimulate private enterprise in defence for example.

- **Government could procure the initial assembly and demonstration of large, functionally specified demonstrators proposed by industry, covering the costs of demonstration system assembly and operational validation, fully paid for via procurement contracts.**
- **Industry would be responsible for preceding development of the constituent elements at its own expense.**
- **This approach is essentially a variant on the idea of a prize, but with the industrial partner(s) proposing the objective. This would be a 'competition' style approach in which applications/ proposals are chosen by government to be taken forward, e.g. similar to the Longitude Prize.**

Benefits: This would have the advantage of demonstrating to investors and other potential customers not only the 'product' but also the existence of a reference customer. It would also encourage commercial customer/contractor relationships rather than grant-focused subsidy approaches.

Such an approach has the potential to increase industry investment in the R&D and to avoid state aid regulation issues. ARPA-style programmes should not necessarily be deployed via existing UKRI channels. To be successful the programme needs an industrial rather than an academic leadership approach. We contend that the Infrastructure for deploying an APRA-style vehicle already exists in the form of the UK's existing, extensive IRT sector. The recent Science Capability Review by the Government Office for Science[15], recognised that certain organisations in this sector which fulfil a 'Public Laboratories' role represent an under-utilised asset. AIRTO advocates the deployment of future APRA-style activities via such Public Laboratories, so that funding is used as efficiently as possible, leveraging existing resources and expertise, rather than seeking to establish unnecessary new facilities from scratch.

KEY LEVER 2: Market Pulled...

To succeed, our national innovation strategy should be based on a 'market pull' rather than a 'technology push' approach. Since 2004, investment in supporting commercialisation of our academic research base has grown, and whilst there are some excellent examples of where such research has been successfully applied to develop innovative products and services, the level of R&D activity overall still only remains at 1.7% of GDP! The lack of progress towards this target may be explained by the strategy adopted for achieving it. The UK needs to stop trying to shove 'square' packages of science into 'round holes' of industrial problems and hoping for success!

The routes for translating technology and innovation to the market, and then to commercial success, occur as a result of complex, and non-linear processes. Industry tends to focus first on the market needs, the customer, trends, and commercial opportunities; the priority is on product (or service) development, reaching out for expertise from third-party organisations as and when it is needed. Academic expertise is often utilised at lower TRLs, before progressing technologies along the maturity scale and through to commercialisation. The IRT sector acts as a bi-directional bridge between knowledge in academia and industry in the UK. The economic impact of this ecosystem for the UK is currently under-supported and sub-optimal. However, much of the narrative then, and still now in the current Industrial Strategy, assumes that there is a linear process of early concepts being researched (often within academia), which are then developed, often via a spin-out company route, to be deployed in the market. Whilst this is a recognised path for innovation to be achieved, it represents a minority of the innovation that is actually deployed into markets. Across the UK, the number of new companies registered in 2018 was 672,890[16], many of which are technology-based enterprises. By contrast, approximately 3,000 intellectual property based spinouts have been created in total by UK universities over the period 2003 – 2018[17], an average of 200 new enterprises per year, equating to 0.03% of the total number.. Hence, the majority of innovation in the UK is still more likely to be derived from non-academic sources, with organisations driven through necessity to be competitive in their respective markets. In industry-driven innovation processes, pace is essential, and whilst universities frequently fulfil a vital role in offering scientific and technical understanding, intellectual property/ know-how and consultancy, the driving force for innovation is the market and customers, and industry responding to those in order to remain competitive. Government should be doing more to help those technology-based start-ups that originate outside of universities with provision of more signposting, guidance and schemes for support.

We must also learn from and emulate some of the successful practices adopted in the private sector, to help our public institutions to become better at innovation. One of these practices is the way in which failure is dealt with. Developing new technologies inevitably involves failure. But failure of a technical process to succeed should not necessarily be treated as a failure on behalf of the people involved, and many businesses successfully learn from failure in order to go on to succeed in developing a technology. Some businesses adopt an ethos of explicitly seeing failure as a "First Attempt In Learning" (a term coined by A.P.J. Abdul Kalam, aerospace scientist and eleventh President of India from 2002 to 2007). Leadership culture is key to successfully moving beyond failure in the innovation pathway. But it is widely recognised that a paucity of high-quality leadership skills is a pinch point for securing investment in businesses, especially those that are scaling-up. One way of developing these skills is to create more opportunities for promising early career innovators to experience a more diverse range of working environments, such that they become proficient in the 'languages' of science and engineering, business, finance, government and academia. One such scheme is the Knowledge Transfer Partnership scheme which has been running for forty years[18] - as described in CASE STUDY 2.

