University of Nottingham Response to

Building our Industrial Strategy Green Paper Consultation

General

1. Does this document identity the right areas of focus: extending our strengths; closing the gaps; and making the UK one of the most competitive places to start or grow a business?

The Industrial Strategy Green Paper and the ten pillars it describes captures the key areas where the UK needs to investment to develop its competitiveness. The paper rightly recognises the world leading position of UK Universities and their immense contribution to science and technology. However it fails to fully acknowledge the contribution universities make to innovation and economic performance through the spin-outs they produce, the large amount of research they directly undertake with Industry where know-how and process innovation can be as critical to productivity as patents, and the critical importance of the higher level skills provided by graduates. To maximise the benefits of the UK's leading science base government should seek to develop and resource an innovation ecosystem with Universities at its heart. This should include a role for Universities as the host of national research facilities as a means to help bridge the gap with industry and re-create a national infrastructure in the most effective, including cost-effective, way.

The paper recognises a key failing in the UK is the low rate of Business investment in R&D measured by Business Enterprise Research and Development (BERD) expenditure. By setting targets to increase BERD to 3% of GDP and providing incentives to target this at translating University research into products and services the UK can develop a coherent innovation system and avoid a disconnect between invention and innovation.

2. Are the ten pillars suggested the right ones to tackle low productivity and unbalanced growth? If not, which areas are missing?

There is a need to give much more emphasis to arts and social sciences disciplines which can provide significant contributions to productivity and growth not only in the dominant service sectors of the UK economy but also in combination with all sectors that are underpinned by science and technology. Universities can play a leading role in encouraging and embedding a transdisciplinary approach to research and innovation, drawing on the full breadth of disciplines to tackle major economic challenges. Also, the role of investment in facilities and equipment and the technical skills that underpin the wider research base should not be underestimated. The University of Nottingham has taken a leading national role in training, developing and considering the career development of the highly skilled technicians that are crucial in supporting and broadening the use of equipment and facilities which generate innovations and help shift the economy to more balanced growth.

3. Are the right central government and local institutions in place to deliver an effective industrial strategy? If not, how should they be reformed? Are the types of measures to strengthen local institutions set out here and below the right ones?

Many of the right government institutions including Local Economic Partnerships are already in place. Vehicles such as Midlands Engine and Midlands Innovation can help to provide the balance between research excellence, industrial demand and local economic development. Government

could do more to encourage stakeholders in these entities to work more closely together through targeted and speculative funding. Universities are in a good position to provide the catalyst and focus for this kind of investment with their strong local links, which includes industry, that also provide a pipeline to multiple international links. They can provide a focus for inward investment, absorptive capacity and developing strong trade links. The University of Nottingham is in a particularly strong position, with its two international campuses in China and Malaysia, to be an enabler in both directions, for geographically based innovation pipelines which contribute to growth and high skilled employment. The University has done this through creating the components for a UK-China open lab networks in advanced manufacturing, electrical machines and power electronics, and composite materials, which benefit UK research and provide links into growing Chinese sectors.

4. Are there important lessons we can learn from the industrial policies of other countries which are not reflected in these ten pillars?

The University of Nottingham's unique global footprint provides a major opportunity to support the international objectives of the Industrial Strategy. We have conducted a review of Chinese and Malaysian economic plans and have identified key areas of mutual interest.

As a key global trading partner attention should be given to opportunities created by the Chinese Governments 13th five year plan. It is clear that many of the measures are calculated to enable China to rapidly develop in certain areas – notably public services and financial institutions. These of course provide UK organisations with market opportunities. In other areas (notably technology development) there are several common themes where there are clear opportunities for collaboration where UK expertise in innovation management can in partnership secure Chinese R&D investment. Thirdly, there will be opportunities to learn from Chinese practices and benefit from technical expertise in handling large infrastructure projects such as high speed rail and marine engineering as well as in the digital space - E-commerce and Tele-health. Finally, it hardly needs to be said but in the wake of Brexit, the importance of the Silk Road Economic Belt and the 21st-century Maritime Silk Road, also known as The Belt and Road initiative, a development strategy and framework, focused on connectivity and cooperation with a focus on international trade cannot be over-stated.

University of Nottingham can support the development of these opportunities. An example of this is Aerospace where we have already worked with Airbus and Rolls-Royce to create research capacity in Malaysia in support of their commercial activities through the Asia Aerospace City Research and Technology Centre which is supported by RM 3 million worth of PhD scholarships by Majlis Rakyat Amanah (MARA) and are now working to support the UK – China Technology Gap Collaboration. This programme, developed by a UK/Chinese Government to Government Working Group (AWG), aims to deepen industry-industry collaboration for mutual national benefit. It will draw on the £1.3bn 'Prosperity Fund' to run a series of Pilot Projects as agreed by UK and Chinese Governments under the Aerospace Best Practices Programme (ABPP). University of Nottingham Ningbo Campus is currently exploring the development of a "School of Aerospace" which will provide a research and training support to both UK and Chinese Aerospace partners.

Investing in science, research and innovation

5. What should be the priority areas for science, research and innovation investment?

We welcome the commitment of an additional £4.7 billion for science and innovation over this parliament. The Government should use these funds to maintain development of investment in fundamental research by continuing to support 'Quality-related' research funding (QR) alongside

new mechanisms to fund translational research such as the Industrial Strategy Challenge Fund. It is also important that the additional investment made by UK Government is not undermined by the loss of significant EU funding for research. Steps should be taken to ensure overall levels of investment are not impacted and international collaboration mechanisms are maintained and enhanced.

