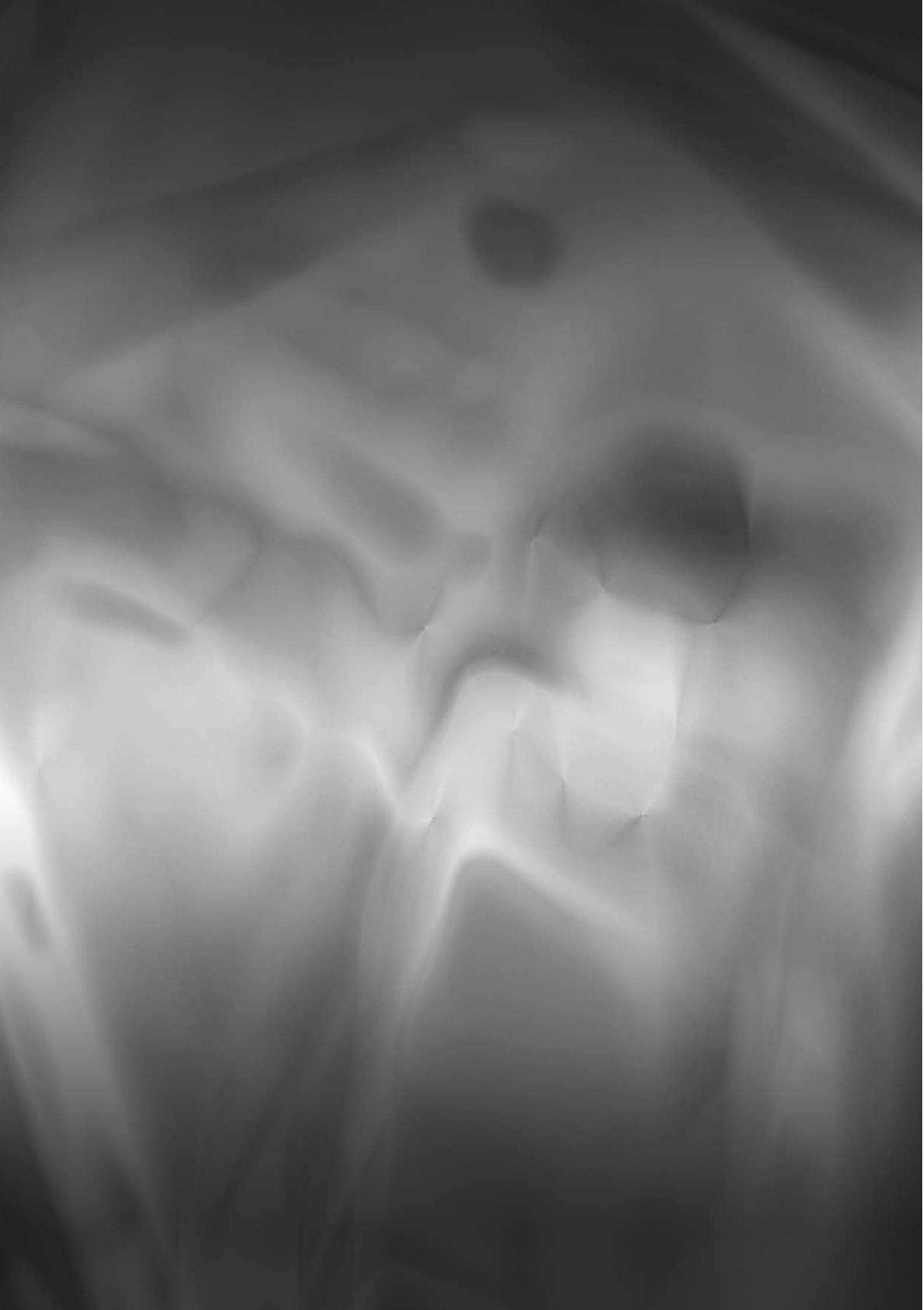


C1	The Challenges	157
C2	Science & Technology Priorities	158
C3	Delivery Process To Speed Up R&D Exploitation	160
C4	Joint MOD/Industry Framework For Investment	162
C5	Working Closely Through Dstl and with the Universities to Support Defence Science and Technology	163
C6	A Well Documented Supply Chain That Stimulates And Exploits Innovation	164
C7	Investment in Science and Engineering Skills of Relevance to Defence Technologies	166
C8	Summary	167
C	Annex A - Priority Technology Summary Table	168
C	Annex B - Innovation in the Supply Chain: Technology Trees	175



C1.1 Having highlighted the broad military capability and related science and technology challenges facing UK defence, this section details what MOD (including Dstl), working with industry, the university sector and where appropriate through collaborative partners, is going to do to ensure that science and technology plays a leading role in helping our armed forces.



Testing of titanium based alloys in turbine design

C1.2 Effective delivery of the DTS comprises 4 key components:

- Science and technology priorities.
- Delivery process to speed up research and development exploitation.
- Joint MOD/industry framework for investment.
- Working closely through Dstl and with the universities to support defence science and technology.

'In response to the wide-ranging environmental changes, the Department's strategy is increasingly changing from one of creating the Technology Base to one of accessing and exploiting it. It is focusing its expenditure on maintaining a knowledge base that covers a wide range of technologies relevant to Defence. Where the Department directly funds Defence specific technology, funding priorities are a direct reflection of the strategic and Defence value of the technology and its availability from other sources.'

National Audit Office Report: The Management of Defence Research and Technology, HC 360 Session 2003-2004: 10 March 2004

These are underpinned by 2 critical enablers:

- A well documented supply chain that stimulates and exploits innovation
- Investment in science and engineering skills of relevance to defence technologies

These are developed below.

C1.3 In delivering the defence vision¹ we must meet the science and technology needs of today, tomorrow and as far as possible in the future ensuring that we are nurturing and making best use of:

- evolutionary technology developments, to enhance and adapt existing capabilities.
- revolutionary developments to create new options and address major challenges.
- underpinning technical skills and expertise to support all aspects of defence.

C1.4 Involving many different organisations and skill-sets, within a TLMC context we will make best use of all the resources available within and to the UK. But much of the potential benefit will only be realised by these different organisations working together to mutual benefit. Accurate forecasting of TLMC depends on the systematic collection of data on all aspects of through life costs. MOD and industry must work together to create and manage these databases.

C1.5 The DIS and Enabling Acquisition Change study² amongst others have highlighted the need to integrate our science and technology investment, our future capability planning, the acquisition and support communities and the resources of UK industry and academia. Detailed priorities for science and technology investment cannot be set in the abstract, but rather will emerge from the creation and application of a joint MOD/industry planning framework strongly focussed on technology outcomes and their exploitation in defence systems. This DTS provides the necessary clarification of MOD's technology needs and priorities to enable this planning process.

¹ *Delivering Security in a Changing World – Defence White Paper – Dec 2004. The Defence Vision challenges us to be fit for the challenges of today, ready for the tasks of tomorrow and capable of building for the future*

² *Enabling Acquisition Change: An examination of the Ministry of Defence's ability to undertake Through Life Capability Management – dated June 2006.*

C2.1 Section B describes in detail MOD's view of its priorities for research and development, including those areas necessary for the UK to maintain its operational independence. A summary is provided at Annex A, key points for MOD are:

- We will continue to control all elements concerning cryptographic equipment to protect classified UK Eyes Only traffic;
- Collaboration with academia and industry to develop smaller (man-portable) biological detection and identification systems and support TDPs to de-risk potential capability solutions, **from Autumn 2006**;
- NEC is fundamental to mission success and we must be more effective than our adversaries in using and controlling information. Consequently it is essential for MOD to take the owner and leadership role in establishing a MOD/industry community of practice¹ to design and develop the defence C4ISTAR system-of-system architecture. We will develop the community of practice **by Spring 2007**;
- Radar remains our most effective all-weather, ubiquitous sensor. Hence MOD, working closely with industry, will produce detailed plans that include commercial arrangements for implementation of the existing outline strategy for radar technology and demonstration **by summer 2007**;
- A resounding message that has emerged in producing the DTS is that signal processing is a core technology where the UK is world class, and must remain so. Therefore MOD will set-up and lead a community of practice to define a national approach and roadmap on signal and data processing for defence **by Autumn 2007**.
- Building on existing work with industry (e.g. the Technology Insertion Major Programme Area) and the emerging MOD funded Software Systems Engineering Initiative to develop approaches and expertise for assurance of modular open systems establishing a framework and programme plans **by Autumn 2007**.
- Military capability will increasingly depend on technologies offering small, relatively low cost and high-precision means to define spatial and temporal resolution. MOD will therefore establish and lead a MOD/industry community of practice to develop a pan-defence roadmap for geolocation and synchronisation **by Autumn 2007**.



A portable biological detector

¹ The concept of a community of practice (often abbreviated as CoP) refers to the process of social learning that occurs when people who have a common interest in some subject or problem collaborate over an extended period to share ideas, find solutions, and build innovations.

- Modelling and simulation is of increasing importance, both for improved military capability and for effective application of our processes. In the latter case we need to make better use of the information flowing from the application of our processes to improve them. Consequently, MOD will lead the development of an MOD/industry framework for modelling and simulation and related data collection to support TLM. The framework will be developed **by end 2007**.
- We will continue to work with the supply base for fixed wing propulsion, to develop exploitable technologies to improve through-life management of MOD's propulsion systems, and via novel technology approaches, address defence specific needs.
- Widening the supplier engagement in research on generic medical countermeasures starting with production of a comprehensive communication plan **by the end of 2007**.
- Support for the European and UK satellite manufacture industries to enhance our information collection and analysis to be considered for **inclusion in the 2007/08 research programme**.
- Working with the defence manufacturers and European Procurement Agencies to identify what UK investment is required to ensure that UK companies will be able to access Gallium Nitride (GaN) circuit technology within Europe **by end 2007**.
- Launch a competition, **by Spring 2007**, for a consortium to carry out research examining advances in designing, manufacturing, modelling and processing of novel materials and their use in structures that contribute to platform protection or reduce through-life costs. This will enable wide participation from both UK academia and industry and will encompass a wide area of low TRL and generic technologies.

C2.2 In rapidly moving areas of science and technology such as sensors and technologies to support C4ISTAR, we will foster and support, via the Research Acquisition Organisation (RAO), the creation of university centres of research excellence to access the knowledge of the leading research groups in defined fields. Dstl staff will work with these centres as an integral part of their activities. The first such centre will be established **by Spring 2007**.

