Written Evidence Submitted by the Royal Academy of Engineering (C190101)

Introduction

- The Royal Academy of Engineering welcomes the opportunity to submit evidence to the House of Commons Science and Technology Committee's inquiry into UK Science, Research and Technology Capability and Influence in Global Disease Outbreaks. The submission draws upon evidence, insights and experience from Fellows of the Royal Academy of Engineering and partners to the National Engineering Policy Centre (NEPC), which collectively represent 450,000 engineers across the UK.[1]

- Through the NEPC the engineering community is providing rapid support and advice on the immediate risks and impact of the COVID-19 for the UK, and beyond the immediate crisis response, to secure a more resilient future.[2]

- This response highlights examples of where engineering input has been, and will continue to be crucial, and some of the challenges in delivering that engineering advice and guidance.

1. **The contribution of research and development in understanding, modelling and predicting the nature and spread of the virus;**

    1.1. Engineering research and development has contributed to the understanding, modelling and prediction of the nature and spread of the virus in a number of ways. For example, engineering input, in partnership with experts from other disciplines, has helped to understand the nature and spread of the virus in real world environments and to form the basis of quantitative assessment of transmission risk.[3]

    1.2. There are a range intervention points where engineering design and technology can play a role in reducing transmission. The nature and effectiveness of these interventions are dependent upon a number of factors specific to the environment concerned. For example reducing the spread of COVID-19 in hospitals is a complex systems problem of the sort engineers are adept at addressing, influenced by the virus transmission routes, the hospital environment and how it is used, and how external people and services interact with it.[4] Hand hygiene, environmental design, personal and respiratory protective equipment, and environmental decontamination have all been identified as points where engineering solutions can play a role. The prevalence of these solutions and the ease of implementation varies, and their adoption will impact patients, staff and visitors differently.

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[1] National Engineering Policy Centre is an ambitious partnership, led by the Royal Academy of Engineering, between 40 different UK engineering organisations representing 450,000 engineers. It provides critical engineering expertise on policy issues of national importance

[2] COVID 19: Engineering a resilient future, Royal Academy of Engineering, National Engineering Policy Centre, June 2020

[3] ENVIRONMENT AND MODELLING GROUP Principles of understanding of transmission routes to inform risk assessment and mitigation strategies, 2020

[4] Rapid review of engineering factors that will influence the spread of COVID-19 in hospital environments

1.3. These solutions should not be developed by engineers alone. Instead it is critical that the engineering and healthcare communities collaborate on this challenge and include human factors expertise, statisticians and epidemiologists for a holistic approach, as advocated for instance in the National Engineering Policy Centre briefing 'Rapid review of engineering factors that will influence the spread of COVID-19 in hospital environments'[5]. This holistic approach should be taken early in any future crisis.

2. The capacity and capability of the UK research base in providing a response to the outbreak, in terms of:

- **advice to government, public bodies and others on managing the outbreak;**
- **the development of testing, diagnostic methods and technologies;**
- **the development and testing of vaccines; and**
- **the development and testing of therapeutics;**

2.1. An effective response requires good technical solutions alongside a clear understanding and development of the implementation routes which accompany them and an integration of these innovations into an operational context. The response to the pandemic by the UK research base has been impressive and has confirmed the UK's strengths in academic research across diagnostics, vaccines and therapeutics. Where many of the challenges have been seen is in the delivery and implementation of the solutions, for example in understanding and managing supply and distribution of PPE, or managing the data from testing. These delivery and implementation challenges are central elements in an engineering approach to developing solutions. To take vaccines as an example, alongside the need for new vaccines to be developed, how they would be disseminated rapidly and manufactured at scale are already being considered. Manufacturing processes are being developed while the vaccine goes through the clinical trial together with innovative approaches to delivery.[6] Similar advancements in research and development and collaboration with industry will be needed to address issues of scale-up, value for money and usability in a range of local and global contexts. The integration of these innovations with effective tracking and tracing and environmental controls must be considered to contain COVID-19 in the short, medium and long term.