Investment in University research has broad economic benefits with Russell Group research finding that on average £1 invested in UK University research projects returns £100 of economic benefit.

In fundamental research the continuation of QR is critical to maintaining the excellence of UK research base. QR meets approximately half the difference between income for specific research projects and the full economic cost of those projects, so the current level of project activity would not be sustainable without QR. The discretion HEIs have over expenditure means QR can be aligned with institutional priorities and can contribute to developing and sustaining research capabilities. This could not be achieved through a system of 100% project funding.

At Nottingham QR support has been critical in encouraging, enabling and pump-priming interdisciplinary research activities. We have established research priority areas which are using these pump-priming funds to build bridges between disciplines and internationally, with many of these research priority areas drawing on industrial links.

We have also used QR to drive research excellence in a number of ways including through our Anne McLaren Fellowships aimed at outstanding female scholars in science, technology, engineering and maths at the early stage of their academic careers; the Nottingham Research Fellowships Scheme that targets outstanding early career researchers in most academic disciplines at the University; and the Birmingham and Nottingham collaboration to develop a distinctive approach to enhance the success of both institutions. It is also important in providing much of the underpinning facilities needed to conduct a wider range of research activity.

The Scheme is exemplified by physicist Dr Clare Burrage, recipient of an Anne Maclaren Fellowship in 2011, Dr Burrage has gone on to become a Royal Society University Research Fellow in 2013 and in 2016 secured a prestigious Research Leadership Award from the Leverhulme Trust to build a research team to continue her work in dark energy one of only 13 such awards in 2016, it will allow her to establish her own research team for the first time.

The QR support for the Nottingham Birmingham partnership has allowed the creation of joint research centres such as the ground-breaking £10m Centre of Membrane Proteins and Receptors (COMPARE). COMPARE is a unique collaboration between the Universities of Birmingham and Nottingham that brings together leading researchers to develop novel methods for visualising single membrane proteins and to use these to identify new approaches for prevention and treatment of cancer and cardiovascular disease. The information from the state-of-the-art imaging technology will enable development of a new generation of drugs that will have reduced side effects by virtue of targeting receptors in their unique membrane environment.

Universities have the potential make a significant contribution to economic growth and societal well-being through the further translation and commercialisation of research outcomes. Nottingham has a strong track record of commercialising its research. More than 100 inventions are managed by the Technology Transfer Office each year which result in around 40 patents, and a good number of these are either licensed to industry or developed further through the formation of spin-out companies. The University has a current portfolio of 23 spin out businesses and has attracted over £107m of investment in these companies since 2000.

The innovation which the University of Nottingham is most famous for is MRI, developed by Professor Sir Peter Mansfield. This has led to both significant commercial activity and a revolution in patient care. There are now over 22,000 MRI scanners in the world, with 60 million MRI examinations conducted annually.

Nottingham innovations such as MRI are now being joined by activity in areas such as cancer diagnosis and treatment, cancer vaccines, treatments for eye diseases such as macular degeneration, wound repair, smart fabrics, crop production, industrial microwave processing, additive manufacturing, energy storage and many other applications.

Recent examples of success include the flotation of spin-out Oncimmune plc, which focusses on a blood test for the early diagnosis of cancer and the strategic acquisition by GE of spin-out company Monica Healthcare for an undisclosed fee, which has produced a foetal monitoring device for use in at risk pregnancies.

A key limiting factor in the successful commercialisation of university IP is the availability of translational and investment funds. The 'valley of death' is still very much in existence and occurs at several stages in the path to research commercialisation. If the UK wants to compete in this space it must look to increase the amount of translational funding made available to its universities and to increase the amount available for individual awards such that it is sufficient to incentivise academics to apply for the funds and so that the funds are sufficient to take the technology forward without the current start/stop cycle that currently exists.

Funds should also be made available to attract good management for emergent spin-out companies, particularly at the pre-incorporation stage, in order to help raise initial external investment. Without this management companies with good potential fail to launch.

Government should continue to support the expansion of commercialisation and business engagement in university research. Vehicles such as HEIF are key to supporting this activity and wider business engagement and should be retained and expanded.

HEIF has been found to be extremely effective at developing knowledge-based interactions between universities and businesses. Evidence from the HEFCE commissioned review 'Assessing the economic impacts of the Higher Education Innovation Fund: A mixed-method quantitative assessment' by Tomas Coates Ulrichsen of the Centre for Science, Technology and Innovation Policy at the University of Cambridge, shows every £1 of HEIF funding results in a return on investment of £9.70 in benefits for the economy and society.

At Nottingham we have developed some examples of very effective use of HEIF funds including an internal fellowship scheme, HERMES, to support proof of concept and industrial collaboration but its reach is limited by the availability of funds.

HERMES Fellowships is a single internal support scheme that was created as the prime vehicle for knowledge exchange. Staff from all Faculties are able to apply for awards of typically between £3k and £25k to pursue a range opportunities for business engagement, technology development, and community outreach activity. An Independent Return on Investment Assessment of University of Nottingham's HEIF 5 spending by O'Herlihy & Co. Ltd found that the HERMES scheme had a return of investment of 15:1. It also found HERMES was especially effective where support was targeted at engagement with key commercial partners. Partner (collaborators, research partners, research funders) engagement allowed the University to raise its profile and build relationships that subsequently led to research income being attracted.