C2.3 MOD will lead in establishing a culture of openness and joint science and technology planning and technology related risk management with industry and the universities, building on successful existing groups such as Towers of Excellence and the Defence Technology Centres. We also need to nurture those new communities of practice that have gelled during the development of this strategy. A critical dimension of this science and technology planning is the balance between military capability pull and technology push. Whilst operational need is rightly the dominant factor in defence acquisition, military requirements essential to maintain a technological lead over potential adversaries are equally technology-driven.

C3.1 A major factor that has hindered the speediest exploitation of research and development is having only a limited definition of an end-to-end process engaging all the key stakeholders. Much valuable work has been undertaken by MOD and industry on this issue. Specifically, the Technology Maturation Study¹ identified the need for Through Life Management Plans underpinned by joint MOD/industry planning and roadmapping using agreed metrics such as Technology Readiness Levels². MOD will ensure that a planning process is in place involving key MOD and industry stakeholders based on technology roadmaps, to address quality and relevance using independent peer review **by September 2007**.



Training using advanced simulators prior to joint US/UK 'Red Flag' exercise

C3.2 Significant progress has been made regarding the step-by-step maturation of technologies where the scientific principles have been established and embedded within a technological approach to meet a defined military capability need. In such cases, we have set out in broad terms MOD's future approach to technology management. The DPA/DLO Technology Management Strategy³ has developed this in more detail for the defence procurement and support communities.

C3.3 Consequently, we will build on the Technology Maturation Study findings and the MOD Technology Management Strategy that supports TLMC and embraces all stakeholders.

C3.4 The most challenging research problems facing MOD are those where there are no known solutions, or where solutions need to be more affordable and the current approach does not lend itself to significant cost reduction within the necessary performance envelope. Therefore we need to stimulate innovation for these most challenging of problems. Critical to success will be the early identification of promising approaches and termination of the less promising ones. We will drive those approaches most likely to provide significant defence benefit hard through to exploitation.

C3.5 This approach is most important when seeking solutions to the most demanding problems encountered on current operations. Good examples are the detection of IEDs in a range of difficult situations, and a number of individual and platform protection measures. MOD will make research support to operations a key component of its revised approach to delivering research (an action from the Enabling Acquisition Change⁴ programme). This will include a fast-track approach to demonstrating proof of principle enabling the earliest exploitation in theatre. A description of a new research delivery scheme will be complete **by December 2006**.

¹ Findings of the 3* Technology Maturation Study, presented at a joint MOD/industry workshop entitled 'Managing Research under Output Ownership' held on 28th May 2004 at the Defence Procurement Agency, Abbey Wood, Bristol.

² http://www.ams.mod.uk/ams/content/docs/trl_guide/trlguide.pdf

³ FBG/36/08 dated 26 May 05

⁴ Enabling Acquisition Change: An examination of the MOD's ability to undertake TLMC – dated June 2006

5 Key Principles of Technology Management

(Taken from Joint DPA/DLO Management Strategy, dated 28 July 2006)

Understanding Technology Opportunities in Projects.

We will work to understand technology opportunities for our equipment project options so we enable realistic choices, through life.

Managing Technology Risks in Projects

We will *identify and manage technology risks as they apply to specific project options.*

Jointly Planning Technology Resources and Outcomes

We will *jointly plan* with other parts of MOD to optimise defence research and development resources, through life.

Equipping our Staff for the Job

We will ensure staffs are *skilled, trained and experienced* in project management, especially in schedule, risk mitigation and estimating techniques and that they have practical and successful experience of applying and developing these to the particular needs of their projects.

Industry and Teams - Working Together

We will ensure *early and effective engagement with industry*, offering visibility and dialogue on our technology plans and options, and seeking visibility and dialogue on their plans in return.

RAO Defence Research Supplier Briefing

The move to partnering with a wider and more diverse supplier network for the non-nuclear research programme can only be successful if those involved understand and are aware of the overall structure, priorities and opportunities in the research programme. The Research Acquisition Organisation, established to define and deliver the non-nuclear research programme, holds an annual Research Supplier Briefing.

This event aims, in a single day, to provide an overview of the non-nuclear research programme highlighting the key priorities, initiatives and opportunities as well as an opportunity to network with key individuals from across the full breadth of defence research. The event has proved to be very successful attracting wide support from across industry (multinational to SME) and academia, with 450 representatives from over 130 organisations and companies attending in June 2005. With the continued expansion of research competition and the research supplier network, up to 600 people are expected on 23 November in London for the 2006 event.

Further information is available at www.science.mod.uk or from science@mod.uk

C3.6 Underpinning the entire process is ensuring suppliers are aware of defence requirements so that they can play a major role in generating solutions.

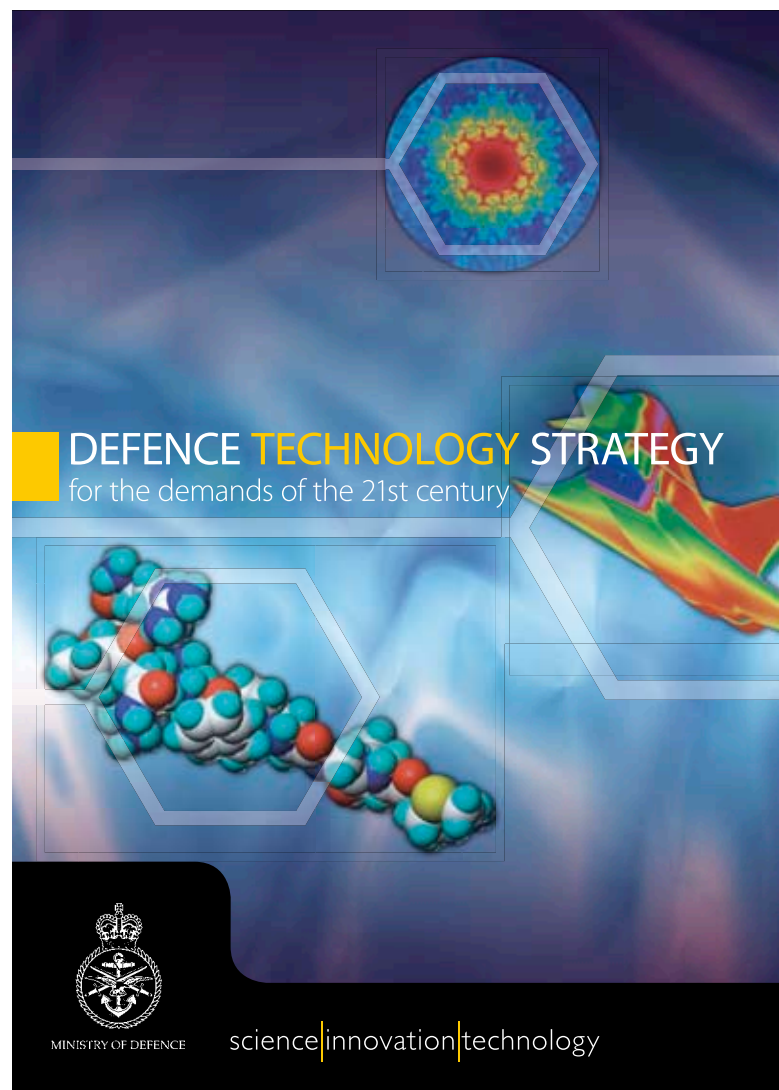
C3.7 MOD will build on its drive to keep suppliers of research informed of priorities and plans, as well as engaged in delivery based on a number of formal and informal means. For example, there is a strong ongoing need for Towers of Excellence and similar MOD/industry technical discussion fora to develop the detailed technology roadmaps and exploitation plans required to deliver against the priorities identified in this DTS. Where, as in the case of C4ISTAR, new communities of practice have evolved from work on this strategy, MOD will maintain this dialogue and interaction. Other opportunities for exchange of technology priorities and plans are provided by a range of Supplier Days, briefings and theme days.

C4.1 The DTS takes the DIS forward, giving greater emphasis to through life capability issues. Analysis has assumed that MOD will, as now, advance technologies to an intermediate technology readiness level (TRL) for the majority of topics showing significant potential. However, driving technologies through to a mature state, particularly TRL 6 and up, will require significant industrial funding.

C4.2 Against this background, the DTS is affordable provided both MOD and industry invest together, but there is much work needed on this.

C4.3 The next step is for MOD with industry to agree the principles of joint funding via the National Defence Industry Council. It will then be possible to develop technology planning on a case-by-case basis. This issue should be a major agenda item for the NDIC beginning in **Autumn 2006**.

C4.4 Resolution of this issue is critical to the UK achieving its ambitions as outlined in the DIS and carried through to this DTS.



C5.1 Dstl is the MOD's principle internal source of scientific and technological expertise. It has a particular role in undertaking research, supporting development and giving broad science and technology advice, particularly in areas that must be retained within government.

C5.2 As such, it is vital that Dstl retains and develops the science and technology skills necessary to fulfil its role. This will be done by a combination of undertaking high quality research in-house, and in working closely with MOD's research suppliers, particularly the universities.

C5.3 Establishing the correct balance for Dstl between undertaking research to address MOD's needs and develop expertise, and gaining knowledge solely to provide advice, needs to be refined. A review to reassess this balance will be undertaken **commencing in Spring 2007**.

C5.4 Furthermore, since Dstl has a key role in helping ensure the MOD has access to skilled scientists and engineers, including supporting recruitment, it is particularly important that Dstl develops a close and effective relationship with the universities.



Electro-optic infra-red turret fitted for airbourne surveillance

C6.1 A major factor affecting defence achievement of the benefits of science and technology through research and development is the stimulation, nurturing and exploitation of invention and innovation.

C6.2 Innovation in military equipments contributes to achieving a battle-winning edge by giving a technological advantage over opponents. The DIS committed MOD to develop a better understanding of the innovation process, to enable better, faster pull-through of new technology into military capability. In support of this, the NDIC (R&T) Sub-Group tasked key industrial partners to map technology trees for a wide range of military equipments. These technology trees have been produced and are providing a most useful insight into our supply chains and the contributions that different players make, further details and examples of which can be found at Annex B. The NDIC(R&T) Sub-Group will issue its innovation report examining technology trees in **Autumn 2006**.

