# Engineering
# Research Infrastructure Roadmap



June 2017

EPSRC
Investing in research for
discovery and innovation

Engineering and Physical Sciences
Research Council

Engineering

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EPSRC

Investing in research for discovery and innovation

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# Capital Roadmap Foreword

The funding landscape for research infrastructure has changed over the last five years and continues to do so. Recent national investments made by Government have perturbed the infrastructure funding landscape and the invention and development of new and existing equipment means that the 'well found' laboratory is much better equipped than it once was. Whilst the days of allowing redundant equipment to gather dust in a corner of an unused lab are coming to an end, the need for additional laboratory space to enable advances in science and engineering is still of critical concern to many, since this comes with a price tag that is not insignificant and continues to rise.

EPSRC has and continues to offer a number of funding opportunities to support equipment and facilities, ranging from instrument development to large test rigs. This support is both for individual investigators to procure new equipment for their own use and for groups of researchers across the UK requiring access to specific facilities. This range of support now has to be tensioned with an increased emphasis on sharing and against the backdrop of recent government reviews and economic constraints that have encouraged greater scrutiny on spending. The role of EPSRC in delivering the large government investments has also been a critical one in recent years, through preparing business cases and providing the peer review to tension the science case of these investments with national and international standards and supporting the community driving the initiatives.

In July 2015, EPSRC began a series of community engagements to promote research infrastructure funding schemes and to identify future infrastructure needs of the engineering community.  Now, two years on, this roadmap has emerged from those discussions to stimulate and focus the infrastructure needs of UK engineering research. The recommendations within this document rely heavily on the research community and funders working together to fully share and exploit the existing infrastructure, promote future infrastructure investments and to establish a pipeline of ideas for future business cases to government that will enhance and accelerate knowledge and capability in engineering for the benefit of UK growth.

Andy Lawrence,
Head of Engineering,
EPSRC,
July 2017

CHAPTER 1

# Current Research Infrastructure Landscape

### 1.1 Background and Context

Research infrastructure ranges from equipment in the local research laboratory to international facilities. The Research Councils provide funding to purchase new equipment for instrument development, upgrade existing equipment and the associated running costs. The Research Councils also fund access to national and international facilities. Annex 1 provides a summary of these.

There have been a number of reports, detailed in Table 1, relating to the importance of research in delivering world class research in the past few years. Recommendations have included better equipment sharing, investment in the 'well-found' lab, and the creation of UK flagship institutes such as Sir Henry Royce Institute, Alan Turing and UK Collaboratorium for Research in Infrastructure and Cities (UKCRIC).

| | |
|---|---|
| 2010 | Wakeham Review of financial sustainability and efficiency in Full Economic Costing of research [**http://www.rcuk.ac.uk/documents/reviews/fec/fecreviewreport-pdf/**] |
| 2014 | BIS 'Creating the Future: A 2020 Vision for Science & Research' the consultation on proposals for long-term capital investment in science & research.[**https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/321522/bis-14-757-consultation-on-proposals-for-long-term-capital-investment-in-science-and-research-v2.pdf**] |
| 2014 | BIS "Our plan for growth: science an innovation". Chapter 3: Investing in scientific infrastructure. [**https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/387780/PU1719_HMT_Science_.pdf**] |
| 2015 | Efficiency, effectiveness and value for money by Ian Diamond, UUK. [**http://www.universitiesuk.ac.uk/policy-and-analysis/reports/Pages/efficiency-effectiveness-and-value-for-money.aspx**] |

**Table 1:** Relevant reports to research infrastructure funding landscape

## 1.2 EPSRC Funding Routes for Research Infrastructure

EPSRC (**https://www.epsrc.ac.uk/research/facilities/**) provides funding for equipment through multiple routes to enable researchers to access the equipment they require to deliver their research in the most efficient and effective way. The figure below demonstrates the EPSRC approach to equipment funding:

