Wales National Research Network
Advanced Engineering and Materials

Identifying and Prioritising Potential NRM Research Topics

Roadmapping Workshop 12th February 2014

Final Report

Executive Summary of NRN Roadmapping Workshop (1)

Background

- The objective of the workshop was to highlight possible areas of research for Advanced Engineering and Materials (AE&M) in Wales
- 30 delegates from industry, academia and government used landscape and topic roadmapping to identify and prioritise possible opportunities
- UK National Competencies from the TSB sponsored High Value Manufacturing project were used to classify capability requirements
- A broad-based prioritisation of Competencies was generated and then examined for relevance for Welsh research
- As always, outcomes are highly dependent upon those involved in the process, particularly the workshop.
- The output is not definitive and provides one input into the discussion and decision making by the NRN Leadership Team information

Landscaping: Prioritisation of UK HVM National Competencies for AE&M

- A layered process was used to landscape Trends and Drivers, Opportunities and Capabilities
- Delegates prioritised Trends and Drivers with 'Energy Mix & Affordability', 'Climate Change & CO2', 'Material Scarcity', 'New Ways of Manufacturing' 'Loss of STEM skills' and 'Rising Cost of Production' most highly ranked
- Delegates prioritised Opportunity clusters with 'Energy Generation and Storage', 'Transport of the Future', 'Modelling Complexity/ Risk Avoidance', 'Self Diagnostic Imaging/Smart Monitoring', 'New Nuclear & Life Extension', 'Intelligent Manufacturing', 'Low Cost Recycling of Materials and 'Accelerated Materials Development/Modelling' most highly ranked
- A combination of measures indicates a possible tiering of needs for Advanced Engineering and Materials in the UK:
  - ✓ Tier 1: 'Systems modelling and integrated design/simulation', 'Smart, hybrid and multiple materials', 'Intelligent systems and embedded electronics'
  - ✓ Tier 2: 'Energy generation, storage, management and security', Design and manufacture for sustainability and through-life', Biotech, biological and synthetic biology processing, 'Automation, mechanisation and human/machine interface', 'Development and application of advanced coating' and 'Net and near net shape manufacture'
- Aerospace & Defence, Energy and Automotive are possibly the most relevant sectors for AE&M at a UK National level
- There is a wealth of ideas behind the top competencies contained in the workshop database

Executive Summary of NRN Roadmapping Workshop (2)

Topic Roadmapping: Comparing Welsh capability with prioritised UK HVM National Competencies

- There is a good/fair match between workshop voting for capability in Wales and AE&M prioritised UK HVM National Competencies.
- Three of the competencies chosen for topic roadmapping ('Energy generation, storage, management and security', 'Design and Manufacture for Small Scale and miniaturisation' and 'Additive Manufacture') lever all three NRN themes and may help access synergies
- Classification indicates possible a approach for Welsh NRN research with 'Systems Modelling and Integrated Design/ Simulation', Intelligent Systems and Embedded Electronics', and 'Smart and Hybrid Materials' appearing to be the prime candidates for seeking research opportunities with 'Energy generation, storage, management and security', Design and Manufacture for Sustainability and Through Life', 'Automation Mechanisation and HMI' and 'Advanced Coatings' also being potentially attractive.
- Critical capability gaps as potential research topics have been identified for a range of these competencies
- 'Additive Manufacture' and 'Design and Manufacture for Small Scale' may need further investigation as proposed Welsh priorities for their fit with AE&M prioritised UK HVM National Competencies
- 'Design for Sustainability' and Automation and Mechanisation and HMI' need topic roadmaps before specific research topics can be identified

Contents

Sêr Cymru - Advanced Engineering and Materials National Research Network

- The Welsh Government is sponsoring the set-up and running of an Advanced Engineering and Materials National Research Network (NRN) connecting the key engineering institutions in Wales: Swansea, Cardiff, Bangor and TWI.

- The Network will foster interdisciplinary research links across Wales, the UK and internationally with fundamental and applied research activity closely aligned to three key research themes: Materials and Innovative Manufacturing Processes, Advanced Sensors and Devices, and Novel Modelling Techniques.

- It is most important that the NRN focuses on industry-inspired early-stage research which has the potential for wealth generation and the development of world-leading capability in Wales. To assist in topic choice, a roadmapping process will be used to obtain input from industry and others.

The objective of the NRN roadmapping workshop was to highlight possible areas of research for Advanced Engineering and Materials

The Sêr Cymru Advanced Engineering and Materials NRN will concentrate on the research themes agreed in the proposal together with appropriate adjacent areas of capability. Agreed themes are:

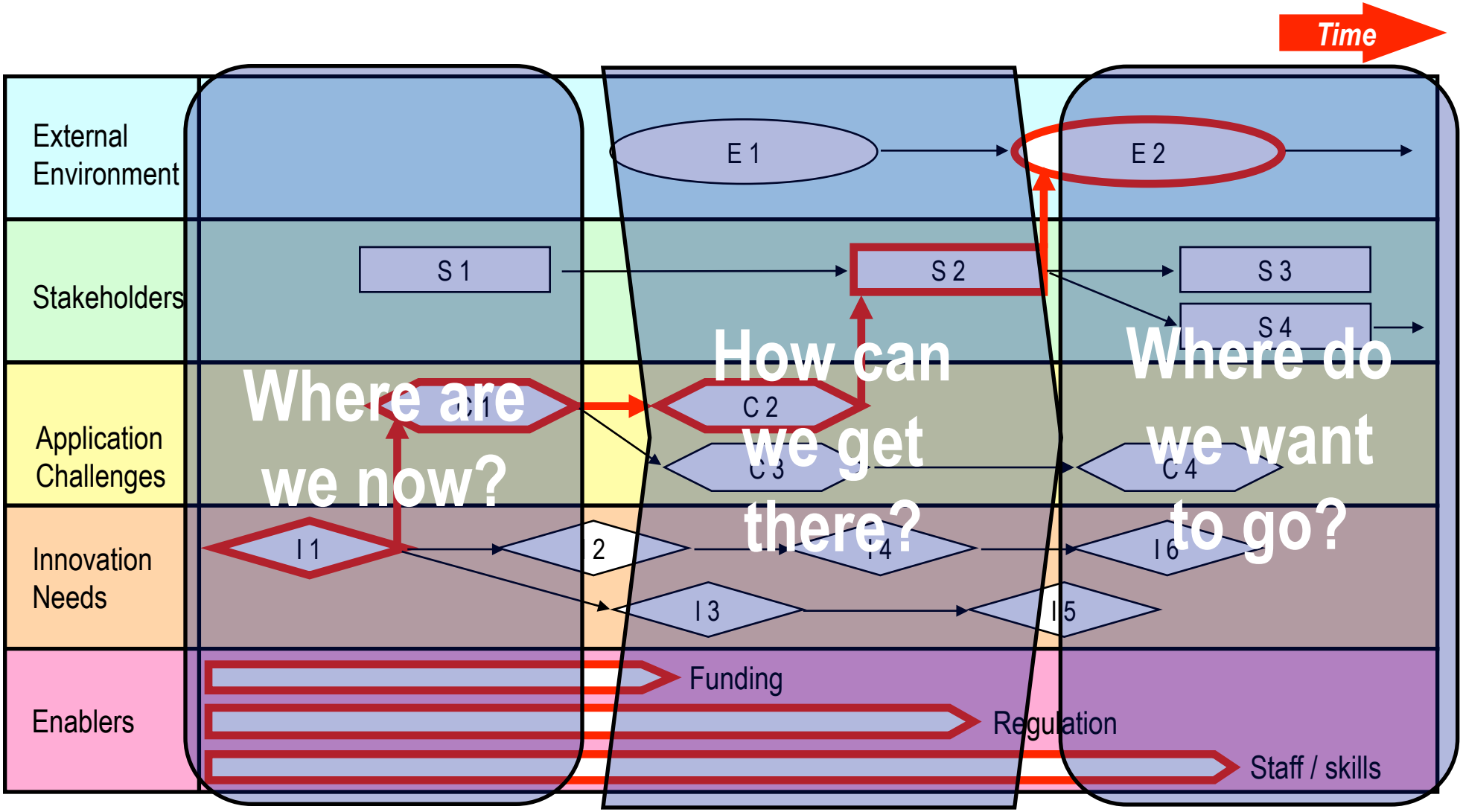
- Materials and Innovative Manufacturing Processes
- Advanced Sensors and Devices
- Novel Modelling Techniques

The objective of the NRN roadmapping workshop is to highlight and prioritise areas of opportunity by constructing landscape and topic roadmaps.

The workshop will start with a wide brief constrained only by the choice of sector participants. However, in the choice of topic roadmaps a filter will be applied to prioritise research requirements falling within the NRN themes.

New topics of research interest will be inspired by future industrial need and will be primarily at an early stage of development (TRL 1-3) with a 10-15 year implementation time horizon. A number of topics may also originate from existing research that has now progressed towards implementation and may deliver in a shorter timescale."

30 workshop delegates used a combination of landscape and topic roadmapping to identify and prioritise possible opportunities

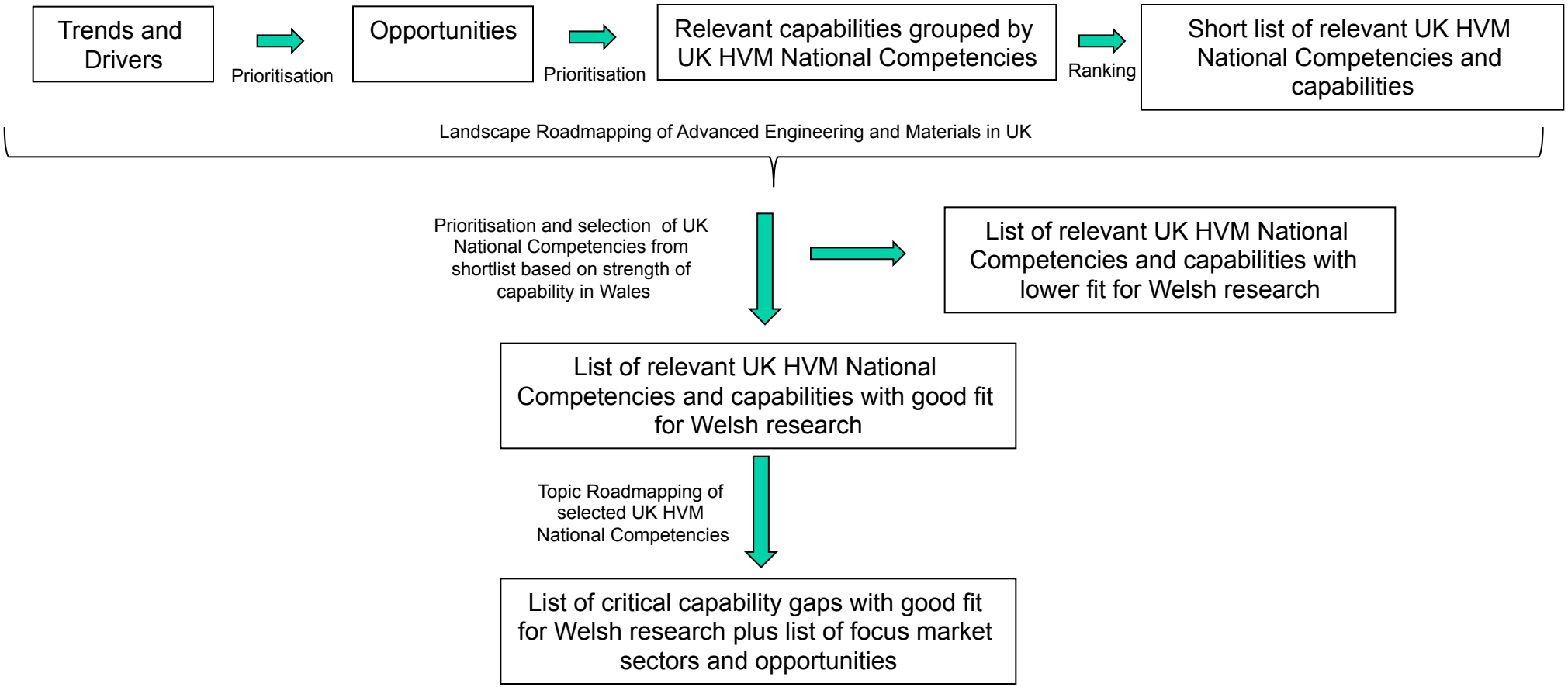


UK National Competencies from the TSB sponsored High Value Manufacturing project[1] were used to classify capability requirements