C6.3 MOD is committed to stimulating inventive and innovative research to address the most challenging defence problems. As part of its approach MOD wishes to create a 'DARPA' like effect¹ within its R&D programme. The key characteristics of DARPA that MOD wishes to capture are the ability to stimulate potentially highly innovative and inventive ideas, and to drive the ones that show real promise hard to earliest exploitation.



Sample phials

¹ Defense Advanced Research Projects Agency Home Page (<http://www.darpa.mil/>)

Academic Engagement with Defence Research

The UK has one of the most effective and efficient science bases within the university research sector. To forge greater links with the university sector, an inaugural conference for the academic research community was held on 19 July 2006 in the Institution of Engineering and Technology, Savoy Place.

The conference was aimed at exposing all those in the academic community involved in formulation and development of research programmes to MOD's research programme and current priorities. Opportunities were outlined for working with the new Counter Terrorism Science and Technology Centre and providing greater innovation through the introduction of simplified contracting mechanisms specifically aimed at universities and SMEs.

Research Directors from the Research Acquisition Organisation (RAO) presented their current technical challenges.

Over 100 universities and research organisations were represented at the conference. We will repeat annually the Academic Engagement Conference, as well as the now regular RAO Defence Research Supplier Briefing, to continue the broadening of the research supplier base.

C6.4 This approach will enable support of more speculative and high risk basic and applied research on advanced technologies of high potential relevance to defence. MOD will produce options for achieving the DARPA effect as part of delivery of the EAC study² by **December 2006**.

C6.5 Ahead of a full review of how to achieve this, a scoping study is under way to cover all of MOD's R&D spend and will build on the approach adopted recently for the capability and alignment study³ of research. These studies are crucial in benchmarking the current position ahead of defining the details of levels of funding and how to achieve the desired effect.

C6.6 However, we need not await the outcome of the review before taking some action.

² *Enabling Acquisition Change: An examination of the Ministry of Defence's ability to undertake Through Life Capability Management* – dated June 2006

³ *Maximising Benefit from Defence Research* – September 2006

C6.7 A major step forward will happen when MOD puts in place a 'Competition of Ideas' process to expose and seek solutions to major defence problems that need innovation and injection of new ideas from a wide range of potential suppliers. This is expected to appeal particularly to universities, SMEs and Research and Technology Organisations, as well as other lower tier suppliers. The scheme will be operational from **Autumn 2006**.

C6.8 The initial budget to kick-start the initiative is £10m, but this will be reviewed in light of the initiative's success in stimulating novel ideas.

C6.9 MOD will also launch a 'grand challenge' competition to provide the best solution to a defined capability need. This initiative is part based on DARPA's concept⁴, most recently focused on autonomous land vehicles to transit a desert terrain, with the third and latest for November 2007 addressing autonomous ground vehicles executing simulated military supply missions safely and effectively in a mock urban area. The DARPA's competitions have been very successful in both attracting many high quality research teams, and in generating innovative solutions.

C6.10 MOD's first competition will be initiated in **November 2006**.

C6.11 As part of stimulating good research proposals from across the science and technology research community, MOD is increasing the proportion of its research programme to be competed to around 60% **by 2009/10**⁵.

C6.12 In addition to scientific and technological innovation, supply chains, for example those forming up around the DIS sectors, need to demonstrate innovation in business process and operation. This is very much a developing scene as each sector involving MOD and the full industrial supply chain work to make DIS a full reality. Critical to success will be to ensure the full chain, involving the critical lower tiers, for example SMEs are effectively engaged. This issue will be addressed in the NDIC(R&T) report referred to above.

⁴ DARPA Grand Challenge website (<http://www.darpa.mil/grandchallenge/index.asp>)

⁵ NAO report *Management of Defence Research and Technology 10 March 2004* (note this refers to what were applied or corporate elements of the research programme which formed the QinetiQ assurance and not the whole research programme).

C7.1 The DIS¹ identified the importance of the science and engineering skills base in the UK. A recent report by the Department for Education and Skills² shows a steadily declining number of engineering and physical science entrants to higher education. The MOD, in partnership with industry, universities and professional organisations is committed to encouraging more students to courses of relevance to defence science and technology. We are developing two new initiatives. First we will fund an initial 1-year pilot scheme for up to 30 Doctoral studentships to be run in partnerships between Dstl, the defence industry and interested universities, in engineering and scientific fields of high importance to defence. Note that it is possible to undertake classified Doctoral degree research, and in such cases the Defence College of Management and Technology within the Defence Academy is an appropriate institution. Second we will fund an initial 1-year pilot scheme for up to 3 postdoctoral research fellowships in partnership with The Royal Society under their University Research Fellowship scheme, to attract some of the brightest and best scientists into defence and security related research. We also intend to develop a similar scheme for engineers in partnership with the Royal Academy Of Engineering. Both schemes will be reviewed after the first year to ensure their efficacy and suitability to meet MOD's needs.

C7.2 We need to have the requisite leadership, acquisition and technical skills to be able to formulate requirements, undertake and exploit R&D. To achieve better delivery of our programmes and projects and more effective TLM, we need to:

- Ensure better alignment of skills and behaviour to business needs;
- Deepen and strengthen our science and engineering skills base to remain an intelligent customer;
- Build closer relationships with industry and the technology supply base in general;
- Work jointly with Other Government Departments (OGDs) and industry to ensure sponsored educational outreach and training programmes are co-ordinated and effective, and aim to attract students to the science, engineering and technology subjects.

C7.3 The science and technology priorities in Section B provide a baseline which allows us to profile our future science and technology skills requirement. Working as required with OGDs, industry, academia

¹ DIS, Section B1 xvi ff.

² *The Supply and Demand for Science, Technology, Engineering and Mathematics Skills in the UK Economy, Research Report RR775, 2006.*

and others, we will develop plans to source, refresh and sustain these skills by:

- Developing mechanisms to measure science and technology related skills across the defence community;
- Developing/employing Government and industry wide standards to ensure effective comparisons can be made across the defence community;
- Co-operating with the other DIS workstrands addressing capacity and demand within the industrial supply chains to identify and address relevant science and technology related skills shortfalls;
- Identifying and addressing common challenges (e.g. demographics and the proportion of students opting for science and engineering courses);
- Identify and encouraging best practice in educational outreach and training programmes.

C7.4 Under the people and skills area we will:

- Launch an initial 1-year pilot Doctoral research scheme (reviewed after the first year) to be run in partnerships between Dstl, the defence and technology companies and interested universities, in engineering and scientific fields of high importance to defence, to support up to 30 students from **Summer 2007**;
- Work with the Royal Society in a 1-year pilot scheme (to be reviewed after the first year) to identify candidates for up to 3 postdoctoral research fellowships **by Winter 2006**;
- Develop the bilateral engagement with industry, through the NDIC (R&T) and Human Resources sub-groups, to develop a joint MOD and industry R&D Skills programme **by Spring 2007**;
- Support the Defence Acquisition Change Programme (DACP) People Programme to ensure a critical review of our need for professional skills in science and engineering, with supporting career structures **by end 2007**;
- Develop an initial Skills Growth Plan to identify the professional skills gaps in science and engineering skills across MOD **by Autumn 2006**;
- Carry out a complete analysis of science and engineering skills, building on current work to define career frameworks to enable professional development and inform training and development plans, define professional standards using competence frameworks, skills "footprints" and the requirements for accomplishments such as licences **during 2007**.

C8.1 Underpinning the science, research and development elements of the DIS, this update of the DTS is a major step forward, explicitly detailing MOD's agenda for change to:

- Deliver an affordable technology strategy to meet our capability needs, within planned MOD funding allocations, subject to the right apportionment of costs between MOD and industry;
- Help ensure the right calibre of people and skills are available to deliver this strategy;
- Sustain vital defence technologies in the appropriate areas of the technology supply chain.

C8.2 In it we have identified:

- The need to sustain vital defence technologies in the long term by harnessing all parts of the R&D chain through government, industry, academia and where there is mutual advantage with our key allies;
- The need to develop a coherent structure and process to ensure research requirements are drawn up and actioned effectively;
- The need to create structures within the R&D programme that are capable of flexible and rapid responses to the changing defence environment and processes that allow rapid technology insertion;
- The need to build on existing and develop new joint working practices to fulfil and deliver the R&D programme and to pull through the fruits of our R&D into world class military capability;
- MOD's strategic vision of the UK's defence R&D requirements over the next 10 years;
- Those priority science and technology research and development areas critical to our national interests and security, areas where our needs can be met through collaboration;
- Those areas that will underpin our Through Life Capability Management;
- The need to invest in science and engineering skills.

C8.3 This is not an end state in developing the DTS; we will ensure progress is regularly reviewed by the Chief Scientific Adviser, the Acquisition Policy Board reporting to the Minister for Defence Procurement, the NDIC (R&T) sub-group, and the DSAC.

C8.4 The task we now face is to build on this planning bedrock. We recognise that taking the DTS forward will require some tough decisions including the fraction of MOD spend that is assigned to R&D, but by working together this ambitious agenda is both deliverable and affordable. We must not evade these decisions as our future military capability, the competitiveness of UK defence industry, and the strength of the UK R&D base depend on it. Together we will rise to this challenge. Our armed forces and our nation deserve nothing less than our very best endeavours to meet the demanding tasks defined in this report. In order to succeed we will need the full support and engagement of both industry and the universities.

C8.5 We are most grateful for all the help, inputs and council received in the production of this DTS from across MOD, industry and academia; we now look forward to working with you all in its delivery.