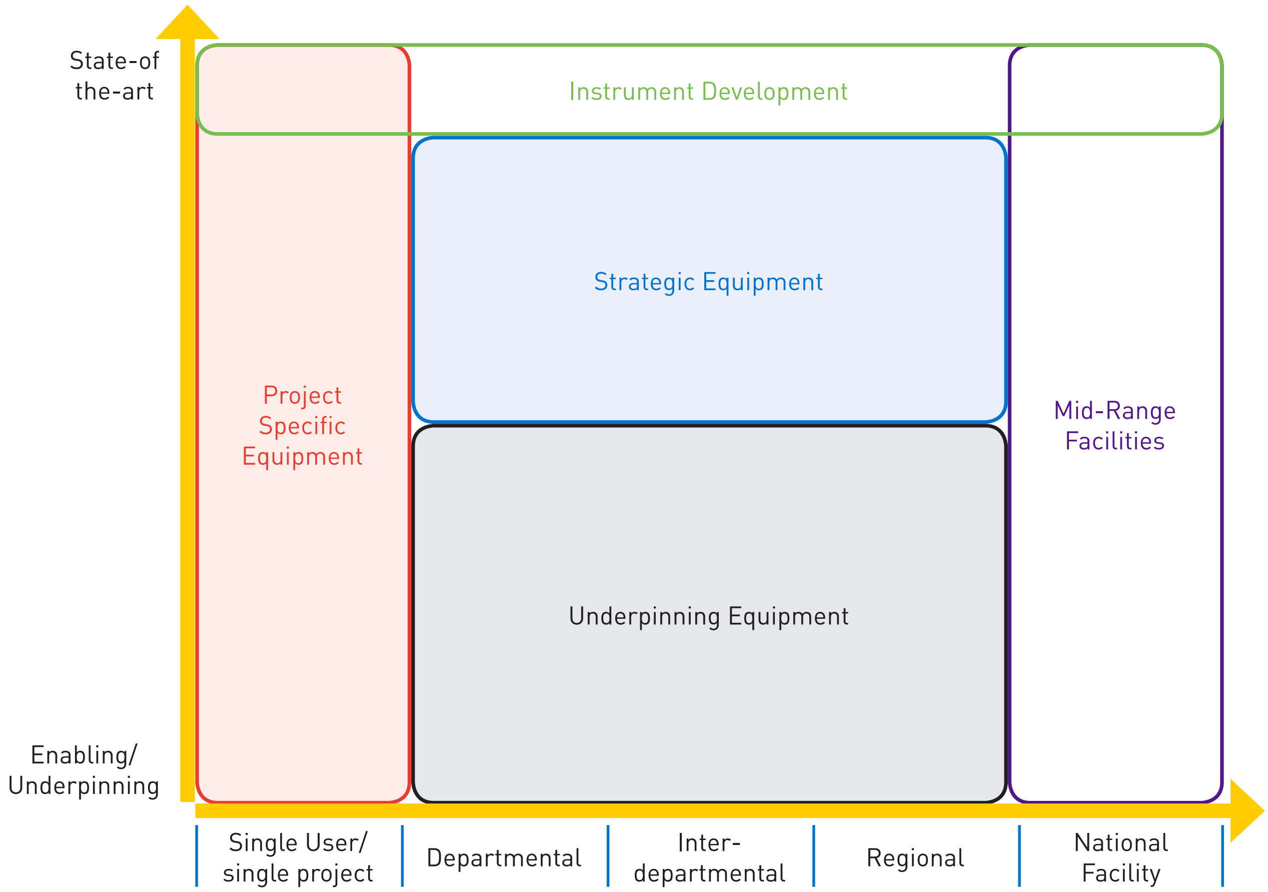


**Figure 1:** EPSRC support for research infrastructure

- **Project Specific Equipment** - this budget funds equipment directly needed for research that has been through a competitive peer review process.
- **Underpinning equipment** - this is essential equipment which provides the underpinning capacity across the breadth of the EPS research portfolio. EPSRC's Equipment Roadmaps will guide investments, to ensure they are targeted at equipment which will have the greatest impact on research that meets the nation's strategic priorities.
- **Strategic equipment** - this budget funds equipment which provides unique capability that is made available to both academic and industrial users.
- **Instrument development** - this funding enables the development of novel instrumentation through research grants which can involve the construction of a wholly new instrument from its basic components or it might involve the substantial modification of an existing instrument. This is essential for the advancement of UK capability.
- **Mid-range facilities** - these enable economies of scale in providing national access to techniques that are core to and align with EPS research priorities. We will continue to use contracts to drive better service for users, maximise value for money and financial sustainability.

Specific details on e-infrastructure funding are also available on the EPSRC website [**https://www.epsrc.ac.uk/research/ourportfolio/themes/researchinfrastructure/subthemes/einfrastructure/**]. The EPSRC has formulated an EPSRC e-infrastructure roadmap with the help of key stakeholders which will be updated on a regular basis. e-Infrastructure includes the use of the cloud as a platform for researchers, high performance computing, software and international activities.

### 1.3 Current Landscape

Between 2012 and 2015, EPSRC invested over £185M in strategic research infrastructure investments in addition to an average investment per year of £7 to 10M on equipment on research grants. A deep-dive into a cross-section of this investment specific to engineering highlighted the following as potential categories of equipment types relevant to engineers:

- 3D fabrication
- Spectroscopy, imaging and microscopy
- Lasers
- Sensors development, testing and implementation
- Specialist environments and testing facilities/rigs
- e-Infrastructure

Further details can be found in Annex 2 of the types of equipment within each category. Investment in engineering research infrastructure is supported by the Engineering, Energy, Manufacturing, Physical Sciences, ICT and Infrastructure Themes within EPSRC.


CHAPTER 2

# Working Together

### 2.1 Introduction

This section aims to engage the engineering community in working together with the Research Councils to:

- Develop new ideas;
- Prepare the strongest scientific case;
- Deliver best practice in sharing.

The engineering community's needs differ across engineering and with other disciplines. In general terms, engineering is frequently solution and application based, and requires both off-the-shelf and bespoke equipment to create a real-life test environment. Engineers use both large facilities e.g. ARCHER, Diamond and mid to lab scale equipment. This can range from characterisation equipment for new materials to large-scale testing rigs to simulating real-world environments.

### 2.2 Pipeline of Ideas

Future infrastructure investment relies heavily on the research community and funders working together. It is essential that there is a collegiate nature focussing on the identification of strategic opportunities for high quality science, and what infrastructure investment is required to realise those opportunities. The National Wind Tunnel Facility is one successful example of engineers speaking with one voice and the resultant capital investment in this sector demonstrates how much of an impact joined up thinking can have.

A unified message is necessary to stimulate advocacy within the research community in order to raise the profile of engineering to a political and public audience. Strategic vision and clear problem statement is central to delivery of both short term solutions, and long term impact.