Strategic Theme	National Competence	Defintion
Resource efficiency: Securing UK manufacturing technologies against scarcity of energy and other resources	Energy generation, storage, management and security	Energy storage, energy management and transport focusing on energy cost, security and novel generation technology. New energy sources including next generation nuclear and energy transmission with low loss and low visual impact.
	Design and manufacture for sustainability and through-life	Design and manufacture of sustainable and innovative products including cleaner processes, low carbon outcomes and less waste. Robust design for disassembly (recycling) and through life engineering.
	Biotech, biological and synthetic biology processing	Alternative bio-and synthetic bio- based sources for new and existing products and processes. Processing of biologics for pharmaceutical and medical applications.
	Design and manufacture for lightweight vehicles, structures and devices	Light weighting to reduce energy consumption and emissions, reduce costs and increase efficiency. Composite, new and hybrid structures design, fabrication, joining and assembly. Multifunction component design and manufacture.
Manufacturing systems: Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems	Process engineering capability across food, pharmaceuticals and chemicals	Development and application of common capability across food processing, pharmaceuticals and chemicals. Redesigning processes to increase their yields and increase operational efficiency.
	Design and manufacture for small-scale and miniaturisation	Miniaturisation, design and manufacturing of smaller products such as specialised drugs, batteries and electronics. High precision and micro/nano-engineered products and processes and integration with macro-scale.
	Systems modelling and integrated design/simulation	Systems modelling and simulation tools, integrated system design, simulation and validation. Virtual prototyping, materials models, functionality and design. System integration of high complexity products.
	Automation, mechanisation and human/machine interface	Process automation and human machine interface. Autonomy applications, particularly in production and servicing.
	Plug and play' manufacturing	Application of modularity to develop a high volume production environment, where the production units can be combined in a flexible manner and serviced more effectively.
	Novel mechanical conversion processes for scale, economy and efficiency	The application of new primary and secondary mechanical conversion technologies and processes e.g. low energy forming/forging, tool-less and one-shot manufacturing, new machine tool technologies and welding processes/applications including e.g. welding to titanium and magnesium.
	Understanding, designing and manufacturing formulated products	Understanding design and manufacture of formulated products for relevant sectors across the supply chain.
Materials integration: Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies	Smart, hybrid and multiple materials	Design, modelling and manufacturing processes of multi-metallic components and high performance materials. Structures and components with integrated functions and tailored material properties and location-specific properties. Enhanced, faster joining capability with a range of materials.
	Intelligent systems and embedded electronics	Robust 'live' data capture and comprehensive capture and use of product/process information. New sensor/NDT devices and smart and multi-functional components which are embedded and/or intelligent. Large area, printable, cheap electronics, integrated with other manufacturing processes for energy management, security, packaging and light weighting. Integration of electronics into product and materials design.
	Development and application of advanced coatings	Development and application of advanced coatings across multiple sectors.
Manufacturing processes: Developing new, agile, more cost-effective manufacturing processes	Flexible, adaptive manufacture	Flexibility of production and manufacturing supporting customised and rapidly reconfigurable manufacturing. Adaptive manufacturing including single step, flexible reconfiguration and process technology that can adapt to feedstock of different types and compositions and mass customisation techniques.
	Combining product development steps in parallel/concurrent engineering	Real-time market analysis and response and systems to reduce development time. Combining marketing, design, manufacturing, standards, regulations and procurement and early user engagement.
	Additive manufacture	Application of additive layer manufacturing techniques or other freeform techniques of joining materials to fabricate intermediate and end use products including direct digital manufacturing methods.
	Net and near net shape manufacture	Initial production of items very close to the final net shape, reducing the need for surface finishing. Tool-less manufacturing with single actions to produce final parts or one toolset for full production system with one pass production.
Business models: Building new business models to realise superior value systems	Managing fragmented value chains to support HVM	Managing complex value delivery across the value chain in multiple locations and exploiting 'economies of small scale' to develop and produce close to the customer.
	Building new business models to support HVM	New business models, with flexible arrangements to create new value.
	Developing and retaining skills to support HVM	Associated training and skills in HVM, provision of employees with cross- disciplinary skills and the ability to combine knowledge.
	Managing risk and resilience to support HVM	Mechanisms to ensure HVM strategy and associated product strategies are inherently compliant to necessary standards across the value chain. Governance to ensure HVM product, service and process outcomes meet strategic intent.

1 http://www.ifm.eng.cam.ac.uk/uploads/Resources/Reports/TSB_UKHighValueManufacturing.pdf

A broad-based AE&M prioritisation of UK HVM National Competencies was generated and then examined for relevance for Welsh research



UK Advanced Engineering and Materials Competency Requirements Analysis (Landscape Roadmapping)

A ‘Why?, What? And How?’ layered process was followed for landscaping

	NRN Landscape		Short Term 2014 - 2017	Medium term 2018 - 2024	Long term 2024+ and Vision
Trends and Drivers	Political				
	Economic				
	Social				
	Technological				
	Environmental				
	Legal				
	Other				
Products and services	Food				
	Biotechnology				
	Chemicals				
	Pharmaceuticals				
	Medical				
	Aerospace, Defence and Space				
	Automotive				
	Rail				
	Marine (incl undersea)				
	Nuclear				
	Energy				
	Oil & Gas				
	Mining				
	Built Environment				
	Electronics				
	Retail, Entertainment and Consumer goods				
	Digital economy (incl Infrastructure), Communication and Security				
	Other				
Capabilities	Resource efficiency: Securing UK manufacturing technologies against scarcity of energy and other resources	Energy generation, storage, management and security			
		Design and manufacture for sustainability and through-life			
		Biotech, biological and synthetic biology processing			
		Design and manufacture for lightweight vehicles, structures and devices			
	Manufacturing systems: Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems	Process engineering capability across food, pharmaceuticals and chemicals			
		Design and manufacture for small-scale and miniaturisation			
		Systems modelling and integrated design/simulation			
		Automation, mechanisation and human/machine interface			
		Plug and play' manufacturing			
		Novel mechanical conversion processes for scale, economy and efficiency			
		Understanding, designing and manufacturing formulated products			
	Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies	Smart, hybrid and multiple materials			
		Intelligent systems and embedded electronics			
		Development and application of advanced coatings			
	Manufacturing processes: Developing new, agile, more cost-effective manufacturing processes	Flexible, adaptive manufacture			
		Combining product development steps in parallel/concurrent engineering			
		Additive manufacture			
		Net and near net shape manufacture			
	Business models: Building new business models to realise superior value systems	Managing fragmented value chains to support HVM			
		New business models to support HVM			
		Developing and retaining skills to support HVM			
		Managing risk and resilience to support HVM			
	Other				
Enablers	Infrastructure				
	Skills				
	Funding				
	Other				

What external trends, drivers and stakeholder needs will influence the development of Advanced Engineering and Materials related opportunities

Why?

What are the Sector Opportunities (Products, Services and Systems) which will be needed to respond to external trends and drivers?

What?

What Capabilities will be required to deliver these products and services?

How?

What other Enablers (e.g. Skills, Resources, Infrastructure and Policy instruments) are needed for success?

Landscape Summary

The following pages capture the output from the workshop. Relative priorities are indicated for Trends & Drivers and Opportunities by the number in each chevron and colour coding. For Capabilities the number of post-its is shown as a surrogate for priority.

	Trend & Driver	Opportunity	Capability
Importance			
High			
Medium			
Low			

Detailed content in each layer is to be found in the database in the Appendix

Delegate prioritisation produced a rank order of Trends and Drivers

	Industry attendee Votes	Non-Industry attendee votes	Total Votes
Energy Mix & Affordability	9	11	20
Climate Change & CO2	9	10	19
Material Scarcity	9	7	16
New Ways of Manufacturing	5	9	14
Loss of STEM skills	5	8	13
Data & Data Handling	5	4	9
Smart/Performance Materials	4	5	9
Fusion of Engineering & Biology & Medicine	3	6	9
Robotics, Automation & HMI	3	5	8
Shift to Lower Scale of Manufacturing & Innovation	2	5	7
Rising Cost of Production	6	1	7
Demographic & Population Shift	3	2	5
Mass Customisation	3	2	5
Geopolitical-Wars and Conflict	3	2	5
Communications & Intelligent Systems	1	2	3
Social Systems & Media	0	1	1
Geographic Shift in Skills	1	0	1

Focus on Health and Safety
Lightweighting
Sustainable/Ethical Innovation
Financial Support for Manufacturing
Manufacturing as USP for UK Companies
Novel Systems
Antibiotic Resistance
More Democratic Politics and Business
Low Cost Integrated Housing
Public Willingness to Fund Based upon Disruptive Technologies
Disruptive Technologies
Land Use

- Attendee prioritisation produced a clear rank order of Trends and Drivers that may influence opportunities requiring Advanced Engineering and Materials capabilities
- There was little significant difference between Industry and Non-Industry voting except for ‘Rising Cost of Production’ which was seen as a greater priority by industry
- A further set of clusters was added after the workshop but are unlikely to affect the priorities based on a review of number of Post-It ideas per cluster