Summary of Defence Priority Technologies

Function	Priority Technologies	Technology Supply Route	
		Sovereign	Collaboration
Cross-Cutting Technologies (Section B.2) and General Themes			
Campaign, Ops, Mission planning & management, Battlespace Management	Assessment, decision support, situational awareness, delivery, interface, data utilisation, risk and asset management tools	Requirements definition, intelligent customer, experimental and assessment, data fusion and utilisation, understanding of interfaces and algorithms.	Implementation of algorithms
Concepts, design & integration	Systems and platform integration, assessment tools	Design, safety assurance including maritime and airworthiness	Validation tools, integration
Simulation, Modelling, Acceptance, Certification & Assurance	TLCM and synthetic systems/environments modelling, affordable assurance, design, interface specifications. Performance modelling, Support to Operations.	Access to skills, intelligent customer, methodology.	Exploiting collaboration in various areas.
Processing and RF technologies including transmit/receive modules	Leading-edge processing techniques and technologies including certain manufacturing capability	Research, design, develop, modify, maintain and test, manufacture and integrate technologies into radar systems	Technology development/maturity. Compact RF payloads for tactical surveillance
EO and other Sensors, EO Protection Measures and Counter-measures	Higher performance detectors, protection devices and maximising innovation to generate novel exploitation approaches.	Capability to design, evaluate, manufacture and integrate into systems	Beam control technologies, and UK access.
Uninhabited systems	Power sources, autonomous control capabilities, sensors, modelling, integration and certification	Autonomy, intelligent customer, design development and cost-effectiveness assessment, access, integration	Power sources, implementation of autonomous decision making algorithms, UAV platform and interface specifications
Electronic Warfare	Systems, processes and manufacturing capabilities in surveillance (ES), attack (EA) and defence (ED) across all environments and range of platforms including C41STAR	UK national capability to research, design, manufacture, programme, supply, integrate, test and evaluate and optimise performance. Intelligent customer status.	

Function	Priority Technologies	Technology Supply Route	
		Sovereign	Collaboration
Signal Processing	Novel/ advanced techniques and capabilities	Ability to research, design, evaluate, exploit and integrate advanced signal processing algorithms into systems	Possible whilst maintaining UK capability advantage and control of our sensitive systems
Secure & Robust Comms and Information Management	Areas of manufacture, test & evaluation, certain algorithms, network capabilities, modelling, assurity and technologies	Intelligent customer across a range of capability areas	Interoperability aspects.
Human integration and interoperability	Human ¹ /cognitive/ technology dimension of interpretation and exploitation of shared awareness.	Cognitive models, aircrew survivability	Understanding of human performance and behaviour. Effect of drugs on performance. Technology Watch. Cross-cultural issues. Duty of care issues.
Training	Embedded and collective.	Intelligent customer, specifications, test/ assessment. Bridging the gap between man-in-loop models and large scale OA simulations.	
Integrated Survivability	Systems engineering approach, design and modelling, solutions, threat assessment.	Assess, design and understand survivability technologies. Design authority and/or capability of key systems, deep understanding of current and emerging threats.	Access to tools, skills and technology.
Power source and supply technologies	Power management, reduced power demand and power sources including low weight , high energy density, portable power systems.	System design, exploitation of civil developments and technologies to support through life ownership.	Technology watch.
Advanced materials	Low observable and advanced materials, smart materials, modelling.	Design, support for ceramic armour, manufacturing, integration, modelling and exploitation.	Exploitation of smart materials. Supply chain for specialist steels. Technology watch.
Open Systems & Architectures	Design, integration, test and evaluation.	Own, maintain and where necessary develop standards. Control of certain platform architectures and interfaces.	
Electronics Hardware	Obsolescence and systems reliability.	Intelligent customer and user.	Access.
Geolocation and Synchronisation	Atomic clocks, position measurement, interoperability.	Access to technology, ownership of designs and standards.	

¹ Research involving human participants undertaken, funded or sponsored by MOD must meet acceptable ethical standards. Ethical standards are upheld by the MOD Research Ethics Committee..

Function	Priority Technologies	Technology Supply Route	
		Sovereign	Collaboration
Platform supportability	Availability and supportability technologies.	Platform specific.	Platform specific.
Logistics	Wide range of environment-specific technologies.	Intelligent customer.	
C4ISTAR (Section B.3)			
Shared Situational Understanding	Data management, standards, calibration, situational awareness and collation technologies	Algorithms.	Standards, methods of sensor calibration, metrics and measurement techniques. Common data sets.
Collection Co-ordination and Information Requirements Management (CCIRM)	Assessment, decision support, situational awareness, delivery, interface, date utilisation, risk, asset management and tasking information track tools	Algorithms, processes and understanding of equipment interfaces and capabilities.	Implementation of algorithms.
Collaborative distributed and co-located working	Leadership and information sharing technologies.	Exploitation of commercial products.	Tools and information sharing technologies.
C2	Adaptive, HQ effectiveness and audit tools	Exploitation of commercial products.	C2 tools.
Communications and radar surveillance	Detection, prosecution and location capabilities and UAV payloads	Prototype demonstration.	Optional route.
Active EO/IR, Multi-spectral and Hyper-spectral imaging	3D terrain model collection and target geolocation, optical design, detector/ filter cold shield and smart focal plane processing techniques		Terrain model collection techniques and target geolocation and all associated with Multi-spectral and Hyper-spectral imaging.
Acoustic sources	Under water based - contact payloads for survey and reconnaissance. Ground – unattended sensors.	Underwater - ability to demonstrate TRL 6 maturity. None.	Optional route. Unattended ground sensors.
HumInt	Behaviour prediction and mental models	Sense and predict human behaviour.	Mental models.
Cyber	Network, monitoring, analysis, integration and data fusion technologies	Prototype demonstration when no COTS/tailoring.	Case specific technologies.
Meteorological, oceanographic, hydrographic	Optimising data collection.	None.	Optimisation methods.
Non-traditional and open sources	Integration	Integration.	Annotation with appropriate metadata.

Function	Priority Technologies	Technology Supply Route	
		Sovereign	Collaboration
Networked sensor control, management and cueing	Use, understanding and integration technologies	Algorithms, understanding of equipment interface.	Implementation of algorithms.
High altitude platforms	Design and integration	None.	All.
Small satellites	Design and integration of satellite and payloads, C2 systems and data reception	Payload integration.	Procurement of satellite bus and payload.
Data fusion, mining and reduction	Characterisation, processing and management.	Algorithm design, modification and integration into UK equipment.	Implementation of algorithms.
3D target geolocation	Sensors, accuracy improvements and geolocation processes.	Algorithm design and the skills and knowledge to modify and integrate into UK equipment.	Implementation of algorithms.
Automatic target detection/recognition, and positive identification	Target and background modelling, simulation and processing. Sensor performance modelling. Imagery Classification and emitter identification.	Algorithm design, modification and integration into UK equipment.	Implementation of algorithms.
Battle damage prediction/ collateral damage estimation	Effects prediction, assessment and recording.	Algorithm design, modification and integration into UK equipment.	Implementation of algorithms.
Image exploitation and translation/cultural awareness	Processing and recognition technologies.	Algorithm design, modification and integration into UK equipment.	Implementation of algorithms.
Satellite communications	Robust, secure telemetry, tracking and control, dynamic bandwidth allocation and high bandwidth optical (laser) links.	Robust, secure telemetry, tracking and control.	Dynamic bandwidth allocation, high bandwidth optical (laser) links.
HF, VHF & UHF comms	Software defined radio, waveform design and integration, self-organising nets, IP over HF, cognitive radio.	Waveform design and integration.	Software defined radio, self organising nets, IP over HF, cognitive radio.
Broadband wireless networks	Interference suppression and interoperability.	None.	Interference suppression, interoperability.
Tactical data links	Size/weight/volume reduction, plus various process, capabilities and technologies.	None.	All.

Function	Priority Technologies	Technology Supply Route	
		Sovereign	Collaboration
Waveform design, spectrum and bandwidth management	Technologies and management, plus UK eyes only cryptographic techniques.	Ability to integrate certain techniques into capability. Implementation of UK eyes only cryptographic techniques.	Synchronisation schemes, coding schemes, modulation techniques, smart spectrum usage. Integration of information management with spectrum management.
Network information distribution layer and mobile / ad hoc / dynamic networks	High assurance internet protocol encryption (HAIZE), auto-configuring, self healing and scalability.	UK version of HAIZE.	UK/US collaboration on HAIZE specifications plus all others. Auto configuring, self healing and scalability for large numbers of users.
Operating Systems (OS)	Design and operation understanding OS, test facilities.	Design understanding and operation; test facilities.	To meet MOD's needs.
Cryptography	HAIZE, Secure Comms Internet Protocol, disk encryption, software and programme crypto, key management and chip design.	All.	International specifications.
Computer Network Defence	Intrusion detection systems and protection, sensors, analysis, reaction, denial of service prevention.	All.	None.
Secure Information Exchange Techniques	Critical technologies.	Message sanction and release techniques, digital signatures.	Guards, one-way diodes, labelling and tagging.
Identity management / access control	Critical technologies.	None.	Biometrics; RF ID, PKI credentials, smart cards.
Information presentation	Information extraction and presentation.	Tailoring of COTS.	Commodity items.
Knowledge stores and repositories	Information handling technologies, high speed IO.	Tailoring of COTS.	Information search, tagging and representation technologies.
End-to-end network, information and security management	Appreciation, various networks, data and security management technologies.	Methods of managing commercial and military networks, all security aspects.	Understanding the problem and interoperability.
Close Combat and Combat Support (Section B.4)			
Mounted Platform Systems	Battlespace Management Systems, key technologies, EMP/EMC, Survivability.	System design and integration.	
Soldiers Systems Platform Integration	Physical, electronic and human systems' architecture.	Design, integration, specification and assured access.	
Lethality	Various weapons systems and ammunition types.	Intelligent customer, integration, T&E.	

Function	Priority Technologies	Technology Supply Route	
		Sovereign	Collaboration
Mobility and Structures	Electric drive and other key elements, novel structures.	Intelligent customer, integration, T&E.	
Counter-mine, gap-crossing and counter-mobility systems	Systems, sensors and neutralisation.	Specification, prototype design, integration and T&E for gap crossing and counter mobility systems.	Specification, prototype design for sensors, intelligent customer status for neutralisation of mines.
CBRN (Section B.5)			
Hazard assessment & management, detection, identification, T&E	Broad range of characterization, sampling, detection, diagnostic and testing technologies.	Understanding of agents, rapid detection and identification technologies including “stand off”, decontamination technologies, exposure levels, development of algorithms.	Dispersal understanding, command and decision tool, access facilities, development of common standards for equipment.
Physical protection	Materials, physiology and filtration.	Design, development and understanding.	Limited areas where appropriate.
Medical counter-measures	Range of medical and clinical technologies.	Knowledge, access, application, design and development.	Limited areas where appropriate.
Counter Terrorism (Section B.6)			
Notwithstanding the sensitive nature of its CT programmes, MOD will seek earlier engagement with key List X suppliers including SMEs and academia to support these niche areas.			
Complex Weapons (Section B.7)			
Software	Key functionality.	Design, develop and understanding.	
NEC	Datalinks, comms, crypto and integration.	Understanding.	Share experience.
Propulsion, aerodynamics and airframes	Range and propulsion technologies.	Design, modelling, manufacture, integration and understanding.	Composite case technology and composite propellants.
Payload / effects	Conventional, DEW and non-lethal technologies.	Critical safety, integration, design and assessment.	
Survivability	Stealth and countermeasures.	Design, understanding and assessment.	Sub-system research, sensor hardware.
General Munitions And Energetic Technologies (Section B.8)			
Design and performance	Intelligent design, Integrated Modelling, effects and its modelling.	Integration, certification, understanding, design and test.	Open architecture designs, obsolescence, modelling.
Safety and ownership	Insensitive Munitions and Munitions safety, monitoring, disposal, T&E.	Understanding and ownership tools.	Various IM aspects, disposal, access to T&E facilities.

