Report on the outcomes of the Advanced Materials Monitoring Portfolio Evolution Pilot

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1. Introduction

Through the Monitoring Portfolio Evolution (MPE) exercise we aim to measure quantitatively and qualitatively how well we are progressing towards our published trajectories and strategies; both in terms of relative size of research areas (i.e. grow, maintain, reduce) and strategic direction (e.g. a focus on early career research). It is not our intention to change any decisions or strategies at this stage but rather to identify trends and changes within our portfolio to help plan future activities.

Specific objectives for MPE are:

- To understand the nature of changes and trends within our portfolio
- To capture examples of where the portfolio has been successfully shaped and developed
- To identify any actions EPSRC could undertake to better enable us to achieve our published portfolio strategies or funding trajectories

Before we implement MPE across our entire portfolio we undertook a pilot exercise. This focussed on how the area of 'Advanced Materials; has evolved since 2011. This area is covered by 20 research areas across a number of themes including Energy, Engineering, Healthcare Technologies, ICT, Manufacturing the Future, Mathematical Sciences and Physical Sciences. We asked Strategic Advisory Teams (SATs) and Scientific Advisory Committees (SACs) to engage with their peers in the research and user communities using one of three engagement approaches in order to explore whether one approach was more effective than another. A framework of questions was provided to help structure this engagement.

A Strategic Advisory Network (SAN) working group with Prof Anne Anderson as the Council member representative performed an integration role across SATs. The outcomes of this working group were presented to Council at their March 2014 meeting where they were asked to make a decision on whether to proceed with the full MPE exercise.

This report contains the outcomes of this pilot including: the SAT outputs on the Advanced Materials area, the SANs conclusions and recommendations on the piloted methodology, Council's decision, and EPSRC's planned next steps on MPE.

2. Advanced Materials

2.1 Context for Advanced Materials

Exports containing Advanced Materials are estimated to be worth £53BN to the UK economy with 15% of UK GDP being dependant on materials. This importance of Advanced Materials to the UK economy has been recognised by Government most visibly in January 2013, when Advanced Materials was identified as one of its Eight Great Technologies.

Each of the Government's 11 industrial sector strategies recognise the pervasive value of materials innovation as critical to achieving success in the sector. Many have highlighted critical materials needs and requirements and this serves as a useful framework for National Importance assessment.

A number of strategic actions by Government have substantively shaped the Advanced Materials research portfolio including £50M to support Graphene Engineering, £45M additional capital for research infrastructure as part of the March 2013 budget statement and more recently £270M for research and training into Quantum Technologies where again materials has a critical role.

EPSRC support for Advanced Materials research is derived from nearly all of the Delivery Plan Challenge and Capability themes and totals £385M in current research and training grants across 23 institutions. £106M is leveraged in contributions from businesses across a wide range of industrial sectors reflecting the pervasive nature and value of materials technology.

Since publication of the shaping strategies in 2011-12, EPSRC has taken a number of strategic actions in order to influence the shape of the materials portfolio, the most significant of which include calls for proposals in; materials substitution £10M, Centres for Innovative Manufacturing £33.2M, Energy & Physical Sciences £5M, Nanoscale Designed Functional Materials £1.2M, Resource Efficiency Sandpit £4M, Ground & Structural Engineering £3M and finally Centres for Doctoral Training £507M.

For the purposes of this pilot exercise Advanced Materials are defined as: Materials and their associated process technologies with the potential to be exploited in high value added products or services.

20 Research Areas (RAs) (see Annex A) have been identified as having either primary relevance (central to advanced materials research) or secondary (having some significance through process technologies or end-use). Common topics to the shaping strategies published are:

- Focus on applications and societal drivers: The majority of strategies emphasize the opportunities for new disruptive technologies in energy, manufacturing and healthcare, as well as novel applications in sectors such as electronics.
- Grand challenges: Strategies indicate high relevance to the Physical Sciences Grand Challenges, in particular to "directed assembly of extended structures with targeted properties" and "nanoscale design of functional materials".
- Resource efficiency: Several strategies discuss issues around resource stocks e.g. lowering dependence on rare earths from China and using more abundant elements.

