The Defence and Security Technology Competency Report
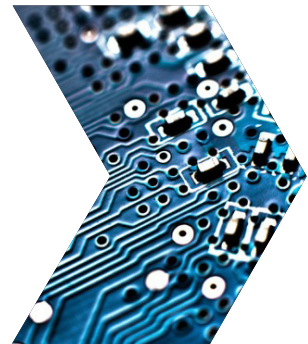
Collaboration and leverage towards the UK 2035 landscape

IfM Education and Consultancy Services

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With increasing levels of scientific and technological development worldwide, there is a growing volume of primarily civil-related technology that can both potentially impact and be exploited into defence and security capability.

This report summarises one of two studies commissioned independently from the IfM Education and Consultancy Services (IfM ECS), University of Cambridge and RAND Europe to investigate technology landscapes out to 2035 and provide different perspectives and insights into future technology and innovation models which will be relevant to the Ministry of Defence (MOD).

Technology foresight is notoriously poor in 'picking winners'. Rather than do this, the landscaping studies attempt to identify the relevant 'races' that defence and security organisations must address, and the skills and expertise we must develop to exploit or influence emerging winners. In particular, for the MOD the studies identify where wider investment (for example, Technology Strategy Board, Research Councils, and other Government investment) can be leveraged or complement future defence science and technology investment.

The studies provide independent views of the technology landscape. Although by necessity both are limited in scope, each has identified a number of valuable insights and recommendations. While we do not endorse all the findings, and indeed highlight that some of the issues identified are already being addressed successfully, we commend this report to all those involved in planning defence and security science and technology.

Alex Churchill, Defence Science & Technology Deputy Head Strategy, Ministry of Defence

Richard Biers, Programme Lead Future Science & Technology, Defence Science and Technology Laboratory

This report seeks to identify key themes which are likely to be important in reflecting the future needs of defence through manufacturing capability. It builds upon the framework developed for the Technology Strategy Board's High Value Manufacturing study published in 2011 using a similar cross-sectoral consultation process but substantially extending its scope and developing a clear focus. It provides the opportunity to inform public investments to maximise the potential impact on defence capability but also recognising the opportunities for civil applications.

Professor Sir Mike Gregory, Institute for Manufacturing, University of Cambridge

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1. Summary

This study highlights the importance of addressing technical competencies that cut across defence and security and other sectors. It indicates clear opportunities to develop the Ministry of Defence's (MOD) priorities as part of wider national technology investment and specific technology areas where collaboration with funding bodies across government can leverage wider resources.

The work was commissioned to help inform development of MOD strategy for research and development in technology, in line with the direction set in the *National Security through Technology* White Paper (2012). The key objective was authoritative assessment of the opportunities for MOD to engage with cross-government partners in order to harness wider UK investment in technology strategy.

The framework developed for the study is a UK defence and security science and technology 'landscape'. A significant proportion of technologies and industrial capabilities identified as potentially important to defence and security capability in 2035 also feature in the Technology Strategy Board's (TSB) High Value Manufacturing (HVM) landscape and the associated HVM strategy (2012). The work has shown the following strategic themes in the TSB HVM strategy to be particularly relevant:

- Securing UK manufacturing technologies against scarcity of energy and other resources
- Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems
- Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies
- Developing new, agile, more cost-effective manufacturing processes.

This analysis suggested that technology 'pull through' generated by TSB and the HVM Catapult should be expected to offer opportunities of specific relevance to defence and security. That proposition was tested through cross-sector and cross-government 'deep-dive' consultations in two technology areas:

- Power generation, energy management and storage
- Intelligent sensing and detection (including quantum sensing).

Mapping of priorities across TSB, Engineering and Physical Sciences Research Council (EPSRC), Biotechnology and Biological Sciences Research Council (BBSRC) and Science and Technology Facilities Council

(STFC) activities suggested opportunities for joint exploitation and investment in power generation, energy management and storage, particularly as regards novel, non-traditional power sources, and advanced storage (including batteries and super capacitors).