Function	Priority Technologies	Technology Supply Route	
		Sovereign	Collaboration
Pyrotechnic stores	IR and RF Countermeasures.	Design, development, assessment and manufacture capability for air platform expendable IR and RF decoys.	
Energetics & Energetic Materials	IM aspects, smart initiation, modelling, Material Characterisation, T&E.	Understanding, design, testing and development areas.	Underpinning S&T. Access to non-UK materials and components.
Fixed Wing, UAVs And Helicopters (Section B.9 and B.10)			
Low Observability	Various signature and its manufacturing technologies	Intelligent customer, integrated design development and cost effectiveness assessment.	
Propulsion, Aerodynamics, Structures and Control	Performance monitoring analysis, and technologies to support through life performance.	Intelligent customer status and technology watch.	Engine supportability.
UAV	Autonomy, prototyping, enterprise and economic models.	Airworthiness, design, development and assessment, T&E.	Approaches to regulations of UAV operations in controlled airspace.
Helicopters	Operational and capability assessment, design, airframes, rotor systems, vibration, noise and power management, survivability, sensors, mission systems	Design, develop, evaluate, integrate and understanding. Intelligent customer status.	
Maritime (Section B.11)			
Survivability	Submarines acoustic materials and structures, non acoustic signatures	Design, development, systems integration, testing, manufacture and through life capability management	Collaborate with US to maintain national expertise. Test facilities may be obtained overseas.
Combat systems	Torpedo defence, sonar	Threat analysis, design & development, test & evaluation, integration	Collaboration to be exploited where appropriate, e.g. maintaining intelligent customer status for sonar systems and facilitating interoperability.
Platform	Power, hydrodynamics, submarine atmosphere control	Intelligent customer, design, development, and in-service support for quiet submarine propulsions and atmospheric management technologies, duty of care	Test facilities, information exchange

1. The NDIC R&T subgroup is leading work to better understand innovation in the supply chain. In support of that work industrial partners have mapped technology trees for a wide range of military equipments. This annex is based on early findings from that work.
2. A technology tree is a hierarchical diagram which breaks an equipment down into its contributory elements, starting at systems level and working down through sub-systems to underlying technologies. For this exercise, suppliers were identified at each level in each tree. Information was also gathered on the nature or role of the supplier (large company, SME, RTO¹, or University), their geographical location (UK, US, EU, etc) and on the extent to which the product supplied was innovative through a simple classification (COTS, MOTS, bespoke, ongoing development, or innovative).
3. A total of 36 technology trees were produced which, although not constituting a comprehensive dataset in all areas of capability, provide some useful insights about the supply chain and the contributions different players make. However, whilst technology trees give a snapshot of the supply chain for the end product, they tell us little about the process or mechanisms of innovation *per se*. For the purposes of this document and to improve readability and clarity the completed trees have been edited to highlight the innovative elements and simplified to round up those 'branches' without specific innovative elements.
4. To understand how innovation happens we need to know how the technologies were developed for a given equipment; this requires a case history to supplement the information in the tree. Such accompanying narratives were also collected where possible.

The Role of SMEs in Innovation In Defence

5. SMEs typically are niche suppliers of particular materials, products or services, which lie outside the span of the major prime contractors. A major source of SME involvement in innovation is in the form of "spin-off" ventures, either from the University sector – where they provide a knowledge transfer mechanism from academia to industry – or from major companies – where individuals set up on their own to take forward an idea.
6. In some equipment sectors, however, SMEs enjoy a greater degree of success. Where there are immediate capability gaps and operational requirements lying outside the mainstream activities of the major Defence contractors, and where the scale of procurement is more limited, SMEs are very much to the fore – notably in the CBRN and Counter-Terrorism spheres of activity. An important characteristic of the latter sector in particular is a greater emphasis on short-term procurement (against Urgent Operational Requirements, for example). This is an area where the flexibility and responsiveness of SMEs comes into its own – they can play to their strengths
7. The technology tree for the 2193 Mine Hunting Sonar illustrates the role of SMEs and Universities in innovation for small-scale equipments. All of the SMEs involved were niche suppliers of specialised sonar technology elements. In other trees involvement is more limited but still of value.

2193 Mine Hunting Sonar Technology Tree

Brought into service in 2005, 2193 is high-frequency active sonar manufactured by Thales and installed on Hunt class mine countermeasures vessel. It is a highly innovative design and can detect mines with small acoustic signatures at depth. The technology tree reveals the involvement of four niche SME suppliers of specialised sonar technology elements, and two universities under a programmes led by DERA (now QinetiQ) Winfrith.

Development was driven by DERA working with the Universities and SMEs in question. Although innovative in a number of respects, the most ground-breaking innovation was the invention and use of 1-3 composites in the sensor (hydrophone). These materials were developed by Strathclyde University and are comprised of piezoelectric ceramic pillars embedded in a polymer matrix, giving the hydrophone a unique wideband response and sensitivity. The SME materials supplier is a spin-off venture from Strathclyde University, including a member of the original academic research team as a key player.

¹ Research & Technology Organisation

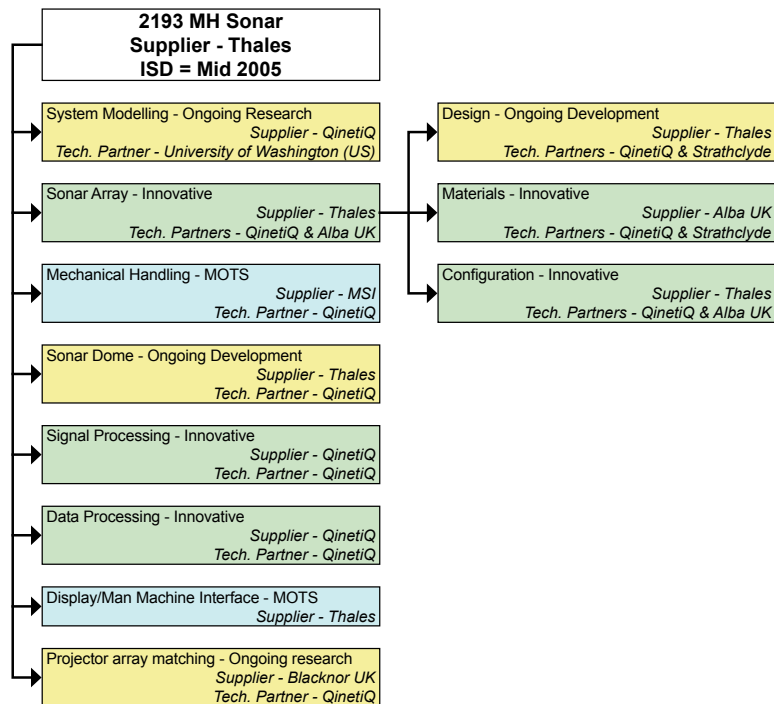


Fig 1. Sonar 2193 Technology Tree

The Role Of Academia In Innovation In Defence

8. All innovation begins with creative ideas², and there is no shortage of knowledge or of the skills of invention in the United Kingdom. A recent HM Treasury study attests to the fact that the UK has a world-class science and engineering academic infrastructure; we remain second only to the US in global scientific excellence, as measured by citations³.

9. The HM Treasury Lambert Review on business and university collaboration established that a new trend is reshaping the way companies undertake research and development⁵. It identified that companies are moving away from a closed approach to innovation in which most of their research and development is controlled and done in-house, to one in which they are actively seeking to collaborate with others.

10. The view from academia is that progress has been made since the Lambert Review; however more can be done to improve the transfer of knowledge and technology between universities and businesses. It seems that the best technology transfer has come through exchanges of staff, particularly through the secondment of industry personnel to universities. The contacts and industrial perspective that these industrialists bring can be invaluable.

11. Technology trees can give some indication of the role of academia, however, the principle conclusion is that the extent of University involvement in particular is under-represented in the current set of trees, because their involvement is only exposed at the very extremities

of 'complete' trees, or in associated narratives; whereas, many of the trees do not extend this far down the supply chain hierarchy.

12. A distinction must be made between equipment procurement-led involvement of the Universities, as described above, and their involvement in longer-term research through the MOD Research Programme, Defence Technology Centres, and Towers of Excellence. In those cases, the linkage to the equipment supply chain is more tenuous, as the Universities are not undertaking research aimed at supporting a specific requirement; but emerging technologies are expected to find their expression in future (as yet unspecified) military capabilities.

13. The following technology tree, produced by Selex Sensors and Airborne Systems Ltd, highlights the inherent role that academia plays when we investigate the underpinning science and research programmes that support generic capability areas.

