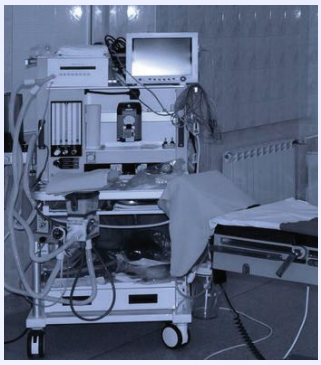
Knowledge Transfer Network

HealthTech and Medicines

The future of High Value Manufacturing in the UK

Pharmaceutical, Biopharmaceutical & Medical Device Sectors





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Acknowledgments

This High Value Manufacturing (HVM) report was prepared on behalf of the Technology Strategy Board by the HealthTech and Medicines Knowledge Transfer Network (Health KTN) and IfM Education and Consultancy Services Ltd, based at the University of Cambridge Institute for Manufacturing. The editors of the report are **Sue Dunkerton, Co-Director** and **Dr Mark Bustard, Technical Director, Medical Biotechnology of the Health KTN**.

Grateful thanks are due to those who participated and supported the workshops for each of the sectors. The names of those involved are listed in the Appendix.

1. EXECUTIVE SUMMARY

This report follows on from a study into the future of High Value Manufacturing. (HVM) in the UK commissioned by the Technology Strategy Board and published in February 2012[1]. One of the HVM study recommendations was that particular manufacturing sectors should be explored in greater depth. This report presents the findings from studies of the pharmaceutical, biopharmaceutical and medical devices (including diagnostics) sectors[2]. Workshops were held for each sector attended by representatives from industry, government bodies and the research community. The aims were to:

- Identify the needs and capability gaps to achieving innovation in manufacturing in each sector through to 2025
- Determine priority actions to meet these needs and build capability to enable innovation in manufacturing in each sector over this time scale
- Better define the HVM landscape with additional data from the Life Sciences sector.

Strategic roadmapping techniques were used to help participants explore each sector's key trends and drivers; the novel products, processes and services which could be developed in the future; any technologies and capabilities required to support these opportunities; and the enabling factors that would help the sector respond successfully. The list of potential new products, processes and services was prioritised to identify key areas where it was thought the most valuable opportunities for innovation exist. A Case for Action was developed to justify further work in each area, outlining the potential benefits, critical gaps and steps required.

This report covers those sectors within Life Sciences which impact on human healthcare, addressing specific manufacturing requirements for each of pharmaceutical, biopharmaceutical and medical devices as well as examining where synergies across all three sectors exist.

[1] Technology Strategy Board 'A landscape for the future of high value manufacturing in the UK' February 2012

[2] The terms pharmaceutical and biopharmaceutical are used in this report to describe chemical entity manufacture and biologics manufacture respectively. This is not the BIS OLS definition as used in the Strength and Opportunities report which is based on company size.

KEY AREAS IN PHARMACEUTICALS MANUFACTURE

The study identified a need for more flexible production facilities and early consideration of manufacturing needs. These could significantly cut costs and development times as well as delivering a better service to patients. Manufacturing for personalised medicines that tailor therapies to the needs of each patient could improve patient outcomes, as well as reducing healthcare costs. Novel methods for how drugs are given to patients, combined with 'smart' technologies, could integrate formulation, packaging and delivery to ensure prescribed treatments are followed more closely – improving results and reducing waste. New developments in formulation design could minimise use of valuable resources and maximise shelf life. Reconfiguring the supply chain could support radically new business models based on patient needs and wellbeing. These exciting developments all raise multiple, new manufacturing challenges.
To a great extent manufacturing approaches in the pharmaceutical industry are still stuck in the past, following long-established practices that are ill suited to the needs of the 21st Century. There are now real opportunities for radical change and improvement.
A further key driver for this sector is the so-called 'patent cliff' by which expiring patents result in plummeting revenues.

KEY AREAS IN BIOPHARMACEUTICALS MANUFACTURE

In this still emerging biopharmaceutical sector (manufacturing of biologics) the study identified the need to provide new, low-cost routes to market including manufacture for innovative therapies so that value can be retained in the UK. Improvements in analytics would enable products to reach the market more quickly through greater process knowledge, and therefore at lower cost and with reduced waste. Increased understanding of biopharmaceutical formulations could help to develop more stable and effective medicines, and improve delivery to patients. New approaches in biological production technology could enable individually tailored treatments to be produced more quickly and cheaply.
Furthermore industry feels the need to continue to build on successful industry-focused academic research managed programmes (such as the BBSRC - Biotechnology Biological Sciences Research Council BRIC (Bioprocessing Research Industry Club) and that the Technology Strategy Board may play a role in developing structures and key deliverables to ensure that the vision of the biopharmaceutical industry based in the UK is realised. A good example here is the new National Biologics Manufacturing Centre as part of the HVM Catapult.

KEY AREAS IN MEDICAL DEVICES MANUFACTURE

The diversity of the MedTech sector made this a more challenging area to examine and draw out clear manufacturing themes. However, there was strong consensus in the need to deliver solutions to support changing healthcare needs which predominantly requires greater functionality, personalisation and cost effectiveness. Key products for the future were seen in remote monitoring and point-of-care testing, smart wearable or implantable devices and patient-

managed diagnostic and administered medication delivery devices. These then need to improve clinical outcomes, deliver a better service to patients and at the same time support the NHS in reducing costs.

Technologically, new methods which incorporated hybrid additive manufacture/3D printing, novel surface functionalities, precision and nano-scale manufacturing as well as the better integration at system level were seen as opportunities. Systems integration in MedTech is seen as multi-faceted, ranging from integrated biology and physical devices (biocompatibility and bioactivity), to integration of multiple hardware and software components (often produced by multiple small and medium size enterprises), to integration of devices with data enabling post-market surveillance and further intelligence to feedback into manufacturing processes. Further, better use of simulation (even to individual patient level) to deliver right-first-time surgical interventions were seen as key competencies to support MedTech manufacturing.

There are many emerging medical technologies and enabling manufacturing processes, but in all cases there is a need to be clear about market demand and routes to adoption, which can best be met by close collaboration from an early stage between clinicians, patients and industry.

Also highly relevant to HVM, radical new business models and economic analyses were agreed as two priorities to stimulate growth of the MedTech sector. Cost of ownership together with life cycle costing models are needed to develop return-on-investment-based accounting methods for easier demonstration of value to support manufacturing investment decisions and new business models incorporating product with service were seen as value adding and a stimulant to export potential.

With the diversity of this sector, the roadmapping exercise, plus other inputs, has highlighted the lack of an obvious or coherent supply chain which could benefit both large and small Original Equipment Manufacturers.

SYNERGIES

Although each sub-sector had its own emphases based on maturity of the sector and specific technological needs, there were not surprisingly some areas of synergy to deliver to common drivers.

Generally products for the Life Sciences sector, even if noted sometimes as commodities, can be high value in comparison to other sectors, and as such HVM is a key part of getting the products to market and can subsequently contribute significantly to a nation's wealth creation and GDP. The UK is building its R&D and clinical trial capability to attract Life Science businesses and a favourable market now exists for innovation which can and should be extended to more HVM in the UK.

A key area was one of personalisation including all aspects of how to deliver customisable products close to the customer. Others included compliance and how use can be made of devices, diagnostics and engineering approaches to support optimum use of any healthcare/therapeutic product. Capturing and using more intelligence at point of delivery and how new data can be gained to support manufacturing approaches were also highlighted.

The life sciences sector has a few large businesses and many small ones, and there are opportunities for the sector to learn from each other on new manufacturing approaches, but also from other sectors, using open innovation tools with an emphasis on manufacturing strategies and technologies.

Other potential areas of synergy, but may have sub-sector specificities, include:

- Improved supply chain design to manage complexity and encourage co-location of facilities
- Distributed manufacture
- Green manufacture.

Comparing the workshops for pharmaceuticals (chemical entities) and biopharmaceuticals (biologics), further demonstrated the difference in maturity between the two areas. Mainstream pharma addressed new factory approaches including distributed manufacture, proximity to the customer and compliance issues whilst biopharma addressed more innovative technological manufacturing approaches including how to improve yields and control final product efficacy. As these latter methods mature, it was felt the manufacturing developments for pharma would also benefit biopharma.

The Health KTN also plan further workshops to bring the manufacturing communities together and help define future networking/knowledge transfer needs to help advance some of the themes highlighted by these roadmaps. The reader is also directed to Section 7 in the main report which highlights some current initiatives (eg HVM Catapult http://hvm.catapult.org.uk/) which are already addressing the points raised in this report.

NEXT STEPS

There is already evidence that the challenges facing these sectors are stimulating some innovative responses and generating a real appetite for change. The UK is in an excellent position to take advantage of these opportunities. Many of the world's major pharmaceutical companies are located and manufacture here, while at the same time the sector benefits from hundreds to thousands of small, highly innovative businesses. The existence of an open regulatory body is another important enabler for change. This study highlights the vital importance of close collaboration between industry, academia, Government and the regulatory authorities to support new manufacturing developments and to enable their impact on industry and the regulatory framework to be identified as early as possible.

This report is now being disseminated widely and being used to support future manufacturing investment decisions at the Technology Strategy Board, to provide background to support life science manufacturing policy within BIS (the Department for Business, Innovation & Skills) and to frame future research agendas by the Research Councils.

2. PURPOSE OF THIS REPORT

This report follows on from a study of High Value Manufacturing in the UK commissioned by the Technology Strategy Board and published in February 2012. The original study involved a broad consultation exercise with industry, academia and government in order to develop consensus on the trends, drivers, challenges and opportunities for UK manufacturing across all sectors over the next 15-20 years.

The HVM study created a framework – a high value manufacturing 'landscape' – against which industry and government can review their future strategies and policies. The material was collected in a structured and systematic way allowing the analysis to be constantly refreshed to reflect changing circumstances.

This previous study identified five cross-cutting strategic themes as well as the key national competencies required to meet future challenges, delivering a framework against which other studies could be added. Its findings are being used to help inform public policy, investment and research in order to build and sustain UK manufacturing competitiveness across a broad range of industry sectors. The first HVM study recommended that particular sectors should be explored in greater depth using the framework created. One key area is Life Sciences which forms a major part of the UK's manufacturing capacity. This report presents the findings from a consultation exercise within Life Sciences, focused on the specific manufacturing requirements of the pharmaceutical, biopharmaceutical and medical devices sectors.

This report is the summary of the outputs from a series of workshops involving representatives from the three main Life Sciences sub-sectors highlighted above, which were among those identified in the HVM study as fast-growing, R&D-intensive areas with significant technological advantages for the UK. It will remain a working document, as new inputs arise or as new initiatives open to address some of the priorities identified.

3. SECTOR STUDIES

3.1 OBJECTIVES

The aims of the studies described in this report are to:

- Identify the needs and capability gaps to achieving innovation in manufacturing in each sector (pharmaceuticals, biopharmaceuticals and medical devices) through to 2025
- Determine priority actions to meet these needs and build capability to enable innovation in manufacturing in each sector over this time scale
- Better define the HVM landscape with additional data from the Life Sciences sector.

3.2 APPROACH

Workshops were held for each sector attended by representatives from industry, government and academia and facilitated by IfM Education and Consultancy Services with the HealthTech KTN (a full list of participants and collaborators can be found in the Appendix of this report). The workshops used the IfM roadmapping methodology, a graphical, interactive approach to strategy development that allows participants to capture a wide range of interconnecting issues and to identify their linkages and dependencies.

3.2.1 Stage 1: Generating a sector landscape

In the first stage participants developed a high-level, sector 'landscape': a schematic on which the sector's opportunities, challenges and needs were identified in terms of four areas:

- Key trends and drivers likely to affect the sector
- Novel products, processes and services which could be developed
- Technologies and capabilities required to support these opportunities with a focus on manufacturing challenges
- Any enabling factors that would help the sector to grow and innovate.

These areas were derived from the HVM landscape framework ensuring that the findings can be directly mapped onto the national competencies and strategic themes identified by the HVM study, as well as used to update the original HVM data.

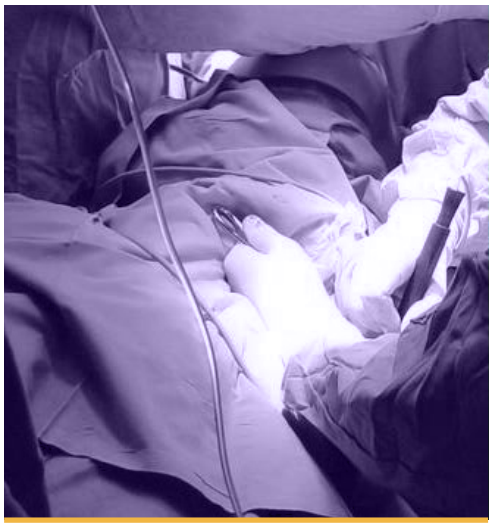
3.2.2 Stage 2: Focusing on the emerging priority areas

In the second stage participants reviewed the novel products, processes and services identified for each sector and ranked them in order of importance to create a list of priority areas. These were discussed in detail to:

- Develop a 'case for action' to justify further work in each area
- Identify critical capability gaps and key actions required.