Similarly, in intelligent sensing and detection (including quantum sensing) opportunities for joint exploitation and investment might exist in data handling and intelligent processing, and short-range sensing and smart arrays, and possibly also as the technologies mature in long-range sensing and quantum sensing.

Specific actions have been recommended to further exploit these opportunities:

- Work with the four military commands to conduct 'deep dives' into further specific technology areas where collaboration with funding bodies can leverage wider resources
- Further joint exploration of opportunities with TSB HVM and the HVM Catapult
- Collaborative review of science and technology innovation processes for the future context of UK defence and security.

Additionally, the work has reaffirmed the key technologies in the 2035 defence and security landscape identified in other studies. Its findings will play a part alongside other inputs in supporting the development of MOD strategy for research and development in technology. The key contribution of this study is in identifying potential areas for cross-government/industry collaboration.

2. Context

This study was undertaken for Defence Science and Technology Laboratory (Dstl) in collaboration with MOD. It was conducted by IfM Education and Consultancy Services (IfM ECS) between January and October 2013.

Tasked with developing 'a future landscape for UK defence and security science and technology', the study drew on landscaping techniques developed by IfM ECS in *A Landscape for the Future of High Value Manufacturing in the UK* for TSB HVM Catapult (2012).

A key motive for the work was to identify areas in which MOD and TSB might work together. The study is explicitly linked to the TSB HVM landscape endorsed by TSB following the 2012 study, and uses the same 'national competency framework' where possible. These linkages have been made as a means of establishing a common terminology and framework concerning the exploitation of future technologies and capabilities relevant to high value manufacturing across industrial sectors. The TSB HVM landscape is also considered a 'robust platform' by BIS and as providing 'strategic focus' by EPSRC.

Employing such techniques to envision future landscapes, contributors from across government and industry examined, developed and confirmed a number of competencies in science and technology relevant to defence and security. They also expressed a level of confidence in predicting the impact of each for the UK by 2035. Many of the competencies were those identified in the previous HVM study.

These and other outputs, summarised below, are not intended to constitute the sole method of support for

identifying defence and security priorities in science and technology. Other studies have also identified and categorised important technologies. This study is well aligned with others such the parallel study led by the RAND Corporation. The study thus **reaffirms the key technologies in the 2035 landscape identified elsewhere**.

The particular contribution of this study is to help indicate **opportunities to develop MoD/Dstl's priorities as part of wider national technology investment**. Its conclusions and recommendations in this regard are based upon:

- an initial assessment of the scale of potential 2035 impact of the technologies in the identified competencies across key military and security capabilities. This assessment is described in sections 5 and 6.
- an examination in more detail of two specific technology areas (deep dives): intelligent sensing and detection; and power generation, energy management and storage (section 7).

The deep dives into the two specific technology areas **highlight areas where collaboration with funding bodies across government can leverage wider resources**.

