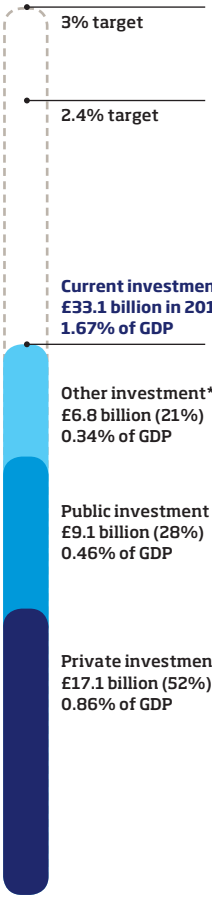
ROYAL ACADEMY OF ENGINEERING

Increasing R&D investment: business perspectives

Introduction

Where are we now? Total investment in UK R&D as a percentage of GDP in 2016[1]



*Other investment refers to funding from private non-profits from overseas, including from non-UK business and EU funding programmes.

The UK government has committed to increasing investment in R&D in the UK from the current 1.7% of GDP to 2.4% by 2027, with a longer-term goal of 3%.

This is an ambitious target that will require further public investment. But it will also need businesses to do more: that they invest in more R&D, conduct more R&D, and do more with that R&D.

The people at the centre of businesses' decisions around R&D are chief technology officers, chief engineers, and in some businesses, chief executives. They are the ones that make the case for R&D within the business and direct it, including where it is done and how it is used to drive business success.

The decisions they make are complex and sensitive to the individual nature of the company. They are also affected by a diverse set of factors in the business environment both in the UK and abroad.

Understanding how they make those decisions, and which aspects of the current UK environment encourage or discourage further R&D and innovation, is crucial not only to hitting the target, but to realising the potential benefits of doing so in terms of better jobs and better outcomes for people in the UK.

Businesses in sectors that are tightly linked to engineering are responsible for a significant amount of R&D expenditure in the UK, delivering innovation across a vast range of industries, from technology and construction to aerospace and energy.

The Royal Academy of Engineering has spoken to the people responsible for business decisions about R&D at engineering companies across a range of sectors, sizes and locations. This report presents the findings of these interviews.

Interviews revealed numerous factors that influence their decisions on R&D investment. Many of these are complex topics, involving numerous stakeholders, with conflicting drivers and barriers. However, they broadly divide into two groups:

- **Building on strengths** – Areas where the UK is strong, such as R&D or innovation support mechanisms often focused on early-stage R&D. These are the factors that drive companies to make R&D and innovation investments in the UK.
- **Action needed** – Areas where the UK performs poorly relative to competitor countries. In general, these areas fall outside traditional R&D or innovation policy support mechanisms and relate to the broader policy and business environment, and the pull through of new technologies to market. Action here has the potential to transform how businesses invest in R&D.

Building on strengths	Action needed
Engineering workforce	Late-stage development and demonstrators
Innovation funding	Public procurement
Non-financial innovation support	Joined-up government approach
Collaboration with universities	Ownership and financial structures
Collaboration between businesses	Innovation in engineering services
Tax incentives	Innovation across sectors

Engineering R&D and innovation in context

"Now is the right time to ask ourselves some big questions when it comes to our public R&D investment. How can we do more to ensure our investment crowds in private money?"

Sam Gyimah MP, Minister of State for Universities, Science, Research and Innovation, 6 July 2018

Many of the themes identified here have also been highlighted in the Industrial Strategy, which was welcomed by the engineering community, together with the 2.4% target. It is now time to act and ensure that they deliver the social and economic benefits of innovation to the whole of the UK.

R&D and innovation are at the heart of the engineering companies interviewed, and these companies are the lifeblood of R&D in the UK, spanning sectors from artificial intelligence (AI) to construction. R&D and innovation allow companies to stay ahead of market competition.

Decisions to invest in R&D and innovation are not made in isolation and take place in different ways across companies and wider contexts, depending on how R&D fits into each company's business strategy. Understanding this context is critical to identifying how the 2.4% target can be achieved.

Engineering R&D and innovation looks different across companies

The following factors are all influential:

- Whether it offers services or products.
- The industrial sector it operates in.
- Company size.
- Stage of product or service development.
- Ownership, including nature of investors.
- Whether R&D is conducted internally, in collaboration or contracted.
- Heritage of the company.
- Stage of company growth.

This diversity means that no two companies make decisions about R&D investment in exactly the same way. The package of factors that are important to one company may differ from the next.

Therefore, **there is no one-size-fits-all solution** to encourage engineering businesses to invest more in R&D and innovation in the UK. Instead, a range of measures are required to attract and support future investment across the business environment.

R&D and innovation are global activities

- Nearly all companies interviewed are developing products and services for a global market. This means that they conduct R&D in close collaboration with customers around the world.
- There is significant international competition to attract business R&D investment. Several of the UK companies interviewed said that they had been approached by foreign governments offering attractive incentives to locate R&D activities in their countries.
- Many companies look for the best innovation partners, regardless of where they are in the world. This means that companies collaborate on R&D with universities, other companies and suppliers across the globe.
- Many companies strongly value international diversity in their R&D teams. This provides cultural understanding, language skills, and a diverse source of ideas, facilitating the development of goods and services for a global market.
- Most multinational companies have R&D sites around the world and small companies interviewed either have or are considering opening R&D sites outside the UK in the coming years. Having sites in multiple countries supports access to local customers, a broader knowledge base and a greater range of expertise.
- Not all R&D can be conducted in the UK. In industries such as mining or oil and gas, some of the work needs to be conducted near relevant natural resources. However, the design, commissioning and management of the R&D for this work is internationally mobile and could be placed in the UK, bringing in high-value jobs.

R&D and Innovation

R&D is defined as 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 and includes basic research, applied research and experimental development.

Frascati manual[2]

R&D has an internationally agreed definition and is used for national accounting, which is why it is the focus of the UK government's target.

However, elements of late-stage development and demonstration are excluded from the definition of R&D.

Innovation is the process by which ideas are converted into value, in the form of new and improved products, services and approaches. Innovation activity amounts to more than is captured in the definition of R&D and while innovation often draws on R&D, with technology a common source of innovation, it can also derive from developments in design, business modes and mechanisms of service delivery.

While this project is set in the context of the government's R&D investment target, the discussions in the interviews went beyond the definition of R&D and even innovation, capturing **what really matters to businesses in creating value from investments in R&D and innovation**.

An overly narrow focus on the Frascati definition of R&D risks failing to realise the full societal and economic benefits from R&D and innovation.

How are decisions on R&D made in a company?

Deciding on how much, where and what R&D to do is a complex process, informed by top-down business strategy and bottom-up technology opportunities.

R&D investment depends on a broad range of internal and external factors. The factors outlined in the explainers that follow are some of the elements that shape investment decisions and are embedded into companies' broader decision-making processes.

R&D investment decisions are not made independently of the rest of the company: they are integrated with and flow from the broader business strategy. The areas where the UK performs poorly do not relate specifically to the R&D ecosystem in the UK, but refer to the broader environment that supports companies to pull innovations through from idea to market in the UK.

- The budget for R&D investment is often set by the board and senior management team.
- If companies are incentivised to do more R&D, or the value of R&D to their company increases, they will do more.
- Companies need to balance R&D investment against spend in areas such as production and marketing as they are vital for company revenue and growth. Many of these other areas are intertwined with R&D. For example, customer engagement and marketing informs product development.
- Spend in different areas varies depending on the stage of company and product or service development. For example, a new startup where products have not yet reached market will spend proportionally more on R&D than an established company.
- Understanding of future market trends and needs is an important determinant of R&D direction and strategy for all engineering companies. Feedback from close collaboration with customers also helps to inform technology strategy.
- Feedback from technology groups on emerging technological opportunities and threats can inform R&D direction and spend.

