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## 1.0 Introduction

### 1.1 Background

The UK has a history as a world leader in the manufacturing sector and despite recent decline the UK continues to hold 4.7% of high value manufacturing market share globally. With £139 billion contribution to the UK gross domestic product in 2012 and accounting for 53% of all UK exports, the manufacturing sector continues to be of vital importance to the resilience and future growth of the UK economy. However the recent Foresight: Future of Manufacturing Report and other major reports on the UK manufacturing sector highlight rapid changes brought on by technological, digital, environmental and social factors which present new opportunities and challenges for UK business, policy and research.

These changes and the vision of the future of manufacturing set out by these recent reports has been described as 'Re-Distributed Manufacturing', a term which aims to encapsulate the rapidly changing geographies, organisational structures, value chains and distribution networks associated with new advances in materials sciences, engineering, 'smart' and flexible machining and digital and enabling technologies. These developments include a shift towards smaller-scale local manufacturing, caused by changes in transport and labour costs, the availability of materials and energy, the need for sustainability and access to information. Such smaller scale manufacture has been made possible by a combination of new technologies; for example developments in ICT as an enabling technology, flexible manufacturing equipment, and new manufacturing processes which in turn are driving the development of new business models and value chains, changing dynamics of work and community, and have immediate implications for industrial and social policy.

In light of this context EPSRC and ESRC have committed to exploring the extent of research currently addressing these topics and identifying gaps and opportunities for new research activity that may be required to help the UK understand and meet these significant challenges. The complex nature of these changes, and their implications for UK society, will require contributions from a range of academic disciplines. EPSRC and ESRC therefore held a workshop with the aim of bringing together a range of academics with an interest in Re-Distributed Manufacturing to help understand the issues and explore the most suitable opportunities for RCUK involvement.

Prior to holding the Workshop, EPSRC and ESRC had developed a working understanding of re-distributed manufacturing as:

***Technology, systems and strategies that change the economics and organisation of manufacturing, particularly with regard to location and scale.***

In order to illustrate this understanding, the following examples of potential research challenges relating to this concept were provided:

- Manufacturing equipment
- ICT capabilities including manufacturing intelligence
- Manufacturing processes for example additive manufacturing
- Manufacturing strategy and business models including supply chains
- Workforce skills and training

- New economic models and value propositions
- Product, process and organisational innovation
- 'Servitisation' and the relationship between manufacturing and services

The workshop was held on Thursday 7<sup>th</sup> – Friday 8<sup>th</sup> November 2013 and was a productive opportunity for different communities of academics to engage around an area of common interest and explore potential avenues of future research.

The results of the workshop, comprising this report and the notes taken during the day will be used to assist the EPSRC and ESRC to understand re-distributed manufacturing, the questions involved and the direction RCUK support should take to address these challenges.

## **1.2 Aims and Objectives**

Drawing on the advice of Research Council steering panel, the priorities and strategy of both EPSRC and ESRC and recent reports relating to the field of re-distributed manufacturing, the following objectives were identified for the event:

- To encourage discussion between a diverse selection of the manufacturing, business and wider community, resulting in:
  - The definition and scope of Re-Distributed Manufacturing
  - Explore research areas within the theme of Re-Distributed Manufacturing
  - Exploring who might make up a 'Re-Distributed Manufacturing' community, and how best to engage them.
- To help develop our joint understanding of this priority and the directions research should take to address it.
- To help identify the possible approaches for funding a programme of work.

The intention of this workshop was to feed into the future strategy for Re-Distributed Manufacturing. This will be scoped by EPSRC and ESRC and will be strongly influenced by the issues identified during the workshop with the aim that the outcomes may result in individual calls, activities in partnership or a series of calls.

## **1.3 Attendance**

A call for Expressions of Interest was issued, encouraging applications from a range of disciplines, institutions and research interests across both EPSRC and ESRC's research communities. The workshop attendees were then selected by a combined EPSRC and ESRC steering panel to ensure a balance of participants across the following criteria:

- Relevance of research interests to the theme
- Balance of research interests across the participants
- Balance of institutions and departments
- Vision for individual contribution and benefits from attending this workshop.

There were 38 delegates in attendance at the event from a range of disciplines including economic geography, industrial sustainability, manufacturing, innovation, process design materials science with representation from BIS and TSB (for delegate list, see Annex 1).