2.2 Observations and Perceptions in the Advanced Materials Portfolio

The following observations and perceptions (*not necessarily related to Shaping Capability*) in the Advanced Materials portfolio have been highlighted by SATs following their engagement with stakeholders:

Positive perceptions drawn from the SATs

- A shift towards more industry relevant research, with more industrial collaboration generally seen and an increase in awareness of cradle to grave life-cycle analysis.
- A shift towards: multi-functional materials, the design of materials, self-assembled materials and bottom-up integration, soft materials, and nanomaterials.
- A greater shift towards interdisciplinary research and more larger grants and large centres.
- Targeted calls have had a positive impact on behaviour.
- Shaping Capability has initiated some diversification of research direction for individual scientists, particularly at the early career level.
- Strategic capital investments have had a positive impact on research and have worked to shape the portfolio to some extent.
- Mathematical sciences make a core, underpinning contribution to the whole of the Advanced Materials area.

Perceived concerns highlighted by the SATs

- Funded research is now less adventurous and risky.
- In several device research communities, there was not the expected level of consideration of novel materials and potential manufacturing process, alongside 'isolated' device research.
- Some SATs believe that workshops have had a negative impact on behaviour.
- Several of the areas listed as "maintain" have in fact reduced in size. If this reduction is statistically significant, EPSRC need to ensure that this reduction is not damaging the RAs, and that these areas are being properly prioritised.
- Funding is not well structured or long term enough to support the career development of young researchers.
- Fellowship areas do not map well onto the shaping capability strategy

The following actions have been suggested through the pilot process to better enable EPSRC to achieve its published portfolio strategies and funding trajectories:

Proactive shaping

- More investment is needed in materials development and scale-up than characterisation in order for there to be more impact.
- Increase specific capabilities not possessed by the UK e.g. efficiency measurement for solar devices.
- Mathematical sciences should play a greater role in advanced materials research.
- Focused calls will increase research in specific areas, and provide a direction for this research.
- Shift to more applied research and a flexible response to user needs.
- Since the rationales were published there has been significant major investments in the area of advanced materials e.g. EU FET Flagships and EPSRC needs to respond to this in considering future strategies and investments in advanced materials.

Suggested ideas

- Encouraging greater equipment sharing – for example funds for technicians linked to equipment sharing.
- Partnership funding for large centres. Case studies to demonstrate that large centres are working.
- Project partners could contribute to research outcome statements and we could collect 'Problem statements' from industrial end-users in advance. Also, develop research links between different industrial sectors.
- Case studies to demonstrate that great ideas will be supported even at small scale. Flexible funding mechanisms, including small grants for blue skies research and early career stage researchers and larger grants for more established researchers.
- Make early career fellowships available across all/broader areas (e.g. "Advanced Materials") – this will give a stronger field of applications and will support a baseline of skills across the portfolio. EPSRC could also work with universities to ensure that fellows are offered a permanent position at the end of their fellowship.
- Networks & workshops to help to bring communities together.
- Greater aggregation of RAs and redefinition of RAs to give better coincidence of academic and industry perspectives.
- Clearer definition of shaping actions – what this really means and how researchers can target within that. In addition to the information already provided on the RA web pages, a short concise summary of the strategy could be included to help focus the imagination.
- More direct communication to researchers (e.g. road shows).
- Any published strategies for cross-cutting themes – such as advanced materials – must be incorporated by clear narratives that would explain the context, rationale, importance and opportunity presented by the particular

theme – it must be clear to the community why they should care, and why they should respond.
- Take care to maintain and demonstrate transparency in the funding process.
- More could be undertaken to examine the response of the community in peer review (of all forms) to ensure that considerations of portfolio strategy were being adequately taken into account.

2.3 SAN conclusions

- The UK research landscape is a complex environment against which many drivers and influences are evident. For the EPSRC portfolio it remains early days in terms of identifying major impacts of shaping capability, and it is hard to ascertain whether the approach to applying by applicants or the research approach undertaken itself has changed. This pilot monitoring activity has highlighted what we believe to be a number of early indicators of Shaping Capability in Advanced Materials.
- Overall Shaping Capability is broadly on track to meet our strategy for each of the Research Areas (RAs) – the majority of grow areas have grown in proportion, reduce have reduced and so on. There are some exceptions where additional actions may need to be taken to ensure areas realise published strategies. It is observed in a minority of cases that just labelling an area grow, maintain and reduce does not appear on its own to necessarily produce the desired outcome.
- Thematic calls appear to influence research areas in a positive way e.g. the impact of additional funds into graphene engineering has substantively shaped the advanced materials portfolio.
- There is anecdotal evidence of more collaborative applications and that people are thinking about shaping capability.