Advisory Group

Chair: Professor Sir Jim McDonald FREng FRSE, Principal and Vice-Chancellor, University of Strathclyde

Members

Ed Daniels FREng, Executive Vice-President for Commercial and New Business Development for Upstream International, Shell UK Limited

Dr Steve Denton FREng FRSE, Head of Civil, Bridge and Ground Engineering, WSP

Sir David Grant CBE FREng, Chairman, NPL; Senior Independent Director, Renishaw plc; Senior Independent Director, IQE plc

Professor Neville Jackson FREng, Chief Technology and Innovation Officer, Ricardo

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Companies interviewed

Interviews were conducted with chief technology officers, chief engineers, heads of R&D or, in some cases, chief executives from 31 companies, including:

- Anglo American plc
- Babcock International
- BAE Systems plc
- Blatchford Group
- BOXARR Ltd
- BP plc
- CCm Technologies Ltd
- Electricity North West Ltd
- GreenSpur Renewables Ltd
- Intelligent Ultrasound Ltd
- ITM Power plc
- JCB Ltd
- KENOTEQ Ltd
- Kier Group plc
- Laing O'Rourke plc
- M Squared Lasers Ltd
- McLaren Applied Technologies Ltd
- Mercedes AMG High Performance Powertrains Ltd
- Mondelez International
- Process Systems Enterprise Ltd
- Quanta Dialysis Technologies Ltd
- Radio Design Ltd
- Ricardo plc
- Rolls-Royce plc
- Siemens UK plc
- Surrey Satellite Technology Ltd
- Vivacity Labs Ltd
- Vodafone Group plc
- WSP Global plc

1 *Gross domestic expenditure on research and development, UK*: 2016, Office for National Statistics, 2018. Note: figures are rounded.

2 *Frascati Manual 2015, Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities*. OECD, 2015. OECD Publishing, Paris.

ROYAL ACADEMY OF ENGINEERING

Engineering workforce

Summary

The availability of skilled people is a major factor for influencing business investment in R&D: being able to hire the right people with the right skills at the right time is vital for successful R&D.

The UK engineering skills base is of good quality and supports existing R&D investment.

But, quantity is a limiting factor: more engineers are needed in the UK, particularly in emerging fields such as artificial intelligence (AI) and software engineering[1].

Engineering R&D in the UK is undertaken by an international workforce: maintaining this after the UK's departure from the EU will be fundamental to increase business investment in R&D.

Engineers are inherently innovative and play a central role in business R&D and innovation. Sectors with a high concentration of graduate engineers report higher than average levels of innovation[2].

The **quality** of engineering and R&D skills in the UK is considered good when compared with competitor countries, especially where wages are lower.

But, the **quantity** of engineers in the UK is a challenge. The interviews reflected the broader engineering skills gap in the UK, with forecasts of an annual shortfall of up to 59,000 engineering graduates and technicians by 2024[3].

One in three interviewees find recruitment challenging due to a lack of skilled applicants.

Availability of skilled staff varies by sector:

Digital skills and software engineering ▼

The skills gap in this area is well-recognised, because of the rapidly developing nature of the field, and its increasing importance across all business sectors. A 2016 government report found that 72% of large companies already have tech skills gaps[4]. The interviews revealed that some countries, such as Singapore, have access to a better pool of digital talent than the UK. This may drive companies to relocate R&D, particularly since digital R&D is more mobile than capital intensive work.

Motorsport ▲

The UK has a significant heritage in motorsport, with seven out of ten of the current Formula 1 teams having UK bases. This has created a cluster of R&D activity and a strong skills base.

Medtech ▼

The large majority of companies in this sector are SMEs, with 49% employing fewer than five people[5]. Small companies can find it difficult to access the range of skills they need. This includes engineers, as well as people with an understanding of production, standards and regulatory pathways.

Small companies

Attracting R&D staff is particularly difficult for small companies who compete with large companies offering greater salaries, benefits and security.

Initiatives to encourage more graduates to consider careers in small companies could be explored. These could include greater support for SMEs to create student placements and internships, increasing CASE studentships in SMEs, or increasing the visibility of SMEs at graduate careers events.

An international workforce

Companies interviewed actively seek engineers and R&D staff from across the world, not only to provide the skills needed but also to realise the benefits of diversity in their teams.

This diversity provides multicultural understanding, language skills, and a broad range of ideas, facilitating the development of goods for a global market. Additionally, if international staff return to their home country, it can help companies develop international research networks.

The vibrant nature of the UK's cities, particularly London, helps to attract and maintain this international R&D workforce. For some companies, this is an important factor for locating R&D in the UK. There are significant concerns that if attracting international staff becomes more difficult after Brexit, it may be harder to retain R&D activities.

"If we were unable to maintain an internationally diverse team in the UK, it would be a challenge to maintain the level of R&D work here."

Jeni Mundy, formerly Product Director, Vodafone Group

The UK engineering workforce is international. **Over 15% of staff** working in professional, scientific and technical activities in the UK **are born outside the UK**[6]. For many of the companies interviewed, it was much higher, with one product development team made up of 75% non-UK nationals.

To increase business R&D investment:

- Build the UK's engineering skills base, increasing the number of engineers, particularly for emerging sectors.
- Government should continue to work with industry to develop the UK digital skills base, including implementing the commitments outlined in the AI sector deal and *Made Smarter Review*.
- Recruitment of skilled people from around the world and transfer of R&D staff into the UK must not become harder after Brexit. Any new immigration system should be streamlined to be more efficient, fast, fair, and transparent, and make the UK more competitive in the global market for talent.

This explainer is part of a series based on interviews with individuals responsible for making decisions on R&D across a wide range of engineering companies.

See ***Introduction*** explainer to find out more.

1 *Growing the Artificial Intelligence industry in the UK*, Professor Dame Wendy Hall and Jerome Pesenti, 2017.
2 *Assessing the economic returns of engineering research and postgraduate training in the UK*. Technopolis, 2015.
3 *The state of engineering*, Engineering UK, 2018.
4 *Digital skills for the UK economy*. Department for Business Innovation and Skills and Department for Culture Media and Sport, 2016.
5 *Strength and opportunity 2016: The landscape of the medical technology and biopharmaceutical industries in the UK*, Office for Life Sciences and Department for International Trade, 2017.
6 *Number and proportion of people in employment: by country of birth, nationality, occupation and industry, ages 16 and over, April 2015 to March 2016 (user requested data)*, Office for National Statistics, 14 July 2016.

Innovation funding

Summary

Public funding for innovation in small companies plays a vital role in enabling high-tech startups to survive, grow and scale. For larger companies, this funding facilitates collaborative R&D and supports R&D investment in the UK.

Funding programmes delivered by Innovate UK and several other public funding agencies are excellent at supporting engineering innovation. However, there is a notable gap in support for late-stage development and demonstration activities.

Agencies should continue to provide and develop innovation funding programmes, exploring opportunities to increase flexibility and models for participation.

Innovation funding for small companies

Innovation is an inherently risky process, and the benefits may only materialise over very long timescales. Consequently, government funding has a pivotal role in supporting small high-tech companies to conduct R&D and develop innovative products and services before they can reach market or attract significant private investment.

Innovation funding creates the following benefits for companies:

- Increases the amount of R&D done.
- De-risks investment in highly innovative work.
- Drives collaboration and access to a broader R&D network.
- Acts as a signal of quality to private investors.
- Consortia-based projects improve understanding of the sector and create access to potential customers.
- Non-financial support linked to funding is also hugely valuable.

See also ***Non-financial support for innovation.***

Innovate UK, the UK's innovation agency, is a major route for UK public innovation funding. Since 2007, it has delivered around £2.5 billion in innovation grants and supported more than 8,000 organisations[1].

Interviewees highlighted other organisations that provided a positive experience of public funding, such as:

- **Regional agencies** – Scottish Enterprise
- **Government departments** – Department of Health and Social Care's National Institute of Health Research and the Department for Business, Energy and Industrial Strategy's Energy Entrepreneurs Fund
- **Public-private sector initiatives** – Aerospace Growth Partnership
- **Independent organisations and charities** – the Royal Academy of Engineering

All small companies interviewed have received public funding and emphasised that it played **a vital role in their survival**, **innovation** and **growth**.

"Our experience working with Innovate UK has been very positive. The grant has allowed us to explore new ideas and to engage with new partners, and the management of the whole process has been very efficient."

Professor Costas Pantelides FREng, Managing Director, Process Systems Enterprise Ltd

Innovation funding for large companies

Large companies also work with Innovate UK and other funders as recipients of grants, collaboration partners, and sources of matched funding for collaborative projects.

Similarly to small companies, funding facilitates high-risk R&D projects, helps attract or maintain R&D projects in the UK, and drives collaboration, including between companies that may not otherwise work together.

"Working in consortia-based public innovation projects has supported our growth, through both technology development and increasing understanding of the future market."