KNOWLEDGE TRANSFER PARTNERSHIPS

CASE STUDY 2

Knowledge Transfer Partnerships (KTP) is a UK-wide programme that has been helping businesses for the past 40 years to improve their competitiveness and productivity through the better use of knowledge, technology and skills that reside within the UK Knowledge Base.

A Knowledge Transfer Partnership serves to meet a core strategic need and to identify innovative solutions to help that business grow. KTPs often deliver significant increased profitability for business partners as a direct result of the partnership through improved quality and operations, increased sales and access to new markets.

One such partnership established by TWI with Vascutek Ltd involved the KTP Associate working on the design and identification of automated manufacturing procedures using novel joining techniques for a high-quality vascular graft, for human implant to treat patients with life threatening abdominal aortic aneurysms. The project aimed to draw on TWI's expertise in joining materials to develop an endovascular device with stent attachment and the associated manufacturing methods for the device in order to complete a qualified manufacturing unit. The project led to preparation of tubular endovascular devices using the new techniques, which reduced the stent attachment time to less than ten minutes from nine hours.

For more detail see: **https://www.twi-global.com/pdfs/pdfs-public/vascutek-ktp-summary.pdf**

CALL TO ACTION

- **Expand schemes such as the KTP programme to include RTOs and PSREs as knowledge providers so that they are utilised more as knowledge base partners. At present, many universities are involved with the scheme, but there may be scope to grow involvement of the IRT sector.**
- **Listen more to the needs of businesses in order to respond to the 'market pull' rather than adopting a 'technology push' approach.**
- **Invest in a programme of 'leadership for innovation' to fuel the pipeline of skills that are going to be needed as the UK grows the number of innovative businesses developing solutions in response to mission-led challenges.**

HOW COULD IT WORK BETTER?

Develop a national apprenticeship scheme for innovation:

To develop more programmes to grow the available leadership skills for innovation in the UK, AIRTO contends that the government should aim to establish a national apprenticeship scheme for innovation. Such a scheme would draw on best practices in schemes such as the KTP programme, but it should focus on the leadership rather than the technical aspects of product development.

KEY LEVER 3: Applied...

The ratio of public spend on R&D is suboptimal and needs rebalancing. In the UK the ratio of 'R' to 'D' is approximately 15% for development and 85% for research activities[19]. In competitor nations, such as Germany, the proportions are closer to 50:50. Indeed, the language in Germany has much more recognition, not just for 'Technology Readiness', but also for manufacturing and 'Manufacturing Readiness', representing the "D" end of the spectrum. It is important to understand that development itself can include a number of 'Ds' including **design and demonstration**. AIRTO advocates that in order for the UK economy to benefit more from the national R&D portfolio of activity (taking place across academic institutions, PSREs, Catapult Centres and independent RTOs and in large companies which invest here, and SMEs and start-ups) consideration must be given to achieving a more balanced mix of 'R' versus 'D'. In other words, there needs to be more applied development activity occurring rather than front loading the 'lion's share' of public resources into early stage research. **The UK's strategy of placing the majority of its public investment in R&D into early stage research, is one where effectively *'all the eggs have been placed in one basket'*. Investing in 'More D' means creating more infrastructure in which development can occur, which will gear in industry money.** This focus on supporting development and the increased investment in R&D by industry will significantly contribute to reaching the 2.4% goal by 2027.

However, AIRTO cautions that **rebalancing of the UK's R&D portfolio must be achieved without diluting the world-leading research base** that has been built up over the past century. In considering this, it may be useful for policy to consider delineation of the 'R' and 'D' in 'R&D', recognising that they are separate and distinctly different activities, not a single amorphous endeavour. Furthermore, AIRTO contends that new mechanisms for achieving and deploying increased spend on 'D' activities need to be identified, and piloted if we are to succeed in the national mission to gear in more private investment into R&D activities.

