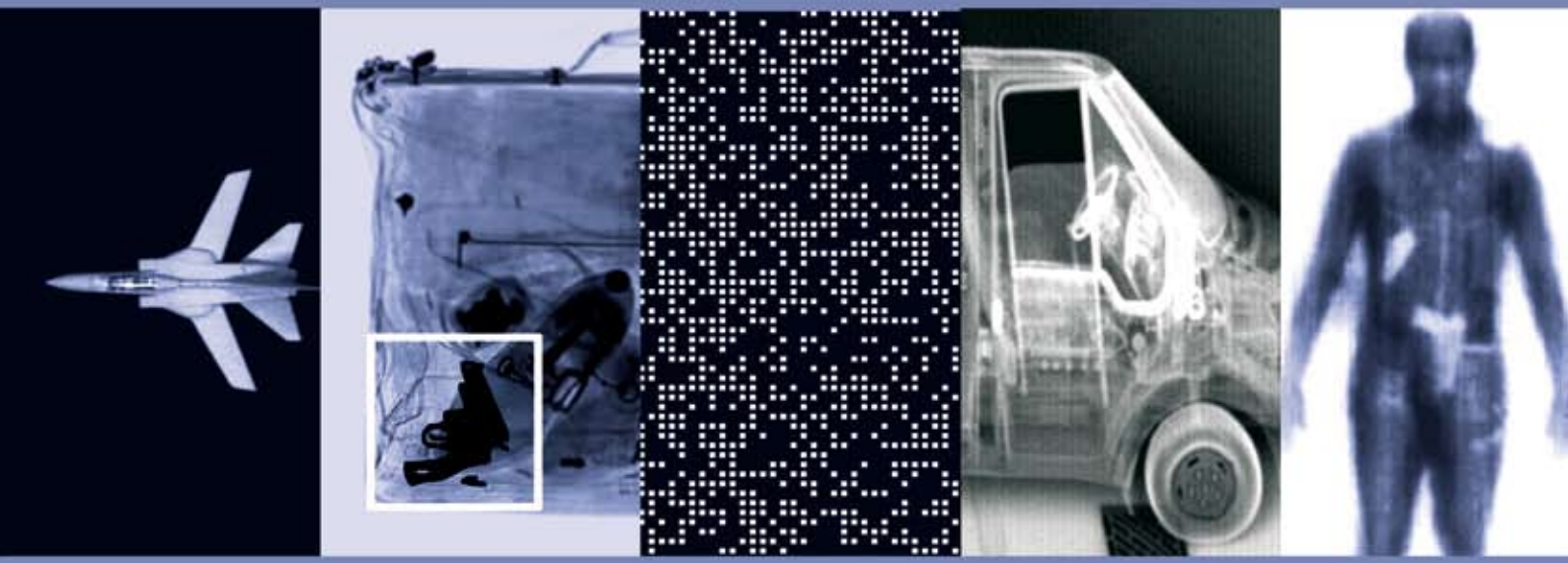
Maximising Benefit from Defence Research

A review of defence research and technology for alignment, quality and exploitation



MINISTRY OF DEFENCE

science | innovation | technology

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 SEP 2006	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Maximising Benefit from Defence Research: A review of defence research and technology for alignment, quality and exploitation	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Ministry of Defence London, United Kingdom**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**40**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Front Cover: Images of pattern and target identification, recognition and tracking,
courtesy of QinetiQ Photonic Structures and Processing, mm-wave and Centre for Human Sciences Groups. © QinetiQ & Dstl

Maximising Benefit from Defence Research

Contents

Foreword

by Lord Drayson, Under Secretary of State and Minister for Defence Procurement

The Defence Industrial Strategy[1] emphasised the need to ensure our research is aligned to capability needs, that it is of the necessary quality, properly exploited and that we get best value for money from our investment. We announced in the Strategy that we had set in place an evidence-based peer review of research alignment, quality and exploitation, not as a one-off exercise, but to set a benchmark for future biennial reviews of our research programme. This report sets out the results of the review.

Through the use of external peer reviewers to assess the quality of our research, we ensured the study was as independent and objective as possible. The resulting assessment of our research programme is therefore particularly welcome for its assurance that the vast majority of the work we commission is relevant to defence needs and of high quality. This does not mean we can be complacent. Inevitably, there are things we can do better and the study has made a number of useful suggestions for how we can improve yet further on our current performance. We will attend to these as rapidly as possible.

Most importantly, we have now established a proven methodology we can use in future reviews of the research programme and a benchmark against which we can regularly measure our performance in this vital area of defence activity. This will help ensure we continue to provide our world-class Armed Forces with the leading edge capabilities they need.