Dr Caroline Hargrove FREng, Chief Technology Officer, McLaren Applied Technologies

While innovation funding is an area of strength for the UK, there are opportunities for improvement. Interviewees suggested several ways that programmes can help increase collaboration and investment by large companies in the UK:

- UK innovation funding lacks agility compared to competitor countries, particularly in Asia, making it difficult for large companies in fast-moving sectors to participate and for thematic programmes to meet real business needs.
- Opportunities for some large companies can be limited by the high amount of investment and strict criteria required for participation in R&D programmes, particularly those in sectors with lower profit margins and with traditionally low investment in R&D, such as process engineering for consumer products or the construction sector.

"Funding calls can be narrow and limited. To engage with collaborative projects we really need them to be available when we have a business need."

Emma McLeod, Research Principal - Process Technology, Mondelez International

"Public innovation funding has been the lifeblood of our company to date. Without it we could not have got our game-changing green product to this stage."

Dr Sam Chapman, Chief Executive Officer, Kenoteq

"Collaborative R&D projects, including those funded by Innovate UK, have allowed us to innovate beyond the scope of our company, and to grow and scale up more rapidly as a business and achieve more high value engineering and science jobs here in the UK."

Professor Graeme Malcolm OBE FREng FRSE, Chief Executive Office, M Squared Lasers

To increase business R&D investment:

Government funding for innovation is incredibly valuable. However, interviews identified areas with potential to leverage further business participation and investment in R&D:

- **Increase flexible funding opportunities**. Greater flexibility in scope, timing and size of programmes would allow more companies to access the right support at the right time to meet their business needs. Open programmes amounted to only 5% of Innovate UK's allocations in 2017/18[2].
- **Streamline processes**. While companies appreciate the importance of a rigorous process, application and grant management can be burdensome, particularly for companies with non-academic roots.
- **Protect grant funding.** In contrast to grants, many companies find loans an unattractive option for supporting risky R&D and innovation activities. However, innovation loans may have a role to play in supporting near-to-market innovation activities.
- **Increase support for late-stage development and demonstrator projects**. The gap in funding for late-stage development must be addressed. See also ***Late-stage development and demonstrators.***
- Design grants to meet the needs of service-based companies. See also ***Innovation in engineering services.***

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See ***Introduction*** explainer to find out more.

1 *Annual Report and Accounts 2017/18*, Innovate UK.
2 *Annual Report and Accounts 2017/18*, Innovate UK.

Non-financial innovation support

Summary

Government support for innovation extends beyond funding, and can include a wide range of mechanisms, such as schemes for building research networks, business strategy advice, trade support, and simple introductions.

Non-financial support can provide game-changing opportunities for companies that lead to long-term growth in R&D investment in the UK. This work should be boosted, valued and promoted as part of the package that facilitates business R&D investment in the UK.

UK government departments, agencies and other publicly funded organisations provide a diverse range of support for R&D and innovation that extends beyond funding. This may be provided alongside financial support or as a standalone offering. Such support is critical for businesses to create value from investments in R&D and innovation. It can cover a broad range of activities including:

- introductions and access to networks
- business strategy advice
- mentoring
- management skills training
- regulatory advice
- marketing advice
- export guidance
- trade missions
- intellectual property advice.

Non-financial support is unlikely to be a major factor in attracting business investment to the UK, but **it can be transformative for companies**.

"While government innovation funding was invaluable, the broader commercial support they provided has had an equally significant impact on our business."

Pawel Kisielewski, Chief Executive Officer, CCm Technologies

Business support

A cleantech/energy sector SME company that won support through the BEIS Energy Innovation Programme found the innovation funding helpful, but the broader business support offered through Carbon Limiting Technologies as part of the award was revolutionary. This included assistance in creating complex financial models and the development of a short video explaining and showcasing their technology. They regularly share this video with potential customers, meaning they do not need to rely on others to explain or present their technology. This has radically improved their engagement with customers, supporting the transition from concept to market.

Navigation support

A large multinational company considering new R&D investment opportunities in the UK worked with BEIS and the Research Councils to help them understand and navigate the UK research and innovation landscape. This included introductions to potential partners and input to the company's internal business proposal for investment in the UK. This has led to investment in the UK through long-term strategic research partnerships with seven universities.

Catapult Centres

The Catapult Centres are now an integral part of the UK's innovation landscape. They provide physical and digital infrastructure to support late-stage R&D to turn innovative ideas from concept to reality. The Catapults recognise that innovative companies need extensive non-financial support to succeed and they provide this through a variety of mechanisms.

- The Offshore Renewable Energy Catapult has provided a range of support for one small company interviewed. This has included access to specialist mechanical engineering and metrology expertise, and large-scale testing facilities, but also business strategy support from experts with a deep understanding of the offshore sector. This business advice has been at least as important to the company as the technological input in helping them maximise the value of their R&D investment.
- Representatives from a large company interviewed recently attended an innovation event organised by the Satellite Applications Catapult. Contacts made through the event and the Catapult staff led to a successful R&D collaboration with a UK-based SME, generating value for both the large and small company.

Non-financial support is an important element in helping businesses to innovate and it is found across the innovation landscape:

See also ***Collaboration with universities***.

See also ***Collaboration between businesses***.

See also ***Late-stage development and demonstrators***.

See also ***Joined-up government approach***.

See also ***Innovation across sectors***.

To increase business R&D investment:

- Non-financial support for innovation should be boosted, valued and promoted as an important part of the package that government offers companies.

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Collaboration with universities

Summary

The high quality of UK academic research and the ability to collaborate with universities are key factors in attracting early-stage investment in R&D to the UK.

Collaboration with universities is an important route for early-stage and long-term strategic R&D and can play a crucial role in supporting company growth.

However, there is increasing international competition for this collaborative work, with the quality of research in many countries improving rapidly. The UK must work to maintain its leading position in academic excellence.

Collaboration with universities is an important part of R&D activities for many engineering companies: it de-risks R&D investment and facilitates access to cutting-edge research, world-class expertise and research networks, at relatively low cost to the company.

The UK is ranked **sixth in the world** for **business-university collaboration**[1].

Firms that receive a grant for innovation are more successful than peers; but their success is increased if there is an element of cooperation with the public sector, including universities[2].

What drives businesses interviewed to collaborate with UK universities?

- UK academic research is world-class.
- Many academics are interested in working on industrially-relevant problems and maintain a good balance of academic and practical engineering research work.
- Many UK universities collaborate across disciplines to solve industrial problems.
- Universities are open to collaboration with other universities.

The variety of mechanisms for collaborating with universities helps companies make decisions about investing in R&D in the UK, depending on their business needs:

- Collaborative PhD studentships, such as the Research Councils' industrial CASE studentships.
- Fellowships for industry-academia collaboration for senior researchers, such as the Royal Academy of Engineering Industrial Fellowship scheme.
- Long-term strategic partnerships with universities, including funding research projects, laboratories or research centres.
- Short-term, milestone-driven projects, similar to research consultancy work.

(continue overleaf)

Nearly all the companies interviewed have R&D partnerships with UK universities – this is a key factor in supporting their R&D investment in the UK.

"We work with a range of UK universities through collaborative PhD studentships, summer internships and sandwich placements. These give us access to a valuable and varied skill set that we do not necessarily have internally."

Dr Caroline Hargrove FREng, Chief Technology Officer, McLaren Applied Technologies

- Consortia-based research projects, such as those funded by EU Framework Programmes and Innovate UK.
- Knowledge Transfer Partnerships that facilitate partnerships between university and business, with placement of a recent graduate in a company to address a challenge.

"Our collaboration with the University of Leeds through a Royal Academy of Engineering Research Chair award was game-changing for our company. Working with a research group focused on technologies in our sector accelerated our innovation and company growth. As a small company, we could not have done this work on our own."

Eric Hawthorn FREng, Managing Director, Radio Design Ltd

"We try to locate earlier stage in-house R&D close to high-quality academic research in the relevant fields. Many of our internal labs are in the UK and USA for this reason."

David Eyton CBE FREng, Head of Technology, BP plc

To increase business R&D investment:

- Maintain the UK's leading position as an excellent academic research base and increase opportunities for collaboration between academia and business.
- Continue to improve business-university relationships, building on previous recommendations such as those in the *Dowling Review of Business-University Research Collaborations*[3].