Communities need to work together, across both geographical and disciplinary barriers, to generate the best case possible and ensure that any resulting infrastructure is shared appropriately. Having these on-going collaborations in place is crucial to inspire creativity, generate new ideas from the bottom up, and to allow the engineering community to be prepared for when funding opportunities arise.

To stimulate the pipeline of ideas within the engineering arena, the Engineering Theme in EPSRC organised a community workshop on the 22nd/23rd July 2015. 34 people from academia and industry participated in the workshop and their expertise covered the majority of engineering fields.

During the workshop participants considered the current infrastructure landscape which was built up following a survey of current capability (based on the institutions own data that was discoverable through equipment.data) and future priorities for strategic industrial partners and framework and strategic partner universities. This was further supplemented by internal EPSRC data analysis.

Participants then discussed barriers, both technical and collaborative, that were specific to engineering that potentially have a negative effect when support was being sought for infrastructure investment.

The second day of the workshop focussed on the generation of engineering infrastructure priorities. These were based on university responses to a survey as well as the participants own knowledge and interests. The group came up with sixteen priority areas that went to a vote. The top nine priorities were then discussed further and a timeline of activities developed for each one. Following the workshop these nine priorities were further rationalised into five priority areas and further details on each of the priorities and the recommendations for future action to be taken by the community and EPSRC in partnership, can be found below.

All of the developed areas (Chapter 3) have significant elements of community engagement, interaction and need for further development. As a specific case for investment is developed, a number of questions need to be answered; the answers to which will allow business cases to be easily completed when the opportunity arises. Questions include:

- Who are the stakeholders?
- What science will this investment enable?
- What risks are there if the investment is not made? What won't be done?
- What level of investment is sought capital and resource and why is this appropriate?
- What returns/impacts can be expected (economic, social, academic, environmental, policy)? Over what timeframe will these be realised?
- How does this align with other government/ industry/ global priorities?
- How will it be delivered?
- What other options are available internationally?
- Can additional support, e.g. industry, be leveraged?

To facilitate the development of this pipeline some questions to start your thinking are below. The scale of potential interventions is such that they will have an effect on the whole community, therefore it is a good idea to discuss these questions with as broad a range of stakeholders as appropriate.

### 2.3 Preparation of Business Cases

To manage the resources available for capital investment and standardise assessment of research infrastructure across all funding routes research infrastructure applications must be supported with a business cases. Presenting a successful case can be a challenge, Figure 2 summarises key factors to address as highlighted at the Engineering Research Infrastructure community workshop 22nd and 23rd July 2015.

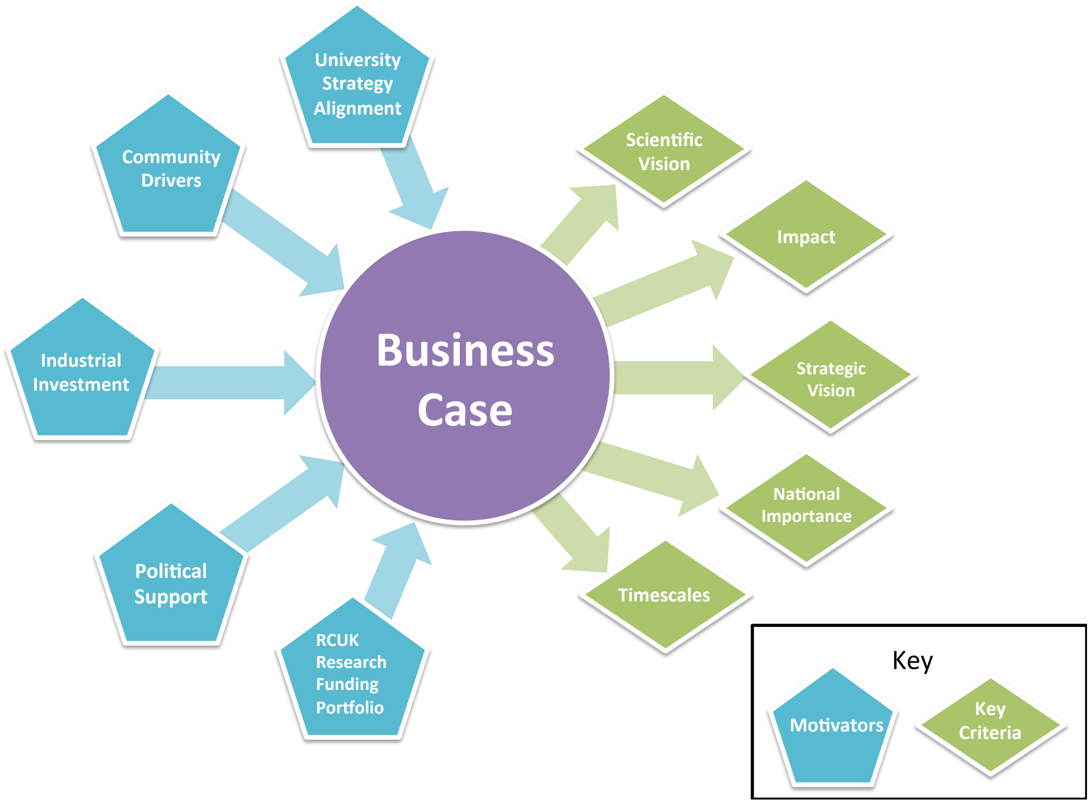


**Figure 3: Key factors to consider when writing a business** case at the Engineering Research Infrastructure community workshop 22nd and 23rd July 2015

- **Community Drivers** – The academic community needs to work together to generate support for Capital investment, building networks and identifying challenges. They need to be speaking with one voice, and are encouraged to think about their bigger vision rather than individual research programmes.