A number of examples have been highlighted by the SATs throughout their discussions as early indicators of positive shaping impacts in the Advanced Materials portfolio. Areas highlighted include: Fuel cells, ceramics, metals and alloys, non-CMOS devices (energy applications), RF and Microwave devices, non-CMOS devices (plastic electronics), statistics, polymer materials, performance and inspection of mechanical structures and systems (PIMSS), biomaterials and tissue engineering, synthetic biology, graphene, and photonic materials and metamaterials. Further details of these impacts are given in Annex B.

3. Monitoring Portfolio Methodology

As outlined in the Introduction the purpose (at this stage) of monitoring the portfolio has been to (a) inform Council of the nature of any changes taking place in response to the published strategies, (b) to identify good practice and (c) highlight any emerging issues or impacts.

To meet these objectives the portfolio has been assessed quantitatively and qualitatively by selected SATs and SACs and SAN membership.

The pilot considering Advanced Materials has enabled testing of the monitoring methodology in two main ways:

- Quantitative Data: Testing different presentational styles with SATs in order to highlight trends and changes in the portfolio

- Qualitative Data: Testing a question framework and three different engagement methods for SAT members to use with research and user communities in order to solicit knowledge about the portfolio.

The SATs piloted three engagement options: focus groups, engagement framework, and a "free" unconstrained approach:

Option	Description	Themes piloting this engagement approach
Focus groups To pilot *how* the information is gathered	EPSRC asked SAT members to hold a focus group* composed of members of the relevant research/user communities **A focus group can be interpreted broadly e.g. a small group of 3 people or a larger group.*	• Healthcare Technologies • Mathematical Sciences
Engagement framework To pilot *who* is engaged with to gather information	EPSRC provided SAT members with guidance on the types of people we expected them to engage with e.g. Pro-VCs, HoDs, leading researchers	• ICT • Manufacturing the Future
Unconstrained To pilot the *how* and the *who*	SAT members were given the scope to use an engagement approach of their own choosing	• Engineering • Energy • Physical Sciences

The SAN working group observed each of the final SAT meetings and were asked to assess the 3 engagement options against the following assessment criteria: *Primary criteria*: a) Quality of advice; b)Efficacy; c)Scalability and *Secondary criteria* d)Translatable; e)Cross-cutting perspective; f) Portfolio analysis; g) Efficiency and cost-effectiveness

Conclusions from the SAN working group on each of the methods are summarised below:

Engagement Approach	Assessment Criteria	SAN Comments Advantages	 Disadvantages
Focus Groups	Quality of Advice (P)	• It was easier to engage the community if the SAT member was reasonably senior	• This approach didn't work well as it was too variable and reliant on individuals

		• The quality of advice could be good • It allowed different interpretations and a set of perspectives from different viewpoints	• They did get some good feedback on occasion but it was biased depending on the people in the room
	Scalability (P)		• This approach was less scalable
	Cross Cutting perspective	• It was the best approach for looking at the cross-cutting perspective – it allowed people to develop ideas and sound-off each other	
	Efficiency and cost-effectiveness	• It did work well if linked into an existing conference/meeting	• It was time consuming
Engagement	Quality of Advice (P)	• Again, it was easier to engage the community if the SAT member was reasonably senior. • Could give a balanced view if enough people were asked	• The Pro-VCs etc. had a different perspective to the academics • They did get good quality information but an awful lot of noise as well
	Efficiency and cost-effectiveness		• Very time consuming and labour intensive for the SAT members
	Quality of Advice (P)	• Some SAT members were very engaged and it allowed good scope to be innovative • The level of involvement and engagement was greater for this approach Approaches used ranged from: focus group, the engagement approach, to a questionnaire	Those who used the focus group approach found it hard to integrate the individual opinions and it was influenced by the group dynamics
	Scalability (P)	Of the methods used, the questionnaire is the most scalable approach.	
Unconstrained	Efficiency and cost-effectiveness	• We could use questionnaire experts to undertake this approach for us	

Translatable – All engagement approaches were translatable across different research areas. This was mainly due to the flexibility that was employed within each approach and SAT.