2.2. The response to the pandemic by the UK engineering base, both in academia and in business, has been rapid, agile and extensive. Engineers are responding in a number of different ways:

- Engineers are **collaborating and rapidly innovating** to provide solutions to pressing problems, such as the collaboration that resulted in the UCL-Ventura breathing aid[7] and the engineers that set up the Nightingale field hospitals on time. Whilst the development of a UK mobile tracing app was frustrated, UK engineers made advances, greatly enhancing the effectiveness of the Bluetooth signals, and modelled responsible tech behaviours by opening up their advances to scrutiny on GitHub.
- Engineers can both take new invention through to application, **or use existing technology** to develop new approaches to emerging problems such as M-squared

[5] Rapid review of engineering factors that will influence the spread of COVID-19 in hospital environments
[6] UKRI – Press release – Creating new vaccines
[7] For a discussion of how the community collaborated on the CPAP ventilator see the Academy's Innovation in a Crisis event: UCL-Ventura breathing aid (CPAP)

lasers and the University of Strathclyde using their novel laser technology for safer UV-C hospital decontamination, and the collaborative activity which rapidly scaled ventilator production.

- This engineering innovation can take the form of pulling new invention through to application, or **using existing technology, processes and know-how** to develop new approaches to emerging problems such as M-squared lasers and the University of Strathclyde using their novel laser technology for safer UV-C hospital decontamination.
- Engineers are **repurposing their activities** and pivoting their businesses to produce much needed items such as personal protective equipment (PPE)[8] or utilise their existing technologies for new purposes, such as DNA Nudge repurposing of their equipment (see section 2.9 below).
- Engineers are **providing advice into government**, for example on topics such as ventilation and engineering controls to reduce the spread of COVID-19 in hospital environment, including through the Scientific Advisory Group for Emergencies (SAGE), the Royal Academy of Engineering and the National Engineering Policy Centre.
- Engineers are **sharing best practice**, for example the Chartered Institution of Building Services Engineers (CIBSE) has published guidance for business owners, managers and employers, which advises on safe working practices and assessing building services when preparing an office for safe re-occupation and BCS has held a webinar on how the coronavirus is changing the cybersecurity threat landscape.
- **Global networks** are also being convened, this has encouraged greater knowledge sharing and fostered international collaboration between experts, cutting through traditional geographical boundaries and national interests. For example, the Academy shared learning from international partner organisations in the early stages of the pandemic[9].
- Many engineers in key sectors, such as communications, food and energy, have **continued working** throughout the pandemic to protect the UK from additional strains and vulnerabilities that arose from the crisis.
- The engineering community is also initiating and participating in discussions to **learn lessons** from the pandemic response which will inform the recovery process and support a more resilient future.
- The engineering community has an important part to play in **economic recovery**, and working effectively in the 'new normal', both by transitioning its working practices (e.g. virtually) and in delivering innovation to support recovery and resilience.

2.3. The engineering community has sometimes felt that its capacity and capability to respond to the pandemic has exceeded the capacity of the government to filter, respond and follow-up on offers of engineering support. Relatedly, when engineering input has reached government it appears it has not always been received by the most appropriate part of government. Offers of support in the production of PPE and ventilators are perhaps the two most high-profile examples of supply of support exceeding the government's capability to effectively manage the input. Given the unprecedented nature of the crisis and the magnitude of pressures on the government and civil service,

[8] For a discussion of how the community mobilised to develop PPE during the crisis see the Academy's Innovation in a Crisis event on the issue: Inside efforts to make PPE for the frontline
[9] https://www.raeng.org.uk/policy/engineering-response-covid-19-coronavirus/international-responses

combined with the scale of the response from the engineering community this mismatch is perhaps not surprising.

2.4. The Academy, understanding how much the engineering community had to offer to the pandemic response and also aware of the exceptional demands on the government and civil service, positioned itself as a filter and quality control of offers of support from the engineering community. As appropriate, connections were then made with the most relevant parts of government, many of which were facilitated through the Chief Scientific Advisors, several of who are engineers, and the Government Chief Scientific Adviser and the Government Office for Science have been extremely helpful in making connections.

2.5. A call to action by the Academy resulted in over 600 ideas, innovations and offers for help from the engineering community. All submissions of ideas and products were reviewed and categorised by an expert panel, and those with the most promise were advanced, for example with a letter of support if further funding was needed, or connected to the most appropriate part of government. Through the call 1000 engineering volunteers were identified for field hospitals, a partnership is being explored for a machine learning tool to support engineering upskilling, and support was provided DNA Nudge. The Academy's approach has now progressed to responding to problems resulting from COVID-19 that are clearly defined by clinicians, public health experts and government, by making connections to engineering expertise, advice and facilities.