- **Industrial Investment** – Support from Industry when writing business cases can substantially widen the outlook of any potential investment. It provides opportunities for the academic community to demonstrate the national importance and impact of the research delivered. Industrial support is paramount to gaining leverage on Capital investment.

- **Political Support** – In the current economic climate understanding political and policy drivers is of significant importance when generating support for any large investments.

- **University Strategic Alignment** – Universities need to demonstrate strategic alignment, allowing confidence that they see the investment as a priority going forward.

- **RCUK Research Funding Portfolio** – There is an expectation that the track record of funding will be sufficient that Peer Review will be confident of the ability to deliver significant return from the investment made.

The Business Case needs to generate a rationale for support through defining certain key criteria:

- **Scientific Excellence** – The link between access to state-of-the-art equipment and scientific excellence needs to be clearly demonstrated.

- **Impact** – Across both short to long-term timescales, on a national and international platform

- **Strategic Vision** – Defining a wider vision than a specific research programme

- **National Importance**

- **Timeliness** – Why is it critical to make this investment now?

- **Governance and mangement**

The EPSRC website provides details the information needed on research grant applications that request funds for equipment (**https://www.epsrc.ac.uk/research/facilities/equipment/process/researchgrants/**)

The HM Treasury Green Book provides guidance for public sector bodies  on how to appraise proposals before committing funds to a policy, programme or project  which includes research infrastructure (**https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent**).

## 2.4 Equipment Sharing

It is important to make maximum usage of the facilities and equipment that are available; whether this is in relation to large scale facilities, stand-alone pieces of equipment within the lab, or data/software systems.

Reports published by the N8 Research Partnership in June 2012 represented the key findings from a series of work strands under the heading of "Sharing for Excellence and Growth". In 2015, UUK also published a report, Efficiency, effectiveness and value for money, highlighting the benefits of sharing equipment.

The recognition was that, with current financial constraints on public funds, facilities need to be used effectively by the research community and users to ensure wise investment of public resources. 4 Work strands focussed on:

- Benefits, barriers and cultural factors
- Identification of equipment sharing opportunities
- Business models for access and costings
- Opportunities for optimising use of medium scale facilities

To promote equipment sharing it is an EPSRC grant condition to publish all equipment funded as part of that grant and the equipment.data database.

At the Engineering Research Infrastructure community workshop on the 22nd and 23rd July 2015, participants also discussed barriers, benefits and cultural challenges toward equipment sharing (see Chapter 3). EPSRC is supportive of and encourages the community to work with them to prepare a strong business case for new investment.

CHAPTER 3

# Engineering Research Infrastructure Opportunities

### 3.1 Introduction

Chapter 1 provides an overview of the current policy and funding landscape for research infrastructure. Chapter 2 highlights working together with EPSRC in trying to build the strongest business case to support the investment. In this Chapter, the outcomes of the initial workshop, aimed at stimulating the pipeline of ideas, are described.

The priorities that were generated at the Community Workshop on the 22nd/23rd July 2015 represent the views of one group of people at one point in time. Therefore, while valid it is not a prioritised or exhaustive list. The community are encouraged to generate their own ideas and priorities within research groups/faculties/departments/universities/research areas/networks and engage with EPSRC to ensure alignment with our priorities.

### 3.2 Initial Priorities from Workshop

16 initial priority areas were identified at the workshop, these included:

- Materials Characterisation
- Machines and components/Propulsion and power
- More/all electric aircraft/vehicles
- Diamond Light Source/ISIS
- Software support
- Materials processing capabilities
- Data capture
- Developing next generation of medical imaging systems
- Energy storage
- Additive Manufacturing
- Wind Tunnels
- Instrumentation
- Graphene and 2D material device fabrication
- Healthcare Tech testing centre
- Engineering Software

The above list was prioritised at the workshop:

- All Electric Vehicles
- Diamond Light Source
- In-situ techniques facility
- Machines & Components/Propulsion & Power
- Materials Processing Capability
- Instrumentation; Acquisition, storage, dissemination

- Materials Characterisation
- Programmer Infrastructure
- Next Generation Medical Imaging Systems

Following the workshop, the Engineering Theme and a sub- group of attendees from the workshop further refined the 9 priorities. This selection was based on overlaps and similarities between them. Six areas are identified as being potential new ideas to consider further for research infrastructure investment, these are listed below and further described in the subsequent sections.

- Materials Fabrication and Sample Handling
  - o Includes; aspects of Diamond Light Source and Materials Processing Capability
- Next generation experimental imaging systems
  - o Includes; Next Generation Medical Imaging Systems has been broadened
- In-situ testing and characterisation
  - o Includes; In-situ techniques facility and materials characterisation
- New Electrical Power Systems and Applications
  - o Includes; All Electric Vehicles and elements of Machines & Components/Propulsion & Power
- Instrumentation, acquisition and dissemination
  - o Includes; Instrumentation; Acquisition, storage, dissemination
- Research Software Engineers
  - o Includes; Programmer Infrastructure

### 3.2.1 Materials Fabrication and Sample Handling

Materials fabrication has been advancing rapidly and the types of materials that can be generated have become more complicated. Fortunately these new materials have enhanced properties and researchers are able to design materials based on the required properties. Materials underpin almost every area of research and therefore advances in this priority can have an impact in many additional fields. For example, there are opportunities for novel instrumentation and research that will allow multi-functional, multi-component materials to be generated via additive manufacturing or advances in packaging material that is "smart".