Delegate prioritisation produced a rank order of opportunity clusters

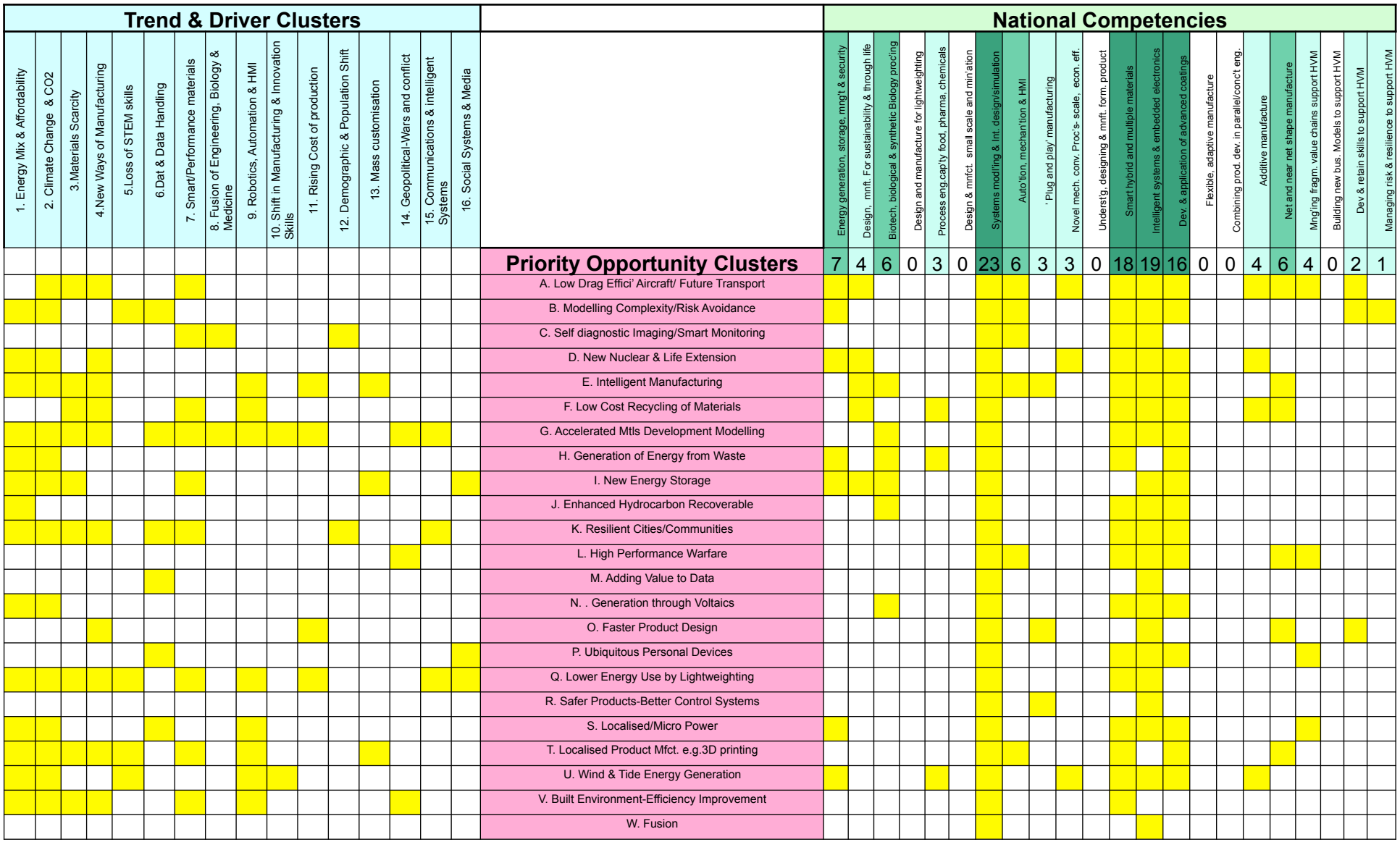
Reference	Opportunity Cluster	Industry attendee Votes	Non-Industry attendee Votes	Total Votes
A	Transport of the Future	6	8	14
B	Modelling Complexity/ Risk Avoidance	6	8	14
C	Self Diagnostic Imaging/Smart Monitoring	6	4	10
D	New Nuclear & Life Extension	5	5	10
E	Intelligent Manufacturing	4	5	9
F	Low Cost Recycling of Materials	2	6	8
G	Accelerated Materials Development/Modelling	6	2	8
H	Generation of Energy from Waste	3	4	7
I	New Energy Storage	5	2	7
J	Enhanced Hydrocarbon Recoverable	4	3	7
K	Resilient Cities/Communities	3	3	6
L	High Performance Warfare	2	4	6
M	Adding Value to Data	3	3	6
N	Generation Thriugh Photovoltaics	3	2	5
O	Faster Product Design	1	3	4
P	Ubiquitous Personal Devices	3	1	4
Q	Lower Energy Consumption of and in products	0	4	4
R	Safer Products Through Better Control Sysytems	2	2	4
S	Localised/Micro Power	4	0	4
T	Localised Product Manufacturing e.g 3D Printing	2	1	3
U	New forms of power generation	1	2	3
V	Built Environment-Efficiency Improvements	2	0	2
W	Fusion	2	0	2
X	New Education Channels	2	0	2
Y	Virtual/Augmented Reality	1	1	2
Z	Home Care Robotics	1	0	1
A1	Replacement Body Parts	0	1	1
B1	Surgical Simulation	1	0	1
C1	Expert Sysytems	1	0	1
D1	Carbon Capture	0	1	1
E1	Smart Clothing	1	0	1
F1	Infection Control	1	0	1
G1	Customised Drug Mixing & Delivery	0	0	0
H1	Improved Raw Material Extraction & Waste Minimisation	0	0	0
I1	More Efficient Computing-Lower Energy Consumption	0	0	0
J1	Supply Chain Management	0	0	0
K1	Robotics and sensors in harsh environments			
L1	New financial structures for manufacturing			

- Voting produced a clear prioritisation of value-adding opportunity clusters
- If all the energy generation and storage activities are summed (excluding nuclear) these form a new high-priority cluster
- There was little significant variation between industry and non-industry attendee votes

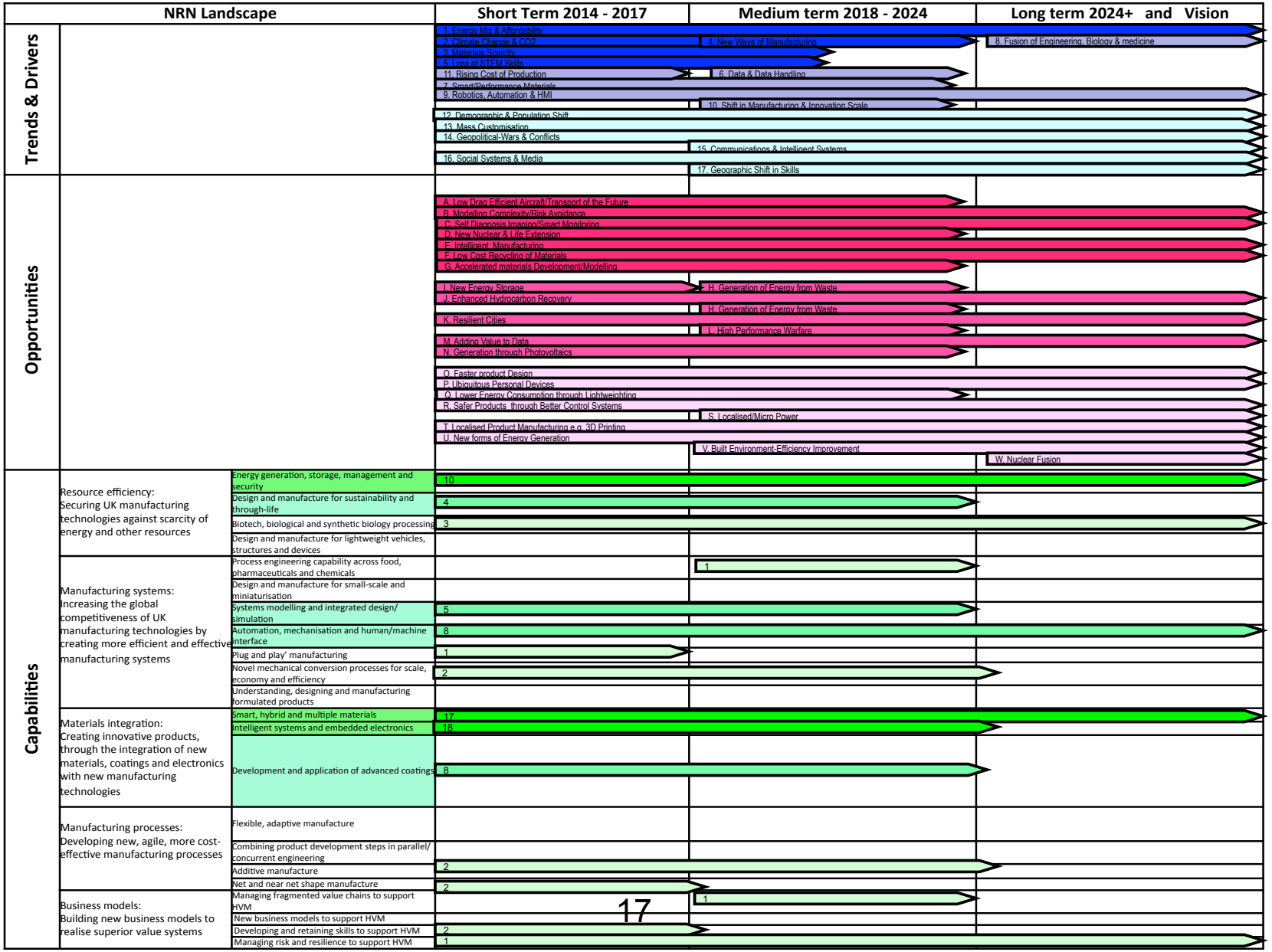
A combination of measures indicates a possible tiering of competency needs for Advanced Engineering and Materials in the UK (See following slides)

National Competency	No. of links with priority opportunities	No. of links with Market Sectors	Number of ideas generated	Summary
Energy generation, storage, management and security				Tier 2
Design and manufacture for sustainability and through-life				Tier 2
Biotech, biological and synthetic biology processing				Tier 2
Design and manufacture for lightweight vehicles, structures and devices				
Process engineering capability across food, pharmaceuticals and chemicals				
Design and manufacture for small-scale and miniaturisation				
Systems modelling and integrated design/simulation				Tier 1
Automation, mechanisation and human/machine interface				Tier 2
Plug and play' manufacturing				
Novel mechanical conversion processes for scale, economy and efficiency				
Understanding, designing and manufacturing formulated products				
Smart, hybrid and multiple materials				Tier 1
Intelligent systems and embedded electronics				Tier 1
Development and application of advanced coatings				Tier 2
Flexible, adaptive manufacturing				
Combining product development steps in parallel/concurrent engineering				
Additive manufacture				
Net and near net shape manufacture				Tier 2
Managing fragmented value chains to support HVM				
New business models to support HVM				
Developing and retaining skills to support HVM				
Managing risk and resilience to support HVM				

Linkages between Trends and Drivers, priority Opportunities and UK HVM National Competencies for Advanced Engineering and Materials