3.3 VALIDATION

The outputs from the workshops were circulated to participants for review and were then made available as word or power point documents for wider consultation. The medical devices roadmap additionally included a webinar to gain further feedback from a wider audience, because of the diverse nature of the sector. This report incorporates inputs from the consultation exercise and is now available as both a reference document and as an input to future planning within the Technology Strategy Board, relevant KnowledgeTransfer Networks and Research Councils. The report provides a snapshot in time, and is expected to be built upon as new knowledge is gained and advances made in some of the Cases for Action.



4. THE PHARMACEUTICAL SECTOR

The UK pharmaceutical sector forms a significant part of the UK economy comprising some 365 companies, with nearly 79,000 employees and a combined turnover of £31.8bn. Of the top 50 global companies, 37 have sites in the UK. The sector is dominated by large companies with 89% of the workforce employed in firms with more than 250 employees. The company size may be a reflection of the age of the sector which has grown rapidly since the early 1900s to become one of the world's major industries[3].

4.1. HIGH-LEVEL LANDSCAPE

Workshop participants identified the sector's opportunities, challenges and needs in terms of the four landscape areas (trends, products, technologies and enablers). An outline of the findings that emerged is given below. The full landscape can be found in the Appendix of this report.

4.1.1 Key trends and drivers

Participants considered the trends and drivers they thought would affect the sector in the short, medium and longer term (up to 2025).

- Smaller lot sizes delivering tailored, more effective treatments
- Complexity of supply chains increasing as manufacturing moves offshore or closer to point of use
- More collaborative approach to product development involving partnerships with other companies or research centres
- Building quality control into the design stage (Quality by Design - QbD) requiring more responsive regulation
- Tailoring drugs to individual genetic signatures requiring complex therapies and formulations
- Lower prices, higher cost of development/quality/goods
- Patent cliff - reduced revenues and increased competition when product patents expire
- Evolving healthcare needs an ageing population
- Wealth creation for the UK
- Time to market for new therapies.

4.1.2 Novel products, processes and services

The (value adding) new products, processes and services that could be developed were identified as:

- More flexible production facilities located to support responsive, adaptable manufacturing capability

[3]BIS Strength and Opportunity 2012: An annual update

- Design for manufacture: Designing products for easier production
- Manufacturing for personalised medicines (diagnosis and drug treatments tailored for each patient)
- Integrated healthcare and treatment to create complete service package
- Making products to order in response to individual patient need and to reduce inventory
- Improved formulations and product platforms to increase responsiveness and minimise waste
- Future drugs and therapies for currently unmet medical needs as scientific understanding and new manufacturing processes develop
- Drug delivery: new ways in which drugs could be administered to patients
- Low volume and 'smart' packaging e.g. technologies to enable monitoring of patient usage
- Better use of existing and new data and better understanding of customer needs through data.

4.1.3 Key technologies and capabilities required

The workshop participants then considered which technologies and capabilities would be required within the sector to enable the products, processes and services they had identified.

- Multifunction equipment with quick turnaround: one plant for multiple products
- Continuous processing across a variety of platforms and unit operations
- Appropriate process controls and associated software and measurement to allow quality control, flexibility and small batch, complex processing
- Single-use components to speed-up product changeover and cleaning validation
- Better construction materials for components used in labs and production to reduce breakdown and improve equipment design
- Multi-dose/multi-pack formats for medication to be reconfigured according to required dose
- New approaches in synthetic biology to create both existing and new molecules
- Electronic prescribing data to reduce lead-time for drug manufacture following patient diagnosis
- Improved knowledge sharing and knowledge management to support new business models; open innovation and incubator facilities
- Improved supply chain design to manage complexity and encourage co-location of facilities
- Generics supply chain addressing cost reduction and sustainability
- Green technologies.

4.1.4 Enablers

Finally, participants discussed the factors that could enable these innovations to take place.

- Better sustainability metrics to inform manufacturing options
- Greater engagement with other process sectors to promote knowledge transfer
- Improved communication between scientists, business and regulators to enable regulatory issues to be considered from an early stage
- Overcoming the manufacturing funding challenge
- Early engagement between researchers and industry to support better technology transfer from applied and basic research to robust manufacturing development and commercialisation
- Fully understanding how patients take their medication
- Driving innovation through the supply chain
- Skills and improved links between industry skills groups
- Financial incentives for manufacturing.

4.2 LINKS TO HVM FRAMEWORK

The national competences identified as part of the original HVM study acted as a prompt for the workshop participants to ensure that all relevant areas were considered.

The outputs from the workshop were mapped onto the framework created by the HVM study to create a comprehensive linkage chart for the sector. Relating the sector findings to the HVM framework in this way enables the original data to be refreshed and updated to take account of new ideas and developments.

The linkage chart created for the pharmaceutical sector can be found in the Appendix.

4.3 PRIORITY AREAS FOR FURTHER INVESTIGATION

Participants reviewed the outputs identified as important for the sector and ranked them in order of importance to create a list of priority areas for further development.
The key areas agreed for the pharmaceutical sector were:

- Flexible production facilities
- Design for manufacture
- Improved formulations and product platforms
- Manufacturing challenges of novel drug delivery and smart packaging
- Manufacturing for 'personalised' medicines
- More integrated supply chain driven by patient demand

A Case for Action was developed to justify further work in each of the priority areas. Participants also identified any critical gaps, barriers and enablers, as well as the key actions required to take the ideas forward.

The detailed case for each priority area is given in the next sections.

4.4 PRIORITY AREAS: MAKING A CASE FOR ACTION

Flexible production facilities

The need	Drivers	Actions to deliver
• More responsive, faster production capability at a lower cost via flexible/modular factories • Reduced risks arising from high costs and complex technology transfer	• Rising production costs • Older population with unmet needs • Rising development costs • Products required in smaller volumes • Current configuration not tenable/fit for purpose	• Define value proposition by mapping benefit to product types • Close technology gaps via open collaborations, research, testing, feasibility • Close skills gaps through training, recruitment • Provide enabling regulatory framework

Rising costs, the need to create products in smaller volumes and the growing requirements of an ageing population are driving the need for more flexible, responsive and lower-cost production facilities. The identification of common ground in manufacturing processes for a range of products so that manufacturing facilities may be kept more generic and can be used for a range of products. The vision is for smaller, modular factories using standardised processes, to reduce capital and operating costs, and to lower the risks involved in complex technology transfer.

While this model is starting to occur in an isolated way, a more integrated approach is required. This will need to be supported by changes to the regulatory framework, improved skills and the development of new technologies and processes. It will also entail greater understanding of the fundamental science underpinning technologies required for such developments as continuous processing and Quality by Design.

Key to enabling more widespread change will be to demonstrate the value of this new business model including enabling companies to learn from the experience of those who have already adopted new approaches. Barriers to their adoption include the risks perceived in making the changes involved.

Design for manufacture

The need	Drivers	Actions to deliver
• Opportunity for the UK to develop a world-leading position by delivering better medicines at lower cost through the integration of design and manufacturing activities	• The necessary skills, capabilities and ambition to achieve this already exist in industry, academia and funding bodies • Proven track record of collaboration and innovation	• Encourage new mindsets to move away from current business models • Transfer lab-based concepts and processes into predictive, commercialised technologies • Develop mechanisms to provide better customer data

The UK has the opportunity to develop a world-leading position in the delivery of medicines that provide a better outcome for patients, at a lower cost with shorter development times and reduced wastage. A more sustainable approach is required with less dependence on critical raw materials. Such changes could be achieved by integrating the needs of manufacturing into the design stages of development to achieve more predictable, commercialised technologies and more flexible, responsive manufacturing. Some examples of this kind of approach exist but there is a need to demonstrate its strategic value in order to encourage wider adoption and reduce the dependence on current business models. More robust technologies and processes need to be developed to ensure critical quality attributes are included in the final product. Looking at the strong design culture across other sectors such as aerospace and automotive may also influence the future of manufacture of medicines.

A more fundamental understanding of chemical and formulation technology is required, building on the UK's proven track record in successful academic collaboration and innovation and supported by the Technology Strategy Board and Research Councils. Closer relationships between the industry and its regulators need to be developed from an early stage to allow regulatory issues to be considered in parallel with manufacturing advances.

Improved formulations and product platforms

The need	Drivers	Actions to deliver
• Improve the design of medicinal formulations based on a better understanding of science	• Respond more quickly and effectively to new and growing markets • Cut costs, minimise use of resources and reduce waste • Maximise shelf life of drugs and chemicals	• Build UK capacity and capability in formulation research • Address regulatory issues

Formulations – how active and delivery ingredients are combined in different ways – have a critical part to play in medicinal products. There is an urgent need for a better understanding of formulation science, to support manufacturing as well as how formulations interact with human systems. Improved formulation design could, for example, enable the creation of products that remain stable without the need for refrigeration, thus reducing costs and waste and maximising the shelf life of drugs. A more effective approach to formulation design could also help bring new products to market more quickly and efficiently.

Significant improvement in simulation and modelling (molecular but also process flows, interactions between particles) is key to achieving a better understanding of formulations. Currently it is limited to single entities and is not predictive. Other critical gaps in our understanding include a lack of physical data required to understand formulated systems, the link between drug structure and immunogenicity, the polymer structures that could enable controlled and sustained release of active ingredients and fuller understanding of the effects of drugs on the human body. In the future, we can envisage water free systems, disease-based formulations, stability at (global) ambient temperatures and model formulation platforms.

An important step to achieving these greater levels of understanding would be to build the UK capacity and capability in formulations (a dedicated formulations research centre), together with active support from funding bodies to encourage further R&D (science and manufacturing). Particular barriers that will need to be overcome include any regulatory issues that may arise as well as the challenge of dealing with product-specific IP - Intellectual Property.

Manufacturing challenges of novel drug delivery and smart packaging

The need	Drivers	Actions to deliver
• Improve ways of monitoring a patient's health • Increase patient compliance with treatment	• Monitoring of patients is poor with long cycle times between measuring and intervention • Compliance with treatment of chronic conditions is very poor	• Repurpose existing consumer electronics (e.g. smart phones) for monitoring • Develop diagnostics to automatically monitor patient health • Develop physical pack standardisation and on line printing as enabling technologies/capabilities

Patients often fail to follow prescribed treatments, particularly for chronic conditions. Patient compliance could be improved by developing technologies to monitor whether a medicine is being taken correctly. Integrating drug delivery and smart packaging as part of the overall manufacturing process, could provide for overall cost savings (reduced waste) and improved health outcomes (greater compliance). More standardisation of the medicine product form (tablets, powder, liquids etc) and universal cartridges, together with smart delivery and communication devices, could provide for more streamlined manufacture to the patient, with opportunity for full feedback on patient use. A closed loop system can be envisaged, where rechargeable delivery devices with diagnostics and consumer

electronics (iPhone) enable consumer/patient prompts and responses and feedback into the manufacturing process. The visionary concept is the 'one device for all'.
It may be possible to build into devices or develop separately a device with the capability for the patient to give feedback on how they are feeling following medication and therefore enable the physician to plan further medication interventions. This may affect manufacturing strategies.

Some of the technology required to achieve these innovative new approaches may already exist, but there will need to be a selection of appropriate cartridges (able to replenish dry substances) and formulations (e.g. mini-tabs into capsules) to determine proof of concept. Consumer electronic devices such as smart phones could be repurposed to monitor whether patients follow their treatment (linking to the assisted living sector). Energy harvesting for self-powering of the cartridges remains a technical gap and will require development.

Such radical new approaches would inevitably have an impact on patients and it would be essential to take their views into account if these new ways of delivering drugs are to be introduced successfully. Understanding and communicating the potential impact of the changes both in terms of patients' health and of economics would be important to ensure success. It would help drive a full life cycle manufacturing approach, giving manufacturers new connections to their customer base, and requiring more standardised but more responsive manufacturing to meet patient need/demand. Population models would provide data which could be linked to the design of medicines and the level of stratification possible. This in turn will inform manufacturing strategies.

It would be essential to involve the regulatory authorities at an early stage to identify any issues in relation to regulations and standards.