The interviews highlighted the following areas where improvements could attract further R&D investment into early collaborative work in the UK:

- University administration can be slow compared to competitor countries, delaying projects and making it less attractive for companies to work with UK universities.
- There are cultural differences between UK academia and industry, particularly in approaches to project management. The welcome introduction of impact measures by UK research funders has driven significant culture change and should continue to be prioritised.
- Negotiating intellectual property ownership with some universities can be challenging and companies may no longer work with a university if it is difficult to reach an agreement. Existing good practices in fair and efficient handling of intellectual property should be shared widely.

CASE awards

Industrial CASE awards are a highly valued route for academic-industry collaboration.

These awards provide access to industrial expertise and facilities for students and academic organisations and can accelerate research impact.

For companies, they provide a low-cost route to access cutting-edge academic research, build research networks and conduct research beyond the scope of the company.

CASE awards are currently only available at PhD level. Extending collaborations with individuals beyond this significantly increases costs to the company, meaning that collaborations forged through CASE awards are often paused on completion of the PhD.

It may be valuable for UKRI to consider a programme to extend CASE awards to early-career, postdoctoral-stage researchers. For example, the Irish Research Council runs an Enterprise Partnership Scheme, delivering two-year postdoctoral fellowships that it jointly funds with industry.

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See ***Introduction*** explainer to find out more.

1 *The Global Innovation Index 2018: Energizing the World with Innovation*, Cornell University, INSEAD, and WIPO, 2018. Ithaca, Fontainebleau, and Geneva.
2 *Estimating the effect of UK direct public support for innovation*, BIS Analysis Paper, 2014.
3 *The Dowling Review of Business University Collaborations*, Professor Dame Ann Dowling, 2015.

Collaboration between businesses

Summary

R&D collaboration between engineering businesses brings a wide range of benefits and takes many forms.

Large companies and innovative SMEs work together to help pull new technologies through to application, supporting growth across large and small companies.

The UK has a vibrant community of innovative SMEs, but so do many competitor countries. To remain competitive and attractive, support for SMEs must continue to improve, including through innovation support schemes and access to finance.

Collaboration across supply chains is important and can bring broader benefits for the UK economy. However, in some sectors the UK supply chain has been hollowed out over recent decades.

Business to business collaboration can happen in a number of ways, from pre-competitive collaboration between large companies in consortia, to corporate venture capital investments in SMEs.

Interviews identified two main types of business collaboration that can influence R&D investment decisions:

- Collaboration between large companies and innovative SMEs.
- Collaboration across supply chains.

Collaboration between large companies and innovative SMEs

In sectors such as defence, large companies work with innovative SMEs to test new technologies in real-world applications. These collaborations help pull technologies through to market and drive growth across large and small companies.

Most large companies interviewed collaborate with SMEs across the world, seeking the best possible partner for the problem at hand.

Large companies interviewed regard the UK as having a vibrant community of innovative SMEs with good opportunities for collaborative R&D. However, there is strong international competition with many countries, such as the US, China and Israel, also fostering the growth of high-quality innovative SMEs.

> "In the chemicals sector, the supply chain has been hollowed out, making R&D in the UK more difficult and forcing investment abroad. In contrast, we found it reasonably easy to find UK suppliers for bespoke engineering or automation work in the manufacturing and R&D areas."
>
> **Former Director of R&D, large company**

Many Innovate UK programmes support collaboration between large and small businesses

A large part of Innovate UK's core funding is spent on business to business collaboration, and it also offers further support via the following:

Innovate UK Knowledge Transfer Network (KTN)

KTN specialise in cross-sector collaboration and mediate networks of business, academics and other providers of innovation support.

For example, FeTu is a Yorkshire-based company that designed a revolutionary 'green' energy device targeting carbon reduction across a broad range of systems and industries. KTN introduced FeTu to potential academic and commercial partners, which led to the company growing and hiring four employees[1].

Catapult Centres

Innovate UK funds Catapult Centres, which are a series of physical centres that bring together businesses, scientists and engineers to work on late-stage R&D to take new ideas into the market.

For example, Catapults offer a platform for large companies to try new solutions with supply chain partners. Train-maker Alstom funded a competition via the Transport Systems Catapult that led to an SME developing a new way to fit train windows that saved days of manufacturing. The four runner-ups were also added to the company's supplier roster[2].

"The majority of our R&D investment is spent in collaboration with SMEs. We work with the best companies and technology wherever they are based in the world. There are great examples of innovative companies in the UK, but also many others in countries from the US to South Africa."

Phil Newman, Head of Innovation, Anglo American

Collaboration across supply chains

All engineering companies depend on good supply chains to deliver successful innovation. This type of R&D collaboration is particularly important in highly fragmented sectors, such as construction.

Many large companies are happy to work with companies across the world but find it easier to work with local partners for certain types of work.

Local supply chain collaboration can result in broader benefits for the local economy, building local jobs, and increasing business access to customers.

Several sectors, such as chemicals manufacturing, have had their supply chains depleted over recent decades, with few mid-sized companies remaining in the UK. This makes it more difficult for large companies to find UK partners, pushing work overseas and increasing imports. As a result, the UK fails to maximise the benefits from R&D investments by large companies. Weakening of supply chains also decreases the skills pool, making the UK less attractive for further investment.

"We find UK SMEs to be highly innovative and a great source of new products that help us deliver better services to customers."

Steve Cox, Engineering and Technical Director, Electricity North West

Case study

Aerospace Growth Partnership

Aerospace Growth Partnership is a UK public-private partnership that coordinates several programmes that are aimed at strengthening the UK aerospace supply chain[3].

Its *Sharing in Growth* programme provides an intensive four-year programme of business support for mid-sized companies, with training in manufacturing, procurement and strategy. It is funded and delivered by industrial and government partners. Since 2013 it has supported 64 companies, securing 4000 supply chain jobs[4].

Its *National Aerospace Technology Exploitation Programme* (NATEP)[5] supports technology development for companies in the supply chain by providing innovation funding and mentoring from large companies. Since 2013, the scheme has funded 113 collaborative technology projects with 267 companies[6].

These programmes have strengthened the UK aerospace supply chain, building skills, jobs and economic growth, and promoting innovation across the whole sector.

To increase business R&D investment:

- The UK should continue to build on initiatives to help SMEs develop and grow to maintain a competitive environment for business collaboration.

  See also ***Tax incentives***, ***Innovation funding***, ***Non-financial innovation support***.

- Develop initiatives to strengthen the UK supply chain in key sectors. These should be developed jointly by industry and government, learning lessons from the Aerospace Growth Partnership and similar initiatives.

This explainer is part of a series based on interviews with individuals responsible for making decisions on R&D across a wide range of engineering companies.

See ***Introduction*** explainer to find out more.

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ROYAL ACADEMY OF ENGINEERING

Tax incentives

Summary

Tax incentives, particularly R&D tax credits, the Enterprise Investment Scheme (EIS), and the Seed Enterprise Investment Scheme (SEIS), support business R&D investment in the UK.

R&D tax credits can encourage large multinational companies to invest in R&D in the UK, as they decrease the relative cost of the work. For small companies, the tax credits can promote R&D investment by increasing cash flow to respond to opportunities as they arise.

Small companies find EIS and SEIS invaluable, helping them to attract finance for high-risk R&D activities.

These schemes should be maintained to provide a stable and competitive fiscal environment, supporting companies and investors to make long-term R&D investment decisions.

R&D tax credits are highly valuable and facilitate business investment in R&D

The UK's R&D tax credits scheme was established in 2000 and offers tax relief depending on a company's corporation tax bill, R&D investment, size, and profit status. Companies can claim tax relief for expenses such as R&D staff, energy and software. From 2016 to 2017, businesses received £3.4 billion in tax relief on £24.8 billion of eligible R&D expenditure[1].

For small companies, tax credits increase their available finance. Unlike innovation grants allocated to specific projects, this allows them to respond to emerging business opportunities and threats as they arise, including through further R&D investment.

"R&D tax credits reduce the relative cost of conducting R&D in the UK, which helps us keep R&D here."

Andrew Cowell FREng, Managing Director, Mercedes AMG High Performance Powertrains Ltd

"R&D tax credits have been invaluable to us. They recognise the value of the R&D investment we have made, and allow us to continue to invest."

Eric Hawthorn FREng, Managing Director, Radio Design Ltd

HMRC estimates that **for every £1** spent on R&D tax credits, **between £1.53 and £2.35 is additionally spent** on R&D by companies in the UK[2].