1 Defence Industrial Strategy Cm 6697 Dec 2005

Introduction

by Professor Sir Roy Anderson FRS, Chief Scientific Adviser

We live in an era of rapid and accelerating progress in science and technology. The pace is such that most industrialised nations struggle just to keep track of recent developments of high relevance to defence, let alone maintain world-class leads in all the key technologies vital for the protection of national security and sovereignty. Although innovation in defence-related research often creates the template for further development by other industrial sectors, the pace of change in technology is increasingly driven by markets in the civil sector. These developments can often be doubled-edged, as in some biomedical fields, where advances that benefit health may often lead to insights that can, in the wrong hands, create new threats.

Our country has a long-established history of ingenuity and innovation in defence science. Examples include the development of radar in the 1930's, our capability in Electronic Warfare, Thermal Imagers and Liquid Crystal Displays in the 60's and 70's, through to more recent developments in sonar, sensors of a wide variety of types, and the production of vaccines and therapies to protect against biological and chemical threats. My task as Chief Scientific Adviser is to ensure this distinguished record of originality and inventiveness continues. This presents a considerable challenge given that the range of technologies we need to cover is ever increasing.

I believe the UK is well placed to meet this challenge. Our ability to punch significantly above our weight (when assessed per head of population and per pound spent on research and development) in terms of scientific impact as measured by publication citations and prizes[2], provides an excellent resource for both Government and UK industries. The science and engineering strengths of our universities underpins this excellent performance.

In order to maintain, and indeed build on, MOD's past research successes we needed to establish a quantitative baseline of the quality of our current research and its relevance to our present defence and security needs. To this end, we established an evidence-based peer review of research alignment, quality and exploitation, not as a one-off exercise, but to set a benchmark for regular biennial reviews of our research programme. In particular, we wish to make external peer review an integral part of how the Department both commissions research and evaluates its output. Indeed, I hope that this objective and impartial study, and the methods of assessment we have developed, may come to be seen as best practice across Government.

The report draws some clear conclusions about research prioritisation, our current balance of investment, and the scope to improve exploitation of our research. In particular, it emphasises the importance of exploitation of successful research, which is a key goal of the research programme. The report's major conclusion based on the process of external peer review is that our commissioning of research to meet our needs is well founded and that, when benchmarked with work funded elsewhere, the vast majority of MOD's research is of high quality and in some areas it is world-leading.

2 D A King, The Scientific Impact of Nations Nature 430 (2004) 311-316 (15 July 2004)

Executive Summary

"To be a world class source of S&T advice and technology to underpin UK Defence and Security [3] "

1. MOD's Chief Scientific Adviser commissioned a study into the relevance, quality and exploitation of the non-nuclear research programme to establish how effectively it currently meets the Department's needs. The study was also to set a benchmark for future regular reviews of the programme to ensure quality, value for money and effective follow up of research output.

2. This was an objective, robust and impartial review based on a comprehensive, evidence-based analysis that generated new data and fresh perspectives on the research programme. This ground-breaking study has enabled conclusions to be drawn on the extent to which the programme satisfies customers' needs and the quality of the research, and has identified areas for further improvement.

3. The study demonstrated that the majority of the current research programme is satisfactorily aligned to MOD's strategic requirements.

4. Alignment would be further improved through the provision of a more comprehensive set of clearly articulated research needs; this could be met through improved coverage in high level Departmental strategies, with a clearer audit trail between them. This will be achieved in part through the work presently in hand to update the MOD Technology Strategy, as announced in the Defence Industrial Strategy [4]. Alignment will also be enhanced by greater collaboration with industry to promote the goals of the Defence Industrial Strategy.

5. New data generated by the study shows that there are marked differences in the extent to which research priorities set out in high level Departmental strategies are presently resourced; this data will provide a basis to review the overall balance of investment across the research programme.

6. External peer reviewers engaged for the study found the majority of the research projects they reviewed to be high quality. They judged 22% of projects to be world-leading and providing the UK with a competitive edge internationally. These were a mix of successful "high-risk high-reward" projects, truly innovative research, and collaborative projects. Just under half the sample was deemed good quality research that would have merited publication in a top-tier research journal.

7. Having demonstrated through this study that extensive external peer review of MOD research is practicable, the Department will set in hand arrangements for future regular external peer review of all research projects both at formation and on completion. The Study Team also suggested that research quality would be enhanced through greater use of external benchmarking, e.g. via peer reviewed publication of research results where possible. This will be encouraged.