Manufacturing for personalised medicines

The need	Drivers	Actions to deliver
• Tailor medicines for individual patient needs • Stronger linkage between diagnostic and therapy leading to smaller volume manufacturing	• Reduce side effects and improve patient outcomes • Reduce healthcare costs • Manage growing needs of ageing population	• Develop adaptable delivery systems • Improve and integrate material and formulation science • Build industrial collaboration across life sciences sector and regulatory buy in

Medicines are not equally effective for all patients and ideally treatments need to be adapted to suit sub-segments of a population (stratification) or personalised to each individual. Tailoring or targeting therapies has the potential to decrease costs and waste as well as reduce side effects and improve outcomes for patients. The vision is to standardise many parts of the drug manufacturing system (bulk drugs, carrier, delivery system, release system, with appropriate quality controls), then tailor at point of care through a 'pick and mix' approach, as in the 'Dulux' paint mixer.

While this is an exciting prospect offering significant potential benefits for patients and the economy, some radical new developments would be required to achieve it. Some of the robotics technology required currently exists, but more integration and automation would be needed. Better understanding and development is needed of the material/formulation science including API (Application programming interface) carrier optimisation, combining different APIs, and nano-screens to separate incompatible actives. A range of technologies lending themselves to new devices / delivery systems, compatible with the broader range of standardised drugs, can be foreseen. Industry-wide collaboration (bringing together pharmaceuticals, devices, delivery systems and diagnostics) would be needed to enable this degree of change, together with support from regulatory authorities. New business and reward models would be essential to encourage this cross collaboration which has not happened anywhere before at this scale.

More integrated supply chain driven by patient demand

The need	Drivers	Actions to deliver
• Supply of medical treatments and products to be driven by the needs of patients	• Current business model not sustainable due to expense, waste and slow service response • Work towards system where payment to drug companies is based on successful treatment of patients	• More flexible supply chain with local distribution systems, based on patient need • Smaller, flexible, more integrated manufacturing operations

The workshop noted the strong cross-over to the previous case, 'Manufacturing challenges of novel drug delivery and smart packaging'.

There is growing consensus that the current supply model operating in the pharmaceutical sector is not sustainable, involving as it does huge costs to the health care service, high-inventory and excessive waste, combined with slow response.

Instead, supply could be linked more directly to the needs and well being of patients, based on real patient data. More flexible, local distribution systems are required to reduce inventory levels and lead times. In addition, more agile manufacturing operations will enable companies to respond quickly to patient demand. Ultimately we need to work towards a system where pharmaceutical companies are paid according to the success rate of their products. In the distant future it may be possible for personalised medicines doses to be dispensed from secure vending machines.

To achieve these changes will require new developments in manufacturing technology as well as the introduction of more flexible, controllable processes and systems (e.g. continuous processing). The supply chain needs to become more integrated, supported by improvements in IT.

Barriers include the challenge of changing long-established structures. Regulatory frameworks may also present a barrier if they are not aligned with the needs of a demand-led supply chain.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5. THE BIOPHARMACEUTICAL SECTOR

The UK biopharmaceutical sector[4] comprises over 250 companies and ca 10,000 workforce that are part of the supply chain involved in research, development and manufacture[5]. Companies offering specialist services are the dominant business segment in this sector. The global biopharmaceutical industry is currently worth over £90 billion, and growing 15-18% p.a. according to research conducted by BioPlan Associates. There are over 300 approved biopharmaceuticals on the market, with ca. 3,400 in the development pipeline[6].

It is forecast that eight of the top ten blockbuster drugs by 2016 will be biopharmaceuticals rather than small molecule, new chemical entities. The global pharmaceutical industry has therefore made a concerted effort to put resource into building biopharmaceutical capability and manufacturing of biopharmaceutical products. Although the UK holds over 200 biopharmaceutical products in research and development, manufacturing is predominantly undertaken overseas. Manufacturing is much more important for biopharmaceuticals than small molecule drugs partly because of the higher unit cost but also because manufacturing is inseparable from the safety and efficacy of the product. Many of the areas for further action detailed in the pharmaceutical sector content above is also common to biopharmaceutical manufacturing.

In the UK although there have been no significant manufacturing investments recently, there have been a number of site expansion projects which are strategically important to the UK and many of these companies may benefit from the Patent Box. This is attempting to capture more value for the companies generating IP in the UK if the manufacturing is also undertaken in the UK. To reflect this further, skills needed for biopharmaceutical manufacturing are significantly different to small molecule chemistry and critical mass has taken time to be established with most skills having supported by UCL as a major centre, for example. World leading activities contained within BBSRC BRIC, EPSRC (Engineering and Physical Sciences Research Council) Centres for Doctoral Training (CDT) and Centres for Innovative Manufacturing are available to be built upon.

5.1 HIGH-LEVEL LANDSCAPE

Workshop participants identified the sector's opportunities, challenges and needs in terms of the four landscape areas (trends, products, technologies and enablers). An outline of the findings that emerged is given below. The full landscape chart and associated landscape element linkages can be found in the Appendix.

[4] The biopharmaceutical sector as defined in this section refers to the manufacture of biologics
[5] Combination of BIS Strength and Opportunity 2012 and Health KTN data
[6] BioPlan Associates

5.1.1 Key trends and drivers

Participants considered the trends and drivers they thought would affect the sector in the short, medium and longer term (up to 2025).

- Manufacturing technology is driven by the molecular class of product being made eg protein, cell, tissue
- Lack of significant manufacturing investment in UK biopharmaceuticals by industry or Government
- Partnerships with regulatory authorities and improved consensus between regulators and organisations making biopharmaceuticals in the UK
- Potential threat to UK pharmaceutical activity from off shoring and overseas competitors
- Chronic shortage of experienced bioprocessing professionals including engineers and other life science skills relevant to manufacture of biopharmaceutical products
- Growing importance of analytics and process knowledge in the development and manufacture of biopharmaceuticals
- The business drivers for biosimilar generic therapies are very different from proprietary innovator products and therefore manufacturing strategies will reflect this.

5.1.2 Novel products, processes and services

Potential new products, processes and services were identified:

- Biopharmaceuticals for neurodegenerative diseases
- New cost effective vaccine manufacturing using non-egg based systems
- Innovative delivery systems for emerging diseases
- Enabling manufacture on demand (just-in-time) for smaller but more frequent batches
- Products to improve patient compliance
- Improve accuracy and speed of genomic sequencing and diagnostic tests to enable stratification of patient sub-populations, leading to challenges in flexible manufacturing strategies
- Biosimilars and biobetters – subsequent versions by other companies of patent-expired biopharmaceutical products
- Gene therapy products including development of Lentivirus platform
- Cell therapy manufacture for allogeneic therapies
- Biological adjuvants may also require novel manufacturing technology
- Secondary manufacture and supply of biopharmaceuticals generating possible new IP

5.1.3 Key technologies and capabilities

The workshop participants then considered which technologies and capabilities would be required within the sector to enable the products, processes and services they had identified.

- Integrated continuous processing strategies and technologies of multiple products for upstream and downstream stages
- Standardising protocols and processes for different kinds of pharmaceuticals within a Quality by Design framework
- Process analytical technology (PAT)/QbD to improve manufacturing success
- Formulations that remain stable at ambient temperatures reducing reliance on cold supply chain
- Capability to manufacture thermally stable products or ingredients able to survive high temperatures in developing world
- Reducing the reliance on conventional cell production systems and the opportunity to develop cell free protein production and synthetic expression technology
- Need for cost effective scale up and scale out for autologous and allogeneic cell therapies
- Non-surgical stimulation of endogenous (internal) cell repair using biopharmaceutical products.

5.1.4 Enablers

Finally, participants discussed the factors that would enable these innovations to take place.

- Simplification of biopharmaceutical manufacture – leads to cheaper and faster processes
- Government policy to support biopharmaceuticals manufacturing sector
- Industry and academia to collaborate on skills development through funded opportunities
- Continued funding of skills provision e.g. apprenticeships and industry facing research such as BRIC or equivalent strategic activity
- Access to expert centres for training and pilot scale manufacture opportunities
- The National Biologics Manufacturing Centre once established should enable increased translational collaborative research for the sector in the UK.
- New regulatory approaches to clinical trials to meet the needs of complex therapies
- Generation of data to show the safety of common production systems to reduce the regulatory hurdle for new therapies and speed up first time in man.
- New commercial manufacturing support services (e.g. testing, analytical or validation services)
- Significant financial incentives for manufacturing innovation in the UK
- Cell Therapy Catapult has a remit to drive the cell therapy manufacturing, analytical and characterisation innovation agenda
- Technology Strategy Board, BBSRC, EPSRC and MRC (Medical Research Council) need to work more closely together to ensure biopharmaceuticals are a common priority
- Access to expertise where SMEs with good bioscience expertise but little process knowledge can gain insight into their future requirements

- Improving Industry's proficiency in working with public sector
- Move from discovery to molecular design of molecules which allows design for manufacture to be integrated with design for safety and efficacy
- Generation of more manufacturing IP

5.2 LINKS TO HVM FRAMEWORK

The national competences identified as part of the original HVM study acted as a prompt for the workshop participants to ensure that all relevant areas were considered.

The outputs from the workshop were mapped onto the framework created by the HVM study to create a comprehensive linkage chart for the sector. Relating the sector findings to the HVM framework in this way enables the original data to be refreshed and updated to take account of new ideas and developments.

The linkage chart created for the biopharmaceutical sector can be found in the Appendix.

5.3 PRIORITY AREAS FOR FURTHER INVESTIGATION

Participants reviewed the products, processes and services identified as important for the sector and ranked them in order of importance to create a list of priority areas.
The key areas agreed for the biopharmaceutical sector were:

- Improved manufacturability of current and future biopharmaceuticals pipeline
- Analytics and characterisation
- Biopharmaceutical formulations
- Innovation in biological production technology.

A Case for Action was developed to justify further work in each of the priority areas. Participants also identified any critical gaps, barriers and enablers, as well as the key actions required to take the ideas forward.

The detailed case for each priority area is given below.

5.4 PRIORITY AREAS: MAKING A CASE FOR ACTION

Improved manufacturability of current and future biopharmaceutical pipeline

The need	Drivers	Actions to deliver
• Agile, rapid manufacturing capability supporting smaller batches to enable more value to be captured and retained in the UK	• Wide range of UK biopharmaceutical therapeutics requiring more rapid manufacture at lower cost • UK has the second largest biopharmaceutical pipeline but lags behind competitors in manufacturing capability	• Improve collaboration between companies and also between business and academia • Introduce more vocational and academic training • Provide facilities for product development and technology assessment

There is a need to create a low cost route to market for individually tailored or stratified medicines, capable of being rapidly manufactured in small batches. Many UK biopharmaceuticals companies are developing innovative ideas and technologies for new therapies but the UK is not perceived globally as a strong place to manufacture. Additional infrastructure is needed to help advance manufacturing technology innovation, building on what already exists in companies and academia. A driver for certain biopharmaceuticals such as monoclonal antibodies is also the yield intensification which contributes to smaller volume processing. Driving costs down and process efficiencies up will be crucial for biosimilars/ biobetter products. Agile manufacture of small batches of products is something that the UK does well.

The aim would be to provide new processes for product development and technology assessment which are migratable to the commercial base. A range of regulatory-approved products and processes could be developed supported by increased funding for industry and industry/academic collaborations. An facilities asset register would help to identify what infrastructure and technology is currently available that may be accessed by organisations across the biopharmaceutical value chain. Critical gaps to be supported these developments include driving an understanding of which process innovations might accelerate manufacture and addressing a lack of appropriately skilled people. Improving access to existing manufacturing facilities for smaller companies would also be beneficial. Smarter utilisation of such facilities and infrastructure within the UK is required to drive manufacturing technology development and validation.

Barriers include the current regulatory framework, which does not support such evolutionary developments although more generally the UK has a favourable regulatory environment with biopharmaceutical experience. There may also be resistance from service providers to the biopharmaceutical manufacturing value chain that may need to be persuaded of the benefits of such an approach.

Analytics and characterisation

The need	Drivers	Actions to deliver
• Develop effective analytical tools to support the manufacture of biopharmaceuticals products and to drive towards fully characterised products	• Effective analytics and characterisation are essential for product quality and safety. They enable products to get to market faster, at less cost, and with reduced wastage, contamination and risk	• Enable improved access to cutting edge tools • Lower cost analytical tools such as sensor development • Predictive models based on the analytical tools

Analytical tools to ensure the quality and safety of products are vital for the biopharmaceutical sector where the purity and structural integrity of samples must be constantly checked at each stage of the process. More effective and accessible analytics would enable products to reach the market quickly, at a lower cost and with reduced waste and be more akin to a Quality by Design approach. To create more effective analytics we need to identify the complex biopharmaceutical products and processes requiring innovative analytics. Predictive models need to be created building on process data, and a range of cost effective analytical tools developed.