However despite the best efforts of Universities and the good work of their Technology Transfer Offices through schemes like HERMES there remains a demand side challenge around commercialisation of research in the UK. As covered in response to Q.1 compared to other countries UK businesses are not R&D intensive and the internationally low levels of Business R&D investment are concentrated in a small number of large firms. All too often inventions from UK universities are fully exploited by non-UK firms. In addition to the acquisition of Monica Healthcare by US firm GE there are several other examples of Nottingham spinouts being acquired by US firms including the acquisitions of cancer drug development firm Precos by California based Crown BioScience for £3.25m and Molecular Profiles, a provider deliver sophisticated analytical and development solutions to the pharmaceutical industry by Boston based Columbia Laboratories for £16m.

6. Which challenge areas should the Industrial Challenge Strategy Fund focus on to drive maximum economic impact?

Future Foods

By identifying appropriate crop and food-related targets for intervention, delivering in-depth plant and crop science to engineer such interventions and ensuring delivery of the appropriate technology to the farmer, food industry and consumer it will be possible to develop and deploy effective and appropriate solutions to the food security grand challenge. The ultimate aim is to deliver novel solutions to address the challenge of providing sufficient quantities of palatable and highly nutritious food to a growing global population.

As the largest manufacturing sector in the UK, Food and Drink has a fundamental role to play in boosting exports and encouraging a resource efficient and vibrant economy, maintaining our national competitiveness and protecting the UK's Food Security. The food and drink manufacturing sector comprises over 6,000 companies and typically £1bn has been spent on R&D each year and 8,500 new products brought to the market. The entire agri-food supply chain, from agriculture to final retailing and catering, is estimated to contribute £96bn to the economy and employ 3.8 million people.

The UK food industry, in common with the global food production system, faces fundamental challenges including; reducing the industry's environmental impact; meeting growing global demand; producing more from less as pressure increases on resources; mitigating the impacts of climate change; reformulating and creating new products to meet diet and health requirements.

Imaging for Precision Medicine

Using imaging to drive the development of personalised therapies in mental health and other chronic diseases, including mental health. Driving discovery and translation of new imaging tools for diagnosis, prediction of outcome and mechanistic evaluation of interventions.

The market for such imaging methods have substantial growth potential. Forecasts indicate that the market for medical imaging systems will grow to $49 billion in 2020. To date, the associated market revenue has been mainly concentrated in industrialized countries and generated by a few international corporations. The BRIC countries, with their booming healthcare sectors, are especially willing to introduce new medical technology. Emerging markets such as China and India will also focus on acquiring advanced imaging equipment, primarily because of the construction of new hospitals. For example, in India sales of medical imaging equipment rose from $550 million in 2011 to a projected $1.27 billion by 2017.

Electrification of Transport

All national and international road maps, strategies and agenda today advocate and champion the need for electrified propulsion; however the reality to date is that the rate of progress is far too slow and incremental. Therefore, need remains to develop the next generation propulsion systems underpinned by innovative sustainable materials, to change mobility and transport vehicles, leading to global benefits in terms of fuel saving and carbon-neutral travel.

The pace of change in electrification of transport is now accelerating faster than ever before. This change is bought about by a combination of technology cost reduction, improved technological performance, more stringent regulations (both CO2 and air quality) and customer demand.

Battery technology development is a primary to this change; battery costs are 50 per cent lower than in 2011 and power density forecast to increase five-fold by 2022 compared to 2011. With a simplicity of manufacture and low in service maintenance, this technology now competes with traditional carbon-sourced powertrains for many vehicle types.
This change is driving a significant increase in forecast demand across all modes of transport. The change will be well-established as we move into the 2020's, the global market for electric cars is forecast to increase from 1.2 million in 2015 to between 100 and 140 million by 2030.

Other forms of electric mobility including buses and two wheelers are forecast to see even more dramatic growth.

On-train electric power supply is now moving into the rail mode. In January 2017, Bombardier announced it had signed a $1.9bn contract with the Austrian Federal Railways (OBB) to provide 300 trains compatible with Bombardier's Lithium Ion technology, deliveries begin in 2019.

In a third mode, aviation, new technology and start-ups, are entering the field. For example Wright Electric was founded in 2016 and by 2030 it aims to have a 130 seater all electric or hybrid plane with a range of 300 miles. Finally, in the marine mode the Scottish-based hybrid electric ferry MV Hallaig, entered service in 2013, can reduce fuel consumption by up to 38 per cent compared to a conventionally powered vessel of the same size. These developments are enabled by the cost reduction and increase in energy density of electrical energy storage, management distribution and machines.

Industrial Biotechnology

Spearheading the transformation from current petrochemical, energy intensive economy to a sustainable or carbon neutral bio-economy that will mitigate against climate change. Creation of a technology platform through the integration of synthetic biology, process engineering and sustainable chemistry.

The emergence of a vibrant bio-economy is an inevitability, predicted to double in size by 2030. Successful implementations of Industrial Biotechnology now span the globe; providing productivity gains, more efficient processes and faster access to larger consumer markets. The UK aims to achieve a £10bn UK synthetic biology market by 2030, capable of delivering substantial societal and economic impact nationally and internationally. To achieve this, the UK must commercialise cutting-edge science and technology through a healthy innovation pipeline, a highly skilled workforce, and an environment in which innovative businesses can thrive.

Monitoring slavery in supply chains

Applying transdisciplinary methods to global challenges, using cutting-edge measurement technologies (including earth observation), evidence-based intervention and rigorous evaluation to provide industry tool kit to effectively manage supply chains and help end modern slavery and related rights violations.