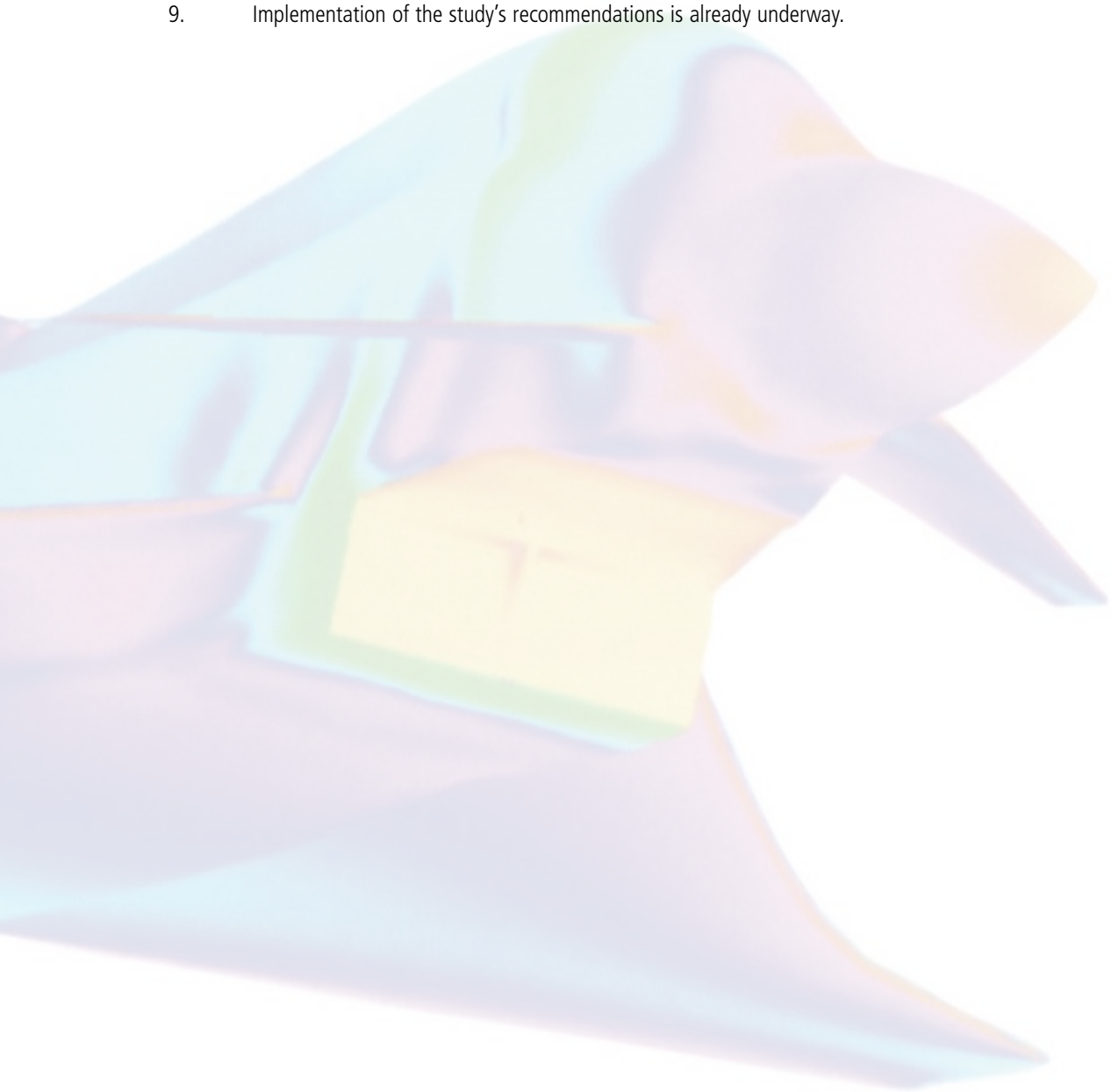
---

3 Mission statement of MOD's Science Innovation and Technology Top Level Budget

4 Defence Industrial Strategy Cm 6697 Dec 2005

8. The Study Team found that exploitation [5] of MOD research is acceptable, but that there is room for improvement in a number of areas. The Team found evidence of increasingly widespread use of exploitation planning for current research, but that this is still of variable quality and plans need more effective execution. The Team made a number of recommendations to improve exploitation in future; these include the development of the existing Capability Working Group concept and the establishment of similar "Research Working Groups" for more basic research. Such groups would act as owners of exploitation, involve known or likely end-users to improve visibility of the research programme, and undertake regular reviews of exploitation as a project progresses.

9. Implementation of the study's recommendations is already underway.



5 For the purposes of this study, exploitation of research was interpreted broadly as timely advice to decision-makers or wider exploitation into the civil sector, not just exploitation of technology directly into equipment

Study Context

"Technological superiority is a key driver of military capability and success. It is crucial to achieving the speed, accuracy and precision that we demand from our operations. [6] "

1.1 The UK's defence capability depends on a robust and vibrant research programme that delivers crucial scientific and technological advantage as well as essential advice to decision-making. Over the years, MOD's wide-ranging research effort has generated often world-leading science and technology in support of the Armed Forces, their equipment and operations.

1.2 It is essential to ensure that the research programme is optimised to meet customers' needs and delivers the required outputs to an appropriate level of quality. Increasing competition in the acquisition of research and thereby expanding the supplier base will help achieve this goal. However, there is also a need for regular review of the relevance and quality of MOD-funded research and for greater rigour in the formal approval process when launching new work and conducting post-project assessments, both to capture successes and to ensure that research is effectively followed-up. This study was commissioned as an essential first step in establishing a firm baseline of the breadth and depth of current research projects and the extent to which they are aligned to current and future Defence needs.

