Manufacturing Futures Retreat 2018

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Introduction

The manufacturing-related research and innovation landscape has changed significantly in the time since EPSRC set up its Manufacturing the Future (MtF) Theme in 2010. Major changes have included the creation of Innovate UK, the UK Government launching its UK Industrial Strategy, formation of the Catapults and new MtF critical mass investments (Centres for Innovative Manufacturing and Future Manufacturing Research Hubs) . Future changes that might affect the manufacturing research and innovation landscape include Brexit, Industrial Strategy Challenge Fund investments and the formation of UK Research and Innovation (UKRI).

The MtF Theme last examined the strategic landscape in its Frontier Manufacturing Retreat in July 2011 (https://epsrc.ukri.org/newsevents/pubs/frontier-manufacturing-retreat-report/). The advice and areas identified were used to direct the theme and its investments. During 2018, it was felt to be timely to repeat this exercise and examine the future strategic opportunities for supporting manufacturing research (and innovation) going forward.

What is a Retreat?

A Retreat is a multi-day meeting, designed to allow the participants to step outside of their normal routine by withdrawing from everyday noise and pressures. This allows the participants, drawn from a wide range of backgrounds relevant to the Retreat topic, to think freely and explore the unexpected – there are no right answers and it is not about consensus building.

Retreat Objectives

The purpose of holding this Retreat was to:

- Provide evidence for future strategic EPSRC(/UKRI) decisions in supporting manufacturing research in the mid and long term
- Provide advice on opportunities for specific EPSRC interventions in the near term.

At the Retreat itself we aimed to:

- Provide a forum for the participants to explore the manufacturing research (and innovation) space and the major drivers that might affect this space going forward
- Understand how advances in e.g. engineering, ICT, mathematical, medical/biosciences and physical sciences research could transform the future of manufacturing
- Support the development of new research (and innovation) themes for manufacturing, highlighting opportunities from emerging research areas as well as major, long-term challenges facing manufacturing industries.

Retreat Roles

- The **Retreat Chair** brought together the participants at the event to address the Retreat topic. The Chair aided the scoping and design of the Retreat.
- The **Participants** (see Annex 1) were selected by EPSRC and the Chair based on their interest in the topic and their ability to engage in the event. They represent a wide range of backgrounds, disciplines and experiences, with a particular emphasis on inviting early career academics.
- The **Expert Witnesses** contributed the expertise and views of different stakeholders, helping the participants to develop new informed directions and ideas. They did not attend for the whole Retreat but contributed early in the process.
- **EPSRC** staff organised and managed the Retreat and ensured the aims of the Retreat were met. The **Facilitators** were responsible for the design and scheduling of the various activities and sessions of the Retreat, working closely with the Chair and EPSRC staff. At the event, the facilitators took the lead on explaining the process and directing the activities.

Event Design and Facilitation

The event was held at the Oxford Belfry Hotel, from 23-25 May 2018. The event facilitation was designed by Centre for Facilitation, in conjunction with the Retreat chair and EPSRC, to give participants an engaging structure for the event, to encourage effective networking and idea sharing on the topic of Manufacturing Futures. An overview of the process is shown in Figure 1.

The event started with a session to provide attendees with the opportunity to ‘speed meet’ other attendees at the Retreat, to understand what expertise was in the room and ensure a levelling of knowledge and understanding.

The expert witness session contributed views from some different perspectives, hoping to provoke unexpected thought channels on this topic.

Attendees were asked consolidate their thoughts on this challenge and contribute their own disciplinary insights in the horizon scanning session, continuing to explore the breath of the challenge for Manufacturing Futures.

The foresight session aimed to stimulate depth of and length of thinking (from 2018 to 2050), exploring the future terrain and consolidating the participants’ thoughts before identifying the emerging themes.

The participants were then asked for their perspectives on the emerging hot spots for Manufacturing Futures. These hot spots were clustered, creating nine distinctive themes for the Retreat.

The final deep dives added further definition to the priority themes and gathered valuable contributions from all attendees on what else could help formulate these research (and innovation) themes. The timescale of the Retreat allowed deep dive sessions for seven of the nine themes.