Modern slavery includes slavery, servitude, forced and compulsory labour and human trafficking. The International Labour Organisation has estimated the total illegal profits from the use of forced labour worldwide at over 150 billion US dollars while human trafficking for sexual exploitation is estimated to cost the UK £890 million each year. Human trafficking and wider aspects of modern slavery remain a high-priority threat to the UK. The Home Office estimates that there may have been as many as 10,000 to 13,000 people affected in UK. There is an opportunity for the UK to lead the world in this area .A 2016 report by the Freedom Fund noted that private funding for antislavery initiatives amounted to $62.9 million in 2012, grew to $71.1 million in 2013 and to $98.9 million in 2014. Worldwide government funding is also increasing. Cumulative spending by OECD countries on modern slavery from 2004 to 2014 amounted to $1.2 billion, but this represented less than 1% of their overall aid spend, leaving much room for growth.

Smart Industrial Systems

Develop future products and smart factory concepts with a focus on smart autonomous products and experiences of the future that can interact with the users and their surrounding environment and create added value; smart manufacturing processes and systems that can be seamlessly scaled and transformed to deliver radical new manufacturing methods and applications in high labour cost economies; and intelligent data analytics, autonomy and the Industrial and Societal Internet of Things to achieve operational excellence and meet consumer needs within a connected manufacturing infrastructure.

Global appreciation of this trend is evidenced by current initiatives such as Industry 4.0 and the Industrial Internet of Things. Accenture estimates the Industrial Internet opportunity at $32.3 trillion, whilst Cisco refers to a $19 trillion Internet of Everything opportunity. The expected impact of implementing future digital technologies is in increased competitiveness and utilisation of opportunities whilst reducing risks and building impetus. It is expected that investment in “Industry 4.0 solutions” will account for more than 50% of capital investment over the next 5 years, estimated to be €140bn p.a. for the European industrial sector. It is therefore as timely as it is important to invest strategically to position Nottingham as the world premier research and innovation centre in digitally enabled industrial systems.

The University of Nottingham is developing a Research beacon of excellence programme in each of these areas as part of a £200m investment. We are actively co-creating research programmes for these programmes with key industrial and end user partners such as Rolls-Royce, Unilever, GSK, NHS, City Council and NGOs.

We are keen to align our Beacons programmes with funding priorities of funds such as the ISCF to ensure maximum benefit from both investments.

We would also like to see stronger recognition of the contribution of arts and social sciences disciplines to innovation not only in their own right particularly in the creative industries sector, which has enormous potential for growth and trade, but also in their essential role in contributing to market penetration and adoption of major scientific and technological advances. The University of

Nottingham is playing a major role in responsible innovation through all its beacons and is ensuring that we can understands the impacts and benefits of research.

7. What else can the UK do to create an environment that supports the commercialisation of ideas?

Universities are highly successful in the commercial exploitation of their research, but we recognise the Government's ambition to boost the UK's performance in taking ideas from lab to market and welcome the opportunity to suggest practical solutions to help improve performance. We support a number of measures proposed by the Russell Group including a boost to HEIF, reforming the tax environment for research and university-business collaboration, development of a wide-ranging proof of concept fund and maintaining a flexible approach to intellectual property.

As well as making more translational funding available to universities (see 6) there needs to be a recognition that technology transfer is a skilled profession and more funding needs to be made available to allow universities to invest in acquiring, incentivising and retaining professionals that can truly deliver at this interface between academia and industry and commerce. There has been some commentary on the need to share best practice between universities in technology transfer, which is important, but being told how to close a deal and having the skill set to close a deal are not the same thing.

As previously discussed in response to Q.5 further efforts are required to stimulate the demand from UK industry for commercialisation of research. To Support this further incentives need to be made available to companies, SMEs in particular, to help to mitigate the financial risk of in-licensing early stage university technologies. Whilst interventions such as R&D tax credits are welcome, they do not go far enough to reduce the risk to smaller companies. In undertaking licensing deals with SMEs, the University is often asked if we can 'share the risk' with the company, which we are currently unable to do. Many potential license deals fall away because licensees cannot afford to pay patent costs on top of development costs.

We look forward to working with the Government on the proposed review of the principles and practices on commercialisation and IP; we are encouraged that this will be used identify and spread best practice and rather than prescribe particular solutions.

8. How can we best support the next generation of research leaders and entrepreneurs?

The contribution that Centres for Doctoral Training (CDTs) and Doctoral Training Programmes (DTPs) have made to this area in recent years should be noted. Furthermore the recent announcement of additional funding for PhD studentships for 2017/18 is to be welcomed although sustained as well as short-term/one off investment is required if the UK is to realise its ambitions in these area. The relatively new models of doctoral support combine structured and comprehensive disciplinary and professional skills development which ensure the talented doctoral holders are equipped to operate as the future research leaders in and/or as entrepreneurs and business leaders contributing significantly to leading the knowledge economy. It is clear that other nations are now following this model with the introduction of universal four year 'structured PhD programmes' in Ireland and similar developments in Australia.

In addition to UK funding many doctoral training programmes are supported by EU Marie Cuire scheme. Nottingham hosts a number of these Initial Training Networks (ITN) covering energy, manufacturing, aerospace and other disciplines. The government should ensure it considers this in discussions around future access to EU research programmes.

A key feature of many CDTs and DTPs are the opportunities they provide for doctoral candidates to collaborate on research with industry and undertake placements and internships as an integral part of their doctoral research. These not only ensure that the doctoral candidates develop the skills required by business and industry but also provide industry with a tangible demonstration of the value that a doctoral candidate can bring to their business.