By focusing on linkages with the TSB HVM framework, the work does not include inputs from non-manufacturing sectors. The strengths and potential limitations of the study's linkages to the TSB HVM landscape are discussed further in section 8 and inform subsequent recommendations (section 9).
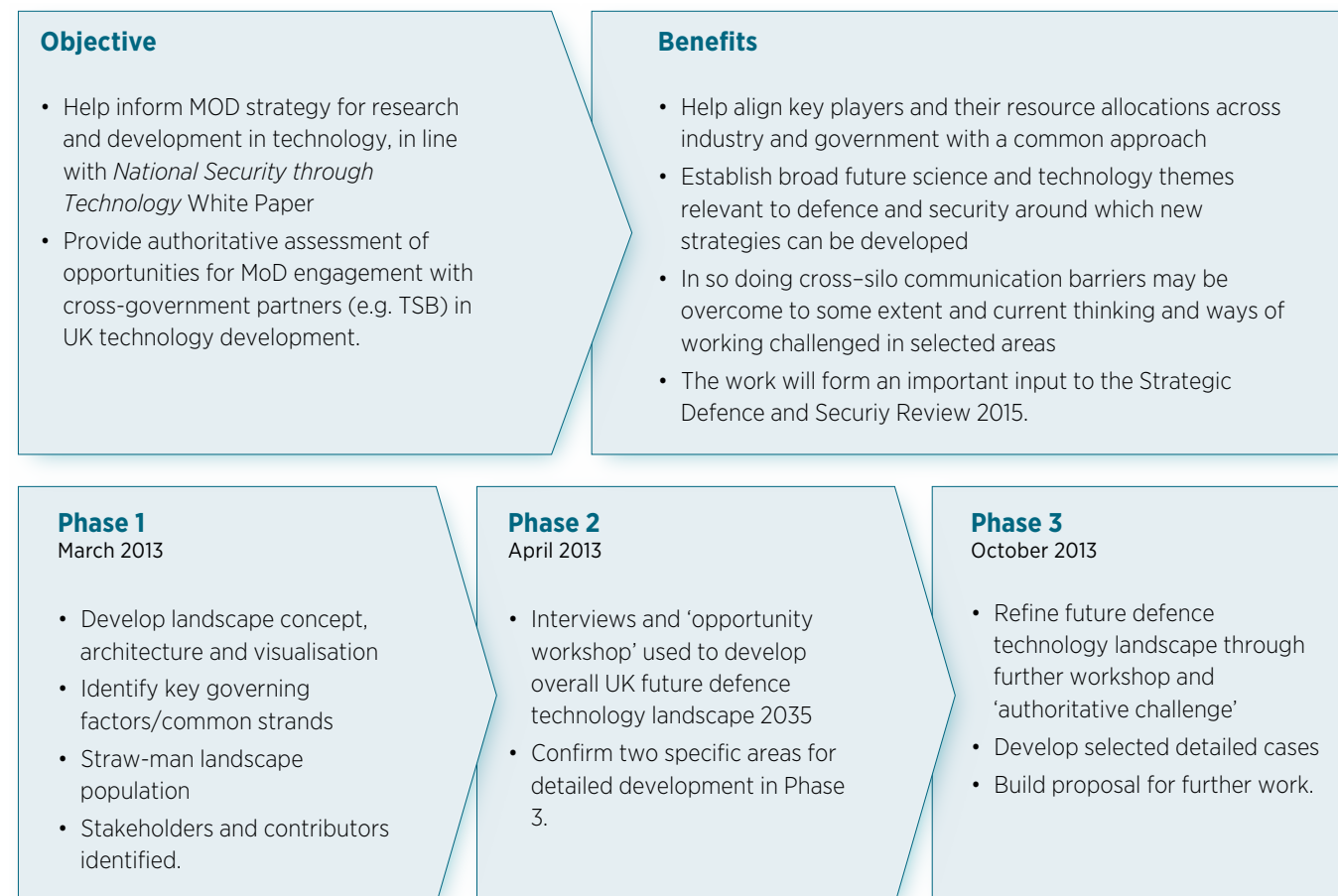
3. Objective and further benefits

The objective of this study was to develop a UK defence and security science and technology landscape in order to:

- help inform development of MoD strategy for research and development in technology, in line with the direction set in the White Paper *National Security through Technology* (MOD, 2012)
- provide authoritative assessment of opportunities for MOD to engage with cross-government partners to harness wider UK investment in technology strategy.

During the course of the study a number of further benefits were identified. Notably, the work demonstrated the potential value of bringing cross-government and industry representatives together to identify collaboration opportunities. Further benefits are outlined in Figure 1.

Figure 1: Study objective and approach

Objective

- Help inform MOD strategy for research and development in technology, in line with *National Security through Technology* White Paper
- Provide authoritative assessment of opportunities for MoD engagement with cross-government partners (e.g. TSB) in UK technology development.

Benefits

- Help align key players and their resource allocations across industry and government with a common approach
- Establish broad future science and technology themes relevant to defence and security around which new strategies can be developed
- In so doing cross–silo communication barriers may be overcome to some extent and current thinking and ways of working challenged in selected areas
- The work will form an important input to the Strategic Defence and Securiy Review 2015.