UK HVM National Competencies for Advanced Engineering and Materials shaded in green with number of ideas generated shown



A heat map of the data shows the most mentioned UK HVM National Competencies and market sectors[1]

Strategic Theme	National Competence	Sector																		Grand Total
		Food	Bio	Chemicals	Pharma	Medical	Aero & Defence	Auto	Rail	Marine	Nuclear	Energy	Oil & Gas	Mining	Built Environment	Electronics	Retail	Digital	Other	All	
Resource efficiency: Securing UK manufacturing technologies against scarcity of energy and other resources	Energy generation, storage, management and security																				
	Design and manufacture for sustainability and through-life																				
	Design and manufacture for lightweight vehicles, structures and devices																				
	Biotech, technological and synthetic biology processing																				
Manufacturing systems: Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems	Understanding, designing and manufacturing formulated products																				
	Design and manufacture for small-scale and miniaturisation																				
	Systems modelling and integrated design/simulation																				
	Automation, mechanisation and human machine interface																				
	Plug and play manufacturing																				
	Novel mechanical conversion processes for scale, economy and efficiency																				
	Process engineering, capability and efficiency development across food, pharmaceuticals & chemicals																				
Materials integration: Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies	Smart, hybrid and multiple materials																				
	Intelligent systems and embedded electronics																				
	Development and application of advanced (materials and) coatings																				
Manufacturing processes: Developing new, agile, more cost-effective manufacturing processes	Flexible, adaptive manufacture																				
	Combining product development steps in parallel/concurrent engineering																				
	Net and near net shape manufacture																				
	Additive manufacture																				
Business models: Building new business models to realise superior value systems"	Managing fragmented value chains to support HVM																				
	Building new business models to support HVM																				
	Developing and retaining skills to support HVM																				
	Managing risk and resiliance																				
TBC																					

1 Based on Post-it count

Cross-checking the heat map with the TSB HVM National Competency map shows some specific differences

In the AE&M heat map there is:

- Less focus on ‘Energy Generation, Storage, Management and Security’ and ‘Managing risk and resilience’
- No focus on ‘Flexible and Adaptive Manufacturing’, ‘Design and manufacturing for Lightweighting’, ‘Design and manufacture for small scale’ and ‘Combining Product Development Steps in Parallel’
- Greater focus on ‘Systems Modelling’
- Greater concentration on Aerospace and Defence, Automotive and Medical sectors

Some of the differences may be due to the concentration on manufacturing in the HVM map but others may need checking at a detail level before confirming decisions

There is a wealth of ideas behind example AE&M prioritised UK HVM National Competencies contained in the workshop database

Energy generation storage, management, & security	Smart, hybrid and multiple materials	Intelligent systems and embedded electronics	Systems modelling and integrated design/simulation	Development and application of advanced and coatings	Design and manufacture for sustainability and through life
Electrical power management	Nano devices and materials	New methods for life assessment risk based inspection	System engineering	Rapid characterisation of new material properties	Waste transmutation
Control of distributed energy sources - complex systems	Bondage joint assessment for composite pipes	Automated MDT of nuclear installations	Combination of - non linear mathematics, computer resources and data storage	Improved materials processing through direct heating or excitation	Optimum material usage fit for purpose
Low-cost energy harvesting materials from light, movement…	Novel modelling techniques for new materials	Real time, in process monitoring of metal cutting processes,	Knowledge storage/application	Good reliable materials data	Manufacture and integrity and monitoring of H2 vehicle tanks
Energy from waste, energy storage	New structural integrity paradigm	Improve or additional multi functionality of data e.g. using traffic cameras to monitor local weather	Analytical software	Coatings and materials for extreme environments - radiation, temperature, mechanical, flexible, chemical, corrosion	Design tool for recycle and reuse
Hydrogen carriers for energy storage	Accelerated materials testing	Automated non destructive testing	Energy efficient web based HPC plus expertise/modelling across length scales which is affordable	Surface engineering for corrosion protection and ware	
Thorium to replace uranium as energy source	High performance semi conductor materials	In process control and monitoring of new processes (ALM, composites)		Transport spray on photovoltaic coating with efficiency greater than 20%	
Scalable non carbon/CO2 contributing based energy storage demonstrators	High throughput materials characterisation labs/strategy	Nano/micro array technology for diagnostics- for sampling multiple species		Functional coatings e.g. storage and energy generation	
40 deg C super conductor	Accelerated material dev alloy/ light weighting improved corrosion resistance, mech props & fabrication	Sensors that work reliably service in harsh service		Low friction coating (DLC or similar)	
Sodium chemistry	Meta materials	Novel inspection techniques + sensors to monitor graphite core integrity in advanced gas cooled reactors			
	High temperature super conducting materials	Sensors, robotics, software, metrology, miniaturisation			
	High performance thermo plastic composites	Structurally embedded sensors for health management			

Advanced Engineering and Materials Competency In Wales (Topic Roadmapping)

There is a good/fair match between voting for competency in Wales and priority Advanced Engineering & Materials UK HVM National Competencies but two topics will need further investigation and two require topic roadmapping

National Competency (Topic Roadmaps in bold italics)	Votes for Degree of Competency in NRN (Academics)	Votes for Degree of Competency in NRN (TWI)	Total Votes for Competency in NRN	Priorities from Landscape	Match/Mismatch
Systems modelling and integrated design/simulation	*4*	*1*	***5***	Tier 1	Good match
Intelligent systems and embedded electronics	*3*	*2*	***5***	Tier 1	Good match
Energy generation, storage, management and security	*3*	*1*	***4***	Tier 2	Acceptable match
Design and manufacture for sustainability and through-life	3	1	4	Tier 2	Needs topic roadmap
Design and manufacture for small-scale and miniaturisation	3	1	4		Not a landscape priority TBA
Automation, mechanisation and human/machine interface	2	2	4	Tier 2	Needs topic roadmap
Smart, hybrid and multiple materials	3	1	4	Tier 1	Good match
Development and application of advanced coatings	4	0	4	Tier 2	Acceptable match
Additive manufacture	2	2	4		Not a landscape priority TBA
Net and near net shape manufacture	3	0	3	Tier 2	Acceptable match
Managing risk and resilience to support HVM	3	0	3		Poor match but lower priority
Biotech, biological and synthetic biology processing	2	0	2	Tier 2	Acceptable match
Flexible, adaptive manufacture	2	0	2		Poor match but lower priority
Design and manufacture for lightweight vehicles, structures and devices	1	0	1		Poor match but lower priority
Process engineering capability across food, pharmaceuticals and chemicals	0	0	0		Poor match but lower priority
Plug and play' manufacturing	0	0	0		Poor match but lower priority
Novel mechanical conversion processes for scale, economy and efficiency	0	0	0		Poor match but lower priority
Understanding, designing and manufacturing formulated products	0	0	0		
Combining product development steps in parallel/concurrent engineering	0	0	0		
Managing fragmented value chains to support HVM	0	0	0		Poor match but lower priority
Building new business models to support HVM	0	0	0		
Developing and retaining skills to support HVM	0	0	0		Poor match but lower priority

- 'Design and manufacture for sustainability and through life' and 'Automation, mechanisation and human/machine interface' matched priorities between voting and landscape prioritisation but were not topic roadmapped to derive the detailed needs. It is recommended that this is carried out.
- 'Design and Manufacture for small scale and miniaturisation' and 'Additive Manufacture' were priorities for Wales but appears inconsistent with Landscape data. This will need further investigation

Three of the competencies chosen for topic roadmapping lever all three NRN themes and may help access synergies

Strategic Theme	National Competency	NRN Theme		
		Materials and Innovative Manufacturing Processes	Advanced Sensors and Devices	Novel Modelling Techniques
Resource efficiency: Securing UK manufacturing technologies against scarcity of energy and other resources	Energy generation, storage, management and security	■	■	■
	Design and manufacture for sustainability and through-life	■	■	■
	Biotech, biological and synthetic biology processing		■	
	Design and manufacture for lightweight vehicles, structures and devices	■	■	■
Manufacturing systems: Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems	Process engineering capability across food, pharmaceuticals and chemicals			
	Design and manufacture for small-scale and miniaturisation	■	■	■
	Systems modelling and integrated design/simulation			■
	Automation, mechanisation and human/machine interface		■	■
	Plug and play' manufacturing			
	Novel mechanical conversion processes for scale, economy and efficiency	■		■
	Understanding, designing and manufacturing formulated products			
Materials integration: Creating innovative products, through the integration of new materials, coatings and	Smart, hybrid and multiple materials	■		■
	Intelligent systems and embedded electronics		■	
	Development and application of advanced coatings	■		
Manufacturing processes: Developing new, agile, more cost-effective manufacturing processes	Flexible, adaptive manufacture	■	■	
	Combining product development steps in parallel/concurrent engineering			
	Additive manufacture	■	■	■
	Net and near net shape manufacture	■		
Business models: Building new business models to realise superior value systems	Managing fragmented value chains to support HVM			
	Building new business models to support HVM			
	Developing and retaining skillsto support HVM	■	■	■
	Managing risk and resilience to support HVM			

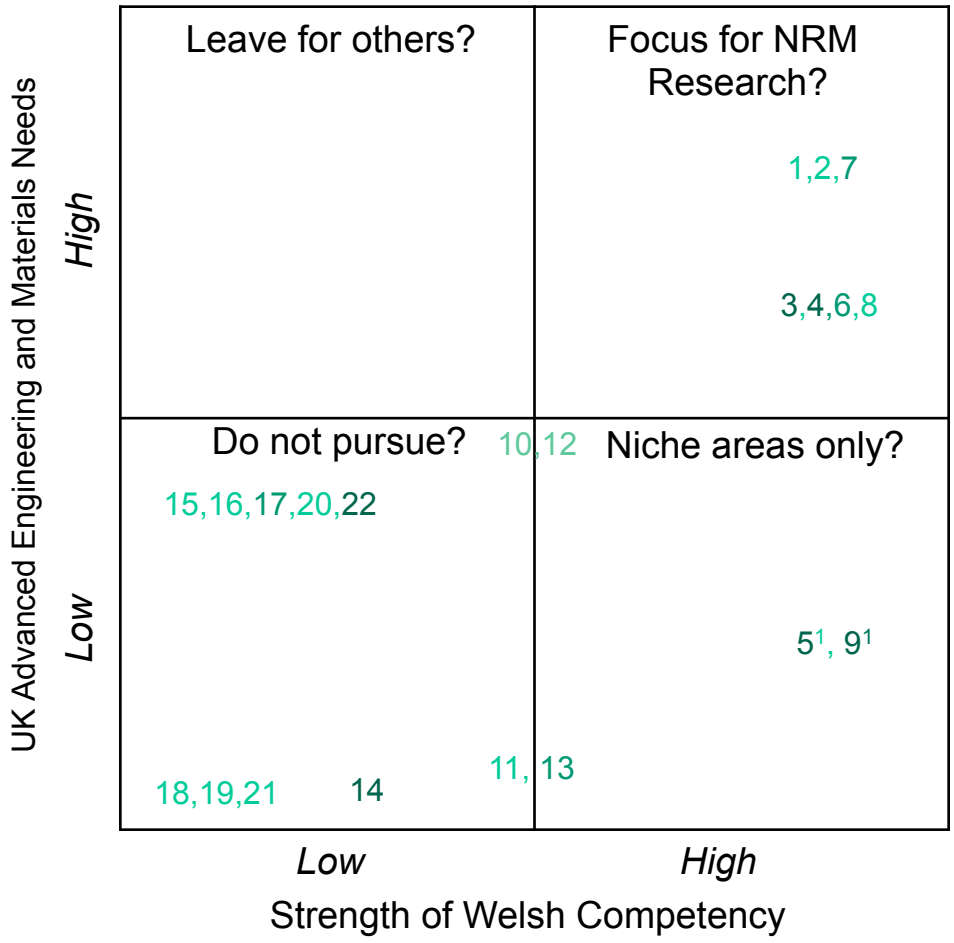
Supports all three themes

Supports all two themes

Supports only one theme

Classification of UK HVM National Competencies indicates possible a approach for Welsh NRM research