Study Scope

1.3 The study addressed three main aspects of the non-nuclear research programme funded by MOD's Science Innovation and Technology Top Level Budget:

a. Relevance/Alignment: Is research meeting the needs of Customers? Are there any gaps in the programme's coverage of key requirements? Does the programme need adjusting to reflect changed priorities?

b. Technical Quality: What are MOD's suppliers' strengths? Are there areas where they are less effective? Are there any gaps in their areas of expertise?

c. Exploitation: Is the work MOD commissions pulled through to meet operational needs? Does it provide timely analytical advice to decision-makers, reduce project risk, capitalise on innovation, and develop specific equipment?

1.4 The Terms of Reference for the study are at Annex A.

Study Team

1.5 A core team, led by a non-scientist, was appointed to carry out the study. Other MOD and external personnel also provided support, primarily during the assessment phase of the study. A Steering Group chaired by MOD's Chief Scientific Adviser guided the study; this comprised several senior MOD customers/stakeholders of the research programme and a number of external advisers (see Annex B).

6 Delivering Security in a Changing World Dec 2003 (Supporting Essay 7, para 7.14)

Study Methodology

1.6 The Study Team undertook an extensive series of initial consultations both to scope the study and to establish its methodology. This included discussions with other Government Departments with large research programmes, the National Audit Office, industry and research institutes to ascertain current approaches to reviewing research. Similar discussions were held with other Governments. Full details of external consultations are at Annex C.

1.7 The Study Team drew on a variety of best practice from this consultation exercise to formulate a Concept of Analysis suited to a review of MOD's research activities. This included the development of an objective set of metrics for each part of the study and a scoring system.

The Research Programme

"The Department's strategic framework for determining funding priorities and planning the research programme is still developing, and there is further work to do in revising and aligning the various levels of strategy. [7] "

Key Facts

- There has already been a number of studies into the research programme in recent years; these have concentrated on process and organisation, resulting in major changes such as the creation of Dstl and QinetiQ, the move to an output-based budgetary and programme management system, the formation of MOD's Science Innovation and Technology Top Level Budget and the establishment of the Research Acquisition Organisation at Shrivenham.
- The MOD research budget has reduced over the past decade both in real terms and as a proportion of the Defence Budget; it has now levelled out at some £500m per annum.
- A number of Departmental strategies, both at the strategic and lower levels provide guidance on priorities in research, and particularly technologies.
- The recently published Defence Industrial Strategy has emphasised the importance of research and technology in the generation of the UK's battle-winning forces.

Background

2.1 The UK has long recognised that the achievement of battle-winning military capability depends heavily on investment in the development and exploitation of world-class science and technology. MOD's strong research effort has its origins in the solid foundations established during the Second World War and further developed throughout the Cold War to maintain NATO's technological edge over the Soviet Union. Following the end of the Cold War, a number of areas once driven by large military research programmes, such as Information and Communications Technology, are now equally stimulated by civil sector demands. The challenge for the Department has been to identify the key areas where, for reasons of security and sovereignty, the UK needs to continue to invest in defence research to meet conventional threats and to redirect its research effort to meet new threats that have emerged.

MOD Research - the Benefits

2.2 The main benefits the Department gains through its investment in research include:

- underpinning the UK's military capability, from support to Front Line operations to far-reaching novel technology solutions;
- underpinning operational, procurement and capability analysis which leads to enhanced performance and new capabilities, cost and risk reductions, and interoperability with other nations;
- identifying emerging threats and potential solutions to them;

7 NAO Report – The Management of Defence Research and Technology – 10 Mar 2004 (Executive Summary para 5)

- allowing the UK to be a major player in the international arena, where UK research investment has secured significant leverage and benefits through collaboration;
- acting as a major enabler in global counter-terrorism activities and providing the information to support it;
- helping to underpin the competitiveness of our national defence industry and increase its innovation; this is vital since most UK defence equipment is made by UK industry or collaborations involving UK industry.

MOD Research – Some Facts

2.3 The research budget has reduced in recent years both in real terms and as a proportion of the Defence Budget. This is illustrated at Figure 1 below. The budget has now levelled out following the Treasury's 10 year Science and Innovation Investment Framework, published in 2004, and stands at some £500M annually. At the start of each new Financial Year, up to 83% of the research budget is already committed.

The Department's spending on research has fallen by 30 per cent since 1994-95. This is significantly more than the 4.5 per cent decline in the Defence budget over the same period.