Phase 1
March 2013

- Develop landscape concept, architecture and visualisation
- Identify key governing factors/common strands
- Straw-man landscape population
- Stakeholders and contributors identified.

Phase 2
April 2013

- Interviews and 'opportunity workshop' used to develop overall UK future defence technology landscape 2035
- Confirm two specific areas for detailed development in Phase 3.

Phase 3
October 2013

- Refine future defence technology landscape through further workshop and 'authoritative challenge'
- Develop selected detailed cases
- Build proposal for further work.

4. Approach

The study was undertaken in three phases:

1. Creation of a 'straw-man' defence and security science and technology landscape – this was based primarily on desk research, earlier IfM ECS work and previous research by the Institute for Manufacturing

2. Development and prioritisation of the landscape – conducted through stakeholder interviews and a cross-government/industry workshop

3. Investigation of two specific technology areas and validation and visualisation of the landscape – by means of further workshops and stakeholder consultation, followed by a whole-study validation process.

Development of the landscape took place with reference to the TSB HVM landscape because TSB is an important cross-government partner in UK technology development for MOD. Moreover, TSB's HVM landscape based on national competencies has been recognised by BIS and EPSRC as offering a robust framework for the exploitation of future technologies and capabilities across industrial sectors.

In Phase 1 IfM ECS created a 'first-pass' populated landscape by pulling together information from 2012 work for TSB and Dstl (noted in section 2) with Institute for Manufacturing research on military capability

definition, supply chain risk and resilience, roadmap visualisation and emerging technologies.

In Phases 2 and 3, the study used a 'layered' workshop approach to gather and analyse of opinions across industry and government. Two aspects of the methodology address the potential objection that outputs are opinion-based and may therefore be subject to individual bias:

- Confidence expressed by delegates in making predictions of impact was used as an indicator of uncertainty (see section 5)
- Further cross-testing of outputs was built into the study design.

Study outputs were subjected to a validation process of 'authoritative challenge'. The challenge process was designed both to obtain authoritative feedback on the draft outputs and identify opportunities for further development both within defence and security and across wider government. For authoritative challenge IfM ECS held consultative meetings with BAE Systems, Thales, MBDA, RAND Corporation, TSB, BIS, research councils and selected senior leaders in Dstl.

The phases of the study are summarised in Figure 1.

5. Key competencies

The study identified a number of competencies, together with contributors' view on their impact by 2035 and the level of contributor confidence in predicting that impact. Contributors' confidence levels vary by competency and reflect the degree of clarity with which outcomes can reliably be predicted as well as inevitable divergences of judgement which exist when different perspectives are brought to bear on long-term projects. In all cases the potential impact of the identified competencies is regarded as reasonably high. The competencies identified are shown in Figure 2.

Potential competencies were identified by IfM ECS in Phase 1 of the study, developed and evaluated by workshop contributors in Phase 2, and further refined and validated by key contributors in Phases 2 and 3.

This process built on the key technologies in the defence and security landscape identified by reports including *A Landscape for the Future of High Value Manufacturing in the UK* (TSB HVM, 2012) and *Advances in Design, Fabrication and Manufacturing* (Dstl, 2012).

Source: IfM ECS analysis of MOD science and technology landscape; cross-industry workshop 10 April 2013

Figure 2: Competencies in science and technology relevant to defence and security