	Competency	Welsh competency voting	Support for NRN Themes	Adv Engi & Material needs
1	Systems modelling and integrated design/simulation	5	1	
2	Intelligent systems and embedded electronics	5	1	
3	Energy generation, storage, management and security	4	3	
4	Design and manufacture for sustainability and through-life	4	3	
5	Design and manufacture for small-scale and miniaturisation	4	3	
6	Automation, mechanisation and human/machine interface	4	2	
7	Smart, hybrid and multiple materials	4	2	
8	Development and application of advanced coatings	4	1	
9	Additive manufacture	4	3	
10	Net and near net shape manufacture	3	1	
11	Managing risk and resilience to support HVM	3	0	
12	Biotech, biological and synthetic biology processing	2	1	
13	Flexible, adaptive manufacture	2	2	
14	Design and manufacture for lightweight vehicles, structures and devices	1	3	
15	Process engineering capability across food, pharmaceuticals and chemicals	0	0	
16	Plug and play' manufacturing	0	0	
17	Novel mechanical conversion processes for scale, economy and efficiency	0	2	
18	Understanding, designing and manufacturing formulated products	0	0	
19	Combining product development steps in parallel/concurrent engineering	0	0	
20	Managing fragmented value chains to support HVM	0	0	
21	Building new business models to support HVM	0	0	
22	Developing and retaining skills to support HVM	0	3	



1 Position re UK Advanced Engineering and Materials Needs requires further investigation

Depth of colour of numbers in matrix represents number of NRM themes covered

IfM Education and Consultancy Services

UNIVERSITY OF CAMBRIDGE

Critical capability gaps which may present an opportunity for NRN research have been identified by topic roadmapping the AE&M prioritised UK HVM National Competencies[1]

National Competency	Market sectors	Opportunities	Opportunity Deliverables	Capabilities	Critical gaps requiring research
System modelling, integrated design/simulation	Aerospace and defence, nuclear, automotive, built environment, oil and gas, energy	New forms of power generation, low drag efficient aircraft, modeling complexity, low energy consumption, nuclear, faster product design, accelerated materials development, adding value to data, resilience cities, high performance warfare, localised power	Completely eliminate physical testing in design and manufacture. Make real time predictions and control complex systems		Multi scale modeling of materials, Modeling complex non linear systems, New structural integrity paradigms through certified computer models
Additive Manufacture	Aerospace and defence, low volume automotive, medical, consumer goods, energy, nuclear	Intelligent manufacturing, HP warfare, low cost recycling, faster product design, prototyping, localised manufacturing, new nuclear components, wind/tide turbine, future transport	Mass customisation and optimisation, fully integrated manufacturing systems,	Understanding critical process parameters, performance and testing of parts, Computer modeling and integration of parts, codes of practice, integrated self monitoring machines, development of raw materials specific to process,	In process monitoring, performance evaluation of parts, improved equipment and process development (speed, precision, surface finish), alt methods for local heating, enhanced range of suitable materials, design for AM, Raw materials, process, part properties (inc inspection), automated intelligent kit, integrated systems
Development and application of Advanced Coatings	Aerospace and defence, auto, built environment,, medical, foundation industries		Optical coating, cosmetic finish, bio compatible coatings, chemical resistance. Energy efficient generating, sensing coatings, absorbent coatings. Invisible shields, coatings carrying/processing data	Real time characterisation. Large area functional coating methods, new coating materials, recyclable. Self coating	Rapid real time characterisation, recyclability, modelling, scalability – large area, low cost alternatives, new coating methods, self coating
Design and Manufacture for Small Scale and Miniaturisation - Large scale mfg of micro/nano sensor systems	Digital economy, Automotive, medical environmental monitoring, smart defence	Ubiquitous computing, context and location specific information delivery in real-time. Monitoring of systems and people to ensure efficient use of resources. Improved accesses to services and goods	Low cost, high end hybrid sensors. High end monolithic system on a chip. Step change in materials, manufacturing processes, cost		Design, fabrication and testing of hybrid devices and sensors. Biodegradable, lightweight, flexible and low power devices. Integration of different technologies. Self-assemble of nanoscale devices
Smart, Hybrid and Multiple Materials	Nearly all	Energy mix and price, material scarcity, data. Cost of product (time to market), climate change. Performance materials, new ways to manufacture, engineering and biology.		Material scientists, characterisation and test facilities combined with modelling, multi materials and joining, manufacturing methods. All taking account of life cycle, recyclability and multi scale effects	Novel material creation, multi scale modelling, lack of qualified diverse material specialists, lack of facilities, lack of relevant materials data.
Energy generation, storage, management and security	All: industry, commercial, domestic	Smart Cities, Load balancing; energy islands – Rural, mobile	Building power; Flexi-plant; Flexible, cheap storage media	Systems network engineering; big data/data management/systems resilience	Energy vector systems, battery technology

1 Two key themes were not topic roadmapped and will need further consideration (Design and manufacture for sustainability and through life; Automation, mechanisation and HMI)

Medical, Aerospace and Defence and Automotive[1] require all or nearly all of the competencies mapped and may be useful target sectors to exploit NRN cross-capability synergies.

All the National Competencies selected for topic roadmapping (based on strength in Wales) address a range of market sectors.

	System modelling, integrated design/simulation	Additive Manufacture	Development and application of Advanced Coatings	Design and Manufacture for Small Scale and Miniaturisation - Large scale manufacture of micro/nano sensor systems	Smart, Hybrid and Multiple Materials	Energy generation, storage, management and security	
Food					■	■	2
Biotechnology					■	■	2
Chemicals					■	■	2
Pharmaceuticals					■	■	2
Medical		■	■	■	■	■	5
Aerospace, Defence and Space	■	■	■	■	■	■	6
Automotive	■	■	■	■	■	■	6
Rail					■	■	2
Marine (incl undersea)					■	■	2
Nuclear	■	■			■	■	4
Energy	■	■			■	■	4
Oil & Gas	■				■	■	3
Mining					■	■	2
Built Environment	■		■		■	■	4
Electronics					■	■	2
Retail, Entertainment and Consumer goods		■			■	■	3
Digital economy (incl Infrastructure), Communication and Security				■	■	■	3
Other			■	■			2
	6	6	5	5	17	17	

1 Topic roadmapping data

Conclusions (1)

The IfM roadmapping process combined with UK National HVM Competencies has provided insight into areas of possible research that the Wales NRN for Advanced Engineering and Materials (AE&M) might progress. As always, outcomes are highly dependent upon those involved in the process, particularly the workshop.

A possible tiering of UK HVM National Competencies for AE&M prior to consideration of Welsh capability is:

Tier 1

- System Modelling and Integrated Design/Simulation
- Smart, hybrid and multiple materials
- Intelligent systems and embedded electronics

Tier 2

- Energy generation, storage, management and security
- Design and manufacture for sustainability and through-life
- Biotech, biological and synthetic biology processing
- Automation, mechanisation and human machine interface
- Development and application of advanced coatings
- Net and near net shape manufacture

with thirteen other UK HVM National Competencies not tiered. Tiered competencies are well supported by example ideas from the workshop.

Conclusions (2)

There is a good/fair match between the workshop voting for capability in Wales and prioritised AE&M UK National Competencies.[1]

Plotting prioritised AE&M competencies against Strength of Welsh Capability suggests a focus for NRN Research:

Prime candidates:
- System Modelling and Integrated Design/Simulation
- Smart, hybrid and multiple materials
- Intelligent systems and embedded electronics

Also potentially attractive:
- Energy generation, storage, management and security
- Design and manufacture for sustainability and through-life
- Development and application of advanced coatings
- Automation, mechanisation and HMI

Borderline areas may be:
- Net and near net shape manufacture,
- Biotech, biological and synthetic biology processing.

Niche areas may be:
- Additive manufacture
- Design and manufacture for small-scale and miniaturisation.

Of the topic roadmaps, three appear to lever all NRN themes and perhaps generate synergies (based upon stakeholder inputs): Energy generation, storage and security; Design and manufacture for small-scale and miniaturisation; Additive manufacture.

For each topic roadmap, required capabilities and critical gaps requiring research have been identified. These require checking for completeness and an understanding of the ability to close the research gaps.

Analysis of topic roadmaps shows three market sectors require nearly all of the competencies considered and may be useful targets to exploit NRN cross-capability synergies. They are: Medical; Aerospace & Defence; and Automotive.