Critical gaps in our current capabilities include low cost and rapidly accessible sensors, immunoassays and biomarkers to support more biopharmaceutical manufacture. It is also important to establish facilities and partnerships to enable organisations to gain easier access to these new developments, as well as high-cost capital equipment, expertise and skills. The regulatory environment can play a key role in supporting change with closer collaboration needed to adapt regulatory frameworks to support these new developments.

Biopharmaceutical formulations

The need	Drivers	Actions to deliver
• Stable and effective biopharmaceutical formulations to enable targeting of the disease more effectively • Better integration with manufacturing processes rather than a traditional silo approach	• More effective formulation design for a wide range of therapy types to improve drug efficiency and life, increase manufacturability and yields of active drug substance and reduce costs	• Develop formulations to support range of new treatment delivery options • Better formulations of biopharmaceutical products enabling reduced reliance on cold supply chain

Biopharmaceutical formulations – the process in which different chemical substances, including the active drug, are combined to produce a final medicinal product – remain something of a 'black art'. There is a need to develop more stable and effective formulations to increase the effectiveness of treatments, improve manufacturability and reduce costs. The vision is to develop a formulation 'toolkit' to potentially create formulations at manufacture and also at the point of care, reducing the need for cold storage in the supply chain and delivering the medication in a patient-friendly form.

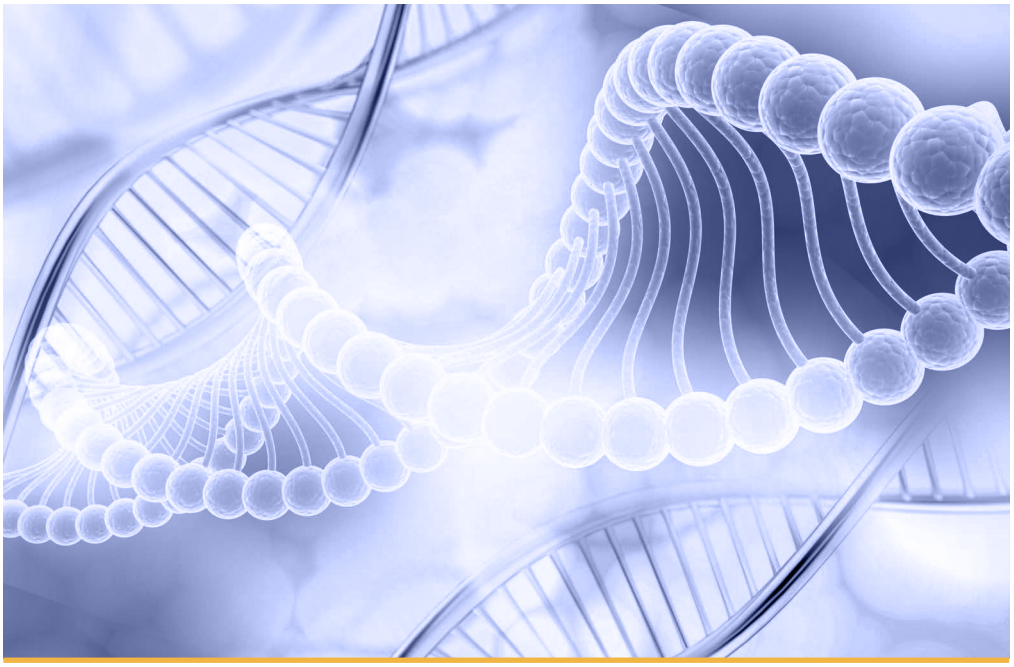
Some capability already exists in molecular modelling and formulation design. However, much still needs to be done including developing techniques for formulation characterisation, understanding precisely how formulations work and why, and building a successful formulation design kit to support accelerated stability trials. Factors that would support this include improved adjuvants and stabilisation techniques, and new business models to deliver pre-competitive technology to market. Liaison with the Technology Strategy Board Formulations Special Interest Group (SIG) may be important as long as it meets the needs of the biopharmaceutical community. A barrier may be the industry's unwillingness to depart from current practices.

Innovation in biological production technology

The need	Drivers	Actions to deliver
• New cell culture systems to increase efficiency and reduce costs • Simplifying manufacture of individually-tailored treatments	• Creating drugs that can be easily reconfigured as medical need changes • Reducing time between diagnosis and drug delivery • Decrease costs and failure rates	• Build links with Technology Strategy Board Synthetic Biology Special Interest Group • Provide dedicated funding to improve collaboration across the supply chain

Synthetic biology is a new emerging area of biological research and technology that combines science and engineering and is viewed as providing a step change in cell line engineering in the future. Its goal is the design and construction of new biological functions and systems not found in nature. New cell culture systems for biopharmaceuticals, which in turn can support the manufacture of individually tailored treatments will be important moving forward. In the future this may help to reduce the reliance on more conventional cell production systems currently seen across the industry (platform processes) and enable a more rational design of biopharmaceuticals should technology be developed. New biological production systems would enable tailored products to be produced more rapidly and at lower cost. The production strategy may also be easily reconfigured as medical needs change. The move to larger scale manufacture using such radical production strategies would demonstrate a step change.

Post genomics tools are already being used to understand cell production systems, but significant development is still required. Mammalian cell production systems are used routinely but a move back to microbial is starting and GM plants are now becoming more evident. Companies spend significant time and money on cell production systems and future IP implications are uncertain. Critical gaps that need to be addressed include more effective models for cell systems, platform production processes for vaccines, and the development of knowledge and skills for cell-based manufacture. Key to success will be close involvement of the Technology Strategy Board Synthetic Biology, SIG and dedicated funding to improve collaboration across the supply chain.



6. THE MEDICAL DEVICES SECTOR

The medical technology sector in the UK is comprised of over 3,000 companies which employ just over 71,000 individuals and have a combined annual turnover of £16bn. The overwhelming majority of medical technology companies are SMEs, 99% of the companies in the sector employ fewer than 250 people. The overall picture is that of a sector made up of small but well established companies. The four largest manufacturing segments within the medical technology sector are single use devices, wound care/ management, in-vitro diagnostics and orthopaedics, with many other segments demonstrating the broad diversity of the sector. Companies in the medical technology sector are also very dispersed across the UK.

6.1. HIGH-LEVEL LANDSCAPE

Participants for the workshop were invited from a diverse range of organisations to represent the range of interests and the process supported collective views across these diverse interests. Workshop participants identified the sector's opportunities, challenges and needs in terms of the four landscape areas (trends, products, technologies and enablers). An outline of the findings that emerged is given below. The full landscape can be found in the Appendix of this report.

6.1.1 Key trends and drivers

Participants considered the trends and drivers they thought would affect the sector in the short, medium and longer term (up to 2025).

- Growth in independent home and community care
- Supply chain gaps
- Pressure to reduce cost and increase value for money (including value to the patient)
- Regulations supporting or impeding growth of sector
- Intelligent systems and smart devices
- Increased ageing population driving new treatment priorities
- More healthcare economic analysis as a stimulus for innovation
- The 'expert patient' – taken here to address a patient centric delivery of future healthcare which means engaging with the patient and user centred design
- Improved pre-clinical simulation of device performance
- Robots replacing/augmenting surgeons.

6.1.2 Novel products, processes and services

The (value adding) new products, processes and services that could be developed after identified as

- Sensors and ICT-enabled health monitoring
- Point of care devices

- Sensor-to-human interface
- Imaging (including Improved high-resolution imaging systems such as micro RAMAN spectral instrument and micro CT)
- Smart implantable/wearable technologies and products
- Drug delivery and compliance devices
- Short-term, non-invasive, light-sourced therapies, e.g. laser, ultrasound
- Health condition monitoring services for preventative healthcare
- Wound management (including smart systems)
- Energy harvesting and power
- Artificial organs
- Energy harvesting and power
- Simulation to aid design and manufacture
- Modular design and self-certification
- Genomics-enabled devices, diagnostics and prediction.

6.1.3 Key manufacturing technologies and capabilities required

The workshop participants then considered which technologies and capabilities would be required within the sector to enable the products, processes and services they had identified (these were added to post-workshop during the consultation phase).

- Hybrid additive manufacture/3D printing
- Manufacturing for introducing specific surface functionality (e.g. antibacterial resistance)
- Precision manufacture including precision injection moulding, machining and joining
- High Volume Nanotechnology manufacturing
- Manufacturing of existing and new materials for devices and sensors (including biomaterials, nanomaterials, multi-material joining)
- Manufacturing of devices containing drugs (combination products)
- Technologies for smart, implantable devices
- Manufacturing methods for scaffolds (including electrospinning)
- Photonics and plastics or flexible electronics
- Systems integration (hardware and software for total systems and combination products incorporating biology with physical devices/structures – latter ensuring no interface issues/rejection of cells etc.)
- Direct design to manufacture - 3D CAD modelling, visualisation and finite element for hard and soft tissues
- Integration of imaging with manufacturing to improve product design and performance at individual level (personalisation)
- Methods to embed patient safety, quality and efficacy in devices (including packaging, anti-counterfeiting and specialised training and validation)

- Self-sterilising systems
- Lifecycle costing /new business models
- Data storage and management to aid manufacturing.

6.1.4 Enablers

Finally, participants discussed the factors that could enable these innovations to take place.

- Government incentives and tax breaks, this includes those incentives already in place such as corporation tax and Patent Box but comment also included new R&D vouchers and SPARK Awards to encourage innovation. The MedTech sector contains many SMEs as noted earlier, and although many of these are closely linked to universities with strong scientific input, others have less strong academic links or the links are not sufficiently multi-disciplinary to ensure more robust solutions are developed. It was therefore felt, enablers for new low risk interaction with new academics (including clinical academic) would be beneficial.
- Centrally balanced sectoral policy (giving appropriate weight to the pharmaceutical, bio pharmaceutical and MedTech sectors). The observation here was that the MedTech sector has not historically received sufficient weight at policy level compared to pharma, which is well represented both at company level and through their larger Trade Association. The past business model for pharma has also been well understood by policy makers, making it easier to develop new initiatives which reflect pharma interests but do not often translate well into MedTech.
- Adoption of effective innovation by the NHS. This is a well understood problem at all levels of the healthcare sector and the OLS Life Sciences Strategy and the Department of Health's Innovation Health and Wealth both include specific actions to pick this up across Life Sciences but also with specific tools for MedTech. It is not a HVM issue specifically.
- Fundamental science to support innovation in processing and manufacturing
- Skills – recognising the multidisciplinary needs across a highly diverse sector, it is noted as difficult to attract skilled graduates with appropriate ranges of technically integrated subject matters as well as commercial awareness. It is hoped some of the EPSRC Centres for Doctoral Training will address this shortcoming but further work is needed for non-academic and employee training.
- New training models for technology transfer commercialisation
- Availability of £5-10k SPARK awards to stimulate new supply chain collaborations . This scheme has been used in Biosciences and in other areas over recent years but has not been actively adopted in the healthcare sector.

- Creation of a national MedTech centre – there was no Group consensus on this topic so the need for and shape of this would need further validation but continued support for sector specific Centres of Innovative Manufacturing was endorsed.
- Sharing open innovation concepts between large companies and SMEs. This comment was received during the validation phase and is taken to pick up on models that have been underway in the pharmaceutical sector but are less well established or understood between UK large MedTech companies and SMEs.

6.2 LINKS TO HVM FRAMEWORK

The national competences identified as part of the original HVM study acted as a prompt for the workshop participants to ensure that all relevant areas were considered.
The outputs from the workshop were mapped onto the framework created by the HVM study to create a comprehensive linkage chart for the sector. Relating the sector findings to the HVM framework in this way enables the original data to be refreshed and updated to take account of new ideas and developments.
The linkage chart created for the MedTech sector can be found in the Appendix.

6.3 PRIORITY AREAS FOR FURTHER INVESTIGATION

Participants reviewed the outputs identified as important for the MedTech sector and ranked them in order of importance to create a list of priority areas for further development. These picked up a combination of novel devices and new manufacturing technologies or approaches.
The key areas agreed for the MedTech sector were: (based on the topics raised at the workshop itself)

- remote monitoring of the patient and point-of-care testing
- technologies for smart wearable and implantable devices
- drug delivery with compliance and combination devices
- hybrid additive manufacture/3D printing
- use of simulation for individual patient to deliver right-first-time surgical intervention
- cost of ownership life cycle costing
- new business models (using a use-case involving high quality hand-held imaging).

A Case for Action was developed to justify further work in each of the priority areas. Participants also identified any critical gaps, barriers and enablers, as well as the key actions required to take the ideas forward.

The detailed case for each priority area is given below.