The University of Nottingham's innovative postgraduate placement project has taken this model a step further by offering flexible placements that are open to all doctoral students, whether or not they are part of a CDT or DTP. It has supported over 200 research students to undertake and gain valuable work experience in local SMEs. Researchers have worked with over 200 local employers who have seen and reaped the benefits and skills that doctoral researchers bring to enhance their workforce. The research student participants have had the opportunity to develop new skills, as well as bringing their analytical, problem solving and creative thinking skills to bear in new and different contexts. The programme is helping to highlight the value that higher level skills can bring to employers in the East Midlands region – an area which traditionally is a net exporter of graduates. It has also led to students gaining employment with the SMEs and being retained in the region as well as enhancing university-industry knowledge exchange partnerships.

Furthermore research leader's doctoral holders have skills that are prized globally and their retention is not just a UK/regional issue. Trade does not just involve Goods and Services but also knowledge. The UK needs to maintain its leading and innovative approach to doctoral training including through models and funding approaches that support and facilitate mobility and collaboration whilst simultaneously retaining talent in the UK.

In addition to the Doctoral Training Programmes the Industrial CASE scheme provides flexibility to promote user engagement and high impact research by encouraging links with key industrial users. We prioritise the allocation of CASE awards to early career researchers to support the development of long term relationships with industry. This has led to development of a number of excellent relationships including with Lucite International a UK-based designer, developer and manufacturer of acrylic-based products. Lucite are one of our Synthetic Biology industrial partners and since 2010 have supported three Industrial CASE awards at the University of Nottingham (two co-funded by EPSRC DTP and one by BBSRC). Andrew Yiakoumetti was awarded an EPSRC-funded Industrial CASE studentship in 2011 to explore bio-based manufacture of methacrylic acid (MMA). MAA is a precursor for methylmethacrylate (MMA), which is essential to the manufacture a wide range of consumer, industrial, dental, optical and medical products and has a market size of 2 Mt and a market value of US$6Bn. Andrew used Synthetic Biology to develop and make the first demonstration of a metabolically engineered biocatalyst to produce MMA. Although this has been talked about for a long time, Andrew's breakthrough was to discover unusual enzymes that can catalyse the last two steps for the pathway, turning the pathway design into reality. This led to the following patent application - Process for the Biological Production of Methacrylic Acid Application no. GB1508582.2. Andrew has just submitted his PhD and his discovery now forms the core of an ongoing development project funded by Lucite, BBSRC, and Innovate UK, involving Lucite, Nottingham and Ingenza, spearheading Lucite's drive to introduce bio-based MMA alongside their petrochemical product within the next few years. Luca Rossoni, the second student co-funded by EPSRC and Lucite International through this collaboration, submitted his PhD in March 2015. His research was on the evolution of enzymes and metabolic engineering for production of MMA and other chemicals from renewable feedstock. Luca is now a Postdoctoral Researcher at Nottingham working on a collaborative project with Lucite and Ingenza. In the last 6 months, Luca has used synthetic biology to construct a carbon efficient biocatalyst to convert xylose to MAA precursors.

The Industrial Strategy identifies STEM subjects as important in this area but government should also recognise the importance of researchers in social sciences and arts and the contribution they make to economic activity in areas such as creative industries and public policy and in cross- and inter-disciplinary research and knowledge exchange. The 2009 AHRC review Leading the world: The economic impact of UK arts and humanities research, found that for every £1 spent on research by the Arts and Humanities Research Council (AHRC), the nation derives around £10 of immediate benefit and a further £15-£20 of long-term benefit. Vehicles such as the AHRC Midlands 3 Cities Doctoral Training Programme, which brings together a critical mass of leading Universities with creative industry partners to develop placement and other collaborative activities that benefit both our research students and partner organisations should be continue to be supported,

The introduction of the Impact element of the REF has greatly helped to incentivise academics to review the outputs of the research to identify new, potentially commercialisable ideas. However, the burden placed upon academic inventors of teaching, research and associated administration, makes a focus on what can be a long journey from initial concept through to successful commercialisation onerous. More fellowships, particularly at a senior level, need to be made available to allow members of academic staff to buy-out time to focus on the commercial exploitation, without adversely impacting on others areas of their academic careers.

Nottingham is working to ensure entrepreneurial education is provided to wide range of students. The Haydn Green Institute (HGI) is among Europe's leading centres for enterprise education and the focus for entrepreneurial skills development at Nottingham. The Institute provides a programme of world class entrepreneurial education with the aim of developing the innovators and entrepreneurs of the future.

The Institute has developed an MBA in Entrepreneurship, seven joint Masters programmes with other Schools at the University, and entrepreneurship teaching across Business School undergraduate programmes. The Institute provides a programme of world class entrepreneurial education; teaching over 4,000 students per annum across Nottingham, Malaysia and China with the aim of developing the innovators and entrepreneurs of the future.

In addition HGI runs the Ingenuity Lab which exists to help University of Nottingham students and alumni to develop their entrepreneurial ambitions. It has over 1,600 members with over 100 new and early stage start-ups at any one time. The members are from across all disciplines and offer a truly international community of innovative entrepreneurs.

