ROYAL ACADEMY OF ENGINEERING

Engineering our way out of a crisis:

mobilising engineering capability

The context

The COVID-19 pandemic presented the engineering profession with unique and urgent challenges. Design and manufacture of ventilators, Personal Protective Equipment (PPE), testing kit, field hospitals and logistic supply chains all rely on engineering. It rapidly became clear that existing products and supplies were not going to be enough and that a rapid response would be needed if supplies were to be maintained and health systems were not going to be overwhelmed.

In response the UK engineering capability mobilised in an astonishingly short period of time. The professional engineering institutions, companies and universities contributed resources to tackle the crisis.

> “From our first meeting we had the first prototype testing in the hospital within 100 hours… we submitted to the MHRA and had approval in 10 days… MHRA is operating under a specific emergency scenario for COVID, it’s been phenomenal”

Professor Rebecca Shipley UCL-Ventura CPAP

What the Academy did to help

As the crisis developed in the UK in March, the Royal Academy of Engineering launched a positive response programme to provide brokerage, policy advice and expertise and funding and support through grant and delivery programmes. As part of the brokerage stream, by using its network, support was provided for innovators and a clear route for government to access the breadth of expertise and capability across the profession was created.

How?

The Academy launched a call for ideas that was advertised through its networks of professional engineering institutions with a reach of almost half a million engineers.

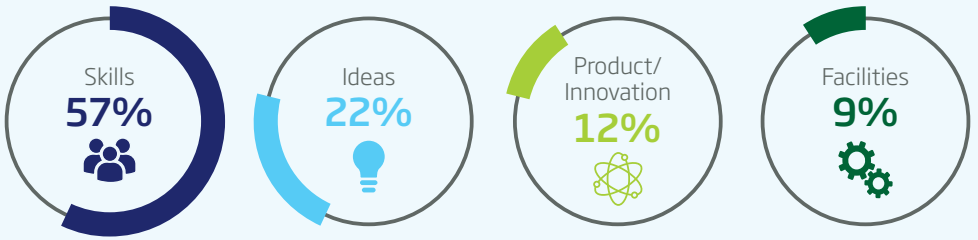
The response was huge. The Academy brought together a group of Fellows with expertise across healthcare, pharmaceuticals, manufacturing, infrastructure and international innovation to review the ideas and products submitted. This expertise triaged shortlisted submissions to identify those that needed fast tracking, those that needed resources and those where the Academy could make the right connections to enable them to make rapid progress.

The Responses

We received 566 responses across four categories

The responses showed the vast range of ways in which engineering could support the response to the pandemic. Submissions fell into roughly four categories:

- Skills – people offering their expertise to support.
- Ideas – highlighting ways in which engineering could help solve specific problems.
- Product/innovation – existing research or product that could be applied in the COVID-19 context.
- Facilities – highlighting factories or warehouses with extra capacity.