## **2.0 Workshop Outputs**

The workshop included nine sessions over the course of two days (for full agenda, see Annex 2). The workshop built from establishing a common working understanding of re-distributed manufacturing towards a more detailed exploration of the specific drivers, barriers, challenges and opportunities presented by this field, aiming to develop opportunities for future research and visions for the development of re-distributed manufacturing. The following discussion provides a review of the outcomes of the workshop and an indication of key areas of interest which were developed during the course of the day.

### **2.1 Defining Re-Distributed Manufacturing**

#### **Activity**

In order to understand what 'Re-Distributed Manufacturing' might refer to and the key areas of interest for discussion, the initial sessions during the workshop established a common understanding of the concept. This was achieved through two activities; first a pre-workshop exercise in which participants were asked to submit three words or short phrases about what they thought re-distributed manufacturing meant. Second, participants were placed into mixed discipline groupings to discuss their understandings of the term and its key components, building on previous conversations using a shared workspace. The outputs from both exercises were recorded and displayed in the room and participants then prioritised which factors, themes, ideas or concepts were central aspects in understanding the field.

#### **Output**

The prioritisation activity identified the following as being key considerations when conceptualising re-distributed manufacturing:

- Localised manufacturing to support local economy and communities
- Cloud manufacturing services
- Dynamic production environments capable of delivering customised/multi-variant products
- A flexible and agile method of operation which allows manufacturing capability to relocate or clone in short ramp up times
- Inter-organisational reconfiguration
- Sustainable/Resource efficiency

Each of these themes incorporate a hybrid of social, economic, digital and technological challenges and potential topics of research and adds further detail to the original understanding, developed in advance of the workshop. For the terms of this report and future activity EPSRC and ESRC will therefore understand re-distributed manufacturing as encompassing; technology, systems and strategies that change the economics and organisation of manufacturing, particularly with regard to location and scale. This understanding will prioritise, but is not necessarily limited to issues of:

- Localised manufacturing
- Flexible manufacturing
- Resilient manufacturing
- Sustainable and resource efficient manufacturing
- Re-configurable and replicable manufacturing



Two additional questions were asked regarding the application of re-distributed manufacturing:

- How is manufacturing going to change as a result of re-distributed manufacturing?
- What would be a 'killer application' to illustrate the potential of re-distributed manufacturing as you understand it?

## Output

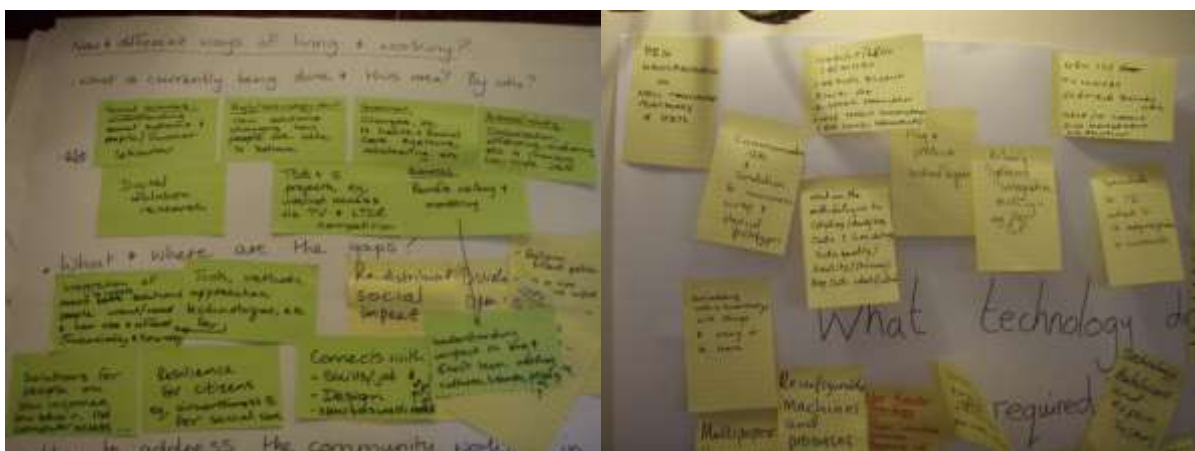
Delegates were asked to use the outputs from the above questions to formulate research challenges. These challenges were clustered into common themes and sub-themes within the broader field of re-distributed manufacturing for further discussion and development.

