# The Defence and Security Technology Competency Report

## Collaboration and leverage towards the UK 2035 landscape

IfM Education and Consultancy Services

UNIVERSITY OF CAMBRIDGE

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**

This study was conducted by IfM Education and Consultancy Services Limited (IfM ECS), the knowledge transfer arm of the University of Cambridge Institute for Manufacturing. Among contributors taking part in cross-government/industry workshops and consultations were: industry representatives from the Energy, ESP (Electronics, Sensors, Photonics), Automotive, Materials and Aerospace Knowledge Transfer Networks; BAE Systems; Thales; Technology Strategy Board (TSB); Engineering and Physical Sciences Research Council (EPSRC); Department for Business, Innovation and Skills (BIS).

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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).

| Competency |
|---|
| Power generation, energy management and storage |
| Design and manufacture for sustainability and through-life |
| Design and manufacture for lightweight vehicles, structures and devices |
| Biological and chemical sensing and control systems and processes |
| Systems modelling and integrated design and simulation |
| Autonomy and HMI |
| Intelligent systems (excluding autonomy) |
| Intelligent sensing and detection (including quantum sensing) |
| Intelligent testing and metrology, including obsolescence |
| Design and manufacture for small-scale and miniaturisation |
| Development and application of advanced materials and coatings |
| Biological materials integration |
| Plug and play manufacturing |
| Flexible and adaptive manufacturing |
| Additive manufacturing |
| Managing risk and resilience |
| Ubiquitous global communication |
| Big data and cyber |
| Software/firmware development and validation |
| Integrated circuit design, modelling, validation, etc. |
| Secret, home-grown software |
| Optical communications |
| Quantum computing |
| Space technology |
| Directed energy systems |

*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

| | Description |
|---|---|
| | Energy technologies to aid in lightweighting, reduce logistics train and reduce dependency on fossil fuels and foreign fuel sources |
| | Design and manufacture of sustainable and innovative products including disassembly (recycling) and through-life services |
| | Design and manufacture of sustainable and innovative products to reduce the strain on the logistics train and on the individual |
| | Threat assessment; new threats; existing organisms; vital signs monitoring; biomimicry |
| | Systems modelling of complex systems. Integrated design methodologies using systems modelling, involving simulation, modelling & validation quickly to produce high-complexity products with advanced functionality |
| | Reduction of cognitive burden whilst keeping intuitive control; thought-driven computing |
| | Software systems exhibiting machine learning and independent thinking behaviour |
| | Gathering signal & state from a domain of interest & conversion of data at various volumes, velocities & abstractions, to derive information & intelligence of value |
| | Non-destructive testing (including self-testing) & measurement, with timing and extent intelligently decided, including testing for obsolescence in whole or in part |
| | Design & manufacture of components enabling smaller products, smaller product runs and miniaturisation without compromising function or efficiency |
| | Advanced materials & coatings for use in a range of applications and functions including hardening, compatibility, reduced friction, sterility and antifouling |
| | Injury assessment and management; point of injury stabilisation & treatment; recovery; extreme environments; bio-enhancement |
| | Modular components enabling interoperability |
| | 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 |
| | Application of additive layer manufacturing or other freeform techniques to fabricate intermediate and end use products (including direct digital manufacturing) |
| | Responding to attacks on personnel and assets; managing failure of assets; maintaining operational sovereignty |
| | Ubiquitous, secure, global communications systems for increased command and control |
| | 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 |
| | Swift and effective development and validation of software and firmware, minimising the time between development and use |
| | Swift and effective development and validation of integrated circuitry, minimising the time between development and use |
| | Individuals or groups creating malicious software for release |
| | Paths of communication using light as the medium |
| | A computation device that makes direct use of quantum mechanical phenomena |
| | Global (Intel, Recon, Survey, Communications, Command, Control, Vector Off), Positioning, Navigation and Timing; countering space threats |
| | 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.

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

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

| | TSB HVM strategic theme |
|---|---|
| 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*

| | 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 |
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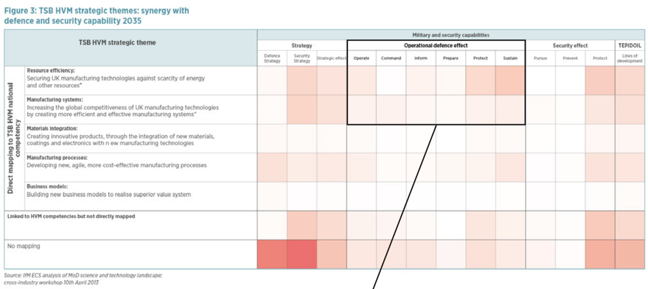
****TEPIDOIL*** *– MOD Defence Lines of Development: Training; Equipment; Personnel; Information; Doctrine; Organisation; Infrastructure and Logistics.*

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.




| 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** | (green) | Relatively certain of significant military impact |
| | (yellow) | Moderately certain of significant military impact |
| | (orange) | Relatively uncertain of significant military impact |
| **Future scale of civil applications** | (green) | Major-medium civil market scale applications identified |
| | (yellow) | Small civil market applications identified |
| | (orange) | Niche market applications identified |
| **Links to non-defence programmes** | (green) | Specific relevant programme(s) identified |
| | (yellow) | Possible relevant programmes/interest areas identified |
| | (orange) | No current programmes identified but future possible programmes recommended |
| **Supply chain risks/gaps** | (green) | No significant gaps identified |
| | (yellow) | Gaps identified but considered manageable |
| | (orange) | 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-capacitators)** | | | | | 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.

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