Following material fabrication there is a need to characterise the result either through in-situ testing or using next generation imaging techniques. However, many materials require controlled environments either for their production or storage. Therefore, opportunities exist for developments and investments in environmental and in-situ cells either for lab based facilities or national facilities such as Diamond or ISIS.

This priority aligns to the wider Advanced Materials strategy and the work being done by the Advanced Materials Leadership Council. Materials also underpin a wide range of research right across EPSRC's remit and therefore this priority has the potential to contribute to all four outcomes; productive, connected, resilient and healthy. Recommendations:

- The community should understand the wider materials landscape and develop specific suggestions for engineering interventions in this space.
- Working with the large facilities, sample handling advances should be co-produced.

### 3.2.2 Next generation experimental imaging systems

Engineering processes happen across length scales. Imaging systems are therefore crucial to increase our understanding in a wide range of engineering problems e.g. surface or internal material structures. Imaging equipment is a staple of any well-found laboratory and there are national facilities such as Diamond and ISIS that researchers can access. The opportunity space within this priority covers the development or repurposing of imaging techniques to allow a wider range of experimental setups to be interrogated such as; better medical diagnostics through to imaging of concrete formulations. It covers all imaging approaches and all scales but does not cover continuous imaging of active processes; this is included within the in-situ testing and characterisation priority.

This priority is a key component of the EPSRC Engineering Grand Challenge on across length scales. Imaging is fundamental to all areas of engineering e.g. medical engineering to civil engineering; this priority is not confined to any subset. We expect this priority to make significant contributions to the productive, resilient and healthy outcomes.

Recommendations:

- The community should come together and carry out horizon scanning activity to look for gaps and opportunities, including transfer of imaging techniques between fields.

- The novel instrument development proposals are encouraged under this priority. These could include the development of multi-modal techniques.

- Researchers in this area should work closely with end users to maximise uptake and impact.

### 3.2.3 In-situ testing and characterisation

A lot of experiments are carried out or modelled in controlled environments to prove a concept; although these experiments can reveal a lot of understanding they are not always reflective of nature or the final processes. Therefore, there is a need to improve our ability to monitor and carry out experiments in real-world environments. For example; can through life service performance monitoring be more widespread? This would enable earlier warning for when something is about to fail or information on how a product/system/structure can be improved during its operation? This priority applies to a wide range of engineering disciplines including; chemical (e.g. continuous reaction processes), materials (e.g. corrosion in extreme environments), mechanical (e.g. varying stress under component operation) and civil (e.g. non-destructive testing of structures).

The recent "Towards Engineering Grand Challenges" call (2015) had a focus on engineering across length scales, from atoms to applications. This Grand Challenge area considers design across the scales for both products and systems, looking at new approaches to bridge the meso-scale gap taking into consideration that many engineering systems are dynamic. Part of this will involve developing robust and efficient multi-scale methodologies which are generic and can be adapted to different engineering problems.

This priority has significant likelihood to support the productivity, resilience and healthy outcomes to achieve their ambitions.

Recommendations:

- This priority should include representatives from across the TRLs and across different organisation types and sectors.

- Interventions under this priority could cover the range of equipment/facility options and EPSRC does not express a view on which is most appropriate.

- Relevant communities should come together to develop detailed interventions under this priority identifying the opportunities and risks.

- The community as a whole should advocate for the prioritised detailed interventions to the relevant audiences.

### 3.2.4 New electrical power systems and applications

In recent years the world has seen a move towards electric transportation systems to reduce greenhouse gas emissions. However, there are still a number of opportunities to impact the development and uptake of these electric vehicles. This priority focuses on the further development of novel battery technology, alternative energy storage systems, electric motors and drives, diagnostics/prognostics, autonomous electric vehicles and consideration of through life performance.

This priority gives engineers an opportunity to address a significant societal challenge and will feed directly into EPSRC's resilience, productive and connected outcomes. There are opportunities for involvement at all scales from designing new materials for batteries to whole systems approaches e.g. autonomous electric aeroplanes.

Recommendations:

- The community should come together and explore opportunities for multi-/cross-sector working and develop ideas for further investigation.

- We would expect demonstrators to be developed and potentially supported through standard EPSRC routes or other routes to test ideas further.

- Researchers should engage with the wider population to explore responsible innovation under this priority and the impacts it could have.

### 3.2.5 Instrumentation, acquisition and dissemination

Every measurement and computational study generates information to be transferred, analysed and stored. Experimental design requires selection of an appropriate sampling rate for the sensors.

Unfortunately, the complexity of modern experiments, with their large sensor arrays means the ability to record the signals can become the limiting factor. Therefore there is a pressing need to improve this and remove this limitation; this could involve the development of faster disk writing processes, data processing (i.e. reduction) on-the-fly or co-creation of new instrumentation with data handling at its heart.