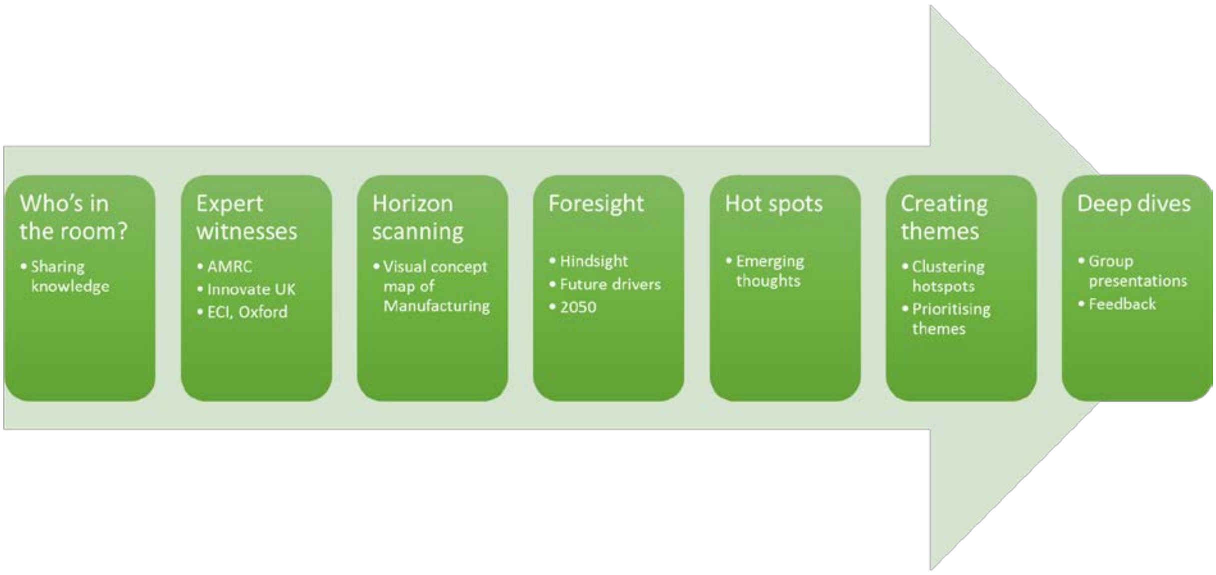

Figure 1: Overview of the Retreat process

Retreat Themes

An overview of the Retreat themes arising from the participants' thoughts and ideas are shown in Figure 2. The detail gained from the deep dives is shown in Annex 2.

Figure 2: Overview of the Retreat themes

Actions following the Retreat

A discussion was held with the Manufacturing the Future Strategic Advisory Team (SAT) to obtain their recommendations on next steps for each theme from the Retreat (see table below).

The Retreat outcomes were highlighted at the recent Manufacturing Regional meetings (held December 2018 – March 2019) and further scoping was undertaken for three of the themes.

Retreat Theme	Next steps
Advanced Bio-Products Manufacturing	• Review existing portfolio, wider landscape and previous activities related to the theme • Further scoping may be required, including discussions with BBSRC/MRC, to explore opportunities in this theme
Disruption Resilient Manufacturing	• Included as a priority in the Manufacturing the Future NetworkPlus highlight notice • No further targeted activity was recommended at this stage • The SAT will review this recommendation once outcomes of the NetworkPlus activity are known
Invisible Manufacturing	• Theme considered to be highly appropriate for a call for proposals • Some additional scoping was recommended via the regional meetings
Made in Space	• Review existing UK and international landscape • Additional scoping (with relevant stakeholders) would be required to identify the USP of a UK activity
Perpetual Transformable Products	• Theme considered to be highly appropriate for a call for proposals – recommendation to consider a two-stage process with feasibility studies followed by larger follow on projects for the most promising avenues • Some additional scoping was recommended via the regional meetings • Potential to work up into an EPSRC ‘Big Idea’ to explore cross-UKRI aspects
Using Nature to Drive Manufacturing	• Review existing portfolio, wider landscape and previous activities related to the theme
Zero Loss System	• This was considered to be an important theme and should be built into all calls and activities arising from the Retreat • Further scoping may be required to identify the manufacturing-specific challenges
AI-Informed Discovery & Manufacture	Not recommended for action at this stage
People-Centred Manufacturing	Not recommended for action at this stage