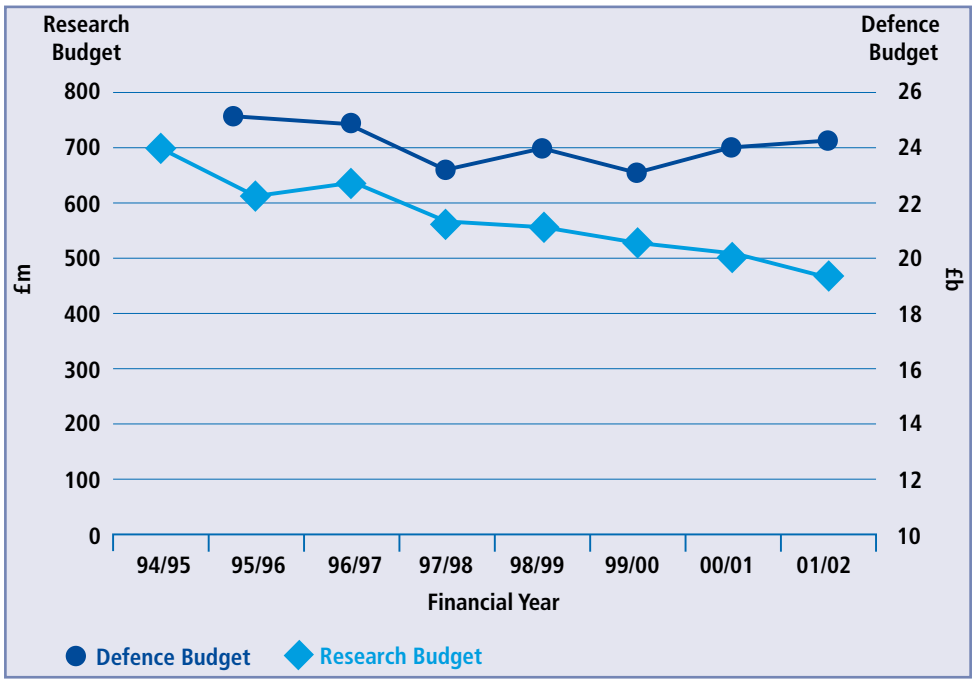


Figure 1: Defence Research and Technology Expenditure [8]

The Strategic Environment for Research

2.4 The Study Team reviewed the key MOD strategies that help direct the research programme. These outline future capability needs and the research priorities likely to support them; prioritise key directed and emerging technologies; and help ensure coherency in technology across the needs of the Equipment Programme or provide research requirements for new and emerging technologies not yet linked to equipment, policy or operational needs.

8 Extract from page 9 of NAO Report – The Management of Defence Research and Technology – HC 360 dated 10 Mar 2004. Figures are adjusted for inflation using 2001-02 as a baseline.

2.5 Several other strategies supplement higher level strategic guidance in the research area. Each research "output" (see para 2.8) has a strategy setting out its purpose and scope; these are used primarily for screening purposes during the development of the Short Term Plan [9]. Within the Equipment Capability Customer organisation, each Director has a Capability Area Plan setting out detailed research requirements. There is also an MOD Science and Innovation Strategy [10].

2.6 The Study Team found that, in practice, the linkage between strategies was not always clear and that more work is needed to rationalise and align them with a strong emphasis on cross-cutting themes that span different funding streams.

Defence Industrial Strategy

2.7 The Defence Industrial Strategy [11] was published towards the end of this review. It notes that "Technology is a key driver for change in the modern world and is crucial to network enabled, adaptable and rapidly deployable forces." [12] It refers to a recent MOD-sponsored study which has shown a "highly significant correlation between equipment capability and Research and Technology investment in the last 5-30 years." [13] The Strategy goes on to note that, recognising the role of technology in driving much of the UK's improvements in productivity and its economic success in recent decades, the Government has established a 10 year strategy to increase national investment in research and technology to 2.5% of GDP by 2014. [14] The Strategy identifies a number of key research and technology challenges for MOD:

- Maintain technological advantage to counter emerging threats;
- Sustain investment levels to maintain our relative global position;
- Develop knowledge management and systems integration skills in the defence sector so that technologies can be matured and integrated into war winning systems for the future;
- Recruit/retain skilled people to act as the MOD intelligent customer for R&T acquisition to meet defence needs;
- Develop design and acquisition processes to enable technology insertion through equipment life. [15]

This report touches on a number of these issues.

9 Short term planning defines the Department's final and intermediate outputs over the coming four years, and allocates resources to budget holders in line with those outputs.
10 Defence Science & Innovation Strategy 2001
11 Cm 6697, Dec 2005
12 Ibid para A5.3
13 Ibid para A5.8
14 Ibid paras A5.3 and A5.19
15 Ibid para A5.14

The Research Programme – Past Studies and Present Organisation

2.8 In undertaking this review, the Study Team noted that MOD's research programme, infrastructure, organisation, and processes have been the subject of several studies in the past decade. Over the same period, there have been numerous organisational changes; these include:

- the transition from Defence Research Agency, through Defence Evaluation and Research Agency to the formation of Dstl [16] and QinetiQ;
- the formation of the Defence Science and Technology Board;
- the change from a 3-part research programme of Corporate (basic) and Applied Research and Technology Demonstration to an output-based system to reflect the introduction of Resource Accounting and Budgeting;
- the formation of the Research Acquisition Organisation at Shrivenham;
- the establishment of the Science Innovation and Technology Top Level Budget;
- the recent QinetiQ privatisation.