Portfolio analysis – The information provided by EPSRC was very positively received. The research information sheets were particularly praised as being a helpful summary for SAT members.

The SAN working group also concluded that given the flexible approach adopted by SATs all engagement methods were easily translatable across different research areas. The SAN didn't endorse any particular approach and further noted that the portfolio analysis information and data sheets prepared by Portfolio Managers were praised as being a useful and helpful summary by SAT members.

4. SAN recommendations and Council Decision

4.1 SAN recommendations

- The SAN working group believe that the best time to run the MPE exercise is ahead of the next comprehensive spending review, ideally between March and autumn 2014. Given the long timescales for change, repeating every year is too frequent to observe significant changes in the portfolio. Therefore a subsequent exercise could take place in 2016 which would follow the anticipated CSR during 15/16.
- Monitoring could be delivered through a two stage process. Stage 1 could consist of a quantitative portfolio analysis of all themes and areas prepared by EPSRC and discussed with SATs. For Stage 2, EPSRC could identify with SATs a smaller, limited number of themes/areas, with a spread of grow, maintain and reduce areas, for more in-depth analysis and possible engagement with a wider group of stakeholders beyond the SAT membership. The breadth and depth of any engagement of both academia, industry and international perspectives should be proportionate to the added value gained.
- Finally, SAN could have a final synthesis role across the portfolio in order to reflect and identify key conclusions for Council.

4.2 Council decision

Council accepted the need to monitor across the rest of EPSRC's portfolio and broadly accepted the two step process recommended by the SAN work stream, with a focus on the quantitative aspects. They recognised the need to manage resource in relation to the monitoring activity, both for EPSRC staff and SAT members.

Members also recognised the need for output-orientated metrics as an important part of our on-going evaluation activities.

5. Plans for the full Monitoring Portfolio Evolution exercise 2014

- Portfolio managers are currently preparing one-page information sheets on all of the 113 research areas

- We are also collecting and analysing data on the whole portfolio
- We will take the information sheets and the data to the SATs conference on 19th-20th May using this opportunity to take a multidisciplinary view of our research areas and to take advice on further action which may need to take place in order to meet an area's strategy or trajectory
- The outcomes of the above will be presented at a Council meeting later in the year with options on how to manage the on-going monitoring of our portfolio

Annex A – List of Advanced Materials Research Areas

Type	Research Area	Definition
Primary	Biomaterials and tissue engineering	Application of engineering methods to create environments to promote cell or tissue growth and function in vivo and in vitro, and application to principles of tissue growth, function and performance. Research into biomedical materials with novel chemical, physical or mechanical properties or use of materials in a range of medical applications and interventions including regenerative medicine.
	Condensed matter: magnetism and magnetic materials	Research into magnetic materials and fundamental principles of magnetism. Includes thin film magnetism, magnetic phenomena, characterisation and growth of magnetic materials, ferro and antiferromagnetic materials and frustrated magnetic systems. Early applications into materials for sensors and data storage are included in this research area. Strong links to spintronics and condensed matter: electronic structure.
	Functional ceramics and inorganics	The synthesis, characterisation and theoretical understanding of functional ceramic and inorganic materials. This area includes electroceramics (including ferroelectric, multiferroic and antiferroelectrics), complex oxides, solid state materials chemistry, inorganic framework and porous materials. This area does not include materials for energy applications, photonic, magnetic, superconducting, polymeric or composite materials or materials processing, as these are all covered in related research areas.
	Graphene and carbon nanotechnology	The synthesis, characterisation and theoretical understanding of graphene, carbon nanotubes and other carbon based nanomaterials. This area includes understanding the fundamental properties of carbon nanomaterials, development of new growth methods, understanding the influence of defects on properties and exploring possibilities for nanoscale carbon electronics. This area does not include device fabrication, carbon composite materials or materials processing as these are covered in related research areas.
	Materials Engineering: ceramics	Understanding, modelling and processing of ceramics with respect to the properties and material behaviour and development of novel materials.
	Materials Engineering: composites	Understanding, modelling and processing of composites with respect to the properties and material behaviour and development of novel materials.