[1] Two prioritised competencies: Design and manufacture for sustainability and through life plus Automation and mechanisation and HMI were not topic roadmapped in the workshop and will require completion later

Appendices

- Topic Roadmapping
- HVM and National Competency Background
- Workshop Agenda
- Participants
- Landscape Taxonomy

Topic Roadmapping
Selected Topics and Teams

National Competency	NRN Lead	Team
Energy generation, storage, management and security	Phil Bowen	Raj Patel, Paul Beasley, Marcia Jones
Design and Manufacture for Small Scale and Miniaturisation	Paul Spencer	Wyn Meredith, Sue Dunkerton, Gareth Derbyshire
System Modelling and Integrated Design and Simulation	Alan Shore	Ian Risk, Ian Cooper, Marcia Jones
Smart Hybrid and Multiple Materials	Steve Brown	Helen Swygart, Paul Woollin
Intelligent Systems and Embedded Electronics	Selected but not mapped	
Development and Application of Advanced Coatings	Phil Wallace	Andy Evans, Brian Edy, Clive Hayter
Additive Manufacture	Adrian Porch	Mark Buckingham, Peter Oakley, Tony Sagona, Graham Evans

Summary & elevator speech

National Competency: System modelling, integrated design/simulation

Team:	Javier Bonet	Ian Cooper
Ian Risk	Allan Shore	

National Competency and description	
Applicable Market sectors	Aerospace, defence, nuclear, transport, built environment, oil and gas, energy
Market opportunities supported	
Market opportunity deliverables (*What will be delivered and when S/M/L)*	
Development of required Engineering capabilities *(How will deliverables be achieved and when will capability be needed S/M/L)*	
Critical engineering capability gaps requiring research	Multi scale modeling of materials Modeling complex non linear systems New structural integrity paradigms through certified computer models
Enablers such as links/ synergy with other capabilities/ opportunities	Synergies: materials
Barriers and risks to success	Lack of funding, lack of understanding of short comings of current techniques, lack of computer power, risk adverse industries unwilling to use new modelling capabilites, lack of well defined modelling standards
Other comments	

We should develop the capability to:

Completely eliminate physical testing in design and manufacture. Make real time predictions of and control complex systems

It supports the following market opportunities:

New forms of power generation, low drag efficient aircraft, modeling complexity, low energy consumption, nuclear, faster product design, accelerated materials development, adding value to data, resilience cities, high performance warfare, localised power

Critical engineering technology and capability gaps requiring research:

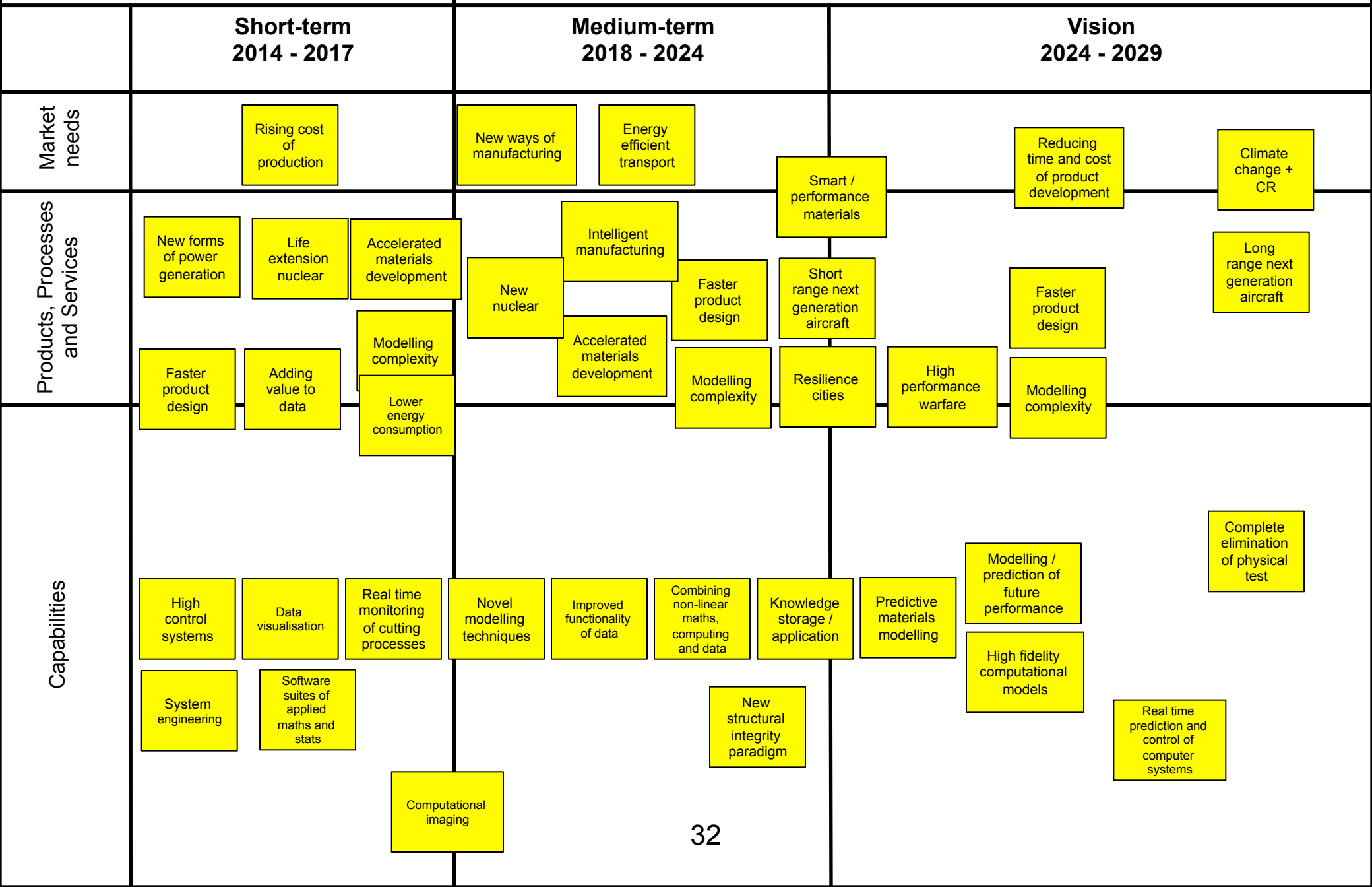
Multi scale modeling of materials

Modeling complex non linear systems

New structural integrity paradigms through certified computer models

National Competency: System modelling, integrated design/simulation

Team: Javier, Allan, Ian C, Ian R



Summary & elevator speech

National Competency: Additive Manufacture

Team:	Graham	Mark
Adrian	Tony	Peter O

National Competency and description	Additive manufacture
Applicable Market sectors	Aerospace, low volume automotive, defence, medical, consumer goods, energy, nuclear
Market opportunities supported	Intelligent manufacturing, HP warfare, low cost recycling, faster product design, prototyping, localised manufacturing, new nuclear components, wind/tide turbine, future transport
Market opportunity deliverables (*What will be delivered and when S/M/L)*	Mass customisation and optimisation (L), fully integrated manufacturing systems (L)
Development of required Engineering capabilities *(How will deliverables be achieved and when will capability be needed S/M/L)*	Understanding critical process parameters (S,M), performance and testing of parts (S), Computer modeling and integration of parts (S,M), codes of practice (M,L), integrated self monitoring machines (L), development of raw materials specific to process (S,M),
Critical engineering capability gaps requiring research	In process monitoring techniques, performance evaluation of parts, improved equipment and process development (speed, precision, surface finish), alternative methods for local heating, enhanced range of suitable materials, design for AM
Enablers such as links/ synergy with other capabilities/ opportunities	Link digital manufacture, materials technology, sensors and embedded systems, data handling
Barriers and risks to success	Cost, acceptance by industry, clear understanding of capabilities, fall out of any high profile component failure
Other comments	

We should develop the capability to:
Use AM effectively, driven by almost all of the applicable market sectors for the NRM
It supports the following market opportunities:
Efficient and effective manufacturing process with well defined role in industry
Critical engineering technology and capability gaps requiring research:
Raw materials, process, part properties (including inspection), automated intelligent kit, integrated systems (long term goal)

National Competency: Additive Manufacture

Team: Graham, Mark, Tony, Adrian, Peter O

	Short-term 2014 - 2017	Medium-term 2018 - 2024	Vision 2024 - 2029
Market needs	Los of STEM skills Fusion of engineering with medicine New ways of manufacturing Robotics, automation and HMI Data and data handling Materials scarcity Smart / performance materials	Shift in manufacturing and innovation scale Nice reductions in cost	Mass customisation and optimisation
Products, Processes and Services	Intelligent manufacturing Low cost recycling of materials Localised product manufacturing High performan ce warfare Faster product design and prototyping	Future transport New nuclear technologies Wind / tidal turbine parts	
Capabilities	In process monitoring of AM Performance and testing of parts made from powder Net shape manufacturing Computer modelling of components Understanding of critical process parameters Surface finish / density Understanding need of post processing techniques	Design / test for ALM Directed materials processing for AM Metals at plastics quality Specifically designed raw materials for AM process	Codes of practice and standards

Summary & elevator speech

National Competency: Development and application of Advanced Coatings

Team:	Andy	Brian
	Philip	Clive

National Competency and description	Metals, glass, organics, coating methods, functional coatings
Applicable Market sectors	Aero, auto, construction, defence, health, foundation industries
Market opportunities supported	Added value products
Market opportunity deliverables (*What will be delivered and when S/M/L)*	S – Optical coating, cosmetic finish, bio compatible coatings, chemical resistance. M – Energy efficient generating, sensing coatings, absorbent coatings. L – invisible shields, coatings carrying/ processing data
Development of required Engineering capabilities *(How will deliverables be achieved and when will capability be needed S/M/L)*	S – real time characterisation. M – Large area functional coating methods, new coating materials, recyclable. L – self coating
Critical engineering capability gaps requiring research	
Enablers such as links/ synergy with other capabilities/ opportunities	
Barriers and risks to success	
Other comments	

We should develop the capability to:

Have more durable lower cost recyclable materials and functional coatings

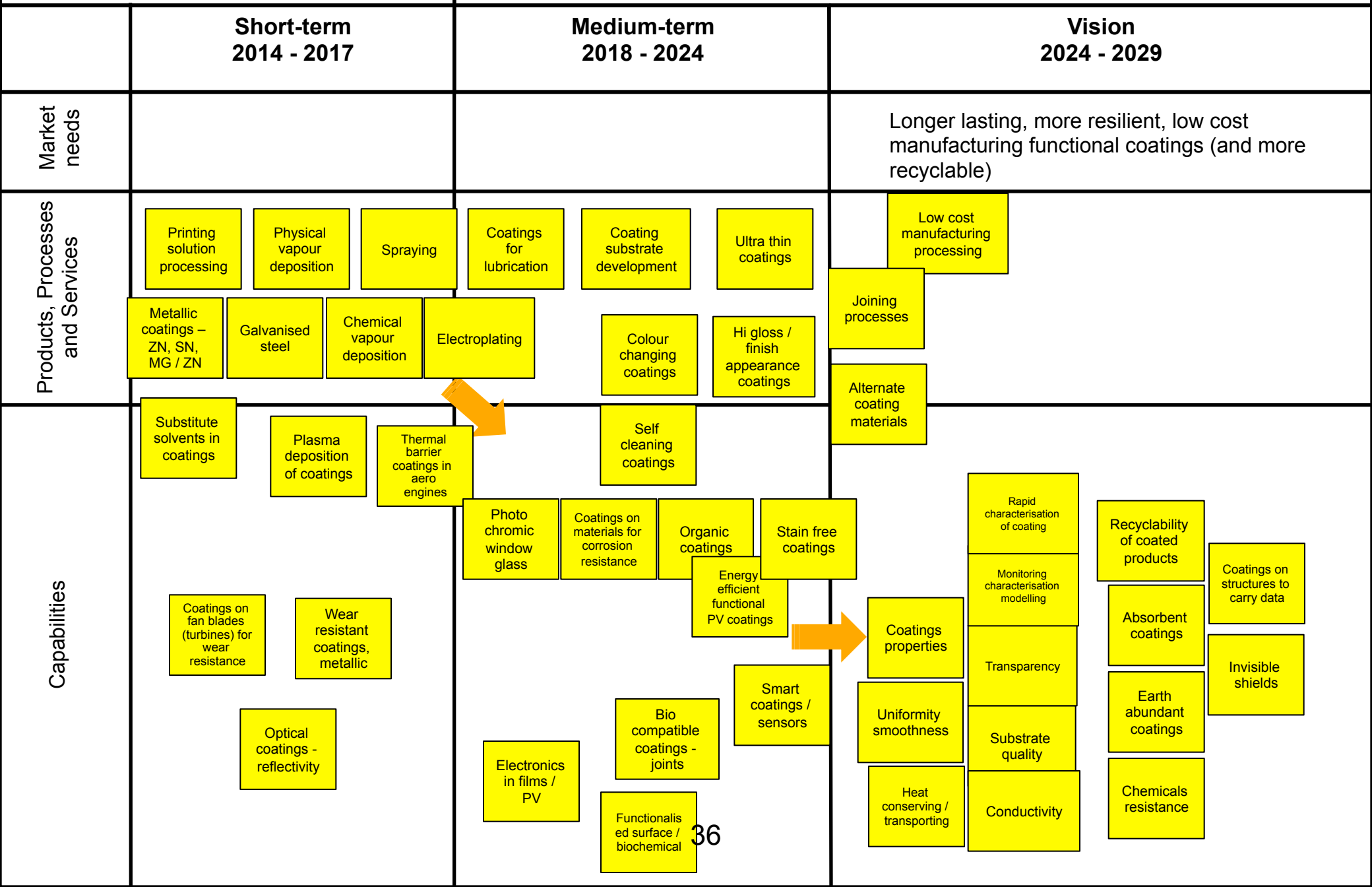
It supports the following market opportunities:

Critical engineering technology and capability gaps requiring research:

Rapid real time characterisation, recyclability, modelling, scalability – large area, low cost alternatives, new coating methods, self coating/

National Competency: Development and application of Advanced Coatings

Team: Andy, Brian, Philip, Clive



Summary & elevator speech

National Competency: Design and Manufacture for Small Scale and Miniaturisation

National Competency and description	Large scale manufacture of micro/nano sensor systems
Applicable Market sectors	Telco / data coms / transport / health care/ environmental monitoring / smart defence
Market opportunities supported	Data sensor transmission, intelligent vehicles, ubiquitous monitoring, smart diagnosis, stand off imaging/sensing
Market opportunity deliverables (*What will be delivered and when S/M/L)*	S – low cost, high end hybrid sensors. M – high end monolithic system on a chip. L – step change in materials, manufacturing processes, cost
Development of required Engineering capabilities *(How will deliverables be achieved and when will capability be needed S/M/L)*	Design, fabrication and testing of nanoscale devices that use novel techniques that incorporate disparate material systems. Increase use of interdisciplinary and multiscale manufacturing facilities. Increase need to fully use more of EM spectrum for communications and sensing applications
Critical engineering capability gaps requiring research	S – wafer scale integration, chip packaging (novel), low cost production (reel to reel), printed electronics. M – mid IR sensors/ sources, integrated optics – micro assembly, microwave engineering, system integration. L – quantum sensors, mass market MEMS (yield +++), meta materials (viable)
Enablers such as links/ synergy with other capabilities/ opportunities	Crossover with bio materials / energy etc. RF coms / crossover into sensor engineering
Barriers and risks to success	Custom specifications at system level must drive component specs – resource hungry – high capex for manufacturing – jump from prototype to viable
Other comments	

Team:	Paul Spencer	Wyn Meredith
Sue Dunkerton	Gareth Derbyshire	

We should develop the capability to:

Design, fabrication and validation of hybrid sensors and devices. Reliability and lifetime testing of hybrid devices.

It supports the following market opportunities:

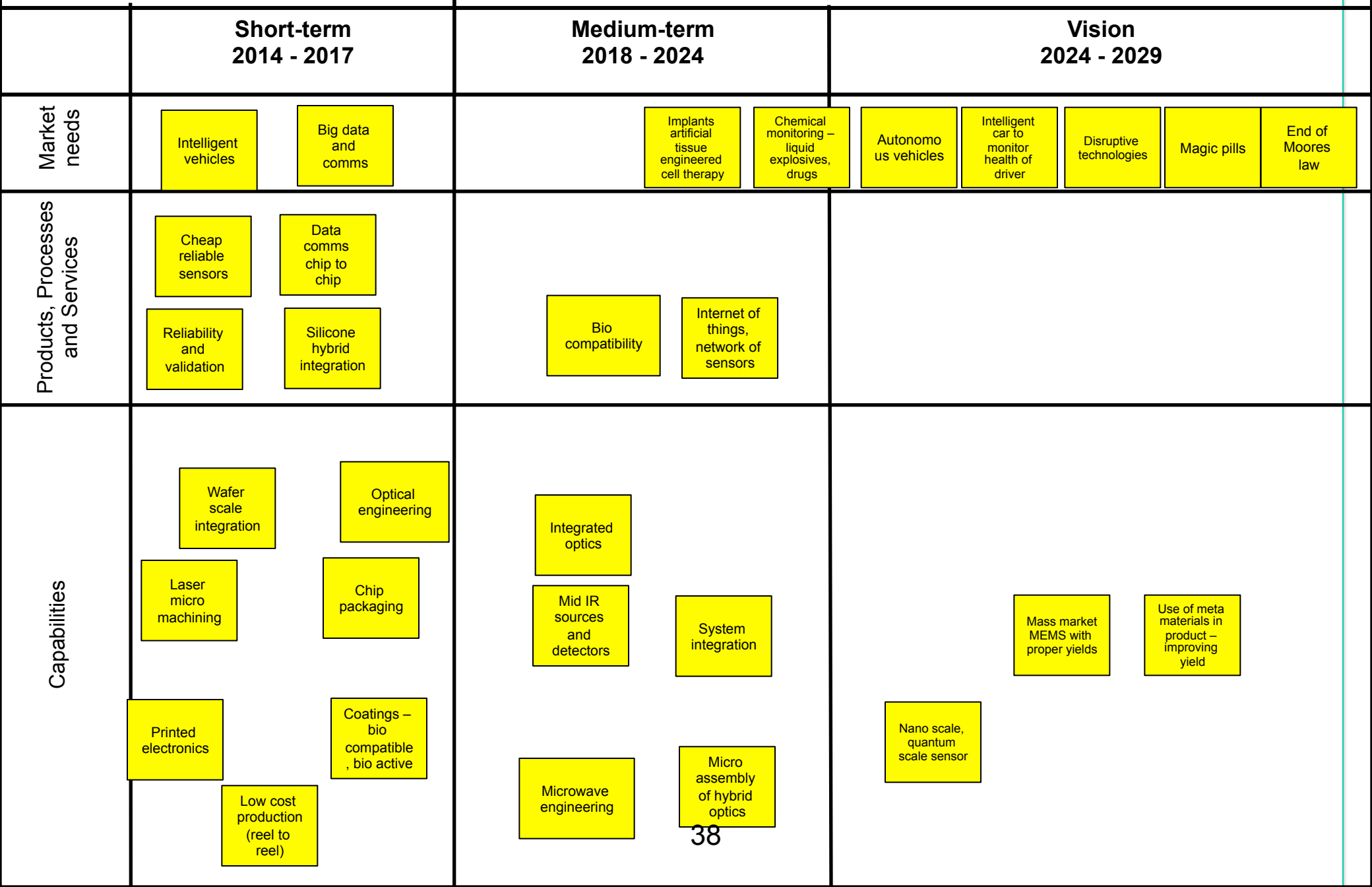
Ubiquitous computing, context and location specific information delivery in real-time. Monitoring of systems and people to ensure efficient use of resources. Improved accesses to services and goods

Critical engineering technology and capability gaps requiring research:

Design, fabrication and testing of hybrid devices and sensors. Biodegradable, lightweight, flexible and low power devices. Integration of different technologies. Self-assemble of nanoscale devices

National Competency: : Design and Manufacture for Small Scale and Miniaturisation

Team: Paul Spencer, Wyn Meredith, Sue Dunkerton, Gareth Derbyshire



Summary & elevator speech

National Competency: Smart, Hybrid and Multiple Materials

Team:	Steve	Paul W
	Helen	

National Competency and description	Design, development and characterisation
Applicable Market sectors	Nearly all
Market opportunities supported	S - Energy mix and price, material scarcity, data. M – Cost of product (time to market), climate change. L – Performance materials, new ways to manufacture, engineering and biology.
Market opportunity deliverables (*What will be delivered and when S/M/L)*	S – Improved materials. L – New material classes
Development of required Engineering capabilities *(How will deliverables be achieved and when will capability be needed S/M/L)*	Material scientists, characterisation and test facilities combined with modelling, multi materials and joining, manufacturing methods. All taking account of life cycle, recyclability and multi scale effects
Critical engineering capability gaps requiring research	Novel material creation, multi scale modelling, lack of qualified diverse material specialists, lack of facilities, lack of relevant materials data.
Enablers such as links/ synergy with other capabilities/ opportunities	Link between material scientists, chemists, biologists, industry, university, intermediate sector.
Barriers and risks to success	Not enough skilled expert staff, trend towards protecting IP, financial stability of manufacturers.
Other comments	

We should develop the capability to:

Develop and test new and/or improved materials to provide data for manufacturers and modellers/designers

It supports the following market opportunities:

The need to reduce time to market whilst reducing costs and mitigating against increased scarcity of raw materials

Critical engineering technology and capability gaps requiring research:

More material specialists needed, advanced materials characterisation and testing facilities, reliable data generated quickly for manufacturers

National Competency: Smart, hybrid and multiple materials

Team: Steve, Helen, Paul W

	Short-term 2014 - 2017	Medium-term 2018 - 2024	Vision 2024 - 2029
Market needs	Material scarcity; Data and data handling; Rising cost of production; Energy mix	Reduced time to market; Smart / performance materials; New ways of manufacturing	Fusion of engineering, biology and medicine; Materials for fusion
Products, Processes and Services	Transport of the future	High performance warfare; Self diagnostic imaging; Modelling complexity; Intelligent manufacturing; New nuclear and life extension	
Capabilities	Plus investment; New material development or existing material; Different /new manufacturing process; Source of materials / metallurgy students	Multiscale; Performance testing of materials; Performance testing of components; Characterisation of materials; Performance testing of system; Performance of multi materials (eg welding); Recyclability lifecycle; Modelling	

Summary & elevator speech

National Competency: Energy generation, storage, management and security

Team:	Phil Bowen Marcia Jones	Raj Patel, Paul Beasley

National Competency and description	Energy Systems
Applicable Market sectors	All: Transport, industry, commercial, domestic
Market opportunities supported	Load balancing; energy islands – Rural, mobile
Market opportunity deliverables (*What will be delivered and when S/M/L)*	Building power (med); Flexi-plant (med); Flexible, cheap storage media (long)
Development of required Engineering capabilities *(How will deliverables be achieved and when will capability be needed S/M/L)*	Systems network engineering; big data/data management/systems resilience
Critical engineering capability gaps requiring research	
Enablers such as links/ synergy with other capabilities/ opportunities	City councils
Barriers and risks to success	Industrial partners
Other comments	