An aligned consideration within this priority is what happens to the data once generated? The complexity of modern experiments mean that they are rarely replicated in full and it becomes more essential to share original datasets. Therefore, the community will have to embrace the open data agenda and work together to develop standards around metadata allowing quick identification and retrieval of datasets. It is also important that the components of this data system are interlinked with suitable analysis systems, e.g. high performance computing.

This priority is broad in nature but it underpins all research and is a key enabler for all EPSRC outcomes to be achieved.

Recommendations:

- The community should develop and share an understanding of what is needed in the area of data acquisition. This could be co-creation of new solutions with ICT researchers or the purchase of high-speed data acquisition infrastructure to be shared by the community.
- There should be closer interaction between researchers and those who provide the e infrastructure systems (i.e. data and compute) so the infrastructure limitations can be understood and overcome.
- Community action around the agreement of metadata standards that will allow easy archiving and retrieval of experimental and compute data.
- There should be national sharing of best practice for data management within engineering.

### 3.2.6 Research Software Engineers

To maximise impact of software developments within engineering it is essential to provide sustainable software which includes good documentation and version control. These activities require specialist skills and can be provided by research software engineers at all career stages who understand the core research area combined with first rate programming skills. Although these skills may only be required for a few months on individual projects (and can be requested through standard mode) that effort can be spread across a longer period of time, therefore these experts tend to work on multiple projects at a time. Therefore, to ensure retention of first class individuals it can be beneficial to pool requirements across a faculty or institution where their salary is underwritten by the institution but reimbursed via grant income. Research Software Engineers are ideally placed to act as advocates for sustainable software, access to suitable compute resources and to build relationships between researchers while also teaching others.

This aligns to EPSRC's focus on research software engineer as evidenced by the fellowship call in 2015. There is also a national movement to get research software engineers recognised and a suitable career structure developed within universities.

Recommendations:

- Applicants to standard mode are encouraged to consider including Research Software Engineer support through their pathway to impacts.
- EPSRC to review the Research Software Engineer fellowship scheme and consider further support opportunities.
- The community should advocate the benefits of centralising Research Software Engineering support within their institutions.

CHAPTER 4

# Case Studies

**EP/C515668/1: Portfolio Partnership in Photonics and EP/L021129/1: CORNERSTONE**

- Contact: Professor David Payne
- *"The proposal concerns the development of a range of novel photonic materials and waveguide fabrication processes. The work is focussed on several key areas of photonics technology: planar lightwave materials and devices, microstructured fibres (holey and photonic bandgap), micro-structured crystalline devices and materials, compound glass processing and fibres, and optical processing of materials."*
- Delivery Plan – 'Data-driven Economy' (Connected) and 'Business innovation via digital transformation' (Productive).

**Case Study**

The University of Southampton houses the £9m ESPRC Centre for Innovative Manufacturing in Photonics, which was joint-funded with 13 industrial partners, including BAE Systems and M Squared Lasers Ltd. The centre supports 30 research groups, which conduct investigations into advanced research areas in photonics such as biosensing, pulsed laser deposition, siliceous and non-siliceous optical fibres, and special fibres for ultrafast lasers. The centre aims to continue to innovate in the field of photonics, increase the UK's contribution to global photonics production (already 2.3%[1]), and help the UK to retain its position at the forefront of international photonics research.

The centre contains over 730m$^2$ of cleanrooms, and houses four main facilities. The facilities allow researchers access to cutting-edge research equipment including chemical deposition lathes, fibre drawing towers, ultrasonic drills, high purity tube furnaces, and ion beam etching stations. Thin-film fabrication can be used to create photonic crystals, memory devices and reconfigurable circuits; the fibre-drawing tower can weave optical fibres up to 1mm in diameter; Acid and ion-beam etching stations give users full control over the creation of custom components. Researchers have freedom to create optical fibres and photonic device components with a wide range of materials, and test them under an array of environments and conditions.

The Centre for Innovative Manufacturing in Photonics brings together talent from across the research landscape to participate in the future of photonics. The research pursued here and at similarcentres such as the CDT in Applied Photonics at the University of Strathclyde can support revolutionary healthcare advances such as beam-based treatment (the useof focused light to identify and cure diseases), lead to enhanced navigation and remote sensing technologies, impact upon global communications.

[1] Centre for Innovative Manufacturing in Photonics (2016). About us.

Read more:

**http://www.cimp.soton.ac.uk/research.html**

**https://www.epsrc.ac.uk/research/centres/innovativemanufacturing/imrcphotonics/**

**EP/M029778/1: National Facility for In Vivo MR Imaging and National Facility for In Vivo MR Imaging (Cardiff)**

- Contact: Professor Derek Jones
- *"This project will develop MRI in new ways to quantify tissue structure at the microscopic scale. The principal method looks at how water molecules moving in the body are impeded by fine structure within the tissue. While diffusion MRI has existed for 30 years, current MRI machines restrict us to measuring only relatively large molecular movements. This blurs our picture of the tissue, prohibiting us from looking at important characteristics, such as the dimensions of individual cells, or the density or packing of nerve fibres."*
- Delivery Plan – 'Transforming community health and care' (Healthy) and 'Improving prevention and public health' (Healthy).