Competency	Description
Power generation, energy management and storage	Energy technologies to aid in lightweighting, reduce logistics train and reduce dependency on fossil fuels and foreign fuel sources
Design and manufacture for sustainability and through-life	Design and manufacture of sustainable and innovative products including disassembly (recycling) and through-life services
Design and manufacture for lightweight vehicles, structures and devices	Design and manufacture of sustainable and innovative products to reduce the strain on the logistics train and on the individual
Biological and chemical sensing and control systems and processes	Threat assessment; new threats; existing organisms; vital signs monitoring; biomimicry
Systems modelling and integrated design and simulation	Systems modelling of complex systems. Integrated design methodologies using systems modelling, involving simulation, modelling & validation quickly to produce high-complexity products with advanced functionality
Autonomy and HMI	Reduction of cognitive burden whilst keeping intuitive control; thought-driven computing
Intelligent systems (excluding autonomy)	Software systems exhibiting machine learning and independent thinking behaviour
Intelligent sensing and detection (including quantum sensing)	Gathering signal & state from a domain of interest & conversion of data at various volumes, velocities & abstractions, to derive information & intelligence of value
Intelligent testing and metrology, including obsolescence	Non-destructive testing (including self-testing) & measurement, with timing and extent intelligently decided, including testing for obsolescence in whole or in part
Design and manufacture for small-scale and miniaturisation	Design & manufacture of components enabling smaller products, smaller product runs and miniaturisation without compromising function or efficiency
Development and application of advanced materials and coatings	Advanced materials & coatings for use in a range of applications and functions including hardening, compatibility, reduced friction, sterility and antifouling
Biological materials integration	Injury assessment and management; point of injury stabilisation & treatment; recovery; extreme environments; bio-enhancement
Plug and play manufacturing	Modular components enabling interoperability
Flexible and adaptive manufacturing	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 inputs of different types and compositions and mass-customisation techniques
Additive manufacturing	Application of additive layer manufacturing or other freeform techniques to fabricate intermediate and end use products (including direct digital manufacturing)
Managing risk and resilience	Responding to attacks on personnel and assets; managing failure of assets; maintaining operational sovereignty
Ubiquitous global communication	Ubiquitous, secure, global communications systems for increased command and control
Big data and cyber	Multiple source data that offers the potential for new information, knowledge and wisdom to be generated; understanding how big data information can be used to create or understand cyber effects
Software/firmware development and validation	Swift and effective development and validation of software and firmware, minimising the time between development and use
Integrated circuit design, modelling, validation, etc.	Swift and effective development and validation of integrated circuitry, minimising the time between development and use
Secret, home-grown software	Individuals or groups creating malicious software for release
Optical communications	Paths of communication using light as the medium
Quantum computing	A computation device that makes direct use of quantum mechanical phenomena
Space technology	Global (Intel, Recon, Survey, Communications, Command, Control, Vector Off), Positioning, Navigation and Timing; countering space threats
Directed energy systems	Weaponry and defence systems utilising directed energy rather than physical projectiles

6. Mapping to the Technology Strategy Board High Value Manufacturing Landscape

Mapping was a major focus of the IfM ECS desk work reviewed by delegates at the Phase 2 workshop in April 2013. The identified competencies in defence and security were mapped to the TSB HVM landscape strategic themes. It was found that a significant proportion of technologies and capabilities feature in the TSB HVM landscape and the associated HVM strategy.

Delegates at the April 2013 workshop developed an initial assessment of the scale of potential 2035 impact of selected technologies in the identified competencies across key military and security capabilities. This process identified substantial opportunities to develop MOD's priorities as part of wider technology investment in the UK.

Aspects of the defence and security science and technology landscape formed from this process are illustrated in Figures 3 and 4. Note that these figures show a view of the assessed impact of identified technologies on selected defence and security capabilities and are not therefore intended to be comprehensive. Figure 3 shows the output mapping defence and security capabilities onto TSB HVM strategic themes in outline, while Figure 4 displays one section as an example in greater detail. The landscape is known as a 'heat map' as illustrated in Figures 3 and 4, with depth of colour used to indicate the concentration of potential high-impact technologies with identified competencies in each represented area of defence and security capability.

Figure 3 shows significant synergy between predicted defence and security capability 2035 and the current TSB HVM strategic themes: the deeper the shade of red, the greater the proportion of potential high impact technologies identified.