Remote monitoring and point-of-care testing

The need	Drivers	Actions to deliver
• NHS reforms/cost containment • Current resources are inadequate/New technologies to free up resources • Community nursing/ social services dedicated to monitoring more than treatment	• Ageing population • Treating 'sicker' patients at home	• Join up technology (integrating technologies through manufacturing) • Prove efficacy/reliability at point of manufacture • Develop software/medical/ information points. • Funding – for more research

6.4 PRIORITY AREAS: MAKING A CASE FOR ACTION

The make-up and needs of the UK's patient population are changing dramatically. Increases in life expectancy have resulted in a prevalence of chronic conditions in older patients. Yet at the same time health services must make cost savings, as well as improve productivity and patient outcomes. The drive to reduce pressure on acute services requires services previously performed in hospitals to be conducted in the community or home – often on sicker patients. It also requires greater emphasis on earlier intervention.

Developing the existing technological base for remote monitoring and point-of-care testing or earlier diagnosis could make a major difference to the NHS's ability to manage this shift effectively. These technologies could help achieve better outcomes for patients and provide reassurance to staff, patients and relatives that conditions are managed effectively outside the hospital setting. The long-term vision is for a tailor-made patient device or implant that enables the patient to self-monitor and manage their condition(s).

Technologically, the themes of relevance here are:

- Hybrid additive manufacture/3D printing
- Manufacturing for specific surface/device functionality
- Precision manufacture including precision injection moulding, machining and joining
- High Volume Nanotechnology manufacturing
- Manufacturing of existing and new materials for devices and sensors (including biomaterials, bio actives, nanomaterials, multi-material joining)
- Photonics and plastics or flexible electronics
- Systems integration
- Direct design to manufacture
- Methods to embed patient safety, quality and efficacy in devices (including packaging, anti-counterfeiting, testing/quality control and specialised training and validation)
- Data storage and management to aid manufacturing.

There is also a need for cross-fertilisation of technology between industrial sectors, including learning from those sectors which understand how to drive cost down through new manufacturing methods.

While this is an exciting prospect offering significant potential benefits for patients and the economy, some radical new developments beyond manufacturing would be required to achieve it, due to critical gaps in the infrastructure of the industrial base and the NHS. Engagement by the NHS depends on changing perceptions of costs versus benefits, which in turn requires the development of new payment/reimbursement models. New therapeutic and care pathways will be required as more work is done outside of a hospital setting. There is also need for training and education of NHS staff, and new clinical technician roles may be needed if there is greater dependence on technology which needs local tailoring/ personalisation.

Technologies for smart wearable and implantable devices

The need	Drivers	Actions to deliver
• Develop principle of smart implantable technologies for added value manufacture • Increased performance and longevity of implantable devices (ability to use on younger patients)	• Improve healthcare for ageing population • Enhance wellbeing for population at affordable cost	• Identify the technology shortfalls • Build capacity for smart implantable devices (academic and clinical) • Build capability in key technical areas (e.g. smart garments, 3-D imaging of body parts, sensors) • Establish suitable collaborators across five to ten known medical clinical specialities (build multidisciplinary teams focused to key disease areas) Set up pilot project – create specification • Demonstrate efficacy, economic & health advantage

Smart wearable and implantable devices could meet the dual needs of improving the health and well-being of the UK's ageing population while also reducing healthcare costs (for example, by minimising hospitalisation). Such devices provide a major area of opportunity for high added value manufacturing in the UK.

Current devices are limited by single functionality, lack of self-repair and high energy usage (batteries). The vision is for patient-friendly wearable or implantable devices that are long lasting, multifunctional and self-maintaining. Smart implants could be developed to communicate automatically with the patient's health care provider. Particular focus is needed on the miniaturisation of smart sensors and developing self-powered devices. The key technical themes cover most of those listed in Section 4.1.3, with specific needs to address biocompatibility/toxicology issues related to any device in physical contact with the body (internal or external).

There is a need to review the regulatory environment and to build on current technologies in more joined-up ways. Research is disjointed and funding lacks continuity. Silo mentalities hamper communication between and among providers and users of R&D. And although health care is increasingly moving from 'hospital to home', education and training of health care providers has not kept pace, resulting in barriers to adoption of smart devices.

Key actions, therefore, are to focus government attention on funding for collaborations between academic, commercial and healthcare provider partners (including the release of clinical-based resources (eg clinicians, research nurses and technicians) for R&D) and to review and conduct clinical trials and comply with regulatory requirements (preclinical and clinical). The workshop considered the need for large multidisciplinary projects, with ambitious targets to trial new ways of working for high risk technology development. This might be developed through innovative supply chain programmes that bring different players and technologies together to address radically new devices or systems.

Drug delivery with compliance and combination devices

The need	Drivers	Actions to deliver
• Medical device which injects (dispenses) a sustained release of multiple drugs • Dose is set electronically by physician, administered at home painlessly (compact) • Uses fingerprint recognition • Is IP (Internet-Protocol) enabled • Automatically monitors compliance & drug levels – tells patient & physician	• Reduced cost to society: less hospital visits, less clinical input, less travel/environmental burden, less error through taking the right drug at the right dose and the right time. • Reduced risk of misuse • Improved compliance • Maintains patient independence • Improves science, understanding via data collection	• Develop new multifunctional materials , mixing devices, biodegradable polymers with the required mechanical, biodegradation and biological properties. • Develop miniature sensors & associated electronics (DFM/ Micro-robotics) • Address regulatory complexity governing medical device & drug delivery systems • Attract substantial funding for complex cross discipline projects

Developments in patient-administered medication delivery devices could have significant economic and social benefits. Patients and clinicians would be saved the time, expense, and environmental costs of hospital appointments. Smart delivery devices would also address the common problem of failure to follow prescribed treatments (patient compliance) and reduce the risk of prescription drug misuse. In addition, data collected by the device and monitored by the patient and clinician could be used to advance scientific understanding.

Technologies already developed include auto injectors, safe biodegradable polymers and electronic systems (e.g. monitoring patches). Specific areas of focus were noted to include, amongst others, biodegradable polymers with specific biodegradation characteristics and miniaturisation in electronics (micro assembly by mini robots) but other topics will also arise.

The challenge is to achieve effective combination of drug and device, of materials and electronics. There may be consideration of combinations of biologics and process manufacturing alongside the mechanical production of devices, or to consider an integrated

manufacturing system bringing personalised medicines and devices together at point of final assembly/delivery. It is also critical to understand how a device containing a drug could be sterilised (when required) without losing its desirable properties.

This cross-discipline complexity is accompanied by regulatory complexity and uncertainty, due to different Directives governing medical devices and drugs or drug delivery. However, attention is being given to regulations for combination products.

Home devices need to be linked wirelessly and IP-enabled to ensure transfer of information seamlessly whilst securely to ensure all have confidence in the use of the devices and use of the data so generated. From a manufacturing perspective, how is this integrated as part of the manufacturing process and/or how does new information derived from market use (including compliance rates) feed back into the manufacturing process.

Major investment is needed to sponsor research by cross-disciplinary teams to ensure the complexity of a whole system can be investigated and developed.

Hybrid Additive Manufacture/3D printing

The need	Drivers	Actions to deliver
• Fabricate complex components in engineered structures (e.g. insulin pump parts) • Generate better dental crowns • Make 3D bone replacement structures – permanent, porous, resorbable • Make scaffolds for organs (cell seeding) • Body valves	• Ageing population demands body part replacement/ durability of replacement. • Younger populations with diseases also require devices/ implants with long term performance. • Cosmetic demands • Quality of life in old age	• Need a greater range of polymer processing capabilities and polymer chemistries in powders • Controlled residual porosity (especially ceramics). Roughness. High solids nanomer slurries (stereo lithography) • Process developments – still relatively new technology and need process/material interaction understanding

The ability to improve and fully customise components – from bone replacement structures to body parts – enables higher treatment efficacy while meeting patients' expectations for extended quality of later life and demands such as durability and aesthetic appearance. Investment in hybrid additive manufacture/3D printing (including 3D bioprinting) also improves sustainable practices potentially replacing or supplementing animal models and implants, speeding up delivery of components and reducing material waste.

The UK draws on a strong base in additive manufacture techniques, materials and laser technology. However, a greater range of polymer chemistries in powders is needed, as well as developments in process understanding and finishing processes. Key specific outcomes include better powder size, shape and packing.

The ultimate vision is to construct complex replacement structures currently impossible via moulding techniques (e.g. insulin pump). The major challenges are not only technical (such as compatibility with sterilisation processes) but also regulatory: A review of the 'hoops to jump' and the pass/fail limits for existing standards will be needed.

Cost of ownership life cycle costing

The need	Drivers	Actions to deliver
• Make it easier to acquire technology. • Better adoption stimulates supply which drives manufacture and R&D and delivers growth in UK PLC	• Technology perceived as too expensive under current accounting mechanisms (budgeting silos)	• Alignment of health economies into accountancy rules • 'Annualisation' of upfront cost over lifetime benefit/outcome'

A major barrier to take-up of innovative MedTech products in the UK is the up-front cost. Purchasers, with limited budgets, and rigid budget boundaries (budget silos), often fail to make the best decisions – for example, buying an £8,000 piece of equipment that will last eight years, rather than an £11,000 one that will last fifteen. So health delivery is less cost effective, with potentially poorer outcomes, while the growth of the MedTech sector is hampered by slow adoption rates.

If return-on-investment-based accounting models could be developed which allowed for easier adoption of technology this would provide a clear signal to the UK manufacturing base. The MedTech sector could thereby grow its skills and capability base, and this in turn would have the important benefit of supporting national health sustainability.

Although there have been advances in quantifying health economies, evidence gaps remain and more research is needed before new economic models can be proposed. The vision is for an outcome-based ownership model which 'annualises' the upfront costs taking into account the lifetime benefits of the purchase.

Hurdles include raising the visibility of this issue and gaining support from all stakeholders – the (disparate) MedTech sector itself, government (HM Treasury, Department of Health), and healthcare providers. A key problem is lack of ownership (who has sufficient incentive for change?). Ways must be found to overcome inertia and the difficulty of quantifying benefit realisation – this latter is needed both at a technology/product specific level (new models) and at a sector level to demonstrate the true potential of the MedTech sector at government levels.

Use of simulation for individual patient to deliver right-first-time surgical intervention

This theme has a broader impact than just HVM as it gives a wider perspective to improve personalisation of healthcare through both modelling and simulation of human physiology and the thorough understanding of biomechanics integrated with bioinformatics and other data to enable, in the future, right first time manufacture of personalised devices. It also extends the tools developed into surgical training aids to support best practice in surgical interventions.

The need	Drivers	Actions to deliver
• Improve surgical intervention & outcomes though new forms of simulation • Drive innovation in medical device manufacturers to increase UK GDP	• Right first time, fit for purpose • Work with clinicians and manufacturers to optimise design of devices • Pre-clinical regulatory	• Fundamental understanding of human anatomy & physiology • Build dynamic simulation models • Automated patient-specific model construction

Demographic factors give special urgency to the case for focusing on ways to improve surgical outcomes. The UK's ageing population fuels a growth in demand for surgery, while risks to patient safety increase as greater numbers of older and obese patients undergo surgical procedures. Surgical errors result in both social costs (e.g. poor quality of life, need for further surgery) and economic ones (such as litigation).

Imagine the impact on right-first-time surgical intervention if a surgeon could carry out a patient-specific 'mission rehearsal' beforehand – using a simulation of the patient which gave visual, biomechanical and physiological fidelity. Such a product would present a major opportunity for the UK's medical device manufacturers to gain competitive advantage.

For research to work towards this bold vision requires a multi-disciplinary effort to map human motion through the activities of daily living, employing the latest imaging technology, bio-informatics, the full range of software and engineering tools (CAE, CFD, FEA etc) and requires a more comprehensive understanding of specific biomechanical behaviour. Another key need is early engagement of surgeons themselves: first recruiting 'clinical champions' and then working towards augmented clinician training. The first step could be to review and discuss limitations of current methods used by the surgeons in plastic, trauma and reconstructive surgery.

New business models: case for high quality hand-held imaging

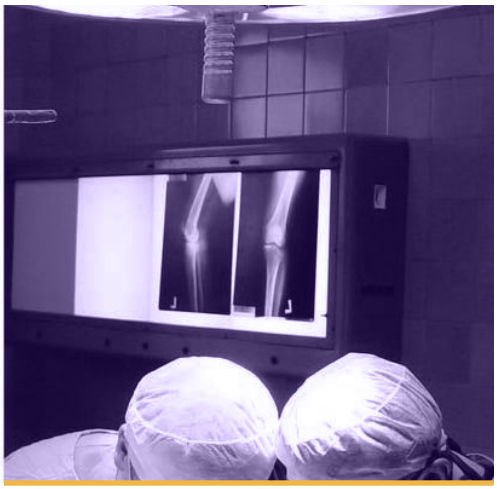
This Case for Action addressed the specific case of hand held imaging as a future innovative product to drive manufacturing innovation, but morphed into the design of a future business model which may have wider applicability in driving changing behaviours within and between companies to add value at a platform rather than specific technology or product level.