**Case Study**

The National Microstructure Imaging Facility opened in Spring 2016 at Cardiff University's Brain Research Imaging Centre (CUBRIC), following funding from EPSRC and the Wolfson Foundation. It is currently one of only two such facilities in the world (the other being located in Boston, USA). The facility contains a 3 Tesla MRI scanner, which has been especially adapted to make the magnetic field gradient (the extent to which the magnetic field varies with position) up to seven times stronger than conventional scanners. This equipment gives an unprecedented level of detail, with the ability to probe tissue on the length scales of a micrometre (thousandth of a millimetre) unlocking new properties of the brain for investigation.

The new facility at CUBRIC is at the cutting-edge of MRI technology. One of the key attributes of the scanner is the ability to map water diffusion through tissues at a much finer scale than was previously possible, even modelling nerve fibre density, and parameters such as diameter and membrane permeability. The processes and features which become measurable can allow for earlier and more accurate identification of brain diseases, making treatment more targeted and effective, and providing new insights into the mechanisms underlying mental illness. It will also improve the ability to measure similar structure in focal lesions including tumours, where cell packing and tissue infiltration are key hallmarks of disease.

This project will re-enforce the position of the UK as an international leader in the field of neuroimaging research. The development of national and international research partnerships has the potential to support interdisciplinary advances in drug development, and new insights into mental health. CUBRIC is now accepting applications from researchers who want to use the facility.

Read more:

**http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/M029778/1**

**http://sites.cardiff.ac.uk/cubric/our-funders/epsrc-funding/**


MRI scanner at Cardiff University's Brain Research Imaging Centre (CUBRIC)

**EP/L005689/1: HIVE and HIVE (University of Bath)**

- Contact: Mike Lawrence (BRE Centre for Innovative Construction Materials)
- *"The HIVE is a building that has been especially designed to allow research into novel building materials and systems which will reduce the environmental impact of the Built Environment. The building has 16 individual cells that have been carefully constructed to be completely insulated from each other, except for one, and in some cases two faces which are exposed to the external environment. The faces are used to install walls made from a whole range of materials and constructive systems, and the performance of these walls is evaluated in real life conditions."*
- Delivery Plan – 'Transformation to a sustainable society: the circular economy' (Productive) and 'Reliable infrastructure' (Resilient).

**Case Study**

HIVE opened in the University of Bath's Building Research Park, following a £1m EPSRC grant. A specialist materials test environment, HIVE was designed with the aim of investigating low-carbon alternatives to traditional construction practices, and making homes more energy-efficient. Around half of the UK's carbon footprint is embodied in infrastructure (244Mt$CO_2$e in 2015)[1], so making efficiency improvements in this sector has the potential to drive progress towards emissions targets.

*"Finding new, sustainable methods of construction - properly tested in a real building such as the HIVE - is essential if the UK is to lead the way in low carbon homes and meet challenging emissions targets."* – Dr Mike Lawrence, Director of the University of Bath's Building Research Park

HIVE's 16 insulated test cells are used to subject materials to flood conditions, extreme weather and horizontal loading stresses. A hygrothermal cell can assess the movement of heat and moisture through the structure, helping researchers to identify where energy is being lost and test new insulation materials. A double height and width stress-testing cell is informing flexible construction designs. HIVE uses sustainable, low-carbon materials such as hemp and wood fibre, which absorb greenhouse gases and airborne pollutants such as Volatile Organic Carbons. HIVE's research into materials that sequester $CO_2$ may even lead to buildings with a net negative carbon footprint.

[1] Committee on Climate Change (2015). *Meeting Carbon Budgets – Progress in reducing the UK's emissions*.

Read more:

**https://www.epsrc.ac.uk/newsevents/news/hivecreatesbuzz/**

**http://www.bath.ac.uk/research/news/2014/09/25/hrh-to-open-hive/**

Hemp panel University of Bath

**EP/K040316/1: Ground Engineering Research (Centrifuge) and CEIGR (University of Sheffield)**

- Contact: Professor Michael Houndslow
- *"Ground Engineering is of critical importance to society through the provision of infrastructure and underpins key challenges relating to energy provision, dealing with the impact of climate change on our infrastructure and manufacturing the future through the use of novel material in construction."*
- Delivery Plan – 'Reliable infrastructure' (Resilient).

**Case Study**

The Centre for Energy & Infrastructure Ground Research (CEIGR) aims to facilitate world-class research into energy geotechnics and infrastructural resilience. It is becoming increasingly necessary to construct buildings that have a low-environmental impact, yet are strong enough to withstand decades of unpredictable environmental stresses. Soil-structure interaction is foundational to the stability of buildings, and understanding the effects of environmental change and long-term weathering on structures will allow us to create a more stable and sustainable infrastructure.

Centrifuge modelling is a powerful experimental technique used to aid understanding of material stress responses. At the heart of CEIGR is a state-of-the-art 4m diameter 50g-ton geotechnical beam centrifuge, which is capable of rotating a mass of 500kg at 150g, giving researchers an unprecedented level of detail. The centrifuge will be open to academics from across the research landscape, promoting an interdisciplinary approach to ground engineering. It is hoped that the research performed at CEIGR will inform contemporary construction techniques, extending the lifespan and increasing the sustainability of infrastructure across the globe.

Advancements in sustainable construction will give structures greater flood and earthquake resistance, reduce maintenance costs, and lessen the environmental impact through more efficient use of resources. The wastage inherent in poorly-built structures has a large environmental and economic cost, especially in the developing world where access to contemporary construction techniques and materials is limited[1,2].

[1] House of Lords (2016). Select Committee on National Policy for the Built Environment. 41 – 55.