Figure 3: TSB HVM strategic themes: synergy with defence and security capability 2035

Key	
A number of significantly impactful technologies	
Moderate number/moderately impactful technologies	
Very few impactful opportunities identified	

TSB HVM strategic theme		Military and security capabilities											
		Strategy			Operational defence effect						Security effect			TEPIDOIL*
		Defence Strategy	Security Strategy	Strategic effect	Operate	Command	Inform	Prepare	Protect	Sustain	Pursue	Prevent	Protect	Lines of development
Direct mapping to TSB HVM national competency	**Resource efficiency:** Securing UK manufacturing technologies against scarcity of energy and other resources													
	Manufacturing systems: Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems													
	Materials integration: Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies													
	Manufacturing processes: Developing new, agile, more cost-effective manufacturing processes													
	Business models: Building new business models to realise superior value system													
Linked to HVM competencies but not directly mapped														
No mapping														

Source: IfM ECS analysis of MOD science and technology landscape; cross-industry workshop 10 April 2013

TEPIDOIL – MOD Defence Lines of Development: Training; Equipment; Personnel; Information; Doctrine; Organisation; Infrastructure and Logistics.
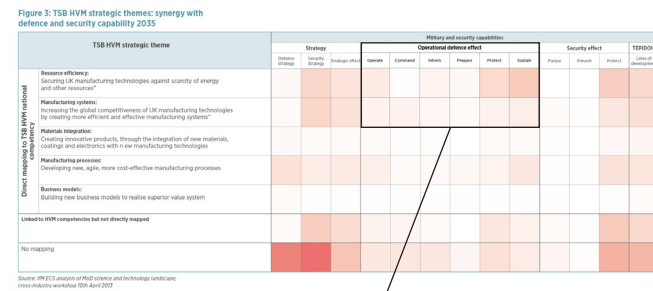
Figure 4 shows one section of Figure 3 in more detail. The added detail comprises the defence and security science and technology competencies (extracted from the full list shown in Figure 2) associated with selected TSB HVM themes, as well as the elements of military and security capabilities potentially impacted.

Figure 3: TSB HVM strategic themes: synergy with defence and security capability 2035

Key	
A number of significantly impactful technologies	
Moderate number/moderately impactful technologies	
Very few impactful opportunities identified	

Figure 4: TSB HVM strategic themes: synergy with defence and security capability 2035 – detailed view of constituent data

		Operational defence effect												
		Operate		Command		Inform			Prepare	Protect				Sustain
TSB HVM strategic theme	**Defence and security science and technology competency**	Improved real-time operational information and navigation	Lightweight infantry equipment	Real-time, risk-based command decision support analysis	Real-time, risk-based command decision support communication	Long-range operational sensing	Real-time, secure command decision support communication	Agile design-to-manufacture capability	Chemical and biological detection	Cloaking devices to avoid surveillance	Enhanced military medical services based on new technologies	Alternative energy and material sources and fuels to reduce logistics train	Improved real-time operational information and navigation	In-theatre manufacturing
Resource efficiency: Securing UK manufacturing technologies against scarcity of energy and other resources	1. Power generation, energy management and storage													
	2. Design and manufacture for sustainability and through-life													
	3. Design and manufacture for lightweight vehicles and structures													
	4. Biological and chemical sensing and control systems and processes													
Manufacturing systems: Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems	5. Systems modelling and integrated design and simulation													
	6. Autonomy and HMI													
	10. Design and manufacture for small-scale and miniaturisation													
	13. Plug and play manufacturing													

Source: IfM ECS analysis of MOD science and technology landscape; cross-industry workshop 10 April 2013

7. Example cross-government collaboration opportunities

Phase 3 of the study focused on two selected competencies in order to enable greater depth of analysis and validate the model employed. The competencies selected in discussion with MOD and Dstl were:

- Intelligent sensing and detection (including quantum sensing)
- Power generation, energy management and storage.

As the process was run as a pilot exercise, the prime rationale for selection, given that relevance to the landscape had been confirmed, was the ease with which a topic might be developed in a one-day workshop. In June 2013, parallel workshops were held to examine each selected competency in more detail. At these deep dives, invited delegates developed key deliverables and refined Phase 2 views on impact, probability and confidence for the associated technologies.