Companies interviewed find the UK R&D tax relief scheme **attractive and competitive**, despite many comparator countries operating similar schemes.

Why do businesses value the UK's R&D tax credits scheme?

- The definition of R&D is broad, covering a wide range of engineering activities, from process engineering in manufacturing to software development for digital products.
- Companies can claim relief on external R&D spend with their suppliers. This is an important mode of R&D for many companies and drives broader economic growth through the supply chain.
- Staff costs associated with the direction, design and financing of R&D projects are eligible for relief. This helps to keep highly-skilled innovation staff in the UK, even if some of the work is conducted overseas.
- The generous definition of SMEs is helpful, providing valuable support to startup companies who reach 500 staff members.
- The process for claiming credits is relatively straightforward. Many companies value HMRC's pragmatic approach as it does not require significant technical input, although small companies can still find it burdensome.

"The nature of our R&D means that some of our work has to be done abroad, near to natural resources. However, R&D tax credits can be claimed on the design and direction of R&D, which helps us maintain many of our strategic R&D team in the UK."

Head of Tax, large company

EIS and SEIS

EIS and SEIS can leverage business investment in R&D in the UK by offering tax relief on investments in high-risk unquoted companies, attracting investment in UK innovation and contributing to the formation of a vibrant UK startup ecosystem.

Small companies find these schemes invaluable, helping them to attract finance for high-risk R&D activities, and reducing pressure on companies to secure investment from venture capitalists too early on in their growth cycle.

"EIS and SEIS have greatly helped us attract investment from angel investors. This has reduced the pressure on us to seek venture capital or private equity investment too early, allowing us to focus on innovation and company growth."

Pawel Kisielewski, Chief Executive Officer, CCm Technologies

To increase business R&D investment:

- R&D tax credits, EIS and SEIS should be maintained to provide a competitive and stable tax environment that enables companies and investors to make long-term investment decisions.
- HMRC should continue to work with companies, particularly small companies, to minimise the administrative burden of claiming tax relief.

This explainer is part of a series based on interviews with individuals responsible for making decisions on R&D across a wide range of engineering companies.

See ***Introduction*** explainer to find out more.

1 *Research and Development Tax Credits Statistics*, HM Revenue and Customs, 2018.

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Late-stage development and demonstrators

Summary

Late-stage development and demonstration is difficult and risky, but is a crucial step in bringing new products and services through to market.

Attracting later stage innovation activities can bring significant benefits to the broader economy. Sites often become the primary location for companies' market development and further R&D, as it convenes technologists, investors and customers, and is often capital intensive.

Compared to competitor countries, the UK is poor at supporting this crucial stage of development.

The UK should prioritise the provision of multiple support mechanisms for companies to develop, test and demonstrate their technological innovations. This should include maximising the use of existing infrastructure as national innovation assets.

After early-stage R&D and prototyping, most new products need to be extensively tested and demonstrated at scale in real-world environments before they can succeed on the market. They also need to be integrated and tested in a whole system. For example, autonomous vehicle technology needs to be trialled in full-scale, city-like testing facilities before it is market ready.

Why is late-stage development work important?

For companies:

Late-stage development work is usually technically challenging and capital-intensive, and is therefore high-risk compared to early-stage R&D.

However, it also:

- allows companies to demonstrate their technology to potential customers, increasing confidence and the probability of successful transition to market
- acts as a focal point for technologists, investors and potential partners, establishing a skills base.

For broader economies:

Attracting late-stage development work can also have broader economic benefits:

- Companies may establish a broader base of work in demonstrator locations, including further R&D, due to the capital-intensive nature of this work.
- Demonstrators can support the development of a local market for new technologies, helping regions become leaders in emerging technologies and sectors.

> "There is more national support for 'risk capital', associated with later stage technology demonstration and scale-up, in countries like the US and China, than there is in the UK."
>
> **Head of Technology, large company**

What do late-stage development and demonstrators look like?

Late-stage development and demonstration projects can be very different across technologies and sectors, from purpose-built test facilities or equipment that can be used by multiple companies, to a real-world environment such as a city.

CCm Technologies has developed a technology that has the potential to reduce UK carbon emissions by converting CO_2 from industrial processes into useful products such as fertilisers. The company has received several innovation grants from public funders, including a recent grant from Innovate UK to develop a full-size sustainable fertiliser production unit that integrates with an anaerobic digestion unit[1]. As well as helping them develop and assess their technology at scale, this has driven a step change in how they engage with potential customers as the technology can be seen working at full scale.

Vodafone 5G networks will provide ultrafast connection speeds and more reliable network performance. Vodafone is leading 5G trials in Milan and its metropolitan area after the Italian Ministry for Economic Development made frequencies available to the company so that it can trial pre-standard 5G at scale in the city using local infrastructure[2]. This demonstration will bring a €90 million investment to the city over four years with 38 partnerships, as well as benefits to early test applications in healthcare and transport[3].

"It has been more challenging to secure funding for our late-stage development work than early stage R&D. Yet it was this late-stage R&D that has been crucial in moving our technology from an idea to a commercial reality."

CEO, small company

The challenge

Innovation funding in the UK is excellent for early-stage R&D but there is very little public support for late-stage development and demonstration work relative to comparator countries. Of active Innovate UK projects in 2017, only 10% are larger than £1 million[4], suggesting large scale, late-stage projects are relatively rare.

See also ***Innovation funding***

Existing support is scarce but very valuable. Large scale facilities are provided by Catapult Centres, such as the High Value Manufacturing Catapult. The Aerospace Technology Institute and Advanced Propulsion Centre have also invested in demonstrators, supported by significant industry co-investment. The Industrial Strategy Challenge Fund is playing an important role in supporting demonstration activities that address specific challenges, such as the smart energy systems. However, companies interviewed emphasised that existing support is not meeting their needs.

For small companies who may have received significant government support for early R&D, it can be incredibly frustrating to lack support for crossing the final hurdle (the 'Valley of Death') and delivering new and beneficial technologies to market.

For large companies this gap often results in late-stage investments being made outside the UK. Since demonstrators are key to pulling products through to market, this has knock-on effects: market development, technology uptake, and further R&D end up being driven out of the UK.

While not all late-stage development and demonstrator activities may qualify under the Frascati definition of R&D, it is nevertheless a crucial part of realising the social and economic benefits from investment in R&D.

Almost a **third of the companies** interviewed find support for late-stage development a considerable barrier to their R&D investment in the UK.

Support for late-stage development and demonstrators can take many different forms:

- The US Department of Energy Title XVII scheme[5] provides loan guarantees to companies developing innovative clean energy technologies. These reduce the risk associated with late-stage projects and help companies to attract private investment to bridge the gap between laboratory and commercial delivery.
- German Fraunhofer centres provide support across the technology development pipeline, including late-stage development. For example, the Test and Application Centre LINK[6] at the Fraunhofer Institute for Integrated Circuits provides testing infrastructure for companies to trial Industry 4.0 technologies at scale without having to interrupt their own manufacturing.
- Meridian, funded by UK government and industry, is developing a coordinated national platform of infrastructure to support the testing of connected and autonomous vehicles in the UK[7]. Continued investment in such projects is essential. Existing automotive testing facilities in the UK are oversubscribed, forcing companies to move R&D to other countries, delay work, or self-fund large projects that put them at a disadvantage compared to global competitors.

To increase business R&D investment:

- Boost support for late-stage development and demonstrator projects that meet business needs.
- Prioritise the provision of high-quality opportunities and diverse support mechanisms for companies to develop, test and demonstrate their technological innovations. Partnerships and co-investment are key, whether between industry and government or collaboration between businesses.
- Use existing UK infrastructure as 'national innovation assets' to provide high-quality testing facilities. For example, use existing airfields for testing drones, hospitals to trial data-driven innovations, or existing factories to trial automation, as well as purpose-built infrastructure such as the Catapult Centres.

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See ***Introduction*** explainer to find out more.

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Public procurement

Summary

Public procurement has the potential to have a transformative effect on companies' investment in R&D in the UK.

It provides a huge opportunity to stimulate innovation. However, engineering companies have found that decisions on public procurement prioritise low cost over best value, and risk aversion hinders the introduction of innovative solutions. If public procurement processes discourage R&D and innovation, it can push businesses to move those activities to other more receptive countries.

Radical change to public procurement in the UK is needed to realise its potential, creating a culture that takes appropriate risks and focuses on outcomes.