Skills
From manufacturing to design, ventilation and data science

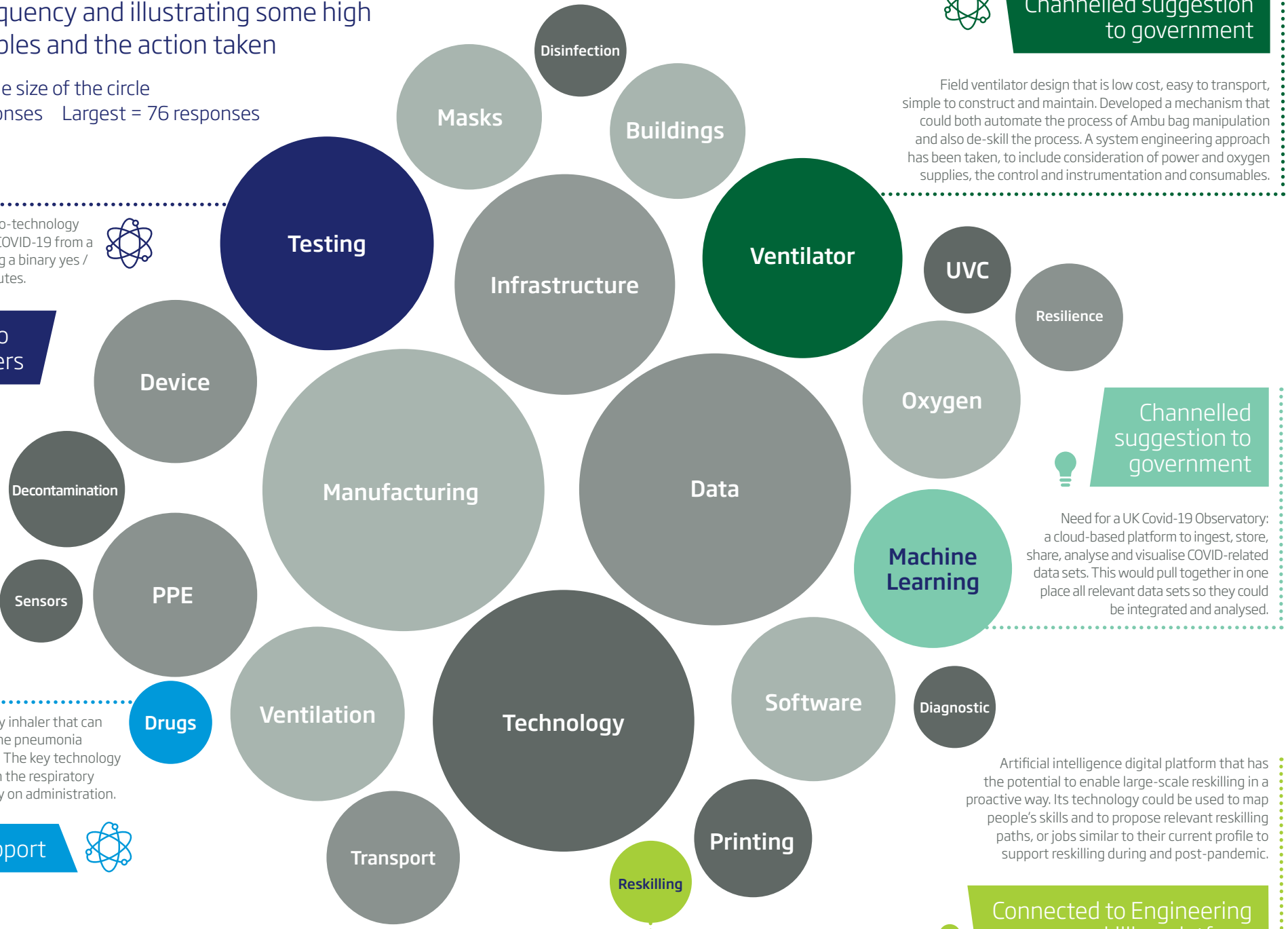
Ideas
Repurposing planes to act as critical care facilities, use of robotics and sensors, a joined up approach

Product/innovation
Decontamination products, apps, therapeutics , PPE, upskilling tools, diagnostics

Facilities
3D printing, volume manufacturing, storage and logistics

The diversity of themes within the submissions with their frequency and illustrating some high scoring examples and the action taken

Represented by the size of the circle
Smallest = 6 responses Largest = 76 responses



Channelled suggestion to government

Field ventilator design that is low cost, easy to transport, simple to construct and maintain. Developed a mechanism that could both automate the process of Ambu bag manipulation and also de-skill the process. A system engineering approach has been taken, to include consideration of power and oxygen supplies, the control and instrumentation and consumables.

Existing solid state nano-technology device that will detect COVID-19 from a saliva sample, producing a binary yes / no result within 15 minutes.

Connected to manufacturers

Channelled suggestion to government

Need for a UK Covid-19 Observatory: a cloud-based platform to ingest, store, share, analyse and visualise COVID-related data sets. This would pull together in one place all relevant data sets so they could be integrated and analysed.

Developing a respiratory inhaler that can deliver drugs to delay the pneumonia symptoms of COVID-19. The key technology targets the host virus in the respiratory tract directly and rapidly on administration.

Letter of support

Artificial intelligence digital platform that has the potential to enable large-scale reskilling in a proactive way. Its technology could be used to map people's skills and to propose relevant reskilling paths, or jobs similar to their current profile to support reskilling during and post-pandemic.