It is also important to consider the potential that SMEs offer to generate significant growth for the UK economy. However, they are, by definition, diverse in their classification, and the needs differ between sectors. During consultation, AIRTO has heard common messages from SMEs, of needing mechanisms that are simpler, quicker, and less bureaucratic, to help them solve problems and bring innovation to the market. It is clear that SMEs need guidance in navigating through the support mechanisms available to them, and practical support in their implementation. More effective mechanisms are needed to deploy applied 'D' funding if we are going to succeed in harnessing the potential that sits in many of our entrepreneurial and innovative SMEs. Our SMEs represent a vital source of new ideas for developing innovative solutions to mission-led challenges. However, to embark on the journey of turning an idea into a real, tried and tested effective and safe product or service, SMEs frequently need to partner with other organisations that have the expertise, facilities and capabilities to succeed. Blue-prints already exist for tried and tested mechanisms for engaging and SMEs with IRT sector organisations, helping them to navigate the complex technical, regulatory and funding landscape that is prevalent in the UK, that should be replicated, such as the Analysis for Innovators (A4I) programme – as described in CASE STUDY 3.

ANALYSIS FOR INNOVATORS (A4I) PROGRAMME

CASE STUDY 3

A4I – Analysis for Innovators is a scheme which can help boost productivity and competitiveness in businesses through solving existing problems. The programme gives UK businesses of any size access to cutting-edge applied R&D expertise and facilities to help solve problems that they have been unable to tackle using standard, widely available technologies and techniques laboratory analysis techniques. Such problems may pertain to product reliability, cost or lifetime. The programme aims to help boost a company's productivity or competitiveness by enabling the UK's top scientists and innovators to utilise their world-class expertise and facilities, which are often otherwise inaccessible, to work with companies to address problems in innovative ways.

Key to the success of A4I are the brokerage meetings that are arranged between the companies and experts from the A4I partners. These meetings allow the company to discuss their problem with experts who are in a position to address the problem. The current fifth round of the programme continues to focus on brokering successful relationships between UK companies and some of the UK's National Measurement Laboratories (NPL, NEL, NML and STFC) and then funding grants for follow-on projects to address a company's technology problems.

Each round of the competition is divided into three distinct parts:

- **Phase 1 - expression of interest**
- **Phase 2 - Brokerage meetings**
- **Phase 2 - Applications for grant funding for a project**

Arguably, this scheme could be expanded with considerable benefits to businesses.

For more detail see: **https://a4i.info/**

CALL TO ACTION

- **Provide more effective schemes for later stage development that are simple and swift for business to engage with, helping them to better access existing knowledge and capabilities to move ideas forward into innovative products and services.**

HOW COULD IT WORK BETTER?

Extend successful models for later stage development:

A potential way of helping more businesses and SMEs to develop technologies, could be to utilise the engagement models already tried and tested with schemes such as A4I, and translate them into other areas. For example, the A4I scheme is focused firmly on bring laboratory analysis capabilities in physics, chemistry and biological sciences to bear to solve product issues. However, the same model could be used to apply other scientific and technical expertise to commercial conundrums by creating a mechanism for businesses to work with innovation organisations in materials science, construction and engineering. A4I, as things stand in a relatively small scheme. However, it is easy to scale, so it should be scaled-up, and could be resourced, in part, by ending other existing schemes that have failed to show effective outcomes.

KEY LEVER 4: Commercially Translated...

It is critical to better understand and fulfil the needs of the markets across different sectors. We need to provide the conditions that could attract more businesses to grow their R&D portfolio, and make the UK become 'the place' to develop revolutionary, world-changing technologies. Much of the fresh private investment in R&D that the UK needs to see realised to reach 2.4% of GDP is going to need to come from Foreign Direct Investment (FDI). The UK needs to plan for strategic investment in capabilities for 'D' that will attract FDI over the coming decade, anchoring high-value jobs, revitalising communities and contributing to the creation of wealth and wellbeing. When the UK gets this right, great benefit can be seen in local communities, such as that brought by Siemens' wind turbine blade plant in Hull[20]; but there are numerous examples of where industry has decided to go elsewhere such as the recent decision by Tesla to choose Germany for its new battery plant over the UK, in spite of the UK government's Faraday Initiative[21]. AIRTO also recognises the importance of the classification of sectors. Sectors matter; they set a climate of investor confidence, especially if government is seen to be supporting particular sectors. Many examples of where the UK has successfully achieved 'world-leader' status in certain sectors already exist, and such blueprints for success should be replicated. One such example is the way that Scotland has served as a test-bed for developing renewable energy technologies – as described in CASE STUDY 4.