The Role Of Larger Industry and RTOs In Innovation In Defence

14. The first main conclusion which can be drawn from this work is that innovation in major military procurements is both customer driven in the form of military capability pull or requirements-led and opportunity driven where advances in science and engineering provide new solutions. Except where there are very substantial export or other wider (dual use) market opportunities, industry tends not to invest in the development of new military equipments. In common with a wide range of complex products and systems

² Luecke and Katz (2003), *Managing Creativity and Innovation*, Harvard Business School Press, pp1154-1155

³ HM Treasury, *Science and Innovation Investment Framework 2004-2014: Next Steps*, 2006

⁵ HM Treasury, *The Lambert Review of Business-University Collaboration*, 2003

(CoPS)⁴, military equipments tend to be technologically complex, produced in small batches, on a project-managed basis, with continuing innovation through life and with substantial customer involvement. This is in sharp contrast to classical market-led innovation, where entrepreneurs look to produce relatively straightforward,

novel products in large numbers to sell to a mass consumer market, with no customer involvement in their development. In military procurement, most equipments are not purchased in sufficiently large numbers to be mass-produced, and Government is the customer, meaning that product development cannot sensibly

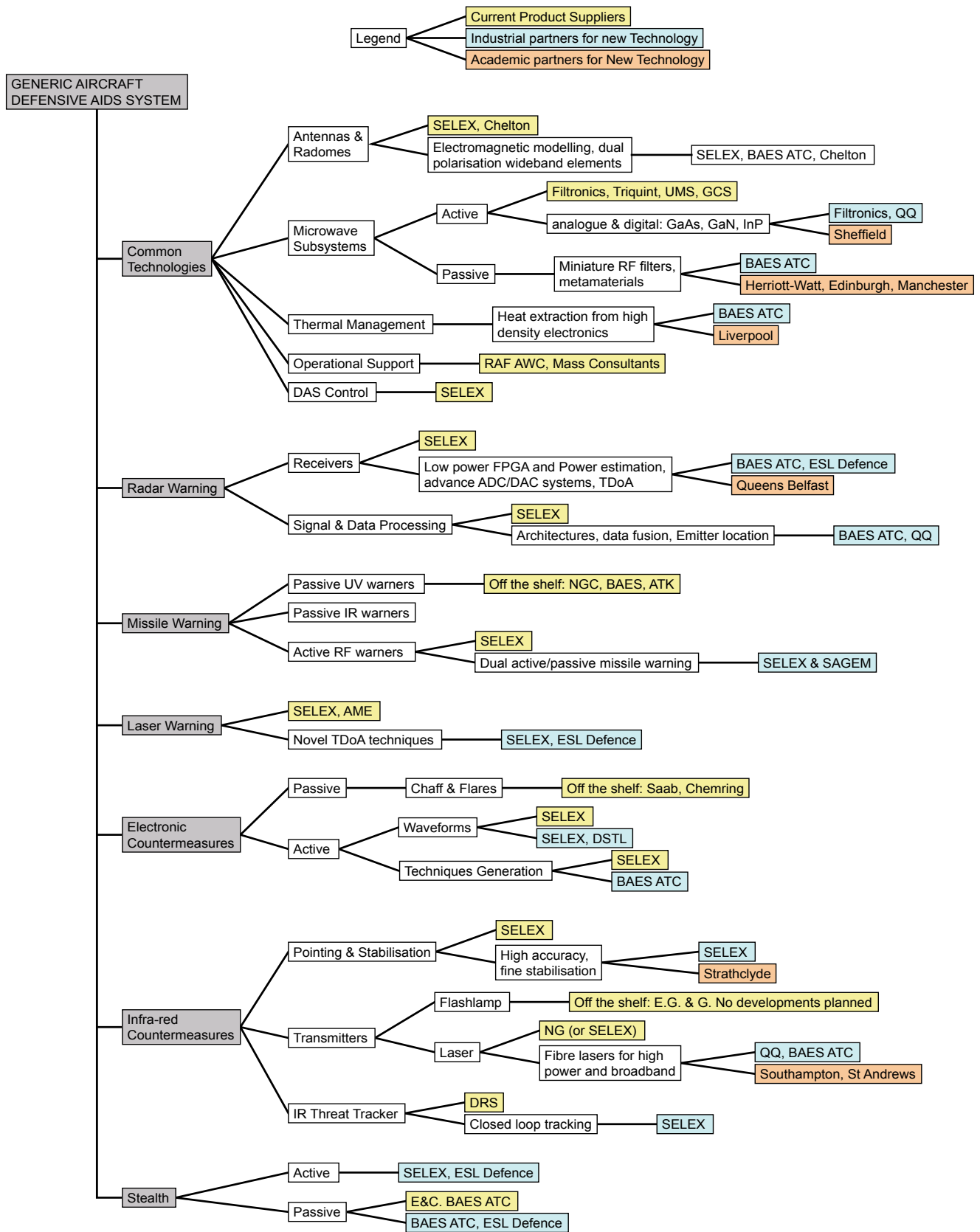


Figure 2. Generic Aircraft Defensive Aids Technology Tree

⁴ Hobday, M, "Product Complexity Innovation and Industrial Organisation", Research Policy 26 (1998), pp 689-710

be taken forward in isolation from the customer. The requirement is therefore all-important.

15. Whilst operational need is the dominant factor in defence procurement, military customer requirements are in no small part technology-driven, precisely because of the need to maintain a technological lead over other nations. The emergence of new technologies presents opportunities ranging from incremental improvements in capability, to fundamental (disruptive) changes in the nature of future warfare, as well as generating new

threats from potential adversaries. The translation of technology opportunities and threats, through concepts, into requirements, is an essential customer-driven step in the innovation process. The requirement is the key driver for taking technology from laboratory proof-of-concept through to mature equipment for manufacture. Equally important is customer commitment to progress delivery of technology (working with industrial partners) against such requirements. Crucially, these two elements together enable the 'valley of death' between laboratory proof-of-concept and manufacture to be bridged.



Challenger 2 battle tank on exercise in Oman

Challenger II Main Battle Tank Technology Tree

Challenger I was acquired as a product by Vickers (now BAE Systems) in the 1980s from Royal Ordnance and had recognised shortcomings. Vickers saw an opportunity to improve it, mainly by substituting a modern private venture turret. Other improvements included fitting a gun with independently stabilised directional sights and an improved transmission. Challenger II was then offered in competition against the US M1A2, German Leopard, and French Leclerc tanks. In contrast, the contractor's proposal to introduce a new engine management system based on a MOTS solution used in helicopters was rejected in favour of the existing MOD-sponsored design. Challenger II offered several other innovations, notably new armour which had been incrementally developed by DERA (now DSTL) to meet the long rod kinetic penetrator threat. The TO Gunnery Sight, although bought as a military off-the-shelf (MOTS) equipment, utilised the TICM II (Thermal Imaging Common Module) which emerged from a QinetiQ Malvern research programme, with the involvement of universities and SMEs.

Challenger II's novel hydro-pneumatic suspension system, which enabled it to travel at higher off-road speeds than most of its competitors, was developed under contract placed by MVEE (now QinetiQ) with an SME (now Horstman). It was a long-standing MOD research programme to improve the design of the tank, spanning a range of research disciplines. Substantial impetus was given by the sponsorship of an export customer and the technology moved very quickly.

This programme was also the first armoured vehicle to use a data bus, resulting from QinetiQ research on vehtronics and crew systems. Crucially, this allowed BAE Systems to select component sub-systems from different suppliers.

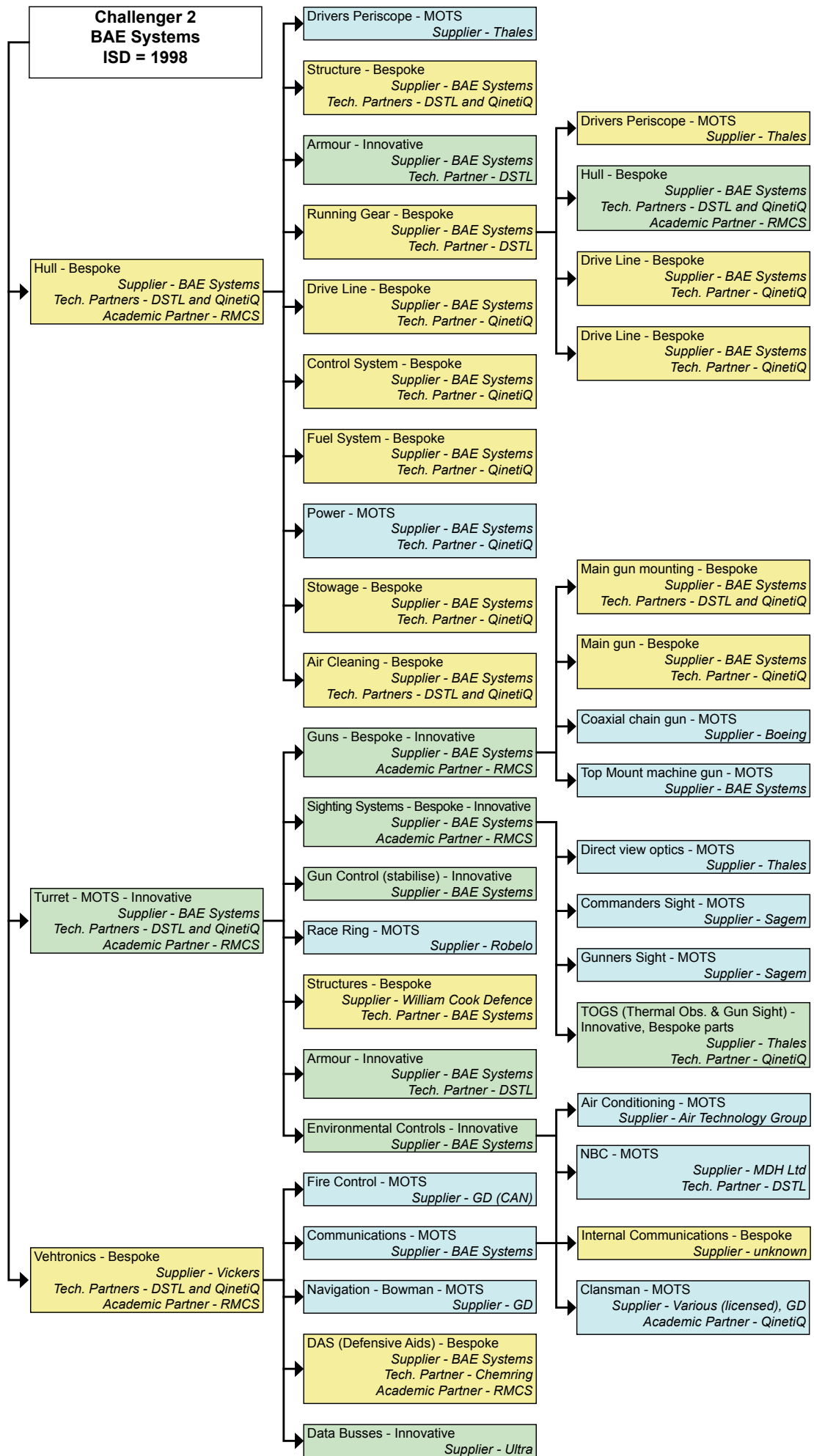


Fig 3. Challenger II Technology Tree

16. Research and Technology Organisations (RTOs) may span the whole range of activities from applied research to development of technology demonstrators or even production (in some cases) of high-technology equipments. They can take the role of academic partners or new technology partners. Examples range from QinetiQ and Roke Manor in industry, to the in-house provider Dstl in MOD. However, the distinction is somewhat artificial, as the major Prime contractors have

their own in-house capabilities who provide the same service (e.g. research arms of BAES for Industry), albeit in a relatively limited number of R&T areas as appropriate.