2.6. There is room to enhance Government's capability and capacity to absorb and use engineering expertise and advice. Engineering advice is related to, but distinct from, Science advice[10], often focussing on the translation of science into practical application, concerned with scale, logistics and cost. It draws upon the experience of industry and enterprise as well as academic knowledge and communicates know-how and systems approaches as well as evidence.

2.7. Attention should be given to recruitment to the civil service and the number of civil servants with an engineering or other technical background, and what technical leadership departments have in place to define upcoming challenges, and to seek out, absorb and use appropriate advice on issues such as logistics, systems approaches, and the interplay between research and operations. Continuing professional development also has a part to play for technical roles in the Civil Service.

2.8. The Academy has launched a programme of Policy Fellowships to support existing civil servants to enhance their understanding of, and ability to access and utilise, engineering advice. Other initiatives address the need to bring engineering skills into government at different levels, such as the work of Public Practice, who source private sector expertise in the built environment into local authorities.

2.9. With regard to the development of testing, diagnostic methods and technologies, vaccines and therapeutics, engineering has a critical role to play. For example, DNA Nudge has repurposed its previously nutrition-focussed diagnostic chip to detect the

[10] See for instance: Adam C.G. Cooper et al, 'Engineering advice in policy making: a new domain of inquiry in evidence and policy', forthcoming in *Evidence & Policy*, Policy Press.

Covid-19 virus. This technology can facilitate the test to be performed on the spot, independent of a lab, with minimal expertise required for operation. The results are delivered in a little over one hour. Government has now placed a £161 million order for 5.8 million DNA Nudge COVID-19 test kits to be used in NHS hospitals from September after it gained regulatory clearance. Fast tracking of the Vaccines Manufacturing Innovation Centre will enable innovative manufacturing facilities that are adaptable depending on which vaccine is successful, sustainable and deliver high volumes quickly.

2.10. COVID-19 has made it harder to rapidly increase production, due to issues with supply chains, and gaps in understanding on where capacity lies in the public and private sector. Spikes in global demand have highlighted the importance of visible supply networks that aren't reliant on single suppliers or countries, and strong communication lines that also provide important mechanisms to share learning.[11] There are opportunities for technological innovation to create manufacturing processes and supply chains that are more resilient to future shocks. We discuss this further in section 7.3 below. Please see the response from the Institution of Chemical Engineers and the International Society for Pharmaceutical Engineering UK Affiliate for a more specific focus on opportunities to increase pharmaceutical supply chain resilience.

3. The flexibility and agility of institutions, Government departments and public bodies, and processes to respond appropriately during the crisis including:

- **the availability and responsiveness of funding; and**

3.1. The speed and agility with which UKRI issued a rolling funding call for ideas that address and mitigate the impacts of COVID is to be commended. The flexibility of the grants combined with the broad remit of the call and eligibility for both businesses and researchers is welcomed. This approach should allow for a broad diversity of ideas to progress rapidly. The Academy would like to see UKRI review the factors which enabled it and its component parts to operate with more speed, agility, and flexibility to inform new processes, and to enable this agility to be maintained when back to 'business as normal'.

3.2. Ensuring the survival of innovative R&D intensive businesses throughout the crisis is necessary for the quick bounce back upon which future recovery and growth depends. Therefore, the £1.25 billion package for firms driving innovation is also to be applauded. The diversity of products recognises that different types of businesses need different types of support. The record number of applications for the Innovate UK Fast Start grants, with applications in excess of double the initial funding commitment of £250 million for the Future Fund being received on the first day alone, demonstrates that there is significant unmet demand from innovative UK businesses.

3.3. With the impacts of the COVID-19 pandemic ongoing the Academy would like to see the government continue to respond flexibly to the evolving needs of the full spectrum of innovative businesses. There are concerns in the engineering community that early-stage angel-backed businesses are at considerable risk with no obvious support for them.