We should develop the capability to:

Provide green affordable reliable energy

It supports the following market opportunities:

Power from buildings

Flexi-plant

Flexible cheap storage media

Smart cities

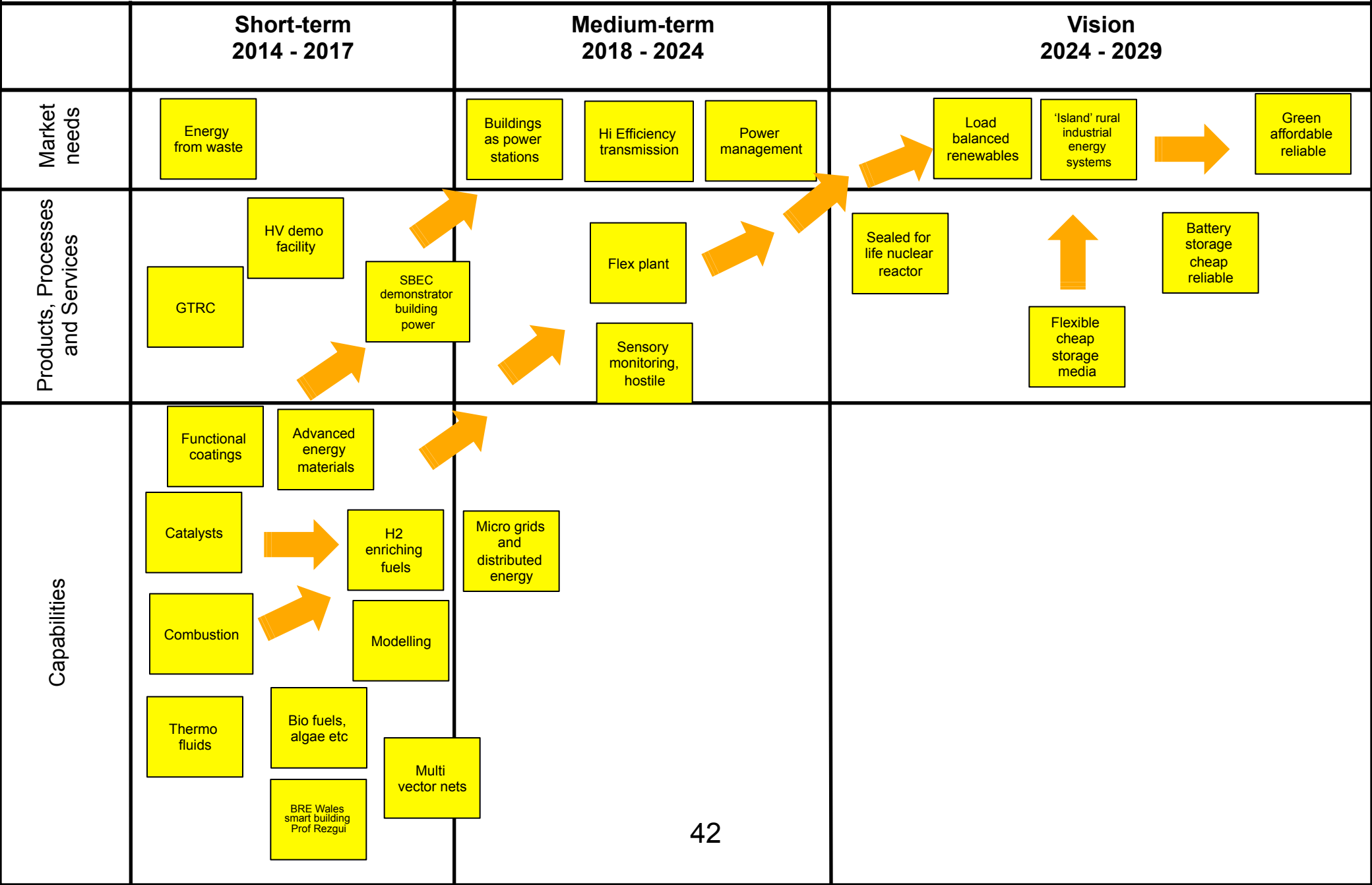
Critical engineering technology and capability gaps requiring research:

Energy vector systems

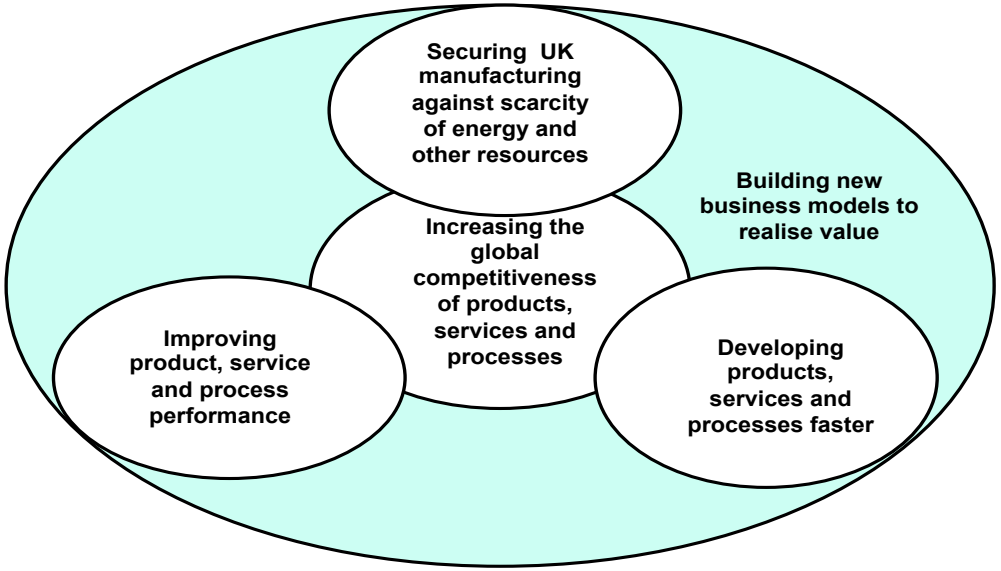
Battery technology

National Competency: Energy generation, storage, management and security

Team: Phil Bowen, Raj Patel, Paul Beasley, Marcia Jones



TSB HVM Landscape



National competency

An attribute of the national manufacturing industry that supports businesses to respond to the key global trends and drivers, be competitive and capture value for the UK in the future

Capability

Skills, processes and technologies a business exploits to supply goods and services competitively

HVM Sectors

Food
Biotechnology
Chemicals
Pharma
Medical
Aerospace/Defence/Space
Automotive
Rail
Marine
Nuclear
Energy
Oil and Gas
Mining
Built Environment
Electronics
Retail, Entertainment
Digital Economy, Communication and Security

Workshop Agenda

8:15	Coffee served
8:30	Introductions and meeting flow
8:45	Review of NRN Objectives and Structure
8:55	Introduce High Value Manufacturing national competence approach and roadmapping
9:15	Review and prioritise business drivers
10:15	Break
10:30	Generate value-adding opportunities and prioritise
11:30	Break
11:45	Generate and prioritise technologies and capabilities relevant to top opportunities
13:00	Lunch
13:45	Identify breakout groups for priority opportunities/technologies
14:00	Explore priority opportunities ➔ elevator pitch and topic-roadmaps
15:15	Break and tour of building
15:45	Present elevator pitches
16:45	Wrap up and next steps
17:00	Close

List of Delegates

	Name	Company
1	Adrian Porch	Dep Dir of School (Research)
2	Alan Shore	Bangor University
3	Angharad Penny Evans	Life Sciences, WG
4	Brian Edy	TATA Steel
5	Chris Constantinou, Dr	Bae Systems
6	Clive Hayter	Director, Science & Engineering
7	Dennis Lewis	IfM
8	Gareth Derbyshire	STFC
9	Graham Evans	Qioptiq
10	Helen Swygart, Dr	Qioptiq
11	Ian Cooper	TWI
12	Ian Risk (Director)	EADS, Innovation Works
13	Javier Bonet	Swansea University
14	Kevin Bygate	TATA
15	Marcia Jones	Welsh Gov, EST
16	Mark Buckingham	Renishaw
17	Nick Tune	Bangor, BRE
18	Paul Beasley	Siemens
19	Paul Spencer	Bangor University
20	Paul Woollin	TWI - Horizon 2020
21	Peter Oakley;	TWI - Horizon 2020
22	Phil Bowen	Director of School, Cardiff
23	Philip Wallace	TWI Wales, Regional Manager
24	Rajesh Patel	TWI
25	Robert Hoyle	Welsh Government
26	Steve Brown	Director of Reseach, Swansea Un
27	Steve Mann	IfM
28	Sue Dunkerton	TWI, Dir Health Technologies KTN
29	Tim Williams	Wales Auto Forum
30	Tony Sagona	Advanced Materials & Manuf, W
31	Wyn Meredith, Dr	IQE. Commerical Director
32	Andrew Evans.	Aberystwyth University

Landscape Taxonomy

	NRN Landscape		Short Term 2014 - 2017	Medium term 2018 - 2024	Long term 2024+ and Vision
Trends and Drivers	Political				
	Economic				
	Social				
	Technological				
	Environmental				
	Legal				
	Other				
Products and services	Food				
	Biotechnology				
	Chemicals				
	Pharmaceuticals				
	Medical				
	Aerospace, Defence and Space				
	Automotive				
	Rail				
	Marine (incl undersea)				
	Nuclear				
	Energy				
	Oil & Gas				
	Mining				
	Built Environment				
	Electronics				
	Retail, Entertainment and Consumer goods				
	Digital economy (incl Infrastructure), Communication and Security				
	Other				
Capabilities	Resource efficiency: Securing UK manufacturing technologies against scarcity of energy and other resources	Energy generation, storage, management and security			
		Design and manufacture for sustainability and through-life			
		Biotech, biological and synthetic biology processing			
		Design and manufacture for lightweight vehicles, structures and devices			
	Manufacturing systems: Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems	Process engineering capability across food, pharmaceuticals and chemicals			
		Design and manufacture for small-scale and miniaturisation			
		Systems modelling and integrated design/simulation			
		Automation, mechanisation and human/machine interface			
		Plug and play' manufacturing			
		Novel mechanical conversion processes for scale, economy and efficiency			
		Understanding, designing and manufacturing formulated products			
	Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies	Smart, hybrid and multiple materials			
		Intelligent systems and embedded electronics			
		Development and application of advanced coatings			
	Manufacturing processes: Developing new, agile, more cost-effective manufacturing processes	Flexible, adaptive manufacture			
		Combining product development steps in parallel/concurrent engineering			
		Additive manufacture			
		Net and near net shape manufacture			
	Business models: Building new business models to realise superior value systems	Managing fragmented value chains to support HVM			
		New business models to support HVM			
		Developing and retaining skills to support HVM			
		Managing risk and resilience to support HVM			
	Other				
Enablers	Infrastructure				
	Skills				
	Funding				
	Other				