Annex 1: Attendees

Name	Organisation	Retreat role
Andy Neely	University of Cambridge	Chair
Adam Clare	University of Nottingham	
Andrew Hodgson	Siemens	
Ash Tiwari	University of Sheffield	
Chick Wilson	University of Bath	
Jo Craig	Glaxo Smith Kline	
Julie Yeomans	University of Surrey	
Kate Goldsworthy	University of the Arts London	
Katy Milne	Manufacturing Technology Centre	
Mike Lewis	University of Bath	
Qasim Rafiq	University College London	
Rebecca Cain	Loughborough University	
Rob Thomas	Loughborough University	
Sam Turner	HVM Catapult	
Sarah Sharples	University of Nottingham	
Tim Ingmire	PepsiCo	
Ben Morgan	AMRC	Expert Witness
Tina Fawcett	ECI, University of Oxford	Expert Witness
Simon Masters	Innovate UK, UKRI	Expert Witness
Katie Daniel	EPSRC, UKRI	Staff
Richard Bailey	EPSRC, UKRI	Staff
Rebecca Williams	EPSRC, UKRI	Staff
Les Sims	EPSRC, UKRI	Staff (Wed only)
Gabrielle Newson	Innovate UK, UKRI	Staff (Fri only)
Lucy Brownsdon	Centre for Facilitation	Facilitator
Richard Vaughan	Centre for Facilitation	Facilitator

Annex 2: Retreat Themes

Advanced Bio-Products Manufacturing

What is this theme all about?

What if we could harness biological levels of efficiency, specificity and functionality to create revolutionary new biological products?

Such advanced bio-products might be:

- Self-adapting, self-regulating enzymes for waste treatment
- A manufactured immune system, consisting of predictive, preventative therapies
- Modules to bio-integrate into other products (self-repairing)

Lower value bio-products such as alternative feedstocks. Such products would require complex biologically-based manufacturing systems with advanced measurement, sensor integration and control mechanisms.

Why do we think it is important?

- Use of advanced bio-products could be a proactive approach to reducing quality of life loss, reducing the economic and social burden of an aging population and chronic patient population
- Biological manufacturing processes could enable an increase in productivity and heterogeneity/selectivity, through consistent, cost effective, scalable manufacturing systems
- Positive environmental impact through process intensification (low energy/clean tech)

What are the research challenges to be explored?

- Translation of emerging breakthroughs in biology to the manufacturing sector, e.g. TALEN, CRISPR/Cas9, ZFN, new gene delivery systems (viral and non-viral)
- Manufacturing technology and processes
  - Development of bio-system controls - metrology, analytics, informatics, modelling
  - Moving from advanced batch to steady state continuous production
  - Miniaturisation for ultra-high throughput development
- Business modelling
  - Distributed manufacture use case
  - Healthcare economics, regulation
  - Cost/benefit/quality/waste

Disruption Resilient Manufacturing

What is this theme all about?

What if our manufacturing system was resilient to any disruption, and could use such challenges to learn and improve its performance?

Whether the disruption was at a global or local scale, through natural or man-made/societal causes, the disruption resilient system would be able to learn from that disruption, would be able to self-repair, reconfigure and eventually find a new balance point for itself.

The system would be trusted to cope with any scenario, whether a disruption to infrastructure (GPS, utilities, energy, ICT, transport) or resources (materials, labour), supporting the decisions of any humans in the loop.

Why do we think it is important?

As manufacturing systems become more complex and the supply chains more interdependent then the potential for disruptions increases and the effects become harder to predict on a holistic level.

Understanding the total system's exposure to risks and its potential responses to disruptions could:

- Identify failsafe systems or fall backs needed for particularly exposed points of the system
- Identify small changes that could avert potentially catastrophic outcomes
- Lead to a system with 'bounce-back ability' – the ability to find a better position compared to the pre-disrupted state, leading to improvement not just recovery.

What are the research challenges to be explored?

- Defining appropriate risk models, categorising root causes of disruption – deliberate vs natural vs accidental – and scales of disruption. E.g. risk mitigation of low probability black swan events, disruption itself can be a business opportunity
- Incorporating existing learning from other sectors, e.g. defence, transport
- Creating an accurate digital twin for the physical system and maintaining system integrity – cyber security, redundancy, traceability, encryption, trust
- System autonomy - how would the system provide decision support, make its own decisions, learn from disruption
- Alternative sources/paths
    - Communication – beyond the internet
    - Resilient energy sources

Invisible Manufacturing

What is this theme all about?