17. Looking at the Technology Trees, we see clear evidence of RTO involvement, and the RTOs are well-represented, as they are typically involved in activities slightly further up the the supply chain hierarchy than the University sector.

Airborne Stand-Off Radar (ASTOR) Technology Tree

ASTOR, which entered service in 2005, is a high-resolution synthetic aperture radar and ground moving target identification radar mounted on a militarised civil aircraft. ASTOR images the battlefield and tracks targets in all-weather conditions, day or night, over a large area. It gives early realisation of some NEC principles through its ability to share data with other reconnaissance assets (RAPTOR and JSTARS). Examination of the ASTOR tree shows that it is supplied by a US prime contractor and not surprisingly, therefore, most of its component systems are US-sourced, giving the impression that ASTOR owes its cutting edge to innovative US technologies.

However the US prime won the competition to manufacture ASTOR working to a UK requirement which drove the prime to adopt innovative design principles. Although the extent of their contribution is not obvious from the technology tree, DERA (now QinetiQ) drove much of the innovation in their role as the research and technology partner, including the dual-mode radar and dual signal processing, the active array of transmit and receive modules, and the motion compensation algorithms (which were produced in Malvern). QinetiQ's contribution was the result of long term research, the CASTOR programme, which in part shadowed similar US research (U2 ASARS, JSTARS) and expertise provided by its long-standing centre of excellence for radar technologies.

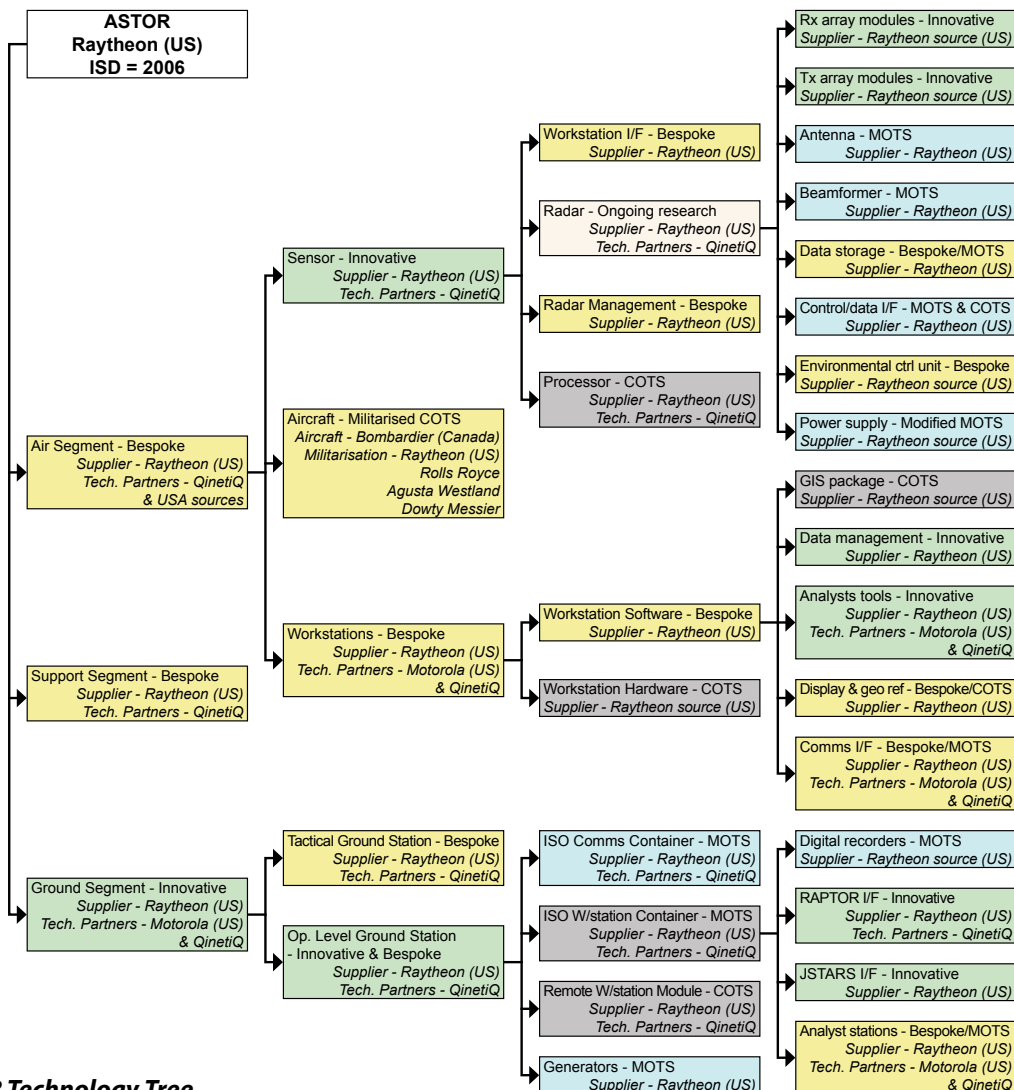


Fig 4. ASTOR Technology Tree

18. The second main conclusion is that world class military equipments currently in service owe much of their success to innovative science or technology which is the result of carefully targeted, long-term military investment in R&D. This represents a realisation of the importance of 'technology-push'. This underlines the need for long-term commitment to selective MOD funding of R&D.

19. Implicit in the above discussion is the existence of a technology 'conveyor belt' that progresses technology through the full range of TRLs from blue-skies research through to equipment manufacture. Historically, that conveyor belt was fed by the MOD's Research Establishments (REs), with industry becoming involved through competition at the technology demonstrator and manufacture phases. Some of the Technology Trees for world-class equipments currently in-service are testimony to the success of that process. With the privatisation of the REs, future increased outsourcing of Defence R&D to a wider market, and the advent of SMART procurement – all of which are positive developments – there is a need to examine how the 'conveyor belt' now operates, how effective it is, and how it can be strengthened to speed up technology pull-through, to tauten delivery against customer needs, and to assure the coupling mechanisms into SMART procurement processes.

20. However, innovation in military equipments not only contributes to battle-winning edge by giving a technological advantage over opponents, it also gives UK Defence industries a competitive edge in the export market. In the absence of a specific military requirement industry may be reluctant to invest in the development of new military technology. However, it is quick to seize the opportunity to capitalise on its investment when it has successfully developed a new equipment in response to a requirement. So the generation of stretching new requirements, fuelled by emerging technologies and successful demonstrators, eventually leads to competitive products. Military funding of targeted long-term research therefore ultimately drives the generation of world class, competitive exports, which in turn sustain the industrial supply base.

21. From a Departmental perspective, selective investment in targeted long-term research fuels the technology 'conveyor belt', which drives innovative requirements and shapes future equipment solutions. If the conveyor belt is decoupled from procurement processes, then not only does this threaten the viability and long-term survival of the UK Defence Industry, but it also puts the MOD in a position of declining technological influence over future equipments and concepts, and renders any prospect of retaining appropriate, adequate sovereignty of supply increasingly unrealistic.

Glossary

AAM	Air-to-Air Missiles	CT	Counter Terrorism
A&SCS	Avionics and Safety Critical Software	CTSTC	Counter Terrorism Science and Technology Centre
AeIGT	Aerospace Innovation and Growth Team	CW	Complex Weapons
ACARE	Advisory Council for Aerospace Research in Europe	CWG	Capability Working Group
A-D	Analogue to Digital	CWID	Coalition Warrior Interoperability Demonstration
AESA	Active Electronically Scanned Array	CWIT	Complex Weapons Implementation Team
AFV	Armoured Fighting Vehicle	D&D	Denial and Deception
AI	Artificial Intelligence	DA	design authority
ALARP	As Low As Reasonably Practicable	DARA	Defence Aviation Repair Agency
ALM	Air and Littoral Manoeuvre	DARPA	Defense Advanced Research Projects Agency
AMSAR	Airborne Multi-mode Solid-state Active-array Radar	DAS	Defensive Aid System
ARTS	Advanced Radar Targeting System	DCDC	Development, Concepts and Doctrine Centre
ASICs	Application Specific Integrated Circuits	DCL	Detection, Classification, Localisation
ASTRID	Ammunition System Two Revision and Interactive Development	DCPD	Direct-Collect-Process-Disseminate
ASW	Anti-Submarine Warfare	DCTA	Defense Clothing and Textiles Agency
ATR	Automatic Target Recognition	DEC	Director Equipment Capability
ATSG	Aerospace Technology Steering Group	DEFCON	Defence Conditions
BABT	Behind Armour Blunt Trauma	DEFRA	Department for Environment, Food and Rural Affairs
BCS	British Computer Society	DEW	Directed Energy Weapon
BDA	Battle Damage Assessment	DIF	Data Information Fusion
BDI	Battle Damage Information	DIF DTC	Data & Information Fusion DTC
BIL	Burst Illumination Laser Imaging	DIRCM	Directed Infra Red Counter Measures
Bol	Balance of Investment	DIS	Defence Industrial Strategy, Defence White Paper, Dec 2005
BVR	Beyond Visual Range	DLO	Defence Logistics Organisation
BW	Biological Warfare	DLOD	Defence Line of Development
C2	Command and Control	DNAE	Day/Night/All Environment
C4ISTAR	Command, Control, Communication, Computers, Intelligence, Surveillance Target Acquisition and Reconnaissance	DoD	Department of Defense
C-DIRCM	Compact Directed Infra Red Counter Measures	DPA	Defence Procurement Agency
CAD	Computer Aided Design	DRFM	Digital Radio Frequency Memories
CB	Chemical Biological	DSAC	Defence Scientific Advisory Council
CBM	Command and Battlespace Management	DSP	Digital Signal Processing
CBRN	Chemical Biological Radioactive Nuclear	Dstl	Defence Science and Technology Laboratory
CCII	Command, Control and Information Infrastructure	DTC	Defence Technology Centre
CCIRM	Collection Coordination and Information Requirements Management	DTI	Department of Trade and Industry
CCM	Counter-Countermeasures	DTS	Defence Technology Strategy
CESSG	Communications and Electronic Security Group	DU	Depleted Uranium
CFD	Computational Fluid Dynamics	DVI	Direct Voice Interaction
CGDA	Common Geographic Database Architecture	EA	Electronic Attack
CIS	Communications and Information Systems	ED	Electronic Defence
CM(IS)	Capability Manager (Information Superiority)	EDA	European Defence Agency
CMT	Cadmium Mercury Telluride	eHALE	electric High Altitude Long Endurance
Conops	Concept of Operations	EI	Environmental Information
COTS	Commercial Off The Shelf	ELINT	Electronic Intelligence
CR	Cognitive Radio	ELS	Expeditionary Logistics and Support
CSA	Chief Scientific Adviser	EM	Electromagnetic
CSEP	Certified Systems Engineering Professional	EMC	Electro-Magnetic Compatibility
CSP	Capability Sustainment Programme	EMCDB	Elastomer Cast Double Base Propellants
		EMRS	Electro Magnetic Remote Sensing
		EO	Electro-optic
		EO	Earth Observation
		EOB	Electronic Order of Battle