2.9 The task of the Research Acquisition Organisation, referred to throughout this report, is to translate diverse and potentially overlapping customer requirements into a coherent research programme, which it then contracts with Dstl, QinetiQ and other suppliers. The Research Acquisition Organisation acts only as a focus for research funded by the Science Innovation and Technology Top Level Budget. It does not contract or manage research originating from the initial (Concept and Assessment) phases of the Equipment Programme in the Defence Procurement Agency or other work sponsored by the Defence Logistics Organisation (for example at the Logistics Analysis & Research Organisation). While the Research Acquisition Organisation provides top level management of the research programme, day to day oversight is exercised by Dstl.

2.10 Noting that past studies had focussed on *process* and *organisation*, the Study Team focussed its effort primarily on the *product* of the research programme.

16 Defence science and technology laboratory

The research programme is aligned to MOD's strategic needs

"In order to ensure that a balanced programme is achieved and all aspects of capability are recognised, the Defence Science and Technology Board should put in place higher level prioritisation criteria to guide output owners' strategies and decisions. [17] "

Key Findings

- Overall, the current research programme is satisfactorily aligned to MOD's strategic requirements.
- There are differences in the extent to which the research priorities identified in high level Departmental strategies are covered by the programme.
- Alignment would be further improved through the provision of a more comprehensive set of clearly articulated research needs; this could be met through improved coverage in high level Departmental strategies, with a clearer audit trail between them.
- The study's analysis of the present coverage of Departmental research priorities provides improved management information for future Balance of Investment decisions; this analysis needs to be further developed and maintained.
- To ensure better alignment and facilitate future analysis of coverage of Departmental priorities, all research business cases should, wherever possible, specify which research priority from high level Departmental strategies is being addressed.

Process and scope

3.1 For its assessment of research alignment against MOD's needs, the Study Team decided that the broad strategic aims set out in the Defence White Paper 2003 and the major priorities outlined in high level Departmental strategies most comprehensively articulated those needs. Since much of the research programme aims to understand and develop technology for equipment, the Team also assessed such projects against Equipment Capability Customers' Capability Area Plans and research requirement documentation. Whilst these strategies do not collectively capture all MOD's needs, particularly in respect of more basic, speculative research, the Team found that they cover its primary strategic goals.

3.2 In order to inform its assessment of the extent to which the research programme satisfies stated MOD requirements, the Study Team developed a new taxonomy to classify projects by anticipated outcome rather than source of funding. This enabled the study better to define the overall benefits of the Department's research investment. The taxonomy identified a number of specific categories of research product within three broad objectives: "Development of Scientific and Technological Competence and Expertise"; "Science and Technology to provide Evidence and

17 NAO Report – The Management of Defence Research and Technology – 10 Mar 04

Support for Planning and Decision-making"; and "Innovative Scientific and Technological Solutions and Technology Development". This approach deliberately cut across both the research budget structure and the then Research Acquisition Organisation structure of 'technical' and 'capability' directorates. In so doing, the Study Team ensured the review did not become channelled along existing organisational lines from the outset. A copy of the taxonomy is at Annex D.

3.3 The Study Team identified over 800 current and planned research "projects" as at 31 March 2005. These varied in size from small research items of £50k - £100k per year to large £5M per year projects for the Defence Technology Centres [18]. The Team decided that this snapshot in time of the research programme should constitute the basis for all its work; any projects added later were not included. The results of the review were, however, presented on the basis of updated financial data at the end. In all, the Study Team reviewed the alignment of some 700 projects, allocating to each a score of 1 to 5. Each project was also assigned to a category in the team's research "outcome" taxonomy.

Overall findings

3.4 The Study Team was able to align 85% of projects to strategic Departmental guidance (Figure 2). This finding validates the Department's overall approach to research formulation using top level guidance and customer led requirements. The Team judged that within this total, many of the projects scoring 3 or 4 could be improved in alignment if clearer and more comprehensive guidance were available in high level Departmental strategies. The Team found that, in some cases, higher level guidance is not sufficiently detailed to discriminate between particular science and technology areas and noted the lack of a clear linkage between different strategies. The absence of coverage of the requirement for research further to develop and sustain existing capabilities is particularly apparent.