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[11] Supply chain challenges, lessons learned and opportunities

- **the optimal functioning of regulatory and ethical processes;**

3.4. The MHRA has responded incredibly quickly to create clear frameworks that have enabled a wide range of innovative solutions to be developed for PPE and ventilators. These were made widely available and were iterated as evidence suggested human factors design considerations needed to be included. This adjustment highlights the need to understand the facilities in which technology will be deployed, such as the availability of oxygen sources for oxygen intensive CPAP designs. The very short timescales for some of the emergency regulations may mean more higher performing designs missed the opportunity for regulatory approval.

3.5. The European Commission relaxed the testing expectations for medical grade PPE to remove some requirements such as shelf life testing. This has enabled the UK Standards bodies and testing facilities to be more agile. NPL, BSI and MHRA have been responsive providing advice and guidance while under unprecedented demand. However, as regulation and standards are inherently complex, clearer support could be provided for innovators to avoid confusion and speed up processes. Some research groups identified through the Academy's call for ideas which were developing novel PPE designs were initially directed towards one standard and then it transpired a different one was required and in one case an entirely new standard was needed, increasing the timeline to deployment.

3.6. For other industries responding to the needs of the healthcare crisis there was a learning curve to get used to the less prescriptive nature of MHRA regulations and understand the additional manufacturing standards required for medical devices. There may be benefit in clearer articulation of where the different standards diverge between sectors in order to be able to quickly identify the additional steps needed if repurposing facilities. This could increase the agility of the UK manufacturing capability.

3.7. Clinical trials are being permitted to make more use of evidence based on precedent in order to enable important progress to be made quickly whilst ensuring vaccine safety.

- **the availability and influence of scientific advice in all Government departments and public bodies—including by departmental Chief Scientific Advisers; and**

3.8. The COVID-19 pandemic has shone a spotlight on the importance of science advice in government and has proven the structures that enable it. The network of UK government departmental Chief Scientific Advisers, led by the Government Chief Scientific Advisor, the Chief Science Advisors for the devolved nations, and the Chief Medical Officers across the UK are central to the system. They are able to offer a broad input of science advice and reach into their own networks, including the Academy and the NEPC.

3.9. The flexible membership of SAGE and its sub-groups allows it to convene experts most relevant to the challenges at hand. The Academy is represented on the Environmental and Modelling Working Group. The COVID-19 response has highlighted the importance of interdisciplinary and multidisciplinary input with systems thinking in formulating advice for complex challenges. Ensuing a broad range of disciplinary input, with consideration also given to diversity and inclusion, should be a priority for all science advice.

3.10. The engineering profession believes the UK would benefit from having more engineers throughout government and the civil service, and attention paid to government's capacity to engage and use engineering advice. Engineers possess a distinct set of skills, complementary to scientists, with particular strengths in systems approaches, logistics, operations and development and deployment, all of which have proven important in responding to the COVID-19 pandemic.

3.11. Scrutiny of science advice is to be expected and is part of the scientific processes. As new evidence comes to light, scientists learn more and advice may need to be updated and altered. While the engineering community welcomed government placing science at the heart of the response to the COVID-19, they found the 'following the science' narrative unhelpful: with ever growing knowledge there is no one thing which constitutes 'the science' and it is the Ministers, not the scientists, that make the decisions, taking into consideration factors that go far beyond the science advice. As and when science advice changes, it is right that Ministers may need to update and change their approach – this is to be welcomed.

- **the extent to which decisions taken drew on that advice;**

4. **The capacity to manufacture and distribute testing, diagnostics, therapeutics and vaccines:**
   - **both standing capacity and capacity able to be mobilised;**

4.1. For the development of vaccines, consideration and funding was given to the need for new vaccines to be developed and disseminated rapidly, with support for multiple projects to ensure access to the most effective vaccine. In order to deliver the volume of vaccine required manufacturing processes are being developed while the vaccine goes through the clinical trial. Collaboration between academia and the deep industrial experience of GSK and AstraZeneca has been important to enabling this for many vaccine designs. Engineers are presently building the Vaccine Manufacturing Innovation Centre and repurposing the facilities at Centre for Process Innovation to be able to take the Imperial vaccine from demonstration to mass manufacture. Drawing on this engineering expertise is vital to ensure the manufacturing provides the necessary scale and consistent quality within budget.