What if our manufacturing system could self-optimise to provide the product a consumer wanted, to their specifications, whilst the system remained to all intents and purposes invisible to the consumer?

The system would be:

- Autonomous, able to predict and plan for product demand
- Automatically able to design personalised products, potentially designing something never previously imagined
- Self-optimising for different input materials, minimising waste reduction and low carbon.

Why do we think it is important?

- This would provide an highly optimised manufacturing system, delivering the right products at the right time, place, cost, and quality
- The system would be optimised for waste reduction and low carbon, leading to a lower environmental impact, as well as a reduction in costs
- The system could deliver a democratised/accessible manufacturing capability – anyone could design, or cause to be manufactured, their desired products, enabling entrepreneurship and creativity and providing a distributed/franchisable system (factory in a box)

What are the research challenges to be explored?

- Development of intelligent hybrid processing platforms that enable new product design and functionality
- Fusion of engineering modelling, human knowledge, creativity and AI
- Predictive design – design (product, manufacturing system) evolution informed by data from being designed, being manufactured, and being in service Architecture and sensors for self-sensing systems, multimode sensors e.g. hyper spectral imaging, imprinting sensors, automation of measurements and actuation
- Standards, both for the hardware and the software elements - how would this work in heavily regulated production industries (e.g. biopharma)?
- Human intervention and creativity – how to capture this to the best effect
- Ethics? Should the system inform user about material/requirements ‘swaps’? What does trust look like and how might it evolve?
- What constraints/rules do you give the systems? How do you make sure it is optimising towards the ‘right’ point?

Made in Space

What is this theme all about?

How could we make things extra-terrestrially, either to exploit the nature of space e.g. microgravity, or to enable further exploration of space?

- Manufacturing in micro gravity, sterile environment, with the possibility of ‘discovering’ totally new materials and/or material properties
- Autonomous assembly in extreme environments – in space, on other planets e.g. ships that build themselves
- Finding resources in space e.g. mining planets, radical delivery/transport solutions (transorbital), unique opportunities for recycling/disposal, energy capture and distribution
- ‘Life on Mars’: Moonshot bringing it all together – propulsion, life support, adaptability of systems

Why do we think it is important?

- Fundamental EPS challenges in this area, e.g. manipulating physics to our advantage
- Possibility of ‘discovering’ totally new materials and/or materials properties
    - New resources and raw materials
    - New drugs/bio products
    - Novel composite structures, e.g. semiconductors
    - Extreme environment manufacturing
    - Miniaturised/lightweight, novel assembler technologies
- Potential for finding new energy sources
- Applications areas may include extreme environments on earth
- Enable migration off-planet through manufacturing

What are the research challenges to be explored?

- Data mining/updating on all the experiments currently performed
- Chemical processing in space
- Biology in space (limited to date)
- How could we do this without new infrastructure?
    - How to test in zero gravity – equipment/facilities
- What are the UK strengths and opportunity to exploit this ‘space’?

Perpetual Transformable Products

What is this theme all about?

What if our products could renew, improve and transform themselves throughout their lives, e.g. self-strengthening wind turbines, clothes that use air pollution to evolve their aesthetic?

Such products would:

- Be self-healing and self-renewing
- Act as their own factory, sourcing and extracting their own resources
- Personalise themselves to you and your needs as a consumer
- Grow with you, evolve to your changing needs with time
- Improve themselves to be always best in class, but yet could also age purposely
- Change their aesthetics according to your aspirations (emotional durability)
- Reconfigure themselves for new consumers.

Such products would challenge existing ownership models, opening up a more sharing economy.

Why do we think it is important?

- Products that could adapt to changing needs of their consumer could lead to a better quality of life, e.g. enabling independence for aging population
- Self-reconfiguring products could encourage a greater utilisation of assets, through a shift from a disposable economy to a sharing economy (with associated social benefits of sharing), reducing obsolescence
- Better resource efficiency as fewer new products are needed – save materials, energy, water etc.
- New models of owning, with positive costs implications of the new way of consuming

What are the research challenges to be explored?