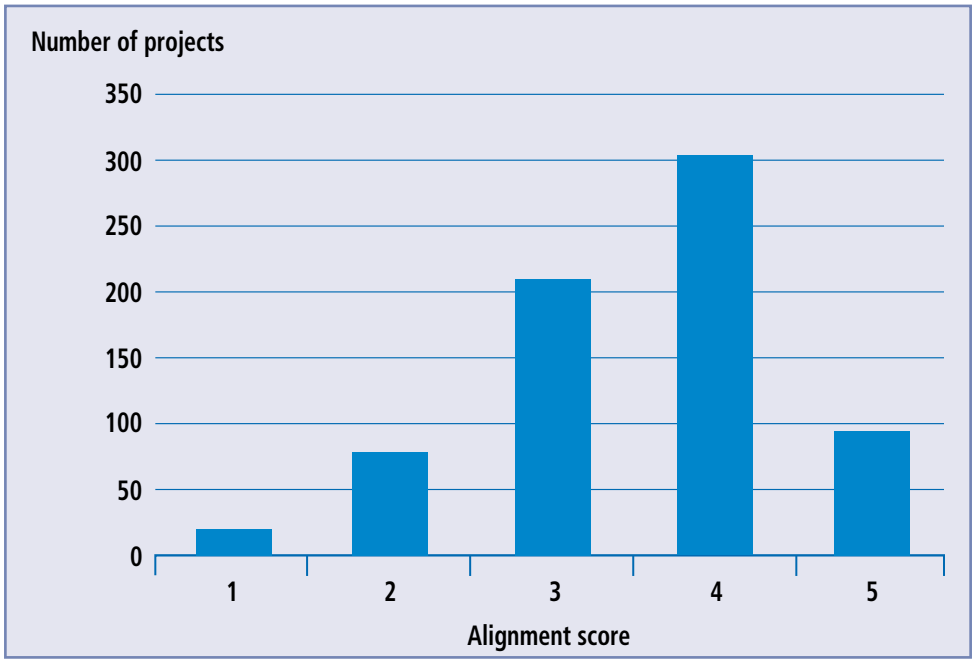


Figure 2: Alignment of the research programme against Department needs

3.5 The Study Team found it difficult to align the remaining 15% of the projects that it scrutinised *using the criteria adopted for the review*. However, while many of these could not be readily aligned to strategic guidance, further analysis showed that much of the work was either management support to help the Department to identify capability gaps and research requirements or

18 Defence Technology Centres (DTCs) are world-class centres of excellence conducting innovative, cutting-edge research for enhanced UK Defence capability.

was 'Knowledge Integration' activity within Dstl (which is a necessity as research is increasingly supplied by a more diverse set of suppliers, many of whom are remote from the integration of technology into military systems). Other projects were designed to enable the Department to retain its intelligent customer status. These types of research are on the right-hand side of the further breakdown at Figure 3.

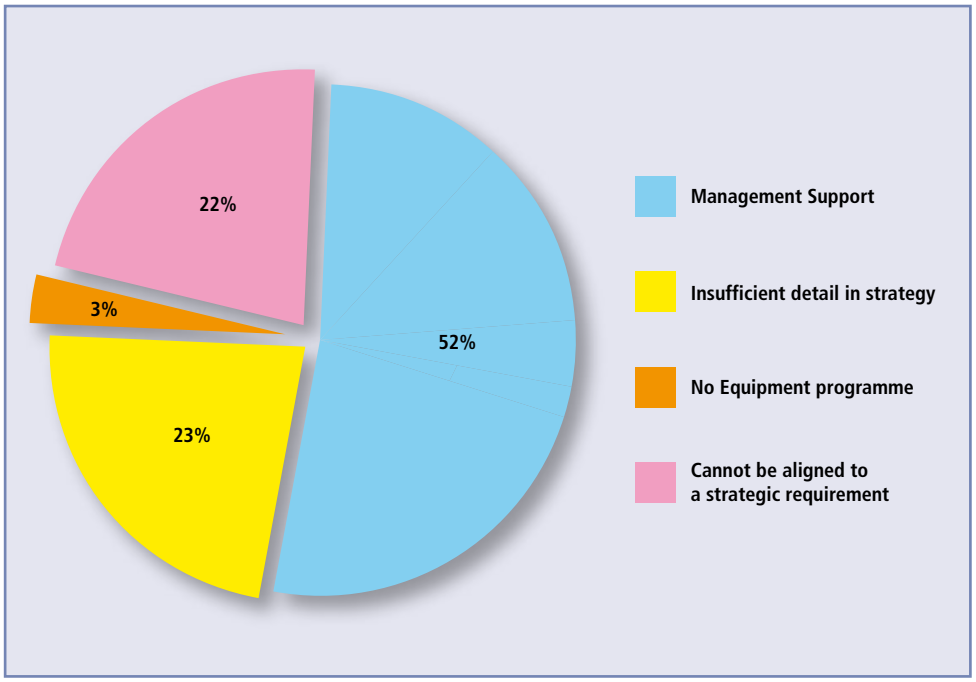


Figure 3: Projects Scoring 1 or 2 by Category

3.6 The Study Team did not question the need for such projects, but suggested that consideration be given as to whether they should be categorised as "research" in the traditional sense since they did not generate new knowledge or technology per se (in its outcome taxonomy the Team classed them as "other work"), and that the proportion of the research budget devoted to such work should be reviewed.