Deep-dive workshop delegates comprised cross-sector industry representatives (via relevant Knowledge Transfer Networks), Dstl subject matter experts, and research council and TSB Technology Leads. They were tasked with identifying:

- the future size of the technology area
- anticipated defence needs and assessment of the likelihood that the associated technologies would provide effective and practical solutions
- links to non-defence programmes and investment
- key skills, facilities and technology gaps
- potential supply-chain risks and mitigations
- necessary interventions between MOD and others (TSB, research councils) to close the gaps
- initial assessment of the readiness of associated technologies
- key enablers and barriers.

The deep-dive workshops employed an opportunity-assessment process, indicated by Figure 5. Delegates considered the outputs in relation to a number of criteria to describe the potential for 'pull through' of civil technologies for defence and security applications. Figure 5 shows how delegate views were categorised in relation to four criteria: technology readiness; future scale of civil applications; links to non-defence programmes; supply-chain risks/gaps.

Figure 5: Deep-dive workshops: opportunity assessment criteria

Criterion	Key	Definition of delegate view
Technology readiness		Relatively certain of significant military impact
		Moderately certain of significant military impact
		Relatively uncertain of significant military impact
Future scale of civil applications		Major-medium civil market scale applications identified
		Small civil market applications identified
		Niche market applications identified
Links to non-defence programmes		Specific relevant programme(s) identified
		Possible relevant programmes/interest areas identified
		No current programmes identified but future possible programmes recommended
Supply chain risks/gaps		No significant gaps identified
		Gaps identified but considered manageable
		Significant gaps identified but possible actions recommended

Source: Cross-industry deep-dive workshop 26 June 2013, followed by IfM ECS analysis of cross-government questionnaire responses

Figures 6 and 7 show the results of the opportunity assessment process. Delegate assessments of the prospects for 'pull through' of civil technologies for defence and security applications are shown in Figure 6 in respect of the competency Intelligent sensing and detection including quantum sensing (columns to the left) and in Figure 7 for Power generation, energy management and storage.

Following the deep-dive workshops, and after completion of the formal study, IfM ECS circulated a questionnaire to cross-government partners to assess their funding

priorities for the two competencies examined by the deep dives. Funding body responses are shown by the columns on the right in Figures 6 and 7: the deeper the shade of red, the more significant is the funding body investment in relevant developments.

A comparison of the cross-government responses with the outputs from the workshops shown in Figures 6 and Figure 7 identifies a number of opportunities where collaboration between funding bodies across government can leverage wider resources.

Figure 6: Opportunities where collaboration can leverage wider resources (1)

Intelligent sensing and detection (including quantum sensing)									
Deep-dive workshop output						Indicative intensity of activity			
Technology theme	Prospects for civil market development				Cross-government initiative recommended	TSB	BBSRC	EPSRC	STFC
	Technology readiness	Future scale	Links to non-defence programmes	Supply chain risks/gaps					
Data handling & intelligent processing					Cross-government funded collaborative R&D programmes to draw out emerging technologies in broadband communications and storage, retrieval security & encryption.				
Short-range & smart arrays					Prototype funding to adapt and transition technology from other sectors and across KTNs, e.g. from Health and Leisure to Transport and Defence.				
Long-range sensing & detection (1 km+)					TSB &/or BIS &/or CDE challenge, perhaps in Magnetic/Gravity/EO Active/ EO wide area. Encourage EPSRC to invest in those technologies on RHS that have significant commercial opportunities if not already in train.				
Quantum sensing technologies & processes					Funded big cluster generation to create critical mass of expertise, know-how and technologies.				

Key: Deep-dive workshop output: see Figure 5. Indicative intensity of (funding body) activity: deeper red indicates more investment in relevant developments
Source: Cross-industry deep-dive workshop 26 June 2013, followed by IfM ECS analysis of cross-government questionnaire responses

Figure 7: Opportunities where collaboration can leverage wider resources (2)

Power generation, energy management and storage									
Deep-dive workshop output						Indicative intensity of activity			
Technology theme	Prospects for civil market development				Cross-government initiative recommended	TSB	BBSRC	EPSRC	STFC
	Technology readiness	Future scale	Links to non-defence programmes	Supply chain risks/gaps					
Novel, non-traditional power sources					Strong academic base already exists. MOD would need to integrate and/or help set industry standards. Possibly joint call with TSB on small deployable wind/wave/tidal turbines?				
Advanced storage (batteries and super-capacitors)					Joint MoD/BIS encouragement for UK investment in vertically integrated manufacturing. Set MOD standards and performance targets. MOD engage with University of Warwick demonstrator.				
Energy harvesting (mW-MW)					UK strategy TSB/RCS/BIS for EH (low power/high power), localised vs. widespread distribution and increased research council involvement in associated R&D. MOD engage with MedTech KTN.				
Energy management					MOD develop associated policies and engage with EPSRC SuperGen programme.				