A TEST BED FOR RENEWABLE ENERGY TECHNOLOGIES

CASE STUDY 4

The Scotland based Offshore Renewable Energy Catapult's world-leading test and validation facilities and expertise provide clients with robotic and autonomous system technology and innovation. Their established test-bed applies to offshore installation, inspection, repair and data acquisition for surface and subsea applications. Capabilities include:

Levenmouth 7MW Demonstration Turbine

Providing a live demonstration site for robotic technologies, this facility provides clients with the ability to test and validate on or within the proximity of a full scale live offshore turbine.

Saltwater docks and replica seabed

With versatile wet or dry docks, clients can design and deploy bespoke technology testing and demonstration in a controlled, representative environment.

Offshore Anemometry Hub

Access to an offshore structure, located 3Nm off the Northumberland coast, enables clients to test and demonstrate robotic technology in a live environment.

These unique subsea testing facilities recently enabled Edinburgh-based Hydrason Solutions Ltd. to undertake a representative programme of testing and successfully complete trials of their innovative condition monitoring technology.

Hydrason's BioSonar technology detecting cables buried in the seabed of the saltwater dock facility.

Credit: ORE Catapult Centre, 2019

For more detail see: **https://ore.catapult.org.uk/testing-validation/**

CALL TO ACTION

- **Provide more facilities to 'test at scale'. Creating technology demonstrators and using local clusters of capability as test-beds for developing new technology opportunities is a tried and tested mechanism for supporting the pursuit of solutions for market need. The digital sector is one obvious area which would benefit from more support for scale-up and adoption.**

HOW COULD IT WORK BETTER?

Create more test-beds across the UK to meet the demands of business:

A potential way of helping more businesses to bring their development activities to the UK, could be to provide more test-bed facilities and demonstrators. There are two types of test-bed: those used for evaluation and those used for technology performance validation. Both types are necessary to successfully develop an innovation and translate it to the market. Businesses could stand to benefit from accessing more ready-made and cost-minimising test and demonstration facilities in key sectors such as telecommunications (e.g. for 5G), in renewable energy, and in healthcare. Such flexible infrastructure makes it as easy as possible for technology developers to learn by doing, with access to impartial expertise to build a bank of performance data on their products in development. Facilities of this sort enable developers and suppliers to learn lessons at minimal cost by reducing the need for their own in investment in large testing plants/facilities. These facilities allow companies to work on continuous improvement of technologies. Manufacturing demonstrators enable companies to identify problems in production processes and develop solutions. This is especially important for SMEs who can experiment before investing in their own facilities. Facilities of this kind enable businesses to operate in a more agile, flexible and swifter manner to develop their products by being able to tap into readily available development infrastructure.

Conclusions and recommendations

The level of R&D activity overall in the UK has stagnated over the past fifteen years and sits at only 1.7% of GDP. Innovation is critical for our national and global survival and competitiveness, and must become the central pillar of our Industrial Strategy. Time is running out to reach 2.4% GDP for R&D by 2027. Efforts to boost R&D to this level over the last couple of decades have failed, despite repeated attempts of successive UK governments. Why? Because the 'technology push' approach has not worked. The strategy is skewed too heavily towards RESEARCH: all the 'eggs have been placed in one basket'. Innovation is NOT always a linear process commencing in a laboratory. A fresh approach is needed to avert failure. The time has come to focus more on the 'DEVELOPMENT' aspects of R&D in our national strategic planning to complement our world-class research base.

To address the lack of progress, **AIRTO contends that** a significant increase in public investment in applied development activities at mid and higher Technology Readiness Levels will result in more 'pull through' by the market across key industry sectors and will result in the more effective use of the UK's public expenditure on science and innovation.

We have identified FOUR KEY LEVERS which must be applied to help the UK achieve its goal of 2.4% of GDP for R&D. Our recommendations are that the government's strategy must be…

1. **KEY LEVER 1: Innovation-led… Innovation is critical for our national and global survival. Our Industrial Strategy must shift in emphasis, such that innovation becomes the central pillar** to face down the climate emergency and other mission-driven priorities by placing the market requirement for practical innovation and the organisations execute it, such as RTOs and PSREs, firmly in the 'driving seat'.