9. How can we best support research and innovation strengths in local areas?

Much work has already been done to identify local research and innovation strengths via the Science and Innovation Audits (SIA). Government should provide a mechanism which allows consortia of industry, academia and public sector to come together and secure funding to address identified priorities. For example the Midlands Engine SIA recognised that the region has clear strengths in transport with a strong industry presence (Rolls-Royce, Jaguar Land Rover), leading research base (Midlands Innovation, Advanced Propulsion Centre, Manufacturing Technology Centre, Transport Systems Catapult) and supportive local economic partnerships. These organisations have come together through the Midlands Engine to create the Transport Innovation Accelerator (TIA) proposal, a vehicle that addresses many of the challenges set out in the strategy. The initial phase of the TIA will be included in the Midlands Engine proposal to government and encompasses a potential government investment of around £100m matched by industrial partners. Three core streams have been identified, following a prioritisation methodology, as being suitable for inclusion in the

Midlands Engine submission to government. These selected technologies maintain the overall coherence of TIA in terms of the systems based and cross-sectoral approach:

1. New vehicle technologies: Will deliver leading edge technological capabilities in digital design and propulsion performance (auto/aero), with the latter also supporting advanced digital design with top of the class validation and verification data, including for engine emissions (£40m)

2. Smart infrastructure: Will create significant gains in advanced vehicular technologies and their interaction with infrastructure in areas such as autonomy, including a rail research and innovation centre and linking to Midlands Connect for testing prototype systems. (£34m)

3. Integrated transport ecosystems: Will optimise transport, treating it as an integrated, interconnected system (comprising vehicles, infrastructure and logistics) to improve people mobility and travel experiences as well as measure and improve the efficiency of transport networks and systems and monitor the impact on the environment. (£27m).

There are also parallel proposals in development involving Midlands Innovation, Industry and other partners for Medical Technologies and Pharma, Low Carbon and Energy, and Future Food Processing.

Government should support the development of such proposals where they address market driven needs identified by the SIAs.

Universities are increasingly been seen as anchor institutions that have a key role to play in local economic growth. Further investment in University Enterprise Zones (UEZs) is an important mechanism to support this function; this is set out more fully in answer to Q.37. Nottingham hosts one of the first UEZs aimed at supporting start-ups and student enterprise. The new Ingenuity Centre opened in late 2016 and has already attracted FDI companies to locate in the area; it is also delivering an incubator programme funded by the UK space agency which provides a model of good practice to link research excellence with high tech start up activity.

Developing Skills

10. What more can we do to improve basic skills? How can we make a success of the new transition year? Should we change the way that those resitting basic qualifications study, to focus more on basic skills excellence?

We would like to see support for the Science Council's initiative to rise the status and profile of technicians and to ensure sustainability of the technical workforce in academia and research. The University of Nottingham is playing a leading role in this initiative and the development of a national Technician Commitment which commits HEIs and Research Institutes to action in five key areas: to ensure that the contribution of technicians is visible within and beyond the institution; to support technicians to grain recognition through professional registration; to enable career progression opportunities for technicians; to ensure the future sustainability of technical skills; and to ensure the effectiveness of actions taken. We would like to see government proactively support this initiative.

11. Do you agree with the different elements of the vision for the new technical education system set out here? Are there further lessons from other countries' systems?

Much of the focus in the Industrial Strategy is on basic skills. Through its relationship with the Djanogly Trust the University of Nottingham, like many other HEIs, is already doing much to support

this agenda in the city. NUAST is a good example of how a University, education provider and industry working together can provide the facilities and expertise required to support technical education.

The importance of higher skills to economic performance should also be considered in the development of industrial strategy. Universities are key providers of graduate skills that are shown to be key drivers of productivity and economic performance. Doctoral Training Centres are a key mechanism that should be further developed to support development of future industrial and academic researchers, and accelerate KE and innovation.

At Nottingham we are working hard to respond to the demand for Russell Group universities to develop provision for degree apprenticeships and welcome the development of programmes up to Masters level. The introduction of PhD level apprenticeships funded by the apprenticeship levy would be sensible next step in this development and underpin the development of industry relevant high level skills to support UK competitiveness.

13. What skills shortages do we have or expect to have, in particular sectors or local areas, and how can we link the skills needs of industry to skills provision by educational institutions in local areas?

The D2N2 LEP identifies a number of skills gaps in the local region. A key area highlighted is the need for greater higher level skills provision and graduate retention. D2N2 highlights tow particular areas of demand

- Transport Equipment Manufacturing –electrical and electronic engineering and manufacture and production engineering.
- Food and Drink – food science, process engineering and business management

The University of Nottingham and D2N2 have worked together to develop a response to shortage of manufacturing engineering graduates in the local areas and have jointly invested in a new Advanced Manufacturing Building which in addition to state of the art research labs will enable the expansion of relevant degree programmes. Consideration should be given about how to support infrastructure for teaching programmes that address key local skills shortages.

Upgrading Infrastructure

15. Are there further actions we could take to support private investment in infrastructure?

Government should recognise the contribution made by Science and research infrastructure. To retain and enhance UKs position as a world leader in research and development continued investment is needed in major national facilities as well as local facilities to support UK wide economic growth. Research intensive Universities such as Russell Group institutions provide a national footprint which can play host to truly national facilities. National infrastructures' could be hosted effectively buy selected universities to provide a competitive advantage to industry and the country as well as help bridge the valley of death…

We welcome the proposal for UKRI to develop a new R&D capital spending programme to support fundamental research. As part of this it is important to ensure funding is provided for ongoing operation and maintenance that ensures that the initial investment in world-class facilities contributes to long term sustainable provision of capability.

It will also be important to ensure that the criteria around private co-investment for any further rounds of RPIF ensure the scheme supports industrial needs and addresses local economic development; one way to achieve this would be to set lower private co-investment rates for projects addressing local needs or with industrial contributions or establish a separate scheme targeted at matching philanthropic donations.