This clustering activity produced a series of ten major themes and participants were then given the opportunity to self-select in to groups to begin developing each theme and identifying the research challenges and opportunities for investment within that field. The sub-themes chosen for further development within the workshop are:

- Robust systems – to include information, data and systems
- Materials
- New and different ways of living
- Skills and jobs
- Management – to include business models
- Institutions and regulations – to include governance
- Design
- Economics
- Production technologies / Manufacturing processes
- Sustainability

In addition, three other themes were identified during the clustering activity but were not chosen for further development by the participants, these were:

- Consumers and markets – to include stakeholders
- Products
- Competition and Collaboration



*Some outputs from the workshop*

## 2.3 Potential RCUK activity

Following on from the clustering activity in the previous session, the participants were then asked to develop each theme, providing detail of the specific research challenges and most interesting areas of inquiry for potential development. This activity took up the remainder of the workshop time and provided creative thought about what RCUK support would do for research in this area and where investment should be prioritised in order to address this emerging area of interest.

### Activity

Delegates self-selected groups using the previously themes identified in the previous session, they were asked to develop each theme using the following points as stimulus:

- What is currently being done in this area? By who?
- What and where are the gaps?
- How to address the community working in this area?
- Why is now the time for research in this area?
- Where this research should be happening? Is there an international context?
- Roles of users and beneficiaries?
- What are the risks? Drivers? and Barriers?
- Why does research in this area warrant RCUK support?
- How should research in this area be undertaken?

The delegates were finally then asked to combine groups and create and pitch ideas to a panel. The groups were asked how they would structure investment using the following questions:

- If you had...
  - £25 million
  - £5 million
  - £500,000
- Which research areas to focus on? What resources you would support? What would be the type of support?

This final activity aimed to explore how each group would prioritise investment at differing scales. Given the likelihood of some level of resource constraint on RCUK investment in the topic of re-distributed manufacturing, it was interesting to see how groups addressed the research challenges and priority areas they had identified with differing levels of resource availability.

### Output

The development of the subthemes showed some gaps as well as current research and started the delegates thinking about what research is needed in this area.

The pitches provided a range of ideas both in terms of what and how RCUK should progress including networks, sandpits, targeted calls and centres. From the pitches and the feedback it was evident that there was a large amount of interest in re-distributed manufacturing and a large potential for RCUK support and activity. However there was a wide degree of disparity with regards to more detail within each themes and many of the pitches indicated that they would



begin by engaging in more detailed scoping activity to ensure a strategic approach to re-distributed manufacturing rather than an organic growth.

Given the breadth of the community interested in this field, the lack of coherence around a specific course of action and the number of participants who suggested that more detailed scoping would be essential to ensuring a strategic and supportive approach, it is probable that the first actions developing from this workshop will be the conduct of significant further scoping activity.

## **2.4 Final outputs**

The findings of this workshop may be expressed in four core fields which are cross cut by four further issues which must be addressed by each theme.

These themes aim to collect together the clustering and research challenge activities and broader discussions and notes during the workshop and to provide a degree of coherence around the core issues and thinking developed during the workshop during the sessions.

***Geographies of Manufacturing:*** The decentralisation of manufacturing, moving away from a concentration of resources through complex global distribution channels into concentrated clusters of assembly and production facilities serviced by large labour forces and their associated secondary economies, will imply significant changes on local, regional, national and international scales. This theme seeks to explore what those changes, both necessary and corollary, will be and their effects on the environment, individuals, communities, societies, global trade flows, economies, businesses and more. This theme also addresses the technical and logistical requirements of such changes including; development of local urban factories; fuel, energy and other resource provision; production in transit; local waste reclamation and circular economies; advances in materials; networking and computing infrastructures; transport, fuel and other infrastructures; software and computing hardware requirements, and similar technical challenges. This theme will also involve evaluation of the impacts of disaggregation of economic and business clusters and the potential changes that this will have on the lives and work routines of individual people, along with the macroeconomic and international political implications of such changes. This theme would also need to consider the societal changes and effects which within the workshop were phrased as 'new and different ways of living'.

***Enabling production technologies:*** A fundamental aspect of re-distributed manufacturing is the technological development leading to smaller scale and flexible production. This has greater levels of automation, complexity and a greater diversity of 'smart' machines allowing for faster, more efficient production. This theme concentrates on the engineering and computing developments which will be required in order to realise the potential of redistributed manufacturing. The theme also addressed issues of machine, product, process and service design which such developments will require in order to be successful, along with the organisational management changes and individual skills which will need to be developed as the vision of one person + one machine = any product comes closer to reality. Rapid prototyping, flexible and smart machines, robotics, additive layer and future forms of '3D printing'

are also covered under this theme, including their deployment in a range of different sectors. Problems of personalisation, bespoke and on demand production are also addressed and the theme will also consider the business models required to produce and sell such developments and products.