Key: Deep-dive workshop output: see Figure 5. Indicative intensity of (funding body) activity: deeper red indicates more investment in relevant developments
Source: Cross-industry deep-dive workshop 27 June 2013, followed by IfM ECS analysis of cross-government questionnaire responses

8. Conclusions

The study highlights the importance of addressing cross-cutting technical competencies and:

- Reaffirms the key technologies in the 2035 defence and security landscape identified in other studies
- Indicates opportunities to develop MOD's priorities as part of wider national technology investment, for example the TSB HVM landscape (http://www.ifm.eng.cam.ac.uk/uploads/Resources/Reports/TSB_UKHighValueManufacturing.pdf)
- Highlights specific technology areas where collaboration with funding bodies across government can leverage wider resources. These have been developed in detail for the competencies Intelligent sensing and detection (including quantum sensing) and Power generation, energy management and storage. The process could be applied to each of the competencies identified in this study.

The authoritative challenge process which concluded the work (see section 4) highlighted ways in which the explicit linking of the study to the TSB HVM landscape is both a strength and a potential limitation and signalled the need for further examination of outputs:

- The linkages have been made as a means of establishing a common terminology and framework, already recognised by TSB, BIS and EPSRC, concerning the exploitation of future technologies and capabilities across industrial sectors

- There are potential limitations from the initial manufacturing focus of the TSB HVM Landscape concerning inputs from non-manufacturing sectors
- An initial rough pass was made over the wide subject area using 'confidence in predictions' as an indicator of uncertainty and the range of opinions inherent in limited delegate involvement
- Deep-dive development topic outputs are opinion-based and may be subject to individual bias, however, 'confidence in predictions' was again used as an indicator of uncertainty, and further cross-testing of the outputs is planned with TSB, BIS, research councils and industry
- Outputs cannot in themselves be used to set priorities, but rather to highlight areas for cross-government/industry collaboration
- The approach presently favours capabilities which underpin many, rather than are critical to a few, military capabilities, although further development of the heat map output will support trade-offs between the former and the latter
- It is possible that 'underpinning many' technologies and capabilities will most likely emerge from the civil sector whilst 'critical to a few' ones may potentially require MOD investment. Next steps should therefore include cross-testing of outputs, investigation of limitations and examination of further competency areas in detail.

9. Recommendations

Recommendations focus on:

- Working with the four military commands to investigate further specific technology areas by means of deep dives, where collaboration with funding bodies can leverage wider resources
- Joint exploration of opportunities with TSB HVM Catapult
- Collaborative review of science and technology innovation processes.

Specifically, it is recommended that MOD:

- Undertakes deep dives with the four military commands to establish the practical application of the landscaping approach
- Commissions further deep dives with selected capability themes to establish a wider mapping for the cross-government opportunities
- Conducts a pass and 'innovation lens' (possibly through research collaboration) over existing structures, which is then processed to potentially identify areas for transformation
- Further develops engagement with TSB (particularly HVM) in addition to continued engagement with research councils and BIS.

It is also recommended that MOD:

- Considers wider engagement of non-manufacturing sectors such as finance, media and creative arts in further studies to widen the scope of opportunity assessment
- Considers a 'shallow pass' at further themes:
  · energy and power security
  · new computing paradigms e.g. DEC, QC BC, energy-efficient computing and authentication of digital transactions

and that TSB asks IfM ECS to:

- Undertake development of the heat map linkages algorithm as part of the 'HVM refresh pre-work' TSB study.