The need	Drivers	Actions to deliver
• Improve health delivery through imaging • 21st century healthcare • Global • Scale of challenge requires 'disruptive' service	• Clinical need • User need • Generate income in UK and export • Reduce cost of healthcare	• Create new company to source and integrate existing technologies •Pilot – gather evidence • Engage commissioning • Engage consumers not just patients • Source technology

The model proposed is to create a new service business with a strong emphasis on engaging/ consulting with (service) users, which first establishes shortfalls in existing services, then seeks available products and technologies that can deliver the new service, before undertaking development on technology integration and a new service model. A strong business plan and rigorous IP would be prerequisites of the subsequent roll-out stage. This approach is a design led approach to establish a need in future healthcare provision for which a disruptive service innovation is needed. Innovative businesses could address such gaps in the market by integrating existing but innovative solutions to deliver new product and service platforms. The developing business models theme is a cornerstone to the broad UK HVM strategy, where new value can be created.

The rationale in this Case for Action was to see how this approach works for new means of imaging, where new technologies are arising that can provide disruptive service paths, and which needs early engagement of all interested and affected parties to deliver a value added service with strong appeal to users, procurers, patients etc. A similar approach could be adopted to evaluate new business models in other areas where medical technologies impinge on new and disruptive patient pathways.

A means of stimulating businesses or entrepreneurs to pick up quite risky propositions is needed, with the SBRI mechanism being a potential source of driving changes such as these based on challenging and radical problem statements form the healthcare service.



7. EXISTING INITIATIVES WHICH SUPPORT LIFE SCIENCES MANUFACTURING (IN ALPHABETICAL ORDER)

Since the start of the roadmapping exercise, a number of new or extended initiatives have been launched, some in part informed by this exercise. These and their direct relevance to HVM are highlighted below.

AMSCI (Advanced Manufacturing Supply Chain Initiative) – AMSCI is a BIS initiative in support of their Industrial Strategy and sets out to provide a flexible package of support (grants and loans) with the aim of helping existing supply chains grow and achieve world class standards while encouraging major new suppliers to set up and manufacture in the UK. This programme has been developed over recent years to make it increasingly applicable to businesses in the Life Sciences sector.

BBSRC BRIC – This initiative has provided £26m of funding for industry-driven academic research and will continue to operate until 2016. It has currently 15 industry members and has been viewed by the sector as a leader in terms of quality, outputs and industry interaction. It has also enabled 28 BRIC PhD studentships to be aligned and taken up by the industry members. The Health KTN has also been key in ensuring industry engagement and latterly overall programme management.
A bid to establish a new network in biopharmaceutical bioprocessing (BioProNet) has been submitted and should enable further interaction from academics and industry in wide ranging research challenges.

Biomedical Catalyst – This joint initiative between Technology Strategy Board and MRC has been pivotal is moving early stage products and technologies into or towards clinic. The recent announcement to continue this funding stream has been strongly welcomed by the key Trade Associations.

Formulations Special Interest Group and proposed Formulation Centre – The Formulation SIG has engaged a cross sector community to attempt to define some common needs. A potential output may be the establishment of a Centre that could enable technology to be developed and translated through industry-industry or industry-academic collaborative programmes. Scoping is still underway.

MISG – This Ministerial Industry Strategy Group is tasked with developing a shared understanding across key stakeholders of the existing support available and challenges for industry and proposing a cohesive strategic vision for medicines manufacturing in the UK. It will cover issues relating to the manufacturing of all types of medicines including small molecules (pharmaceuticals), biologics and advanced therapies such as cell and gene therapies, both for clinical trial and licensed product manufacture.

MMTSG – This Ministerial Medical Technologies Strategy Group is similarly (to MISG) tasked with developing a shared understanding across key stakeholders of the major issues facing the medical technologies sector and how support mechanisms can be optimised to enable a responsive and competitive sector. Amongst other things, it addresses issues related to manufacturing across all sub-sectors and the supply chain.

Catapult Centres – Catapult Centres are a Technology Strategy Board product and were launched to address the need to transform the UK's innovation potential in key areas where a critical mass of expertise is required coupled with an enabling and high cost infrastructure which has some form of open access to large and small businesses.

- Two Catapult Centres are relevant here: High Value Manufacturing[7] and Cell Therapy.
- The former comprises seven Core Centres which provide both mechanical engineering capability of potential relevance to the MedTech sector (e.g. additive manufacture, plastics electronics) and process engineering. An important new Centre within this is the National Biologics Manufacturing Centre, which is still being formed (and informed by this report and on-going input of the Health KTN).
- The Cell Therapy Catapult[8] addresses a part of this roadmap, but will also form its own manufacturing roadmap and is a major contributor to unblocking the commercial and clinical realisation of cell therapies.
- A new Catapult is also now being proposed: Diagnostics for Stratified Medicines Catapult – This was announced in August 2013. The Catapult will help identify and provide the right care for individual patients, allowing businesses to develop new treatments and reducing the cost of healthcare.

Cogent – £25m pilot scheme for the Science Industry Partnership (SIP) led by GSK. The SIP is a proposed national, skills and education focused Partnership for the science-based sector to develop ambitious end-to-end skills solutions for the industry.

EPSRC – EPSRC supports basic research and skills development in a range of manufacturing technologies (alongside other themes). Of particular note are their Centres

[7] HVM Catapult - http://hvm.catapult.org.uk/
[8] CT Catapult - https://ct.catapult.org.uk/

for Innovative Manufacturing for which one already exists in Medical Technologies[9], one in Emergent Macromolecular Therapies, one in Regenerative Medicine and to address skills there will be new Centres for Doctoral Training (2014) which aim to develop post-graduate engineers with strong commercial awareness alongside academic excellence.

HealthTech and Medicines Knowledge Transfer Network[10] – The Health KTN retains a High Value Manufacturing Priority Theme to support Life Science businesses with knowledge transfer and networking needs. There are active technical groups within the bioprocessing space focussing on both product and process challenges and the potential to deliver more workshops on topics raised through this roadmapping exercise. The Health KTN will respond to demand from its members as well as running workshops which can inform some of the government investment plans. The Health KTN also delivers the Annual bioProcessUK Conference which is viewed as the main technical networking event for key stakeholders and opinion leaders in the biopharmaceutical sector.

Technology Strategy Board[11] – Technology Strategy Board - is the UK's innovation agency and its goal is to accelerate economic growth by stimulating and supporting business-led innovation. The Technology Strategy Board has a Life Sciences and HVM team that are responsible for calls directly related to these areas. The HVM team have released very relevant competitions that have been informed by this roadmap as well as other inputs. In recent years, relevant Calls have included: Driving cross sector collaboration in formulation technologies, Additive manufacturing.

Europe (EU) – the aim of the EU investment in Health research is to improve the health of European citizens, to address global health issues and to boost the competitiveness of European health-related industries. In the area of Life Sciences including HVM the Horizon 2020 for Health is the EU's new programme for investment in research and innovation, is expected to include more than 7 billion EUR for the 'Health, demographic change and wellbeing' challenge. There are also other EU wide schemes running that relate to this sector (Eureka, Eurostars etc.).

Other – The main Life Science Trade Associations of the BIA (The BioIndustry Association), the ABPI (Association of Pharmaceuticals Industries and the ABHI (Association of British Healthcare Industries) have been highly supportive of this roadmapping exercise and in the case of the ABPI and BIA have on-going Special Interest Groups which address topics to support UK manufacturing. Additionally, the UK regulatory agency, MHRA (Medicines and Health products Regulatory Agency), continues to support The Health KTN and the industry in taking an early engagement in manufacturing developments such that a regulatory perspective can be included and developed alongside.

[9] http://www.epsrc.ac.uk/newsevents/news/2013/Pages/newcentres.aspx
[10] www.healthktn.org
[11] Technology Strategy Board - www.innovateuk.org

8. CONCLUSIONS

This report has highlighted both significant manufacturing challenges and exciting new opportunities for the life sciences sector. The roadmapping process has provided a structure to establish consensus, has enabled the different sub-sectors to be evaluated independently and then allowed for some synergies to be drawn.

As an overall report, it can be clearly seen that all parts of the life sciences sector have significant manufacturing activity in the UK and there is a strong demand from business to support and indeed encourage radical change in manufacturing practice to retain/grow this manufacturing base in the UK. There are variations between each sub-sector, based on state of the market and diversity. Biopharmaceuticals is an emerging sector by comparison, pharmaceuticals is well established but has not embraced modern manufacturing processes and the MedTech sector is highly diverse and fragmented, making it difficult (but not impossible) to draw out manufacturing themes and commonality on the broader underpinning challenges.

Overarching drivers for all parts of the Life Sciences sector included managing an increasingly ageing population with growing healthcare needs, providing therapies tailored to suit individual patients, reducing unsustainable development costs and developing a more adaptable, responsive regulatory framework.

The Case for Action for each of the priority areas outlined in this report provide an insight into some of the benefits such change could achieve across a range of areas. The UK is in an excellent position to take advantage of these opportunities. Many of the world's leading pharmaceutical companies are located and manufacture here, while at the same time the sector includes hundreds of small, highly innovative businesses that can contribute new approaches and technology. The UK also boasts excellence across life sciences and manufacturing with particularly commitment to drive up skills and cross fertilisation. The existence of an open regulatory body, the MHRA, is another important enabler for change. This study highlights the vital importance of close collaboration between industry, government and the regulatory authorities to support new manufacturing developments and to enable their impact on industry and the regulatory framework to be identified as early as possible. The identified challenges are already stimulating some innovative responses across both areas with evidence of a real appetite for change. Specific conclusions for each sub-sector were:

Key areas in pharmaceuticals manufacture

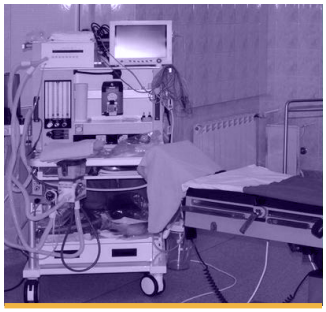
The study identified a need for more flexible production facilities and early consideration of manufacturing needs. These could significantly cut costs and development times as well as delivering a better service to patients. Manufacturing for personalised medicines

that tailor therapies to the needs of each patient could improve patient outcomes, as well as reducing healthcare costs. Novel methods for how drugs are given to patients, combined with 'smart' technologies, could integrate formulation, packaging and delivery to ensure prescribed treatments are followed more closely – improving results and reducing waste. New developments in formulation design could minimise use of valuable resources and maximise shelf life. Reconfiguring the supply chain could support radically new business models based on patient needs and wellbeing. These exciting developments all raise multiple, new manufacturing challenges.

To a great extent manufacturing approaches in the pharmaceutical industry are still stuck in the past, following long-established practices that are ill suited to the needs of the 21st Century. There are now real opportunities for radical change and improvement. A further key driver for this sector is the so-called 'patent cliff' by which expiring patents result in plummeting revenues.

Key areas in biopharmaceuticals manufacture

In this still emerging biopharmaceutical sector (manufacturing of biologics) the study identified the need to provide new, low-cost routes to market including manufacture for innovative therapies so that value can be retained in the UK. Improvements in analytics



would enable products to reach the market more quickly through greater process knowledge, and therefore at lower cost and with reduced waste. Increased understanding of biopharmaceutical formulations could help to develop more stable and effective medicines, and improve delivery to patients. New approaches in biological production technology could enable individually tailored treatments to be produced more quickly and cheaply.

Furthermore industry feels the need to continue to build on successful industry-focused academic research managed programmes (such as BRIC) and that the Technology Strategy Board may play a role in developing structures and key deliverables to ensure that the vision of the biopharmaceutical industry based in the UK is realised. A good example here is the new National Biologics Manufacturing Centre as part of the HVM Catapult.

Key areas in medical devices manufacture

The diversity of the MedTech sector made this a more challenging area to examine and draw out clear manufacturing themes. However, there was strong consensus in the need to deliver solutions to support changing healthcare needs which predominantly requires greater functionality, personalisation and cost effectiveness. Key products for the future were seen in remote monitoring and point-of-care testing, smart wearable or implantable devices and patient-managed diagnostic and administered medication delivery devices. These then need to improve clinical outcomes, deliver a better service to patients and at the same time support the NHS in reducing costs.

Technologically, new methods which incorporated hybrid additive manufacture/3D printing, novel surface functionalities, precision and nano-scale manufacturing as well as the better integration at system level were seen as opportunities. Systems integration in MedTech is seen as multi-faceted, ranging from integrated biology and physical devices (biocompatibility and bioactivity), to integration of multiple hardware and software components (often produced by multiple SMEs), to integration of devices with data enabling post-market surveillance and further intelligence to feedback into manufacturing processes. Further, better use of simulation (even to individual patient level) to deliver right-first-time surgical interventions were seen as key competencies to support MedTech manufacturing.