	Materials Engineering: metals and alloys	Understanding, modelling and processing of metals and alloys with respect to the properties and material behaviour and development of novel materials.
	Materials for energy applications	The synthesis, characterisation and theoretical understanding of functional materials to be used for energy applications. This includes fundamental studies into potential materials for photovoltaics, fuel cells, batteries and other energy storage materials. Included in this area are studies into polymeric, complex oxide, nanoionic, electrocaloric, magnetocaloric and porous materials for potential future energy applications. The research covered in this area will evolve as new technologies and materials properties emerge. This area only includes research into the materials systems for current and future energy technologies and does not include technology development which is covered in related research areas.
	Photonic materials and metamaterials	Research into the synthesis, characterisation and theoretical understanding of photonic materials i.e. materials which can mould the flow of light under certain conditions. This area includes: liquid crystals, photonic crystals, metamaterials, organic and inorganic semiconductors. This area does not include materials for energy applications, electro- active ceramics or polymers or material integration into devices. This research is included in related research areas.
	Polymer materials	Research into the synthesis, characterisation and theoretical understanding of novel polymer materials. This area includes studies into novel polymer synthesis, polymer drug delivery, polymer nanocomposites, responsive polymers, block co-polymers and soft nanotechnology. This area does not include research into polymers for energy applications or photonic polymers, this research is included in related research areas.
	Superconductivity	Research into the synthesis, characterisation and understanding of the properties of novel superconductor materials and devices. This area includes, for example, research into materials such as Magnesium Diboride (MgB2), Iron-based materials, multi-functional oxides and cuprates. Some of the research into materials with superconducting and/or magnetic properties may be covered under "functional ceramics and inorganics" with some internationally recognised researchers having moved into these areas e.g. functional oxide

		materials.
Secondary	Continuum Mechanics	This portfolio covers research into modelling materials as continuous media. It is generally sub-divided into fluid mechanics and solid mechanics. Research is also undertaken at the interface between fluids and solids, such as complex fluids, granular materials, porous flows and composites. A significant aspect of continuum mechanics concerns wave phenomena.
	Fuel Cell Technology	The study of electrochemical devices which generate electron flow through an internal redox reaction. Includes the materials, fuel and utilization of such devices. This topic also includes any socio-economic and environmental issues related to fuel cell technologies.
	Manufacturing Technologies	Research focused on key enabling technologies that will allow manufacturing processes, products and systems to function with high precision, efficiency, reliability and repeatability. The area has strong linkages with Process Systems: Components and Integration, Materials Engineering - Metals & Alloys, Materials Engineering – Composites, Optical Devices and Subsystems, Optoelectronic Devices and Circuits, and Performance and Inspection of Mechanical Structures and Systems.
	Non-CMOS Device Technology	Research concerning new device or circuit concepts and architectures beyond or integrating with current CMOS technologies. The theme covers quantum or spin based devices, bio electronic devices (including interfacing biology with silicon), MEMS/NEMS devices and sensors and their integration with CMOS platforms and carbon based nanoelectronics. Also included is non display printed and organic electronics.
	Optical Devices and Sub-Systems	Planar wave-guide and fibre-based devices. Design, modelling, fabrication and processing of new or improved devices whose quantum unit is the photon, including UV, visible, IR and microwave radiation. Bulk optical components such as high-speed sources and modulators. Nonlinear optical devices and solid state lasers. Gratings, sensors and sensor arrays. Optical computing and data storage. Photonic band-gap structures. Integrated optical sub-systems to perform specific functions. Interactive development of components and systems.
	Optoelectronic Devices and Circuits	Research into semiconductor-based structures, devices, lasers, LEDs, photodiodes, amplifiers, detectors, receivers and switches. This area also includes quantum dots, wires and wells and

		photovoltaics. Optoelectronic integrated circuits are covered as well as the design, modelling, fabrication and processing of new or improved devices using electrons and photons, including UV, visible, IR and microwave radiation.
	Performance and Inspection of Mechanical Structures and Systems	This research area is about the development, analysis, monitoring and optimisation of mechanical structures and systems. This theme includes both the experimental and modelling techniques that underpin our understanding of the performance of materials and mechanical structures, the development of non-destructive evaluation techniques, tribology and surface engineering, dynamics and transmission. Relevant elements of acoustics research are also included within this research area.
	RF & Microwave Devices	This research topic covers the design and development of novel device architectures such as custom antennae, transmitters, amplifiers, switches, filters, transceivers, linearisers throughout the radio frequency (RF) and microwave/millimetre wave and terahertz domain.
	Solar Technology	The research and development of devices to harness incident solar radiation and conversion to other vectors or direct use. This includes solar heating/cooling and all PV technologies. This topic also includes socio-economic and environmental issues related to solar technologies e.g. the public acceptability of large scale deployment of solar cells in the built environment.