The public sector is a major customer for many innovative engineering sectors

energy | construction and infrastructure | health | telecoms

For companies where the government is a major customer, public procurement processes are a key determinant of R&D spend. Market requirements, trends and buying patterns play a huge role in determining the strategy for engineering companies, including R&D investment and its direction.

The UK public sector spends **£268 billion a year on procurement**, equivalent to 14% of GDP[1].

The challenge

Public procurement is one of the most significant interventions that government makes in the economy. Companies find UK public procurement too focused on achieving the lowest cost and an accountable process. This is important, but can be at the expense of seeking the best outcomes and creates a strong aversion to risk. Public procurers can also be relatively closed to new ideas and approaches. This means:

- **Less money for R&D**. Companies are forced to offer the lowest cost options, leaving them with less money available and less incentivised to conduct R&D.
- **Less incentive for new approaches**. The lack of opportunities for risk-sharing means that companies are not encouraged to propose innovative methods and solutions, so government may miss opportunities that deliver the best results.
- **Lack of collaboration**. Collaborative relationships between buyers and suppliers are vital for successful innovation as they ensure there is good understanding of the buyer's needs and offer opportunities for co-creation of innovative solutions.
- **Innovation relocates abroad**. Companies who supply goods to the public sector in several countries may move their innovative work to places where customers recognise its value.

Innovation can improve the outcomes delivered by public procurement if it is allowed to.

Of the **11 companies interviewed** for whom the public sector is a major customer, **nine said procurement is a barrier for investment in R&D**.

Public procurement is a complex process with the potential to promote or stifle R&D and innovation at numerous stages:

Profit capping

Profit capping plays an important political role in industries such as regulated utilities and defence. However, it can strongly disincentivise R&D investment. Not only does it decrease funds available for R&D, it also makes it difficult for companies to attract high risk investors that are willing to support innovative work.

IP handling

Owning IP is key for many companies so that they can maximise returns from R&D investment. The way IP is handled, both in procurement and in government-funded innovation, must be unambiguous, providing clear incentives for companies to invest in R&D and supply innovative goods and services to the UK government.

"The uncertainties over Intellectual Property ownership need to be resolved so as not to discourage defence innovation happening in the UK."
Dunne Review 2018[2]

Services

There are additional challenges in incentivising R&D investment through procurement of services. This is because procurement tends to be based on person-hour cost, and it is difficult for companies to demonstrate the benefits generated from R&D investment in building experienced and highly-skilled staff. This is a challenge in the private sector as well as the public sector.

See also ***Innovation in engineering services.***

"Strict profit capping in the UK Ministry of Defence defence programmes has led directly to a decreased appetite for R&D spend."

Nigel Whitehead CBE FREng, Chief Technology Officer, BAE Systems

There are discrete examples of UK public procurement processes supporting and benefiting from private sector innovation:

The Small Business Research Initiative[3]

The Small Business Research Initiative awards public sector contracts to SMEs to develop innovative products to meet the needs of the public sector. The scheme started in 2008, and the maximum annual expenditure was £81 million in 2014 to 2015.

Participants find it valuable, supporting them to create new companies, develop and launch new products and attract equity investment.

However, the scheme has been underutilised across government and has had relatively little impact on broader public procurement processes. In addition, the focus on small companies does not address the broader challenges in using public procurement to support R&D and innovation by companies of all sizes.

Highways England Innovation Fund

Highways England has ringfenced £150 million between 2016 and 2021 for innovation[4]. The fund supports collaboration with industry to trial new technologies for improving safety, customer experience or environmental impact. While it has had a slow start[5], companies interviewed are positive about the opportunities that the fund provides for the acceleration of new technologies such as connected and autonomous vehicles, pulling these innovations through into practice in the road network.

Highways England is also adjusting its processes to better support innovation through procurement, such as developing a single point of contact for innovators to propose new ideas.

Building Information Modelling[6]

Public procurement accounts for around 30% of the UK construction market[7]. Building Information modelling (BIM) is a collaborative approach for designing, creating and maintaining infrastructure, underpinned by digital technologies. It increases the efficiency of construction projects and enables collaboration across the whole supply chain.

Government procurement processes have stimulated the development and uptake of BIM in the construction sector through: clear targets for all central government departments to use BIM Level 2 by 2016; training of government staff to use the system; and close working with industry to support embedding of the technology in industry processes.

To increase business R&D investment:

- The need for improved public procurement processes to effectively stimulate innovation and R&D investment in the private sector has long been recognised but it is clear that there is still scope for transformational change.
- Applying best practice in intelligent procurement to incentivise and support innovation by companies of all sizes should be a major focus of the government's work to increase business R&D investment. This must include strong leadership and vision, robust specification and planning, the involvement of intelligent clients, incentives to encourage the right behaviour and good management of risk.
- This is a complex challenge with numerous stakeholders and conflicting drivers and constraints. Further work is required to find solutions, but this must involve cultural change in government and greater willingness to establish and accept appropriate levels of risk.

This explainer is part of a series based on interviews with individuals responsible for making decisions on R&D across a wide range of engineering companies.

See ***Introduction*** explainer to find out more.

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3 *Leveraging public procurement to grow the innovation economy: An independent review of the small business research initiative*, David Connell, 2017.
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5 *Highway England's approach to delivering schemes through its ring-fenced funds*, Office of Rail and Road, 2018.
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ROYAL ACADEMY OF ENGINEERING

Joined-up government approach

Summary

Engineering companies find strategic engagement across UK government organisations frustrating, fragmented, and not joined-up. This makes the UK less attractive for businesses to invest in R&D.

The ambitions in the Industrial Strategy are positive, with the potential to provide a stable and coherent backdrop for private investment in R&D and innovation.

In practice, this will require extensive engagement and alignment across government departments and agencies, and extensive industry input for success.

Throughout the innovation pathway, from concept to market, engineering companies engage with a broad range of government departments and agencies.

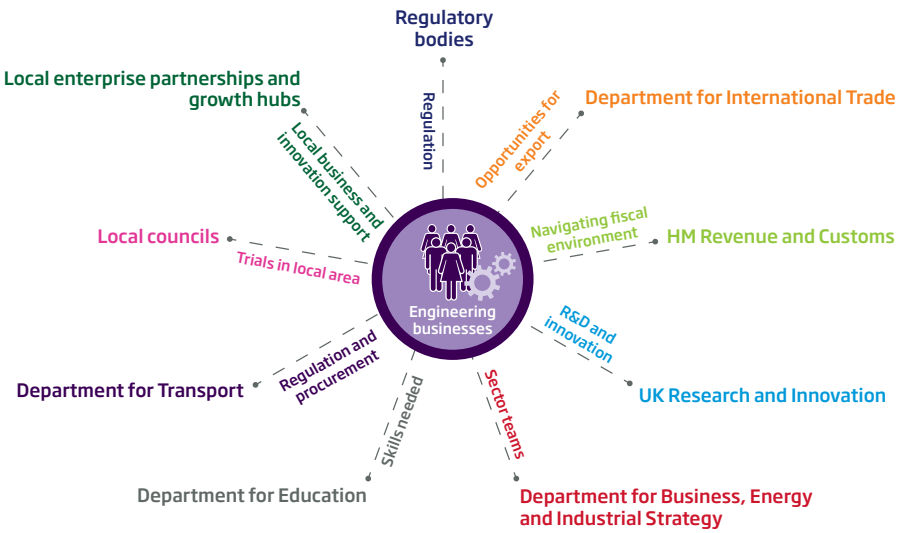
Each of these interactions has the potential to facilitate or inhibit businesses in delivering their strategy, with knock-on effects for innovation and R&D investment.

To create a supportive environment for engineering business R&D and innovation, all government organisations must share a clearly defined vision of success and be well coordinated. This will provide a long-term stable backdrop for business decisions and investment.

"There is much that businesses and academia need to do to help all sectors of government, not just BEIS, to understand how their work can support innovation in industry."

Nigel Whitehead CBE FREng, Chief Technology Officer, BAE Systems

Examples of interactions between businesses and government



The challenge

Many companies interviewed find engagement with the UK government frustrating, fragmented and less joined-up than competitor countries. This creates barriers for businesses to successfully innovate and makes the UK less attractive for businesses' R&D investments. The problem exists across government organisations, although the challenge presents differently across companies and sectors.