4.2. Alongside this, UKRI are also supporting innovative approaches to delivery for both the UK and globally,[12] however additional support may be required to help these products scale to meet the global demand for vaccines. For example, one of the Academy's Enterprise Hub members who founded Ideabatic Ltd. is hoping to identify a manufacturing partner to help scale up the production of SMILE a last mile vaccine carrier developed to solve the issues of cold chain logistics in sub-Saharan climates.

5. **The capturing during the crisis of data of the quantity and quality needed to inform:**
   - **decisions made during the crisis; and**
   - **to maximise the learnings afterwards;**
6. **The mechanisms for communication of scientific evidence internationally, within national governments and with the public:**

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[12] UKRI – Press release – [Creating new vaccines]

- **including the handling of conflicting scientific opinions; and**

7. **The UK's readiness for future outbreaks, including a consideration of:**
   - **the National Risk Register;**
   - **the UK Pandemic Influenza Strategy; and**
   - **PHE's Global Health and Infectious Diseases Strategy.**

7.1. The COVID-19 pandemic has focussed the Academy and NEPC on how to ensure the UK is resilient to emergencies, including pandemics. Building resilience to emergencies requires long-term strategic planning and foresight, and is an area where engineering is well placed to offer advice, and also to input into operations and implementation. The Academy and NEPC have for instance worked with government to harness the expertise of and knowledge of engineers to identify supply chain sensitivities, champion resilient system design and deliver a framework of critical domestic capabilities.

7.2. COVID-19 has put supply chains under severe pressure, revealing both strengths and weaknesses. There have been challenges scaling up production and distributing existing products, designs and innovations. Shortages in critical supplies like personal protective equipment (PPE) and chemical reagents for testing are ongoing challenges as the pandemic disrupts global supply chains. These disruptions include material shortages, uncertainty of access to international supplies and disrupted transport and logistics due to trade restrictions and costs. It is vital these pressures, and how supply chains are responding, are understood both to navigate the remainder of the pandemic and to learn lessons for a more resilient future.

7.3. As an immediate response the Academy carried out an information gathering exercise across the engineering profession with the help of partners NEPC to assess the impacts on supply chains and to learn from them. The consultation focused on current supply chain challenges, mitigation efforts, and the challenges and shortages which may lie ahead, receiving responses from over 60 engineers which were refined at a roundtable attended by representatives with supply chain expertise across sectors, and enriched by further consultation with industry experts in procurement, logistics and finance. The resulting paper found many instances where supply chains responded well. It highlights the importance of supply networks reducing the risk of single point failures, of effective communication across these networks and the opportunity for technology to create more resilient supply chains enabled by effective regulations.[13]

7.4. As the COVID-19 pandemic has brought the issue of interconnectedness and interdependencies to the fore and highlighted certain vulnerabilities, it has led to discussion of the UK's resilience to shocks and strains, and the domestic capabilities which underwrite that resilience and the UK's wider freedom of action and operational advantage.

7.5. The Academy has initiated a piece of work to explore the UK's physical, digital and human capabilities by applying the defence principles of 'sovereign capability' more broadly, with the ambition of working with government to deliver a framework of critical domestic capabilities, informed by engineering, which will support the country's ability to absorb the unforeseeable in the future. Such abilities might include technical skills,

[13] Supply chain challenges, lessons learned and opportunities

networks and co-ordination, and flexible industrial capacity. We are seeking to form a framework for understanding how such capabilities strengthen resilience, to help inform the response to emergencies arising from natural events, major incidents or malicious attack and chronic challenges, such as energy security and other instances where global market economics might fail. Taking a systems approach, proportionate and effective mitigation measures will be identified alongside the enabling factors.

7.6. In summary, engineering has a vital contribution to make across many components of the pandemic response but also in the preparedness of the UK to respond to a pandemic. This may be in world-leading research and development to rapidly turn science into effective and efficient products and processes; in strengthening the connection between science and operations and understanding how to translate science findings, integrate innovations and deliver them in real world contexts; or in fine-tuning operational responses such as the integration of well-designed infection control measures in our buildings and transport system. The Engineering community remains keen to support government and parliament in the ongoing response to this and potential future pandemics.

(August 2020)