Annex B – Early Indicators of Shaping in Advanced Materials

Each of the following 13 examples were highlighted by the SATs throughout their discussions as early indicators of positive shaping impacts in the Advanced Materials portfolio

Fuel Cells: The Hydrogen and Fuel Cells SUPERGEN hub was funded in 2012 at a value of £4M. Additional research capacity in this area was funded through a first challenge call in hydrogen and fuel cells, this funded a further 3 projects with relevance to this area with a combined value of £2.4M. Hydrogen & Fuel Cells was one of the priority research areas highlighted in the 2013 CDT Call.

Ceramics: Targeted funding in the geological disposal of radioactive waste has changed the shape of the Ceramics research area by increasing the research effort on glasses. A £5 million consortium: Decommissioning, Immobilisation and Storage soluTIons for NuClear wasTe InVEntories (DISTINCTIVE) was funded in 2013 and other grants concerned with immobilising Nuclear Waste in glasses have been funded notably in the understanding of irradiation effects on ceramics.

Metals and Alloys: The £5 million consortium: Decommissioning, Immobilisation and Storage soluTIons for NuClear wasTe InVEntories (DISTINCTIVE has funded research into the manufacture and corrosion of storage containers. Other shaping activities have been a Leadership Fellowship in understanding irradiation damage in zirconium cladding and joint projects with India in Nuclear Engineering.

Non-CMOS Devices (Energy Applications): In response to the 2011 strategy published by the Department for Business, Innovation and Skills, EPSRC has invested heavily in Power Electronics via the creation of a multi-university 'national centre' to support the science and engineering research that underpins the UK power electronics industry. This £18M investment is led by the University of Nottingham. Power Electronics was also included as a specific focus area within the 2013 call for Centres for Doctoral Training, and the ICT theme has also supported a new Programme grant on gallium nitride power electronics. The ICT theme continues to receive standard applications that focus upon power electronics, many of which are co-funded by the RCUK Energy programme and/or the Physical Sciences theme.

RF & Microwave Devices: During routine monitoring of its portfolio, the ICT theme has become aware that the RF & microwave device portfolio is not showing the desired relative increase in portfolio size – at best, relative investment is static. The Monitoring Our Portfolio pilot exercise further identified a seemingly low level of community awareness of the opportunity presented by the current Shaping status, and also reinforced the perception that much of the existing portfolio is 'traditional' or 'conservative' in nature. As a result, the ICT theme is now actively considering action to raise community awareness and highlight opportunities for new, multi-disciplinary working within the portfolio. Initially, this takes the form of organised community discussions, working towards a potential community 'all hands' meeting later in 2014.

Non-CMOS Devices (Plastic Electronics): As a consequence of academic and industry input, and in line with Shaping Capability, flexible and large area electronics ('plastic electronics') was one of the highlighted topic areas in the third (2011) call for EPSRC Centres for Innovative Manufacturing, which resulted in the support of a new EPSRC Centre in the area, led by the University of Cambridge. This award has provided an evolution of the work of the Cambridge Innovation and Knowledge Centre, which came to the end of its grant in 2012/13. The ICT theme continues to receive a low but steady volume of standard applications which focus on flexible electronics – these are often co-funded by the Physical Sciences theme. With regards to the 'granularity' of the Non-CMOS Devices research area rationale, the ICT theme and their SAT have discussed the potential for a 're-distribution' of the existing rationale statements during the next Shaping refresh – the status of flexible electronics will be considered as part of that exercise.

Statistics: Mathematical Sciences is a key discipline for EPSRC, with research in this area underpinning all aspects of our portfolio. One really good example of how a mathematical sciences area has been shaped can be demonstrated with a Science & Innovation (S&I) award at the University of Warwick in the area of Statistics. Both International Reviews of Mathematics (IRM, 2004 and 2010) highlighted that Statistics was at risk from structural and personnel issues. EPSRC responded (to the 2004 IRM) by awarding several S&I awards in Mathematical Sciences, to address the lack of capacity in Statistics. Warwick is now one of the strongest departments for Statistics in the UK, and has international standing, with around £9 million investment from EPSRC. The initial investment has led to further funding in Statistics, such as a number of fellows and several programme grants, helping to grow and sustain the UK's strength in this area. Many of the PDRAs on the S&I award, some of which were recruited from overseas, have moved to additional permanent academic positions in the UK, a number at UCL.