EOCM	Electro-optic Countermeasures	ICA	Independent Component Analysis
EOD	Explosive Ordnance Disposal	ICS	Intelligent Customer Status
EOPM	Electro-Optic Protective Measures	ICT	Information and Communications Technology
EP	Equipment Plan	ID	Identification
EPSRC	Engineering and Physical Sciences Research Council	IDM	Improved Data Modem
ERA	Explosive Reactive Armour	IED	Improvised Explosive Device
ES	Electronic Surveillance	IEE	Institution of Electrical Engineers
ES	Electronic Systems	IER	Information Exchange Requirements
ES	Electronic Support	ILS	Integrated Logistics Support
ESM	Electronic Support Measures	IM	Insensitive Munitions
ESAU	Electronic Safety and Arming Units	IMSSA	Integrated Modelling and Simulation Support for Acquisition
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites	IMU	Inertial Measurement Unit
EUT	Emerging and Underpinning Technologies	InAs	Indium Arsenide
EW	Electronic Warfare	INCOSE	International Council of Systems Engineering
FCO	Foreign and Commonwealth Office	InSb	Indium Antimonide
FCS	Fire Control System	IO	Information Operations
FDOA	Frequency Difference of Arrival	IO	Input Output
FIST	Future Infantry Soldier Technology	IP	Intellectual Property
FMCMC	Future Mine Counter Measure Capability	IP	Internet Protocol
FPA	Framework Partnering Agreement	IPR	Intellectual Property Rights
FPE	Force Protection Engineering	IPT	Integrated Project Team
FPGA	Field Programmable Gate Array	IR	Infra-red
FRES	Future Rapid Effect System	IRC	International Research Collaboration
FSA	Food Standards Agency	IRC	Interdisciplinary Research Centre
FSP	Future Submarine Programme	IRST	Infra Red Search and Target
FW	Firmware	ISD	In-Service Date
FW	Fixed Wing	ISEE	Integrated Sensor Evaluation Environment
FWD	Flightworthy Demonstrator	ISMS	Integrated Sensor Management System
GaAs	Galium Arsenide	ISP	Intelligent Signal Processing
GaN	Galium Nitride	ISR	Intelligence, Surveillance, Reconnaissance
GM	Ground Manoeuvre	ISTAR	Intelligence, Surveillance Target Acquisition and Reconnaissance
GMLRS	Guided Multi Launch Rocket System	IT	Information Technology
GMTI	Ground Moving Target Indication	ITP	International Technology Partnership
GPS	Global Positioning System	JCA	Joint Combat Aircraft
GSR	General Service Respirator	JIMSG	Joint Insensitive Munitions Strategy Group
HAIBE	High Assurance Internet Protocol Encryption	JSF	Joint Strike Fighter
HAIPIS	High Assurance Internet Protocol Interoperability Specification	KE	Kinetic Energy
HALE	High Altitude Long Endurance	KUR	Key User Requirement
HCI	Human Computer Interaction	LAASS	Low Altitude Airborne Sensor System
HF	High Frequency	LCAD	Lightweight Chemical Agent Detector
HFI	Human Factors Integration	LED	Light Emitting Diode
HFNAC	Human Factors National Advisory Committee	LEFIS	Link Encryptor Family Interoperability Specification
HI&SCS	High integrity and safety critical software	LFE	Link Encryption Facility
HIFAWS	High Field Asymmetric Wave Spectroscopy	LIDAR	Light Detection and Ranging
HMD	Helmet Mounted Displays	LO	Low Observable
HMI	Human-Machine Interface	LOVA	Low Vulnerability Ammunition
HO	Home Office	LPD	Landing Platform Dock
HOT	High Operating Temperature	LPI	Low Probability of Intercept
HOTAS	Hands on Throttle and Stick	LTPA	Long Term Partnering Agreement
HQ	Headquarters	M&S	Modelling and Simulation
HS	Human Sciences	MASS	Munition Acquisition Supply Solution
HSW	High Speed Weapon	MAV	Micro Air Vehicles
HUD	Head-up Display	MAW	Missile Approach Warners
HumInt	Human Intelligence	MCM	Mine Counter Measures
HUMS	Health Usage and Monitoring System	MEDL	Munition Environmental Data Loggers
HW	Hardware	MEMS	Micro-Electro-Mechanical Systems
HWIL	Hardware in the Loop	MFA	Multi-function Apertures
IAWG	Industrial Avionics Working Group	MIDAS	Military Integrated Defensive Aid System

MIMO	Multiple-Input Multiple-Output	S2C2	Sustainable Surface Combatant Capability
MIS	Maritime Industrial Strategy	S&T	Science and Technology
MLU	Mid-Life Update	SA	Situational Awareness
MMS	Mission Management System	SAA	Small Arms Ammunition
MMW	Millimetric Wave	SAC	Submarine Atmosphere Control
MOD	Ministry of Defence	SAL	Semi-Active Laser
MODAF	Ministry of Defence Architecture Framework	SAM	Surface-to-Air Missile
MOTS	Military Off the Shelf	SAR	Synthetic Aperture Radar
MSR	Major Supply Route	SAR	Search and Rescue
MTBF	Mean Time Between Failure	SAU	Safety and Arming Unit
MTS	Maritime Technology Strategy	SCIP	Secure Communication and Interoperability Protocol
MW	Mid-ware	SCS	Safety Critical Software
NAC	National Advisory Committee	SDR	Strategic Defence Review
NATO	North Atlantic Treaty Organisation	SE	Systems Engineering
NAVWAR	Navigation Warfare Programme	SE	Synthetic Environment
NBC	Nuclear Biological Chemical	SEAD	Suppression of Enemy Air Defences
NBC BISA	Nuclear, Biological and Chemical Battlefield Information System Application	SEAS	Systems Engineering for Autonomous Systems
NDE	Non-Destructive Evaluation	SF	Special Forces
NDEC	National Defence Energetics Community	SG	Support Group
NDIC	National Defence Industries Council	ShyFE	Sustained Hypersonic Flight Experiment
NEC	Network Enabled Capability	SIAP	Single Integrated Air Picture
NELS	Networked Emitter Location System	SiGe	Silicon Germanium
NGOSS	New Generation Operations Support System	SIL	Systems Integration Laboratory
NITeworks	Network Integration Test and Experimentation works	SIT	Science Innovation Technology
NLW	Non-Lethal Warfare	SME	Small and Medium-sized Enterprise
NQR	Nuclear Quadrupole Resonance	SP	Special Projects
NSRP	Nuclear Steam Raising Plant	SSEI	Software System Engineering Initiative
NVG	Night Vision Goggles	STP	Short Term Plan
OA	Open Architectures	SSK	Conventional Submarine
OA	Operational Analysis	SVD	Singular Value Decomposition
ODPM	Office of the Deputy Prime Minister	SW	Software
OEM	Original Equipment Manufacturer	SWAP	Size, Weight and Power
OEU	Operational Evaluation Unit	SWOT	Strengths, Weaknesses, Opportunities and Threats
OGD	Other Government Department	T&E	Tested and Evaluated / Test and Evaluation
OS	Operating Systems	TDL	Tactical Data Link
OSI	Office of Science and Innovation	TDOA	Time Difference of Arrival
OTS	Off The Shelf	TDP	Technology Demonstrator Programme
PBX	Polymer Bond Explosives	TEEMAC	Terminal Effects and Energetic Materials Advisory Committee
PCR	Passive Covert Radar	TI	Thermal Imaging
PKI	Public Key Infrastructure	TICM	Thermal Imager Common Module
PSDB	Police Scientific Development Branch	TLB	Top-Level Budget
PV	Private Venture	TLCM	Through-Life Capability Management
R&D	Research and Development	TLM	Through-Life Management
R&T	Research and Technology	ToE	Tower of Excellence
RAEng	Royal Academy of Engineering	TRDs	Towed radar decoys
RAF	Royal Air Force	TR Module	Transmit - Receive Module
RAM	Radar Absorbent Materials	TRaME	Tactical Radiation Monitoring Equipment
RAO	Research Acquisition Organisation	TRL	Technology Readiness Level
RCS	Radar Cross Section	TST	Time Sensitive Targeting
RCV	Remote Controlled Vehicle	TTP	Tactics, Techniques and Procedures
RF	Radio frequency	UAS	Unmanned Air System
RFI	Request for Information	UAV	Unmanned Air Vehicle
RFID	Radio Frequency Identification	UCAS	Unmanned Combat Air System
RN	Royal Navy	UCAV	Unmanned Combat Air Vehicle
RoE	Rules of Engagement	UHF	Ultra High Frequency
RoW	Rest of the World	UMV	Unmanned Maritime Vehicle
RPG	Rocket Propelled Grenade	UOR	Urgent Operational Requirement
RSS	Really Simple Syndication	UPC	Unit Purchase Cost
RTO	Research and Technology Organisations	URD	User Requirement Document
RWR	Radar Warning Receiver		

UUUV	Unmanned Underwater Vehicle
UV	Ultra Violet
UW	Underwater
UXV	Unmanned Vehicles (Air, Above Water, Under Water or Land)
VFM	Value for Money
VHF	Very High Frequency
WLC	Whole Life Cost
WMD	Weapons of Mass Destruction