Connected to Engineering upskilling platform

The Triage

The ideas and innovations were discussed and reviewed by an expert group of Fellows who scored the ideas based on where they felt the Academy networks could play the most effective brokerage role.

The highest scoring submissions received support through:

- connections to relevant government departments
- letters of support for funding applications
- small support grants
- sharing opportunities with the engineering community
- advertising to the engineering community
- connections across Academy networks
- match-making between submissions to enable learning.

Reinvigoration, a UK based consultancy specialising in integrating operational excellence with cutting edge technologies to transform service operations offered their help through the call for ideas. In collaboration with the Academy and Intellimorph they delivered an efficient automated solution for the process and created the capability to match the skills and products to future problems.

Policy investigations

Infrastructure interdependencies – there were multiple calls for a joined up approach to understand where the next shortages may arise, and this led to policy investigations into interdependencies and supply chains

PPE decontamination – several ideas related to decontamination and reuse of PPE. The implications were explored with international examples and novel systems (such as the use of UV-C lasers) were highlighted in publications.

Limiting transmission within buildings – the Academy received multiple submissions about the role of building design, ventilation, and novel anti microbial and UV-C products. These ideas have been incorporated in policy pieces on the role of engineering to limit hospital acquired infection and restarting public transport, with many put into practice.

> “The Royal Academy of Engineering panel provided the team with the motivation to push the development of the technology, resulting in its funding through the Scottish Funding Council GCRF funds to work with Malawi on trialling the platform to assist healthcare workers’ testing for the disease in low-resource settings.”

Dr Julien Reboud, University of Glasgow

> “Working with the Academy made it possible to bring together all the Engineering Institutions, enabling us to coordinate a vast pool of skilled engineers to support the NHS Nightingale Hospitals”
>
> Dr Helen Meese CEng IMechE, CEO The Care Machine Ltd

Field hospitals

Helping innovation adoption

Visbion is a medical imaging company with over a thousand systems in 10 countries. One of their products is called the Image Cube and it allows data (images and associated data) to be transmitted, using military spec encryption, across the wireless network to clinical databases from other hospitals and mobile trailers. This technology has been applied in various Nightingale hospitals and allows CT scans of patients' lungs to be remotely analysed by expert radiographers, thus limiting the potential spread of the virus. This technology originated from the research of Academy Fellow Professor Richard Kitney OBE FREng.

Identifying volunteers for field hospitals

In response to a request from medtech consultancy The Care Machine on behalf of NHS England, the Academy helped coordinate the recruitment of auxiliary support engineers for the field hospitals across the UK by putting together an expression of interest form, promoting it through all the professional engineering institutions and wider Academy networks, and creating a database of volunteers that could be deployed promptly. This effort resulted in over 1,000 volunteers signing up for placements in Nightingale hospitals across the UK.1

Find out more about how this process worked in this recording from one of the Academy's Innovation in a Crisis Q&A series on Nightingale Hospitals. Other examples of inspiring engineering collaboration can be found here.

Highlighting expertise

The call for ideas enabled the Academy to understand the role that many of the engineers in Academy networks were playing to address the COVID-19 crisis. These included repurposing research labs to be able to 3D print PPE, developing novel decontaminations devices and designing home monitoring systems. The Academy found experts who contributed to various projects:

- International knowledge sharing conversations - the Royal Academy of Engineering hosted conversations with global participants to discuss the engineering dimension of different international approaches to PPE provision, novel diagnostic test methods and contact tracing.
- Project CARE - identified material and test expertise for a programme supporting engineering entrepreneurs to make and supply personal protective equipment that can be used effectively in healthcare facilities in sub-Saharan Africa.
- Engineering a resilient future - a report highlighting the potential engineering challenges in the pandemic and the practical ways that they can be overcome

DnaNudge

Professor Chris Toumazou FREng repurposed a DNA diagnostic chip designed for nutrition so that it could detect the COVID-19 virus.