In addition to the Midlands Engine capital programmes outlined in answer to Q.9 Nottingham are bringing forward proposals for capital investments that will create national facilities in Future Propulsion systems (including electrification of Transport), Imaging for Precision Medicine, Global Food Security, Digital Manufacturing and Industrial Biotechnology. The University is planning to invest its own resources in these schemes and would welcome the opportunity to align this with the new schemes proposed in the Industrial Strategy.

The government should consider the impact of EU Exit on ability to attract research infrastructure funding. The UK can currently access European Structural and Investment Funds (ESIF) to support the construction of research infrastructure in the UK.

For example at Nottingham key investments in the Aerospace Technology Centre, which houses work with Airbus, Boeing, Rolls-Royce and others, the Energy Technology Building and the Bioenergy and Brewing Science Building, which houses the AB InBev UK pilot brewery were all part funded by ERDF grants totalling more than £8m.

Government should consider how it might replace the capital element of ESIF at a national level once the UK leaves the EU. Many of the projects funded through this scheme including those listed above were too small to meet current RPIF thresholds.

16. How can local infrastructure needs be incorporated within national UK infrastructure policy most effectively?

Local, distributed research and development infrastructure, as proposed by Midlands Engine, would help address and support national strategies e. Universities are well placed to host these and make them available to a number of industries and/or cross-sector.

Supporting businesses to start and grow

22. What are the barriers faced by those businesses that have the potential to scale-up and achieve greater growth, and how can we address these barriers? Where are the outstanding examples of business networks for fast growing firms which we could learn from or spread?

Nottingham has developed a strong local business network through our Ingenuity programme. This brings together over 1800 local SMEs to share best practice in generic business issues and to provide easy access to academic expertise otherwise difficult for SMEs to engage with. This activity has mainly been supported by EU funding through the ESIF programme. Government should explore ways to continue to support for such programmes.

For example Enabling Innovation is a £20.3m three collaborative programme involving Nottingham Trent University, the University of Derby and the University of Nottingham provides support to over 2,000 local small and medium enterprises (SMEs) over three years. It is funded by a £10.1m grant via the D2N2 Local Enterprise Partnership (LEP), using funds secured by the European Regional Development Fund (ERDF). Unless suitable replacement funding to ESIF is identified the UK risks losing such programmes which aim to stimulate an innovation ecosystem designed to commercialise

cutting edge R&D, support product and process innovation within SMEs and drive innovation through supply chains.

The Nottinghamshire Manufacturing Network was established and facilitated by the university in order to bring a cross section of manufacturing businesses closer to the expertise and resources of the university. The network has around 30 active businesses employing 1800 people with a combined turnover in excess of £250m. A bilateral agreement exists in order to embed members of the network into the engineering/manufacturing assets of the University for the exchange of knowledge and experience in both directions. This ecosystem is both saleable and transferable to other sectors and as such should be supported within the Industrial Strategy.

Encouraging trade and inward investment

25. What can the Government do to improve our support for firms wanting to start exporting? What can the Government do to improve support for firms in increasing their exports?

The Government should recognise the importance of promoting and recognising successful UK HE TNE initiatives, in particular the value of using Government-to-Government engagement, Ministerial visits, delegations and profile-raising activity to visibly support these initiatives"

As shown by the WIPO's Global Innovation Index, where it ranks second, the UK is a world-leader at innovation and our universities are amongst the best at "bridging the valley of death" between research and real-world application. In addition to traditional TNE, Knowledge Exchange and research commercialisation are both potentially lucrative new markets and powerful tools for UK in building relations with China. The FCO Prosperity Fund should recognise this in its future allocations of multi-year funding.

26. What can we learn from other countries to improve our support for inward investment and how we measure its success? Should we put more emphasis on measuring the impact of Foreign Direct Investment (FDI) on growth?

Universities play an important role in regional economies in working with local authorities and LEPS to attract inward investment from companies seeking to relocate near the stream of talent, innovation and global connectivity that they provide. For example the University of Nottingham played an instrumental role in the decision by major Chinese automotive firm Changan to establish a 200 person R&D centre in the UK in 2010. We would like to see the Government allocate a small amount of funding through DIT to incentivise an expansion of this activity between Universities and local partners, as well as better sharing of best-practice across the UK.

Delivering affordable energy and clean growth

29. How can the Government, business and researchers work together to develop the competitive opportunities from innovation in energy and our existing industrial strengths?

Any new Energy Institution should work closely with existing University expertise from within bodies such as the Russell Group and Midlands Innovation. It should build on existing networks of industry and academia such as the Energy Research Accelerator (ERA), a cross-disciplinary and multi-partner energy research hub in the Midlands. ERA partners, Aston University, the University of Birmingham, the British Geological Survey, Leicester University, Loughborough University, the University of Nottingham and the University of Warwick are working together to pool resources and expertise to address key energy challenges by developing new technologies, bringing down costs and innovating to drive growth, support productivity and create jobs. ERA is supported in its first phase of

development by £60 million Government capital funding, supported by an additional £120 million of co-investment secured from industry and academic partners. The Government's initial investment is expected to generate a return of £323 million.

Work is currently ongoing through a Midlands Engine consortium including ERA, Energy Systems Catapult and Industry to develop plans for a further set of Energy research facilities and demonstrators covering battery technologies (including 'second-life' applications); housing, construction and communities (including retro-fitting and ESCOs); energy from waste; and decentralised multi-vector Energy Systems (including Smart Grids).

In addition as part of the Beacons of Excellence Programme Nottingham will invest around £50m in research activity that supports energy innovation. The Propulsion Futures and IB Beacon both address key parts of the energy supply chain including production of sustainable low carbon fuels and the electrification of transport.