Small companies can find UK innovation support disjointed and hard to navigate, coming from UKRI, other government agencies and local organisations.

Furthermore, the support available does not cover some parts of the innovation pathway, with a particular gap in late-stage development. This delays innovation and growth as companies need to seek external finance to plug these gaps.

See ***Late-stage development and demonstrators***.

Large companies can find that the ambition for business innovation is not shared across government departments. The enthusiasm and drive for R&D investment and innovation demonstrated by one government organisation may not be matched by another. This can lead to delays in decision making or delivery of initiatives, unhelpful procurement practices and potentially conflicting priorities.

The multiple layers of coordinated and complementary support offered in countries like Germany and Singapore is very attractive to companies, including those currently located in the UK. **In this highly competitive and international environment, the role of government in providing an assertive, effective and long-term commitment to innovation is more important than ever**.

"The government support we have received has felt staccato. It has been valuable but would have had greater impact if it were more joined-up and strategic."

Alex Freeman, Project Lead, GreenSpur Renewables Ltd

Strategic support to key sectors

In the past, government has encouraged rapid investment in R&D and subsequent long-term growth in UK engineering sectors by providing a coherent and sustained strategy that aligned support across regulation, funding and government's convening power. The aerospace and automotive industries provide excellent current examples of what can be achieved with this approach.

Today, many companies interviewed feel that the UK is failing to offer long-term strategic support for innovation in their sector, making it less attractive to invest in R&D compared to other countries. Several competitor countries have adopted a joined-up approach to promote growth in priority sectors, like renewable energy generation or green transport, to help them become world leaders in these key industries.

The government's Industrial Strategy, Grand Challenges, and sector deals send a positive message about government's support for innovation. Industry still finds the range of interventions and the connections between them unclear and action is needed to better align approaches across government.

"Coherent government support for the development of a hydrogen refuelling infrastructure serving fuel cell electric vehicles (FCEV), and the convening power of government has built confidence in the UK hydrogen mobility sector. Thanks to the Office for Low Emission Vehicles Hydrogen Transport Programme, several public stations are now operating (where hydrogen is produced by electrolysis and dispensed to FCEVs on demand). This has placed the UK firmly on the international map of early adopters of hydrogen vehicles."

Dr Marcus Newborough FREng, Development Director, ITM Power plc

Focus on outcomes

Government policies such as the Industrial Strategy Grand Challenges and missions should focus on the outcomes to be achieved (such as cleaner transport or improved health outcomes) not the technology to achieve it. This allows companies to participate irrespective of their preferred approach, incentivising R&D investment and innovation across a wider range of businesses and allowing the market to 'pick winners'.

Informed by industry

Industry has a deep, practical understanding of the technological and business challenges in its sector and user design is essential for effective policymaking. Companies feel that UK innovation policy is overinfluenced by academia and does not go far enough in capturing views from business.

Other countries appear to have greater porosity and interaction between government and industry. This helps to ensure that government support is relevant to industry's challenges and has the maximum impact on innovation and economic growth. The appointment of Industrial Strategy Challenge Directors with significant industrial experience and standing is positive, and this approach should be expanded to other innovation initiatives.

Agile delivery

Speed and agility are vital for companies working in fast-moving sectors. Compared to competitor countries, particularly in Asia, decision-making and delivery of innovation support are slow in the UK. Accountability and agility must be balanced to ensure R&D investments do not move to countries where R&D projects can be initiated more quickly, particularly in the case of large multinational companies.

"Historically, strategic UK government support for the space sector has been very successful, generating significant returns on investment in terms of economic growth."

Professor Sir Martin Sweeting OBE FREng FRS, Executive Chairman, Surrey Satellite Technology Ltd

Case study

Advanced Propulsion Centre

The Advanced Propulsion Centre (APC) has played a significant role in the growth of the UK's low carbon vehicle industry through a strategic, joined-up approach to innovation support.

It is a joint venture between the UK government and automotive industry, that aims to make the UK a centre of excellence for the research, development, and production of low carbon vehicles.

With funding from both government and industry, it offers R&D grants, mentoring support for SMEs, and networks for the UK's emerging low carbon vehicle industry.

Established in 2013, the APC has been successful. It has supported 39 projects involving 147 organisations, creating or saving over 22,000 jobs and saving 37.2 million tonnes of CO_2[1].

This success is partly due to the strategic nature of the support offered, based on clear analysis of UK sector needs, and shaped by input from both government and senior industry figures.

To increase business R&D investment:

- ⇢ Ensure that the vision for the UK as a leading nation for innovation, outlined in the Industrial Strategy, is shared across the whole of government. This will require the full support and coordination of all central government departments and agencies, devolved governments and local institutions.
- ⇢ Develop multiple routes for innovation support to cover the diversity of activities along the innovation pathway, designed to work together. Such a joined up approach does not necessarily depend on a single governmental innovation body and must involve alignment at the local, regional and national level.
- ⇢ Internationally promote an ambitious, bold, global vision for the UK, underpinned with an effective, coherent and long-term commitment to innovation to attract inward investment and international talent.
- ⇢ Increase opportunities for industry to inform policy design, building on the success of examples such as the automotive industry.

This explainer is part of a series based on interviews with individuals responsible for making decisions on R&D across a wide range of engineering companies.

⇢ See ***Introduction*** explainer to find out more.

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Ownership and financial structures

Summary

Company ownership and financial structures are important influencers of company R&D spend since they determine overall business strategy and the role of R&D in the company.

Shareholders can sometimes act as a barrier to R&D investment if they are focused on short-term returns or have a low risk appetite.

This is a complex issue without a simple solution. Government, industry and the investment community should work together to explore how to further incentivise strategic investment and ownership of technology-based companies that is focused on long-term company growth, including through R&D investment, rather than short-term returns.

R&D investment decisions are highly complex. They must take into account a broad range of factors including performance of the firm and profit margins, market trends, technological opportunities and threats, and other business priorities, such as marketing and production.

See also ***Introduction.***

The investment envelope tends to be decided by company boards, and can be influenced by:

- Risk appetite of board and shareholders.
- Expectations of shareholder returns.
- Board understanding and expectation around the role of R&D in the company.

These characteristics vary widely across engineering companies and are further influenced by whether the company is **privately** or **publicly** owned. These differences can significantly shape decisions on R&D investment.

- **Private** engineering companies, including comparatively large ones, are often owned by company founders or their families, or by a small group of engaged investors, without publicly traded shares.
- **Publicly** owned engineering companies have publicly listed shares and can have a broad range of shareholders, including UK and foreign pension funds, insurance companies, other financial institutions and private individuals.

> "There is an urgent need to address short-termism exhibited by the UK investment system."
>
> **Professor Neville Jackson FREng, Chief Technology and Innovation Officer, Ricardo**

The challenge

The influence of ownership on R&D spend is complex, but several senior technologists highlighted that this can be a significant barrier to R&D investment.

Privately owned companies interviewed were often strongly committed to R&D investment:

- R&D or engineering is seen as core to their identity.
- They often have a long-term vision for company growth that is driven primarily by R&D.
- R&D investment can be readily increased to respond to technological opportunities or threats as they arise.

While some **public companies** can have a similar approach to R&D, this is not always the case. Maintaining or increasing R&D investment in some public companies can be more challenging:

- Pressure to report regular positive investment returns and dividends can be incompatible with the longer nature of returns on R&D investment.
- Institutional investors, such as pension funds, can have a low appetite for risk, disincentivising novel approaches and highly innovative work.
- Relatively low profit margins in sectors such as construction, utilities and some forms of manufacturing can limit R&D investment by low-risk shareholders. This can be overcome by collaboration between these companies, reducing risks for each individual company and incentivising strategic, long-term R&D projects.

"As a family-owned business, our Chairman Lord Bamford is always open to increasing R&D investment in response to a breakthrough idea that could bring long-term growth to the company."

Tim Burnhope FREng, Chief Innovation and Growth Officer, JCB Group

To increase business R&D investment:

- Facilitate R&D collaboration between companies with low margins to reduce the risk to each individual company.
- Investment and company ownership structures are complex issues with wide-reaching implications. Engineering companies, government, industry and the investment community should explore potential routes to:
  - Incentivise investment models focused more on long-term company growth and less on short-term dividends.
  - Support companies in sectors with low-risk investors but with the potential to increase innovation, such as utilities, construction or manufacturing, to attract mid-high risk investment.