This technology means that a test can be performed on the spot, independent of a lab, with minimal training and, crucially, the results are delivered in a little over an hour. The Academy produced a letter of support for their UKRI funding application. DnaNudge tests are now being used in several London hospitals after gaining regulatory clearance and government has placed an order for 5.8 million test kits.

Respirator development

Providing support across the innovation pipeline - A PPE example

Research

Provided a small research grant to an existing Academy awardee to fund a research assistant for three months to carry out data collection and statistical analysis to prove the effectiveness of masks. This has now progressed to the prototyping phase.

Proof of concept

Additive Instruments, a spin out company from Imperial College London received a small grant to enable them to prototype a novel reusable respirator design with an electrospun nanofiber filter.

Development

The Academy helped to ensure regulation and standards compliance by supporting a number of researchers through BSI and MHRA processes. Academy connections were used to navigate these organisations or companies were supported by Fellows with medical device expertise.

> While there are lots of success stories of products receiving regulatory approval at incredible pace there were also areas where the functions delivered by innovations fell between existing standards or short deadlines stopped new designs advancing.

Scale up

Connections were made between manufacturers and innovators for a range of the products suggested. Promising products were also shared with NHS England to raise awareness of novel solutions to national challenges.

> “Initial seedcorn small support from the Academy has provided important statistical research to test very crucial hypotheses and underpin the design and development of a new respirator mask that could protect users across the world.”

Professor Mohan Edirisinghe FREng, UCL

Lessons learned

Engineering has had a vital role in the response to the pandemic. The engineering community responded rapidly and effectively to a crisis by repurposing facilities and innovations, collaborating rapidly and building networks that brought access to resources. As a result, it was possible to have significant impact within a very short time.

As the crisis developed the ideas received could be seen to change from ventilators, to PPE and then to ventilation and decontamination. Rapid changes in the issues seen to be critical highlighted the importance of cross disciplinary working and information flows:

1. It is vital to have a systems view with elements that might become critical highlighted ahead of time. There is a need for a process to activate engineers globally as the risk of a future crisis heightens and to articulate the areas engineering expertise should be focussed.

2. It is better in the longer run to first address needs identified by those with domain expertise and to incorporate input from the end user at all stages in order to ensure that solutions will work in practice. Although many useful ideas were suggested, those that were based on problems identified by workers on the front line or that repurposed an existing technologies or methods tended to have the most impact.

Engineers contribute most effectively when working in multi-disciplinary teams that have clearly defined goals. Engaging in regular communication with a broad base of expertise is the best way to be effective. An engineering-based, system-led approach ensures that problems are well defined and considered in context. For example the accuracy of a test is irrelevant if it cannot be manufactured at scale or requires two days to deliver the result.

Government needs to be able to identify gaps in its knowledge and have the capacity and pre-existing relationships to access that input rapidly in the heat of the moment. Experts can deliver but they need a vision, goals and a clearly defined frameworks to operate within. Some of the processes developed in this crisis could provide the basis for being better able to respond next time round, these would be worth capturing now.

Some ideas will take time to mature and the results of engineering innovations will continue to be observed as systems and technologies are iterated and deployed based on the changing circumstances and the most pressing needs. Engineers will continue to make improvements to ventilation and air cleaning technologies to increase the safety of offices and public transport, new manufacturing facilities will scale the production of vaccines and ventilator designs will be further modified for the needs of low and middle-income countries.

The Royal Academy of Engineering
is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

ROYAL ACADEMY OF ENGINEERING

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

Together we're working to tackle the greatest challenges of our age.

What we do

Talent & diversity

We're growing talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession.

We're developing skills for the future by identifying the challenges of an ever-changing world and developing the skills and approaches we need to build a resilient and diverse engineering profession.

Innovation

We're driving innovation by investing in some of the country's most creative and exciting engineering ideas and businesses.

We're building global partnerships that bring the world's best engineers from industry, entrepreneurship and academia together to collaborate on creative innovations that address the greatest global challenges of our age.

Policy & engagement

We're influencing policy through the National Engineering Policy Centre – providing independent expert support to policymakers on issues of importance.

We're engaging the public by opening their eyes to the wonders of engineering and inspiring young people to become the next generation of engineers.

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