***New Models of Economics, Business and Investment:*** There are already considerable challenges associated with the valuation and investment of knowledge intensive and service orientated businesses which prioritise intangible assets. The ongoing digitisation, increasing importance of design and the changes envisaged by re-distributed manufacturing will only exacerbate these issues, simultaneously creating opportunities to develop new business models, new value offerings, new services and products and potentially entirely new industries and economies. This theme addresses the management of innovation and change within firms, industries and the economy as a whole. It will address the questions of cluster development and the added value of clusters of SMEs along with exploring the potential new models of business, new services and new organisational structures which may be developed. Additionally the idea of ownership and governance of manufacturing is partially considered here in the context of the role and position of manufacturing within broader global value chains, the questions of UK and foreign ownership and the new models relating to these issues. The theme will also explore how individual firms create and capture value, and the coproduction of value and recognises the multiplicity of value generation, where economic actors are not single units but act in a variety of roles simultaneously: as buyers, competitors and partners. Value co-production is most effective in a decentralised organisation, characterised by asset liquidity and interactivity across firms with less defined and more permeable boundaries such as those anticipated by understandings of redistributed manufacturing. What are the issues around future labour market, innovation policy, spatial policy, land use planning etc. What are the consequences at macroeconomic level? What could this mean for regional disparities (for example the north south divide)?

***Quality, Regulation and Legislation:*** What are the policy implications for Government, regions and other relevant parties (for example trade bodies, universities and local authorities). The inherent complexity of Re-Distributed Manufacturing, with greater decentralisation, lower barriers between firms and greater importance given to intellectual property will require new and improved regulation. New business models that favour greater customisation and localisation of manufacturing will need new methods of quality assurance and control in production, materials and design, bringing new challenges to regulation, taxation and insurance. This theme addresses these broader policy issues such as ensuring the provenance of materials and protection of intellectual property, especially in light of expected greater virtualisation and the potential to digitally distribute schematics to local factories, this will require new thinking on protection and liability around ownership. An extension of the ideas of ownership and governance of manufacturing is relevant here considering the regulations and legislation of these relationships including but not limited to the finance-industry relationships. This theme also addresses the challenges to human resources as skill requirements change and local labour markets face the implications of onshoring and local manufacturing. These new processes and structures will require new legislation to regulate and control along with

addressing the technical challenges in testing and enforcement of such legislation.

There a number of challenges which impact into each of these themes with at least four cross cutting issues that would need to be considered:

**Skills:** The labour requirements of these new technologies have yet to be fully understood and will need to be addressed by each of the themes identified. This issue encompasses manual training, but the factory of the future will increasingly require fewer manual skills and much greater digital and design skills, which present challenges for both management of employees and the training of the population more generally. This issue addressing the existing recognition that specialised skills alone are not sufficient for contemporary business and the need for hybrid or T-shaped skill and training developments which each of the themes will need to address in different ways.

**Sustainable Resources:** This issue accounts for the input of raw natural materials, their efficient use and reuse, development of new advanced and complex materials, management, regulation and distribution of such resources, new fuels and energy sources and refinement of existing processes. The changing use, processing, manufacture and disposal or reuse of resources and materials is a key concern which will need to be addressed by each of the themes identified as some of the new products and processes that are anticipated by re-distributed manufacturing are impossible without the further development of advanced materials with new properties and the resource constraints of the planet are a core issue for every sector and field of research.

**Transitions:** A final issue is the question of transition and understanding how existing businesses, communities, organisations and socio-legal structures will be able to proactively change and adapt to take advantage of the range of technological and scientific advances that are addressed by the rubric of redistributed manufacturing. These approaches and themes represent a potentially quite radical shift in the organisation of labour and production, a considerable break from existing, successful, business models and there will need to be detailed consideration of how to take initial steps towards meeting the challenges set out by each of the themes identified.

**Digital infrastructure:** The rise of computing and particularly the internet provides opportunities for complex networking of communications, hardware and software. Information and communications technologies provide whole new industries which have previously been impossible and these developments continue to expand as the possibilities of sensing technologies, human computer interactions, digital business, digital personhood, cloud manufacturing and big data analytics continue to be explored. Any technological and social development of the future must integrate an awareness and use of digital technologies.