Cultivating world-leading sectors

31. How can the Government and industry help sectors come together to identify the opportunities for a 'sector deal' to address – especially where industries are fragmented or not well defined?

Higher Education is an important sector in the UK comparable in scale and value to many of the sectors identified in the strategy as targets for sector deals. A report produced for Universities UK by Ursula Kelly, Emeritus Professor Iain McNicoll and James White of Viewforth Consulting Ltd in 2014 found that the HE sector makes a contribution of £39.9 billion to UK GDP which accounts for 2.8%. It employs over 450,000 people and has export earnings of more than £10.7 billion.

The sector also has tremendous international reach. An economic impact of international students assessment conducted for Universities UK by Oxford Economics in 2017) found that international students in the UK generate more than £25 billion for the economy and spending by international students benefits local businesses and supports over 206,600 jobs in university towns and cities across the country.

An HE sector deal that ensures that framework is in place to support international competitiveness of the sector would drive even greater value for the UK.

34. Do you agree the principles set out above are the right ones? If not what is missing?

The important role Universities can play in supporting innovation in sectors should be recognised. The Advanced Propulsion Centre (APC) spokes, of which University of Nottingham hosts the Power Electronics spoke, provide a model of good practice that could be replicated in other areas. The APC spokes supported by EPSRC programmes provide a national network to support the industry in the sector with specialist academic, technological and commercial expertise.

This could be replicated in other areas. For example in Digital Industrialisation the EPRSC Network Plus: Industrial Systems in the Digital Age could play a similar function to the APC Power Electronics Spoke providing access to a co-ordinated academic community in Manufacturing, Digital Economy, High-value Design, Human Factors and Business for the sector. UKRI could direct specific funding at the development of such networks aligned to sector deals.

Driving growth across the whole country

35. What are the most important new approaches to raising skill levels in areas where they are lower? Where could investments in connectivity or innovation do most to help encourage growth across the country?

Government should recognise and support the contribution of research intensive universities outside of London and the South East Nottingham. These institutions are ideally positioned to address the challenge of combining research excellence with the expansion of investment in the rest of the UK. Bodies such as Midlands Innovation we can deliver a critical mass of research excellence linked to local industrial demand and address key national challenges. The six Midlands Innovation Universities, according to HESA figures, account for around 90% of all research activity in Midlands HE with collective income of over £400m per annum including around £45m directly funded by industry.

36. Recognising the need for local initiative and leadership, how should we best work with local areas to create and strengthen key local institutions?

The University of Nottingham are working with regional and local partners such as the Midlands Engine for Growth and D2N2 LEP to ensure our response the industrial strategy addresses local economic imperatives. This has included participation in a D2N2 consultation workshop and discussions around how our Beacons of Excellence programme can support local economic growth.

Government could seek to target mechanisms such as RPIF at programmes that address local innovation needs and support local clusters of firms but still meet required levels of research quality.

Creating the right institutions to bring together sectors and places

37. What are the most important institutions which we need to upgrade or support to back growth in particular areas?

Universities have an important part to play in local economics as a source of economic activity in their own right. A 2015 Economic Impact Study found that the University of Nottingham accounts for £676m of Nottingham City GDP which is around 5% of the total every year, supporting <14,000 jobs with one in 24 jobs in Nottingham reliant on The University of Nottingham.

They also sit at the centre of a network which include local government, business and other parts of the education system which supports the creation of knowledge intensive industry clusters. For example the University of Nottingham Innovation Park, part of the flagship Jubilee Campus brownfield regeneration that has been supported by local and national government now houses 60 business that employ more than 600 people.

Government could provide additional support to strengthen the links between local economic partnerships and direct elements of local growth deal by targeted at maximising the benefit of collaboration between Universities and local areas.

One way this has begun to be achieved is through the formation of University Enterprise Zones. These vehicles support both the continued development of innovation from University outputs, an area which Universities should be properly resourced to deliver, but also deliver much wider benefits to local economies by acting as a catalyst for the creation of clusters of innovative business. These companies make a commercial decision to pay market / above rents to locate to sites such as the University of Nottingham Innovation Park so that they can:

- Reduce the costs of acquiring skilled talent. [Graduate Retention & Jobs].
- Reduce the costs of engaging with academic researchers & experts both formally & informally. [Informal & formal innovation/ KE by the transfer of formally recorded & tacit knowledge].
- Reduce the costs of engaging with like-minded entrepreneurs, client companies, & collaborators. [As above but between businesses].
- Access skills development, business development, and financial (investment) at a recognised location. [Reduced frictional costs of developing a business both for the business, investors, & business support organisations].

Government should use a review of UEZ pilots to consider the benefits of further investment in this area as a critical way of maintaining the link between invention and innovation rather than disconnecting the two.

38. Are there institutions missing in certain areas which we could help create or strengthen to support local growth?

In the Midlands context the right institutions are already in place to support the whole range of ambitions set out in this strategy. What is required are the mechanisms to support collaboration and develop networks that will deliver on the objectives of the Green Paper.

Government should seek to support vehicles such as Midlands Engine and Midlands Innovation as means to drive local economic growth. In the case of Midlands Innovation this could take the form of developing critical mass to support further activity around commercialisation building on existing activity around a share enterprise fund to ensure resources are available to support translation at key moments in the innovation cycle.

Government could support the introduction of joint investment funds such as that proposed by the Midlands Innovation networks of universities. This would be one way to mitigate for the loss of EU Structural and Investment Funds which are currently an important source of funding for many universities.