There are many emerging medical technologies and enabling manufacturing processes, but in all cases there is a need to be clear about market demand and routes to adoption, which can best be met by close collaboration from an early stage between clinicians, patients and industry.

Also highly relevant to HVM, radical new business models and economic analyses were agreed as two priorities to stimulate growth of the MedTech sector. Cost of ownership together with life cycle costing models are needed to develop return-on-investment-based accounting methods for easier demonstration of value to support manufacturing investment decisions and new business models incorporating product with service were seen as value adding and a stimulant to export potential.

With the diversity of this sector, the roadmapping exercise, plus other inputs, have highlighted the lack of an obvious or coherent supply chain which could benefit both large and small.

Synergies

Although each sub-sector had its own emphases based on maturity of the sector and specific technological needs, there were not surprisingly some areas of synergy to deliver to common drivers.

Generally products for the Life Sciences sector, even if noted sometimes as commodities, can be high value in comparison to other sectors, and as such high value manufacturing is a key part of getting the products to market and can subsequently contribute significantly to a nation's wealth creation and GDP. The UK is building its R&D and clinical trial capability to attract Life Science businesses and a favourable market now exists for innovation which can and should be extended to more High Value Manufacturing in the UK.

A key area was one of personalisation including all aspects of how to deliver customisable products close to the customer. Others included compliance and how use can be made of devices, diagnostics and engineering approaches to support optimum use of any healthcare/therapeutic product. Capturing and using more intelligence at point of delivery and how new data can be gained to support manufacturing approaches were also highlighted.

The life sciences sector has a few large businesses and many small ones, and there are opportunities for the sector to learn from each other on new manufacturing approaches, but also from other sectors, using open innovation tools with an emphasis on manufacturing strategies and technologies.

Other potential areas of synergy, but may have sub-sector specificities, include:

- Improved supply chain design to manage complexity and encourage co-location of facilities
- Distributed manufacture
- Green manufacture.

Comparing the workshops for pharmaceuticals (chemical entities) and biopharmaceuticals (biologics), further demonstrated the difference in maturity between the two areas. Mainstream pharma addressed new factory approaches including distributed manufacture, proximity to the customer and compliance issues whilst biopharma addressed more innovative technological manufacturing approaches including how to improve yields and control final product efficacy. As these latter methods mature, it was felt the manufacturing developments for pharma would also benefit biopharma.

Next steps

This report is now being disseminated widely and being used to support future manufacturing investment decisions at the Technology Strategy Board, to provide background to support life science manufacturing policy within BIS and to frame future research agendas by the Research Councils.

The Health KTN also plan further workshops to bring the manufacturing communities together and help define future networking/knowledge transfer needs to help advance some of the themes highlighted by these roadmaps.

9. RECOMMENDATIONS

High level recommendations are given here and the reader is pointed to the detail of the text for more specific priorities.

The retention and development of world leading manufacturing capability within the Life Sciences sector must be recognised and invested in alongside other major manufacturing sectors.

Government policy should give equal weighting to all parts of the Life Sciences sector for manufacturing initiatives, whilst recognising and responding to the unique attributes of each.

The priority themes as developed in this work should inform future investment plans by the Technology Strategy Board and relevant Research Councils. In particular, investments which bring about radical change in manufacturing and learning from other sectors are particularly noted.

Sustained, flexible funding opportunities would be welcome in the key challenge areas identified in this report in order to drive further collaboration and to de-risk new products and processes.

Future Technology Strategy Board funding strategy should continue to align a proportion of its Collaborative Research and Development Programme budget to support collaboration with the Catapults and associated Centres while ensuring support across the breadth of the life science manufacturing sector.

Skills to support Life Science manufacturing are required, and the Centre for Doctoral Training model is noted as an appropriate vehicle to build multi-disciplinary and commercially aware capability.

Better awareness and building of effective and flexible supply chains are required which can contribute to future changes in manufacturing practice, including distributed manufacture, localised flexible manufacture with personalisation, engineered and systems approaches.

The Technology Strategy Board Framework for HVM is seen as highly relevant to Life Sciences, and further emphasis on new business models is seen as necessary to facilitate some of the changes required.

Regulation should become an enabler and stimulator of innovation in manufacturing, not least ensuring a 'level playing field' with international competition.

10. NEXT STEPS

The Health KTN can uniquely span manufacturing interests across the key sub-sectors of the life sciences sector enabling a strategic overview of specific needs and challenges as well as the opportunity for synergies across and beyond life sciences. With this background and the ability to link manufacturing priorities into both policy and innovation funding, the Health KTN will now lead future steps to promote this report and work with the key agencies to inform future initiatives (a good example already underway being the shaping of the new Biologics Manufacturing Research Centre within the HVM Catapult).

Specifically, the Health KTN will:

- Work with the Technology Strategy Board HVM team on ensuring future HVM calls address discrete requirements for the sector, and particularly where benefit can be found in matching such needs with other UK manufacturing sectors.
- Develop, with other KTNs, relevant workshops to build on some of the cases for action to develop new collaborative partnerships with clear objectives
- Feed the findings of this report into BIS and its new industrial strategy, and manufacturing support mechanisms, including AMSCI
- Present the report to relevant Research Councils to inform their future funding plans, and the work of the new Centres for Innovative Manufacturing
- Continue and grow the relationship with the HVM Catapult to make it more relevant to the life sciences sector
- Continue to support the Cell Therapy Catapult where synergies exist between cell manufacture and biologics manufacture
- Present the report to UKTI to demonstrate the commitment of the UK life sciences base to invest in innovative manufacturing and make it a location of choice for inward investment.

The Health KTN will also work with the Trade Associations and industry directly to ensure manufacturing remains an agenda item for relevant groups and that this live document can be updated as new initiatives open up and change the landscape from its current base.

Appendix

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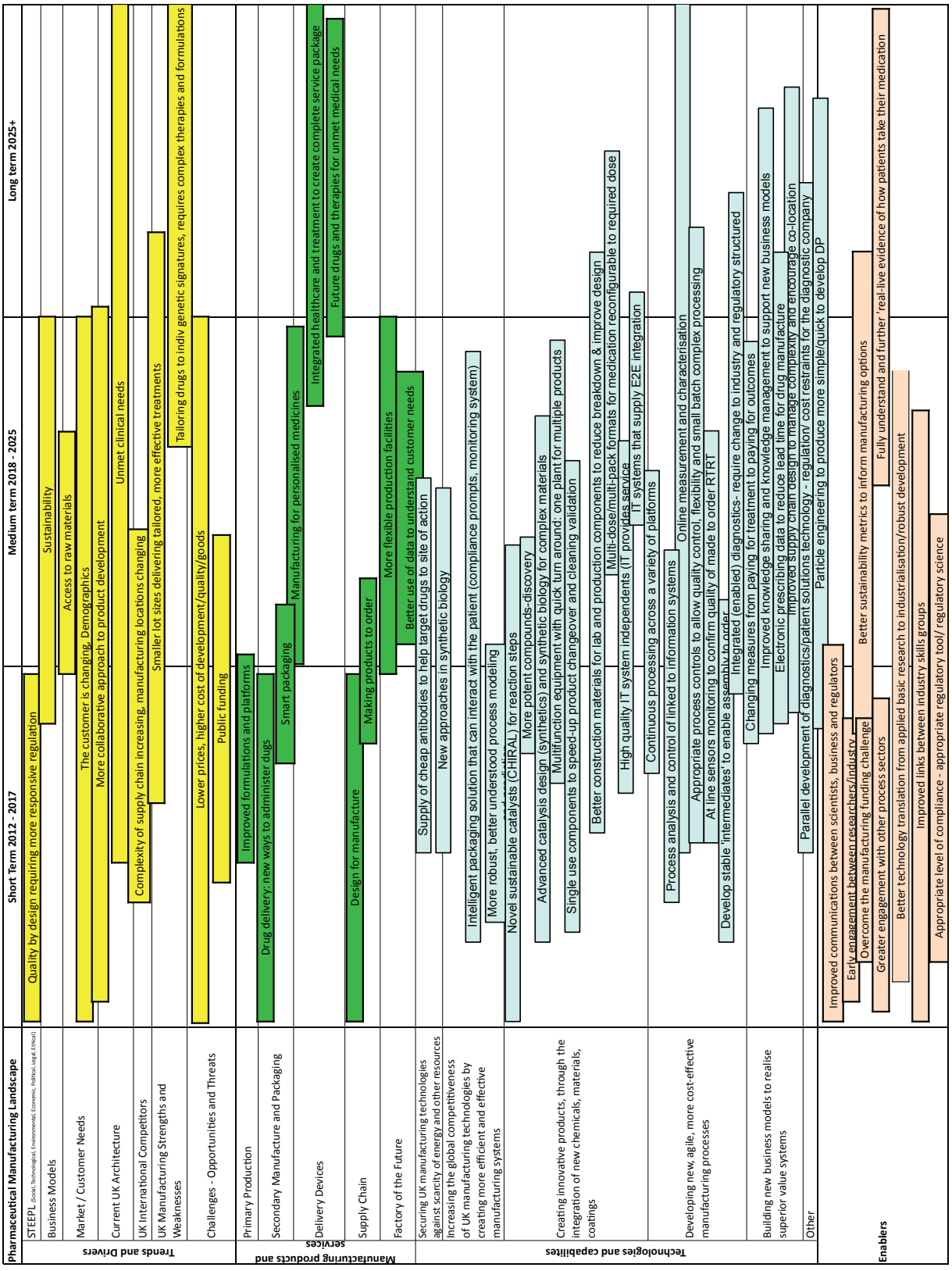
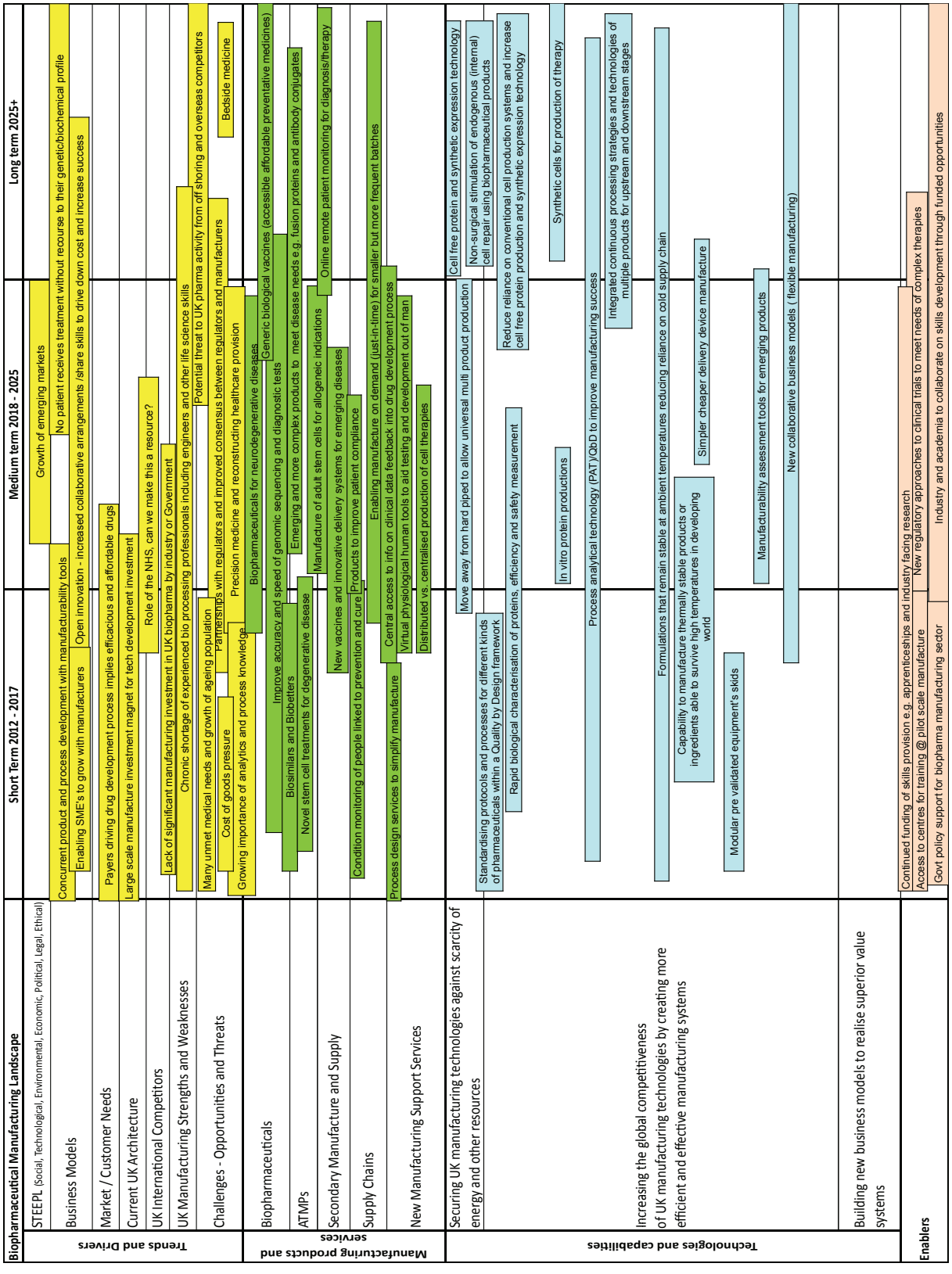
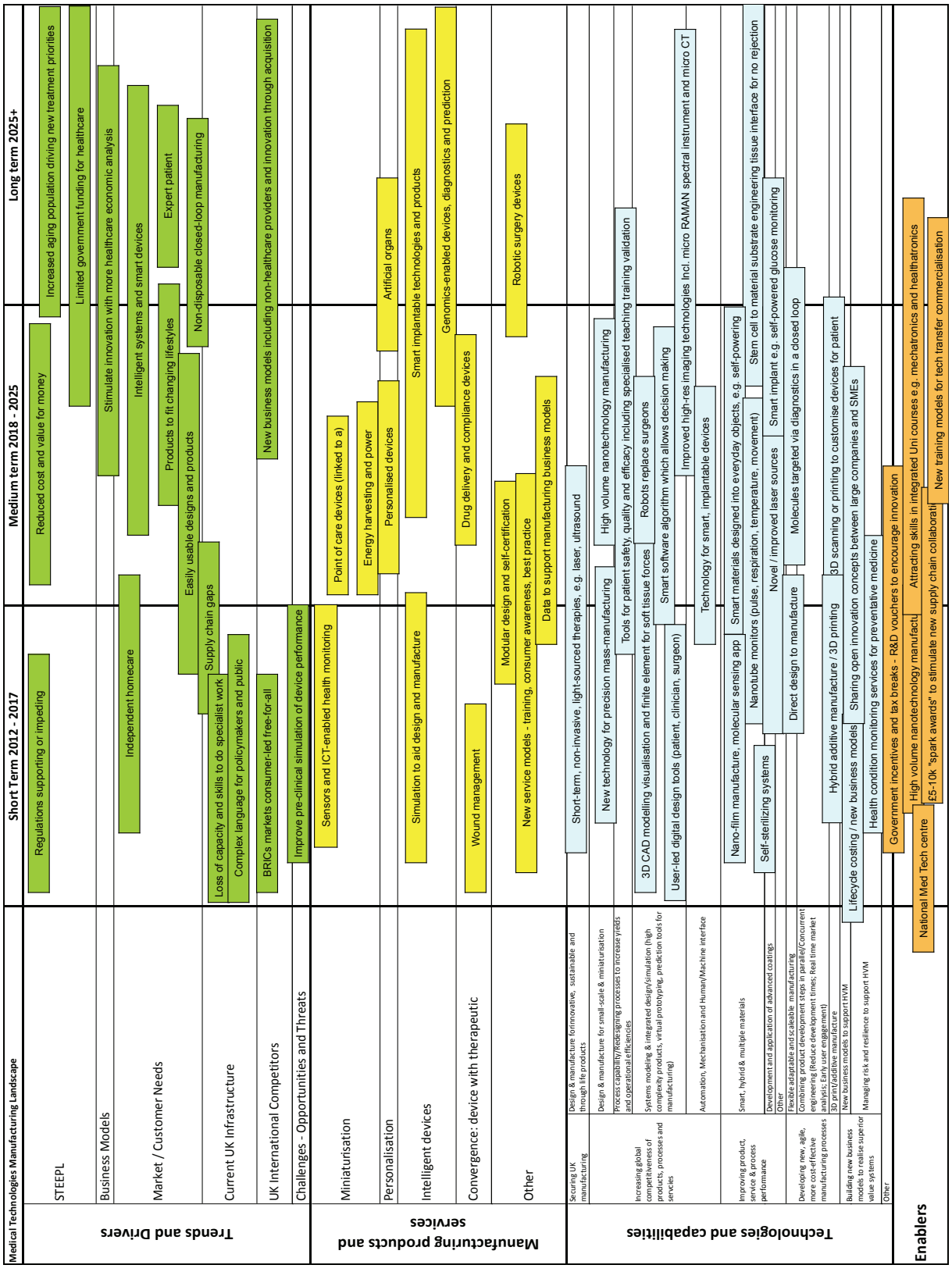
PHARMACEUTICAL Landscape Chart