Each of the four core fields identified above delineates a quite broad set of connected questions, while each of the cross cutting issues are integral to be addressed by all of the core fields. This will form the basis for further scoping activity but should not be taken as a firm indication of the direction of future research investment which will be shaped by the results of further expert advice and the strategic objectives of the Research Councils.

This workshop has provided an initial insight into potential re-distributed manufacturing research and demonstrated that there is significant interest in the concept across multiple research disciplines. As demonstrated in the final session pitching ideas for potential RCUK support, and raised throughout the workshop, there is a requirement for further, more detailed, scoping and development to ensure the RCUK activity is best positioned to support research and the development of re-distributed manufacturing within the UK.

## **2.5 Conclusion**

Re-distributed manufacturing epitomises an on-demand economy with local manufactories (however they may look) reshaping and redefining markets and supply chains, requiring new decentralised business models and having wide ranging challenges and implications. Re-distributed manufacturing may be characterised by greater personalisation of products. Concurrently there are a wide range of engineering, materials, computing, infrastructure and chemical challenges which must be understood and solved if these developments are to be possible. These technological challenges are accompanied by an embedded set of organizational, business strategy, training, regulatory, resource, design, marketing and other challenges that also need to be simultaneously addressed

EPSRC and ESRC will take forward the discussion held as a result of this workshop into the programme planning and future strategy. The outcomes from the workshop along with additional advice and feedback will be used to influence the future of RCUK support in the theme of Re-Distributed Manufacturing.

The content of this report will be disseminated to other relevant EPSRC and ESRC research base programmes, sector teams and RCUK mission programmes.

### **For specific questions or feedback related to Re-Distributed Manufacturing, please contact:**

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**Glen Noble** (ESRC, [glen.noble@esrc.ac.uk](mailto:glen.noble@esrc.ac.uk), 01793 413038)

### 3.0 Annexes

#### Annex 1: Workshop Attendees

Adam Clare	University of Nottingham
Alison McKay	University of Leeds
Andy Gibbs	ESRC
Andy Pike	Newcastle University
Andy Sellars	TSB
Chris Earl	Open University
Christopher Harty	University of Reading
Fiona Charnley	Cranfield University
Glen Noble	ESRC
Hannah Pearson	EPSRC
Harris Makatsoris	Brunel University
Ian Norton	University of Birmingham
Jag Srani	University of Cambridge
Javier Munguia	Newcastle University
Karen Brakspear	EPSRC
Karen Wilson	Aston University
Laura Purvis	Cardiff University
Lisa De Propriis	University of Birmingham
Louise Knight	Aston University
Mark Atherton	Brunel University
Mark Claydon-Smith	EPSRC
Martin Cooke	Angle PLC
Martin Spring	Lancaster University
Matthew Sinclair	Loughborough University
Mike Gregory	University of Cambridge
Mohamed Zaki	University of Cambridge
Nick Medcalf	Loughborough University
Nilay Shah	Imperial College London
Paul Mativenga	University of Manchester
Paul McCaffrey	GO-Science
Philip Shapira	University of Manchester
Richard Pitman	Aerospace KTN
Sarah Sharples	University of Nottingham
Shahin Rahimifard	Loughborough University
Simon Rushworth	Chemistry KTN
Steve Evans	University of Cambridge
Subramanian Ramamoorthy	University of Edinburgh
Svetan Ratchev	University of Nottingham

## **Annex 2: Workshop Agenda**

### **Thursday 7 November**

- 12.30 Arrival & Registration and lunch
- 1.45 Welcome
- 2.00 Introducing Re-distributed manufacturing in the context of wider EPSRC and ESRC strategy
- 2.30 Participants introductions
- 3.00 What is Re-distributed manufacturing?
- 3.30 Break
- 4.00 Important characteristics defining Re-distributed manufacturing
- 4.30 Foresight talk
- 5.15 Drivers and Barriers to Re-distributed manufacturing

### **Friday 8 November**

- 8.30 Start and refresh of day 1
- 9.00 Research challenges within Re-distributed manufacturing
- 9.45 Grouping of research challenges
- 10.30 Morning break
- 11.00 Development of Research themes
- 12.00 Development of Re-distributed manufacturing strategy
- 12.30 Lunch
- 1.00 Pitches of re-distributed manufacturing strategy
- 2.00 Feedback and round-up
- 2.30 Meeting close