- Materials science - Self-healing materials, sacrificial coatings, material degradation modelling
- Reprogramming materials performance and properties for different performance: Impact/strain rate, electrical and magnetic fields, light, chemical absorption
- Digital twin/modelling – Predicting degradation and self diagnosis → prognosis, evolving through data and testing upgrades
- Embedded measurements – the product is the sensor (it has a nervous system)
- Business model challenge relating to sharing economy/services
    - How to monetise the changes
    - Could be very challenging outside expensive capital goods
    - Extended producer responsibility?
- Redefine repair and model manufacture requirements - what happens to redundant parts?
- Does adaptability prevent/discourage step changes? What use would a perpetual diesel engine be? Do people want things that last forever?
- Looking at the issue across scales from the molecular → product → system → to the global. Interface research between various layers could be considered, big integration challenge

Using Nature to Drive Manufacturing

What is this theme all about?

What if we could adapt nature to grow us the products we wanted, e.g. growing chairs from trees, metal-reinforced bamboo scaffolding, house bricks from coral?

This is beyond biomimetics (the imitation of nature) and more than enhanced chemistry. This is 'bio-punk', looking at synthetic biology from a view of refashioning existing natural systems on multiple scales (cellular → biology → ecology) rather than building artificial biological systems.

Why do we think it is important?

- Exploiting natural systems for manufacturing would result in a massive potential for environmental gains
- Ultimate lean manufacturing - low energy processes, minimal raw material and involving no wastage
- Potentially lead to new materials and structures, as well as new manufacturing methods and products

What are the research challenges to be explored?

- Adapting biology
  - Classifying existing biological processes e.g. swarming
  - Starting small scale (repair rather than build)
  - How much is being done in BBSRC space already?
- Making this into a practical, cost-effective manufacturing process
  - Production at scale, speed of production
  - Quality control and consistency, variation and contamination
- Local differentiation of appropriate processing - what is the local bio-asset?

Zero Loss System

What is this theme all about?

What if our manufacturing system was able to produce no waste?

The whole system, as well as all materials, products and processes, would be designed to make maximum use of resources. Feedstocks would be turned into products from the atom up. The system would also include processes for recycling/rework after the “death” of any resources – using intelligent assembly and disassembly, molecular level de-manufacture.

Manufacturing processes would be linked across locations, scales and sectors to make use of local resource streams, logistics and energy. This approach would require a systems approach/multi-layer thinking, leading to acceptable (even positive) environmental impacts from the manufacturing system.

Why do we think it is important?

Living within our global resources limits is arguably the most important challenge we face today.

However planetary protection and stewardship is not just about saving the world for the next generation, it can also provide economic benefits in providing resilience against resource depletion as well as lower resource usage and costs.

What are the research challenges to be explored?

- Drawing the boundaries for systems level thinking, e.g. scale up and boundaries in cross-sector supply chains
- Design of new materials, composites, products and packaging for deconstruction and reuse
    - E.g. concrete, textiles, paper, electronics
- Recycling technology
    - design of energy efficient materials processing techniques
    - How to deal with current day products and materials
- Social acceptance of constraint, especially around cost of products → generational change
- Business models
- Do you start with ‘dirty’ or clean sectors?

AI-Informed Discovery & Manufacture

(no deep dive, comments are from clustering of hotspots)

What is this theme all about?

- Intelligent and accelerated discovery and manufacturing
  - Intelligent materials manufacture, assembly and disassembly
  - Multiple functional material product manufacturing
  - AI replaced scientist
  - Fuse materials science and engineering modelling with AI to accelerate discovery and deployment of new materials
  - Mechanical systems → physics – new materials, more graphene
- AI enabled scientist
  - The AI-enabled scientist
  - Scientific inspiration – Business people, entrepreneurs, artists
  - Sci-Fi/Futurists to inspire scientists
  - Promoting/stimulating human engagement by stimulation different parts of the brain

People-Centred Manufacturing

(no deep dive, comments are from clustering of hotspots)

What is this theme all about?

- (Tomorrow) People centred manufacturing
  - Manufacturing as a lifestyle/experience (at scale)
  - Equitable (fair) manufacturing
  - Transparency and provenance (through big data)
  - Participatory manufacture (gender)
  - Human-centred design (product and process) vs machine design (AHRC)
  - How do we capture (and account for) societal/social value of manufacturing above economic? (ESRC)
  - Which parts of manufacturing are best done by people or best done by machines in order to provide value (economic/emotional/societal)