This explainer is part of a series based on interviews with individuals responsible for making decisions on R&D across a wide range of engineering companies.

See ***Introduction*** explainer to find out more.

Innovation in engineering services

Summary

Technology- and knowledge-based services are an increasingly important part of the UK economy[1]. But there is limited support for companies that offer services to engage in R&D and innovation, including in engineering.

Most support mechanisms, such as grant funding, have largely been designed to support product-based companies. Traditional procurement models, including from government, can also fail to incentivise innovation by service companies.

Government should work with engineering companies offering services to ensure that they can access support for innovation and drive continued growth.

Companies that offer services produce intangible goods rather than products, covering a vast range of companies from fintech to transport. Many engineering companies are also service-based rather than focused on products.

Service-based engineering companies can either be focused on engineering, providing technical services such as prototyping or consultancy, or offer services to the broader economy, such as designing infrastructure, or developing software for smart traffic management systems.

These companies are an increasingly important part of the engineering and technology sector, accounting for at least 15% of business expenditure on R&D[3] and over 16% of engineering businesses in the UK[4].

R&D is a vital for many of these engineering companies for the development and integration of new technologies, to enhance and extend their services, to increase efficiency, and to up-skill staff. However, the intangible nature of services makes the output of R&D less immediately visible than in product-based sectors.

80%

Contribution of services to the UK economy[2]

The challenge

Innovation support

R&D for services looks different to R&D for products, for example:

- In collaborative R&D projects, product-based companies may benefit directly from the outputs, while service-based ones may benefit more from working closely with customers, developing joint solutions and understanding technological trends.
- The intangible nature of services makes it more difficult to evaluate success in innovation, so the monitoring and evaluation of schemes is more challenging.
- Tracing a direct line between R&D spend and return on investment can be more difficult in service innovation, particularly if the company investing is not the

"We find it difficult to engage with UK grant funding programmes that are focused around specific product developments as these are based around use of our existing capabilities rather than creating new engineering process innovations."

Professor Neville Jackson FREng, Chief Technology and Innovation Officer, Ricardo

primary beneficiary of the resulting innovation. For example, in the construction sector a design agency may develop a new approach to an infrastructure project that accelerates delivery and extends the lifetime of the asset. The major beneficiary of this innovation is likely to be the asset owner or constructor rather than the designer.

While UK programmes, such as Innovate UK grants, are available to and accessed by companies developing services, most programmes are designed to support product R&D, with few of them currently tailored for services. Many competitor countries, such as Germany, Sweden and Finland, have service innovation programmes[5,6,7]. These may be in the form of a tailored grant or voucher schemes, design centres, and service innovation incubators.

Procurement

Traditional procurement models across public and private sectors often fail to incentivise R&D investment in engineering companies that offer services because the procurement of services is usually on a person-hour basis. R&D activities often require highly skilled staff, therefore typically leading to higher person-hour costs.

See also ***Public procurement.***

"Price-sensitive person-hour based procurement rarely recognises the value of service companies investing in innovation. This can therefore act as a barrier to R&D investment."

Dr Steve Denton FREng, Executive Director and Head of Civil, Bridge and Ground Engineering, WSP

To increase business R&D investment:

- Increase support for service innovation in a way that recognises its importance to the UK economy.
- Government should work with companies that offer services to explore how initiatives should be tailored to encourage them to invest more in R&D.

This explainer is part of a series based on interviews with individuals responsible for making decisions on R&D across a wide range of engineering companies.

See ***Introduction*** explainer to find out more.

1 *Services tranformed: Growth opportunities for the UK Service Economy*, Government Office for Science, 2018.
2 *Services tranformed: Growth opportunities for the UK Service Economy*, Government Office for Science, 2018.
3 *Business Enterprise Research and Development*, UK 2016. Office for National Statistics, 2018. Figure refers to the total percentage of business expenditure in the following product groups: research and development services; computer programming and information service activities; miscellaneous business activities, technical testing and analysis.
4 *The state of engineering*, Engineering UK, 2018. Figure refers to the percentage of engineering enterprises in the 'Professional, scientific, and technical activities' sector.
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6 *Service Innovation: The key to Sweden's economic prosperity?*, Service Innovation Sweden, 2016 https://www.teknikforetagen.se/globalassets/i-debatten/publikationer/fou/service-innovation--key-to-swedens-economic-prosperity.pdf. Accessed September 2018.
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Innovation across sectors

Summary

Innovation is often accelerated at the intersection of sectors. But it can be riskier for companies to innovate outside their core area, discouraging R&D investment.

Opportunities for cross-fertilisation between sectors to overcome sectoral boundaries are important and can offer significant opportunities for R&D and innovation in engineering companies.

Government should consider the introduction of support mechanisms targeting the application of technologies into new sectors or markets. This could promote new R&D investment in the UK and help bring game-changing innovations to priority sectors.

The Catapults could play an even greater role in facilitating cross-sector innovation.

Companies can learn lessons from those in other sectors facing similar technological challenges, and often collaborate informally to innovate. For example, machinery manufacturers may work with the automotive sector on electrification, or companies in construction may engage with traditional manufacturers to digitise manufacturing processes. Cross-sector collaboration has many benefits and can accelerate innovation:

- ⇢ It helps introduce innovations to established industries.
- ⇢ It develops cross-sector capabilities in businesses, particularly in supply chains.
- ⇢ It can bring increased efficiencies compared to siloed sectoral focuses.
- ⇢ Many companies also see potential applications of their technology to problems in other sectors.

Innovation frequently occurs when different ideas and approaches are brought together, at the interface of scientific or engineering fields, or different industry sectors.

Case study

BAE Systems and London buses

At its heart, BAE Systems is a systems engineering and integration company. They apply technology across land, air, sea and cybersecurity, making them a leading multinational defence company. However, their technology and skills could be applied to a variety of sectors.

Recently, BAE Systems worked with ADL, a leading bus and coach builder, to deliver 39 ultra-low emission buses for Go-Ahead's London bus fleet. These have integrated BAE Systems' cutting-edge electrification technology to reduce greenhouse gas emissions by 37% compared to conventional diesel buses.

The challenge

In established engineering companies, investors and senior teams can be hesitant to invest in R&D outside the company's core sector as this is associated with a high level of risk.

- Companies can lack understanding of how different markets and sectors operate.
- It can be challenging to navigate innovation networks outside core sectors and make useful business connections.
- If the technology or application is highly novel, policy and regulatory frameworks may not be well developed.
- Even established companies can feel like startups when operating across sectors, carrying many of the risks of being a startup without being eligible for startup support, such as funding or mentoring.

There is significant demand for increased cross-sector collaboration from the engineering community. Government and industry should work together to maximise opportunities for this type of collaboration, with clear opportunities to implement this through the Industrial Strategy Grand Challenges and the Industrial Strategy Challenge Fund.

The Catapults are well placed to identify opportunities for innovation across sectors, with collaboration across the Catapult Network accelerating activities even further. Catapults already do a lot in this regard but boosting their cross-sectoral activities, using financial and non-financial support, could bring further benefits for business innovation in the UK.

Case study

Act Blade and Catapult

Act Blade[2,3] is an Edinburgh-based startup founded by a team from the yachting industry. The company has taken textiles used in cutting-edge yacht sails and used them to make new wind turbine blades. These have the potential to be 50% lighter than the standard glass fibre blades, so they can be made longer and more efficient, increasing energy production by almost 10%. The Offshore Renewable Energy Catapult supported Act Blade with advice on the wind energy market, helping the company to attract investment and providing testing facilities for its new blades.

To increase business R&D investment:

- Government should work with industry to create opportunities for businesses willing to innovate across sectors to work together.

This could include:

- promoting collaboration across sectors
- supporting Catapult Centres to accelerate cross-sectoral work
- developing tailored grant mechanisms
- increasing access to business advice across sectors
- showcasing successful examples
- and extending SME R&D incentives to larger companies looking to enter new sectors.

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1 *Engineering an economy that works for all: Industrial Strategy Green paper response*, Engineering the Future, 2018.
2 Offshore Renewable Energy Catapult case study. https://ore.catapult.org.uk/stories/act-blade/. Accessed October 2018.
3 From sailboats to wind turbines: the journey from big idea to realisation, Innovate UK, blog. https://innovateuk.blog.gov.uk/2017/11/30/from-sailboats-to-wind-turbines-the-journey-from-big-idea-to-realisation/. Accessed October 2018.