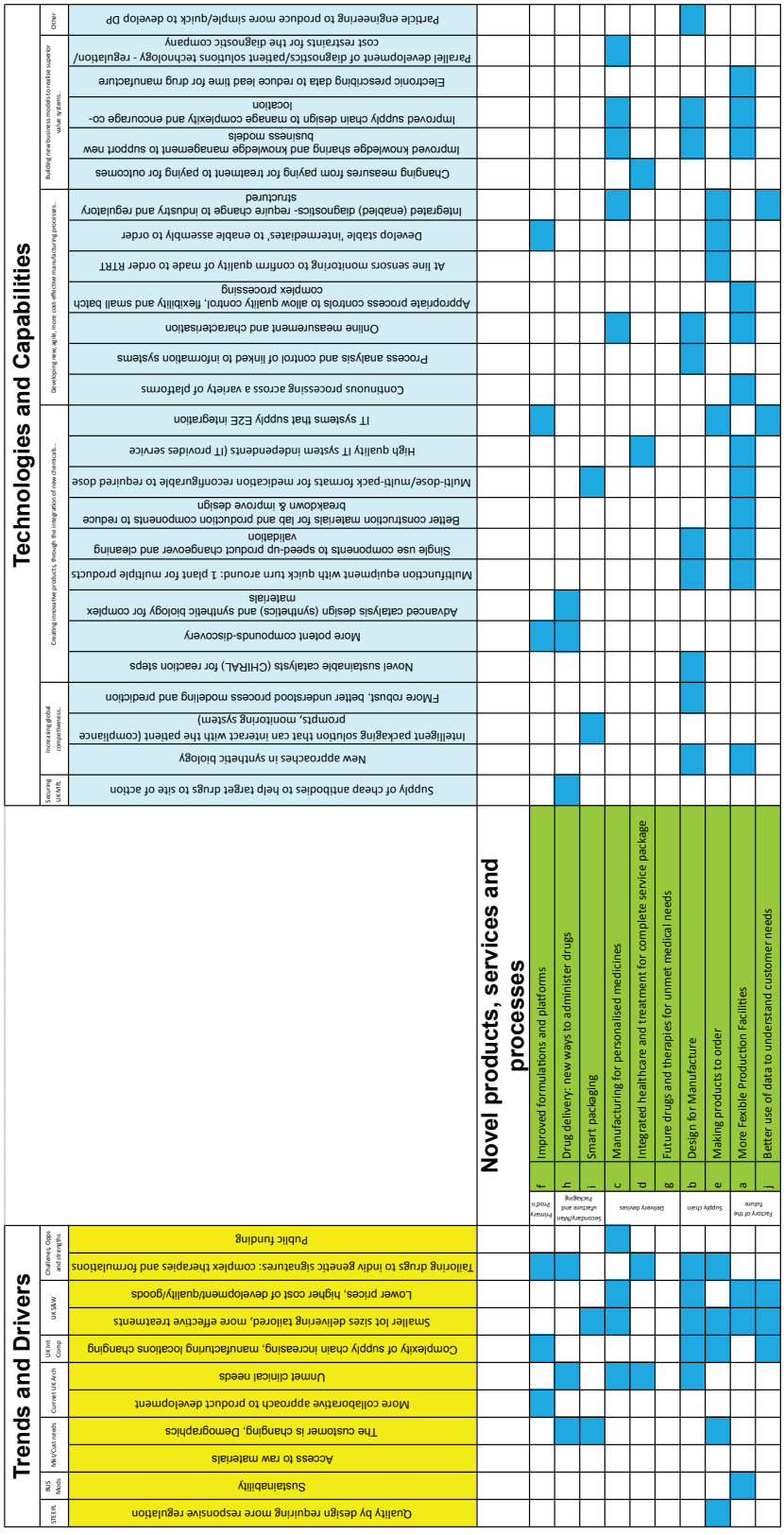
BIOPHARMACEUTICAL Landscape Chart



MEDTECH Landscape Chart

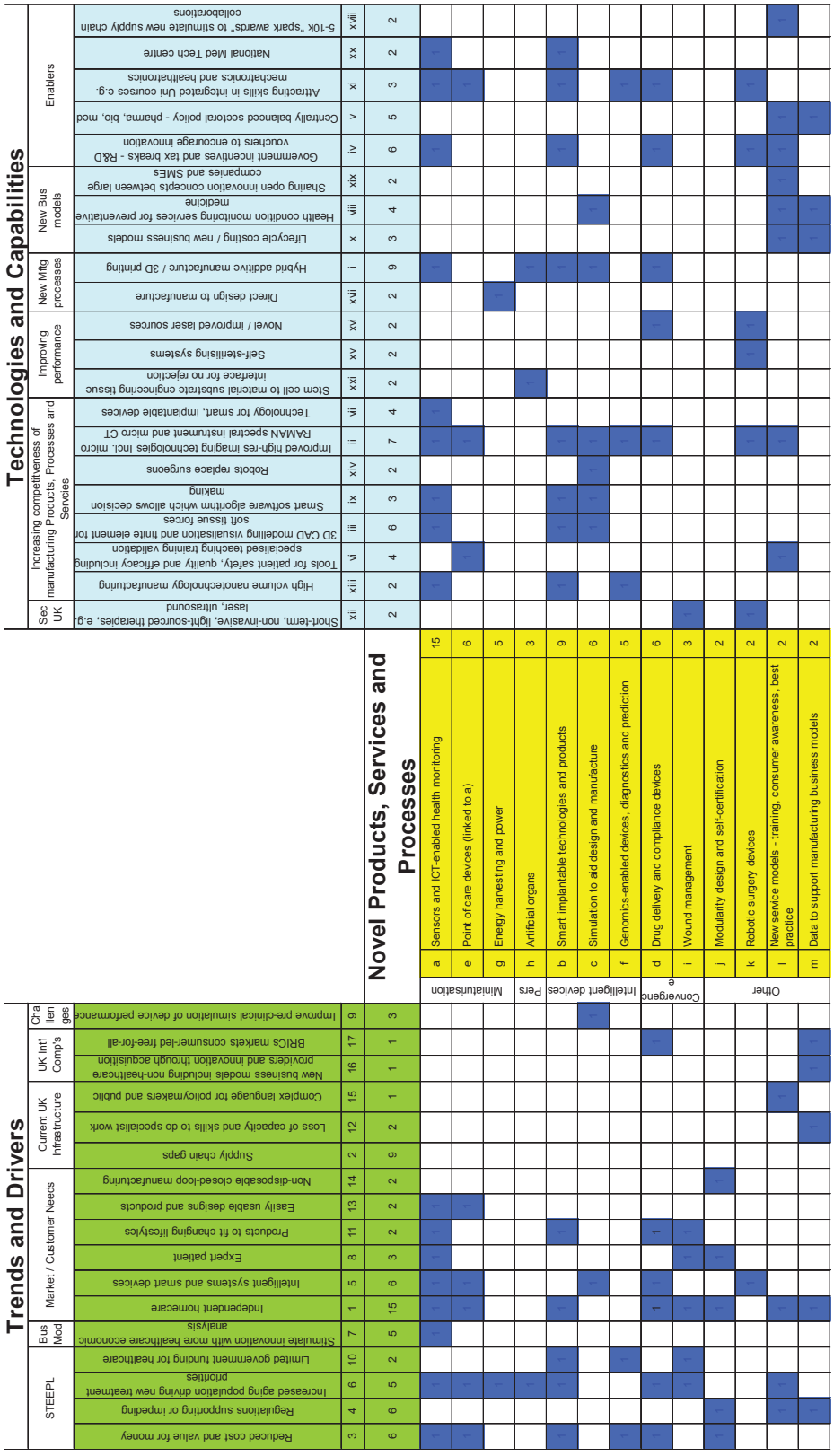


PHARMACEUTICAL Linkage Chart



BIOPHARMACEUTICAL Linkage Chart

MEDTECH Linkage Chart



Knowledge Transfer Network

HealthTech and Medicines

The future of High Value Manufacturing in the UK

Pharmaceutical, Biopharmaceutical & Medical Device Sectors