[2] Bhattacharya, A. (2015). Driving sustainable development through better infrastructure.

Read more:

**http://www.shef.ac.uk/ceigr/about**

**http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/K040316/1**

4m beam

CHAPTER 5

# General Recommendations

1. The engineering community is invited to consider the funding opportunities available to support research infrastructure relevant to their research priorities.

2. The Engineering Theme will continue to work with the Research Infrastructure Theme and the engineering community to consider the bespoke funding mechanisms required to support research infrastructure in engineering.

3. The Engineering Theme and the engineering community should work together to develop new ideas, prepare strong business cases and share best practice in utilising research facilities.

4. The engineering community is invited to consider the ideas generated at the Engineering Capital Workshop and associated recommendations.

# Annex 1

## National and International Facilities

There are a number of facilities supported by the Science and Technology Facilities Council (STFC). Major facilities include;

- **Diamond Light Source** - The UK national synchrotron facility based at the Rutherford Appleton Laboratory.
- **ISIS** - Pulsed neutron and muon source at the Rutherford Appleton Laboratory.
- **Central Laser Facility** -Based at the Rutherford Appleton Laboratory, the facility provides access to large-scale laser systems for researchers from the UK and other EU countries.
- **Institut Laue-Langevin (ILL)** - International research centre based in Grenoble which operates the most intense neutron source in the world.
- **European Synchrotron Radiation Facility (ESRF)** - An international institute in Grenoble which operates Europe's most powerful synchrotron light source.

EPSRC provides support for groups to carry out projects which use the facilities through research grants. Typically EPSRC funds the research staff and consumables needed for a project, with the research group accessing beam time at the facilities free at the point of access. STFC is responsible for allocating access to the facilities.

You need to apply to STFC for funding to cover facility access and related travel and subsistence costs. Any costs for facility time associated with carrying out experiments on the STFC facilities are not an eligible item on an EPSRC research proposal.

For more information see research facilities on the EPSRC website (**https://www.epsrc.ac.uk/research/facilities/access/supportedfacilities/**), STFC website (**http://www.stfc.ac.uk/research/our-science-facilities/**) and the Research Councils UK (RCUK) Large Facilities Roadmap (**http://www.rcuk.ac.uk/Publications/policy/lfr/**).

## Current EPSRC mid-range facilities – As of June 2016

Mid-range facilities provide expertise and access to equipment in:

- **SuperSTEM** – Primary Location; Daresbury Science and Innovation campus
- **Beamline at the European Synchrotron Radiation Facility (ESRF) X-ray Magnetic Scattering (XMaS)** – Primary location; ESRF, Grenoble
- **EPSRC National Chemicals database service** – Primary location; Royal Society of Chemistry
- **EPSRC UK National Service for Computational Chemistry Software (NSCCS)** – Primary location; Imperial College London
- **EPSRC National Crystallography service** – Primary location; University of Southampton
- **Electron paramagnetic resonance spectroscopy (EPR) also known as electron spin resonance (ESR)** – Primary location; University of Manchester
- **EPSRC National Dark Fibre Infrastructure Service** – Primary location; University College London
- **Free electron laser** – Primary location; Radboud University, Nijmegen, The Netherlands
- **EPSRC National Mass spectrometry service** – Primary location; Swansea University
- **EPSRC National Solid-state nuclear magnetic resonance (NMR) service** – Primary location; Durham
- **The UK 850 MHz Solid-State NMR Facility** – Primary location; University of Warwick
- **EPSRC UK National service for X-ray photoelectron spectroscopy (XPS)** – Primary location; Newcastle University
- **EPSRC National Centre for III-V Technologies** – Primary location; University of Sheffield

Further information of these services and relavent contacts can be found on the EPSRC website (**https://www.epsrc.ac.uk/research/facilities/access/currentmidrangefacilities/#iiiv**)

# Annex 2

## Details of engineering equipment by category

A deep-dive into a cross-section of the EPSRC strategic equipment investment relevant to engineering identified 6 categories of equipment types. Some example equipment for each category is given below.

- **3D Fabrication ('made to order' manufacturing)**
  - Printing Facilities
  - Molecular Beam Epitaxy
  - Ferromagnetic Semiconductors Fabrication
  - Thin Film Growth Capabilities facility

- **Spectroscopy, Imaging and Microscopy (general characterisation of 'things')**
  - X-ray Diffraction
  - Mass Spectrometer
  - NMR Spectrometer
  - Transmission Electron Microscope
  - Scanning Electron Microscope
  - X-ray Microscope
  - Microscope testing facility
  - Materials characterisation facilities (advanced, nano-, ceramics, composites…)
  - Dielectric Characterisation equipment
  - Magnetic field characterisation facility
  - Cameras

- **Lasers (Stand-alone laser component of characterisation techniques and equipment for laser development)**
  - Ion Beam Laser
  - Femtosecond Laser
  - Laser Testing facility
  - Quantum Cascade Laser

- **Sensors Development, Testing and Implementation**
  - Sensor Testing facility
  - Biologically-inspired, quantum, acoustic, gravitational, vibrational sensors
  - Sensor networks facility

- **Specialist Environments and Testing Facilities/Rigs**
  - Electronic testing facility
  - Wireless Channel emulator
  - Propulsion systems research facility
  - Tactile Internet Facility
  - Robotics Facility
  - Clean Room
  - Mobile reactor
  - Wind tunnels

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