2. **KEY LEVER 2: Market Pulled… To succeed the UK's innovation strategy should be based on a 'market pull' rather than a 'technology push' approach.** We must abandon the technology push approach for innovation which has been fostered by previous governments over the past couple of decades. Growing R&D investment from business and industry requires the central focus of the strategy to be moved to market need, rather than trying to shove 'square' packages of science into 'round holes' of industrial problems and hoping for success!

3. **KEY LEVER 3: Applied… The ratio of public spend on R&D is suboptimal and needs rebalancing.** In the UK the ratio of 'R' to 'D' is approximately 85:15, in favour of Research activities. In competitor nations, such as Germany, the ratio is closer to 50:50. For the UK economy to benefit more from the national R&D portfolio, consideration must be given to a achieving a more balanced mix of 'R' versus 'D'. The UK needs to stimulate more applied development activity by investing further in the infrastructure for higher TRL activities, rather than front loading the 'lion's share' of public resources into early stage research. However, this rebalancing must be achieved without diluting the world-leading research base in UK Universities that has been built up over the past century and which underpins the UK's stature as a '*Science and Innovation Superpower*'.

4. **KEY LEVER 4: Commercially Translated… Two-thirds of all UK R&D is industry funded. To succeed in growing commercial R&D even further, we must better understand and fulfil the needs of the markets for development activities across different sectors. We need to provide the infrastructure and conditions that could attract more businesses (including SMEs)** and private investors to grow their R&D, and make the UK the place to develop revolutionary, world-changing technologies and applications, including providing strong regulatory alignment, skills development and standards. Consideration must be given to the absorptive capacity of the IRT sector to accommodate future growth in industrial development activities, since this will increase the demand for the demonstrators/test-beds, training,

analytical/measurement, accreditation/certification services that the sector to delivers to industry to support the translation of fully functional products to the commercial market place. In addition, the sector provides significant 'trouble-shooting' capabilities to address industry's requirements to improve productivity, but it is limited under investment in capital infrastructure, so face challenges in responding to market demand, which must be addressed.

In conclusion, the UK has a thriving Innovation, Research and Technology sector, offering people with the right skills and expertise, and substantial resources, to deliver the UK's Industrial Strategy by playing a critical independent role in working with industry to address the unmet market needs across key sectors. Our sector provides solutions to major technological challenges such as attaining net zero carbon emissions, and if harnessed and resourced properly can help underpin the UK's status as a world-class '*Science and Innovation Superpower*'.

The time has come to focus on the 'D' in our national strategic planning to complement our world-class research base to attain greater impact and benefit. If the UK can optimise its strategy for innovation, we believe huge benefits will be achieved along the way, including:

- **Gearing in of private funding - a direct increase in the levels of industrial and private investor support for R&D, helping to reach the target of 2.4% of GDP invested in R&D by 2027.**
- **More exploitation - increased exploitation of research outcomes - a positive driver for improving UK productivity, competitiveness and economic benefit and a boost to the 'return' on public and private investment.**
- **Support for key national missions - an enhanced level of effective support for Grand Challenges and missions, such as attaining a zero-carbon economy in the UK by 2050 for the benefit of the UK economy and society.**

We conclude that critical INTERVENTIONS are necessary to achieve greater impact and translation of R&D into innovation by commercial enterprises and public services, by:

1. **Changing the mix to spread the risk: delineating between the 'R' and 'D' in R&D to invest in more DEVELOPMENT.**
2. **Aiming for MARKET PULL as opposed to TECHNOLOGY PUSH.**
3. **Being more mission-led: driving more collaboration, and focusing less on competition at every step.**
4. **Creating urgency in doubling public R&D spend to gear in the private sector.**

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AIRTO is the Association of Innovation, Research and Technology Organisations. Its membership comprises approximately sixty of the principal organisations operating in the UK's Innovation, Research and Technology (IRT) sector. The IRT sector has a combined turnover of £6.9 billion, employing over 57,000 scientific and technical staff (equivalent to the academic staffing of the Russell Group of universities) and, for comparison, it is significantly larger than the network of Fraunhofer Institutes in Germany both in size and its scope of activities. The sector contributes £34 billion to UK GDP. AIRTO's members work at the interface between academia and industry, for both private and public sector clients.

Members include independent Research and Technology Organisations, Catapult Centres, Public Sector Research Establishments, National Laboratories and some privately held innovation companies.

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