Polymer Materials: Polymer materials is a maintain area, but has reduced by approximately 0.5% as a percentage of the Physical Sciences research areas. There is not enough historical data to conclude whether this is a significant change, this reduction could reflect the interaction of a steady state in the community being influenced by the lack of funding that was available last year, so applications probably dropped. It seems that shaping has caused researchers to diversify their research to more applied areas, such as soft tissue engineering and materials for energy, which classifies these proposals under other research areas.

Performance and Inspection of Mechanical Structures and Systems (PIMSS): This is a maintain area but has seen a decrease in the total value of the portfolio in 2012 due to the end of large strategic investments and other standard mode grants. However, large grant bids have been proactively invited including a renewal of the strategically important Research Centre for Non-Destructive Evaluation which brings together a partnership of 5 leading universities and key industrial partners. We currently fund an Engineering Non-linearity programme grant which has relevance to the area and we are actively working with leading researchers to focus some programme grant applications in tribology. Fellowship opportunities are also available in this research area in both the established and early career stages; this has been actively promoted in the community with 4 fellows currently supported.

Biomaterials and Tissue Engineering: This is a maintain area and its value as a proportion of the engineering portfolio as a whole has remained relatively constant. The area has an important underpinning role for Regenerative Medicine, one of the Eight Great Technologies for the UK; consequently this forms a key part of the strategy for the research area. A number of strategically important investments have been made which address biomaterials and tissue engineering challenges in the context of Regenerative Medicine. These include the EPSRC Centre for Innovative Manufacturing in Medical Devices, the Leeds Innovation and Knowledge Centre, and the EPSRC/MRC/BBSRC jointly funded UK Regenerative Medicine Platform. Fellowship opportunities are also available in Regenerative Medicine in both the established and early career stages; this has been actively promoted in the biomaterials and tissue engineering community. A key question for the area moving forward is whether there is need for funding opportunities which encourage research distinct from that funded under regenerative medicine interventions and we have begun seeking advice from the community on this via our Strategic Advisory Team.

Synthetic Biology: Within the last couple of years EPSRC has successfully grown the size of the Synthetic Biology portfolio relative to the whole of the engineering portfolio. This has been done through a number of investments including an Innovation and Knowledge Centre, three Frontier Engineering Awards, two Leadership Fellows, a dedicated Centre for Doctoral Training, and the Flowers Consortium. We have also been involved in an international call with the Chinese Academy of Sciences and been an active partner in the RCUK Synthetic Biology for Growth capital bid. Four Synthetic Biology fellowships were funded through the recent Fellowships for Growth Call.

Graphene: Some of the increase in funding for Graphene and Carbon Nanotechnology has been due to the additional investment from BIS of which £12M was allocated through the Graphene Engineering call alongside £4M of Manufacturing the Future funding. Further research applications into the fundamental properties of graphene, carbon nano-tubes and related nanomaterials were not specifically restricted as a result of this investment, but did dramatically affect the volume of applications into Physical Sciences standard mode (2013 values funded in standard mode reduced by 60% from 2011 value - presumably since most of the community were involved in the GE call). In summary, this area is a unique example of where targeted calls from EPSRC have been stimulated by additional investment and have subsequently changed the shape of an area (by increasing funding and by concentrating it in areas of graphene applications). For example, one recipient of major funding under the graphene engineering calls commented that he had given up on EPSRC funding before that initiative began. The increased interest in this area has also stimulated applications for fellowships; in particular we funded a Manufacturing Fellow in this area, Geoff Nash, University of Exeter.

Photonic materials and metamaterials: This is a grow area and this has been achieved through the establishment of 5 programme grants in the area at Sheffield, St. Andrews, Kings College, Cambridge and Southampton. The research area was also included in the CDT call and a CDT has been funded at

Exeter. A background of a steady rise in applications and fellowships has also contributed to the area’s growth.