3.7 Over half the projects on the left-hand side of the pie chart are now completed. The Study Team suggested that the remainder should be either re-aligned or discontinued as appropriate.

Research against outcome

3.8 Figure 4 shows the balance of the current research programme in main outcome terms (development of scientific and technical competence, support to decision-making and technology development).

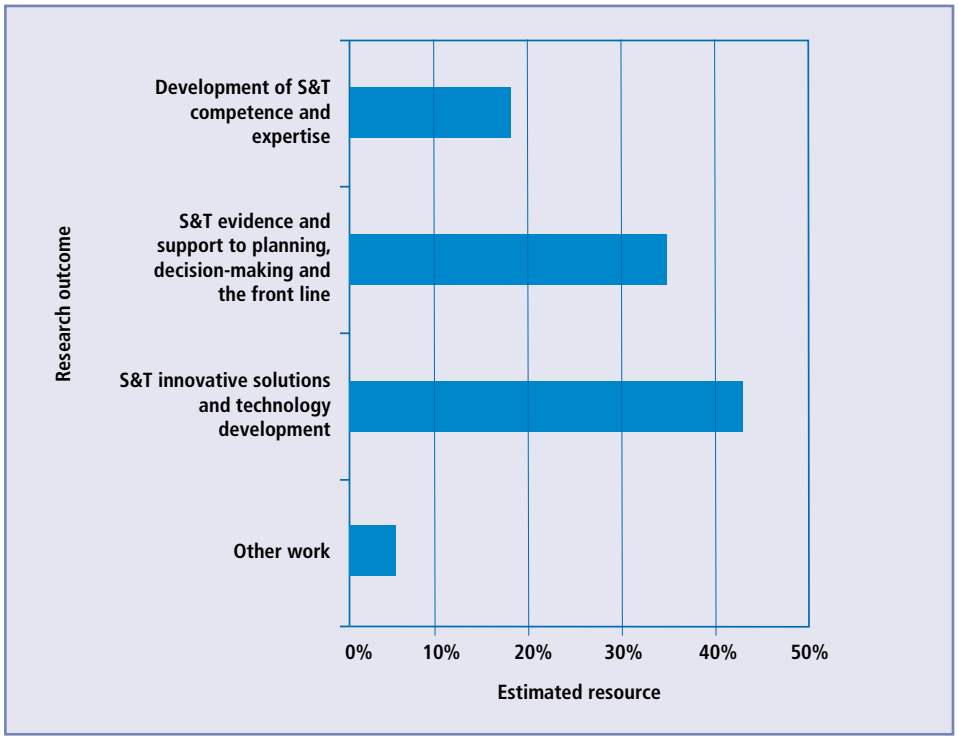


Figure 4: Expected outcomes from the research programme

3.9 The Study Team observed that research aimed at supporting decision-making is firmly weighted towards developing equipment capability concepts through either paper studies or actual demonstration. The level of resources devoted to such research should be seen in the context of the overall value of expenditure flowing from such decisions. The Team concluded that there are clear opportunities to identify new research in order better to support other forms of decision-making or different customers such as Logistics/Through Life Costs, personnel and medical, and the Front Line. The Study Team also noted that, with the exception of Department of Trade and Industry sponsored industry programmes, MOD's financial commitment to technological development for equipment is unique compared to other Government Departments, who utilise science and technology mainly for policy-making and assessment.

3.10 The Study Team also explored the specific issue of scientific and technical support to the Front Line with the Permanent Joint Headquarters (PJHQ) at Northwood. While there is a well established system for addressing specific shortfalls in operational capability through the Urgent Operational Requirement process, Front Line access to scientific and technical advice and support is not as comprehensive. To alleviate this, the Department has a number of initiatives in hand to provide additional assistance to the Front Line that will utilise MOD's science and technology resource and the wider national capability.

Research against high level Departmental strategies

3.11 The Study Team found that the research programme addressed some research priorities identified in high level Departmental strategies very well. For example there is a heavy emphasis on target acquisition research, reflecting the prominence of this requirement in lessons from recent operations and in strategic guidance (it should be noted that this is a very broad area of research). By contrast, some areas assigned equal priority in the guidance attracted only minimal funding. Analysis of the research programme against technology priorities for capability-driven research showed a similar wide variation of effort and the same emphasis on target acquisition compared with other priorities. Clearly, not all research priorities require the same level of effort. Moreover, the research programme forms only one source of funding in support of technology development of capability – for example, Equipment Programme funding also needs to be taken into account. The Team concluded however that there would be advantage in using the new data it had generated to review the present balance of investment across the research priorities.

3.12 The Study Team found a number of research projects that did not fit neatly into high level Departmental strategies. In other instances the capabilities specified in high level Departmental strategies were not sufficiently detailed to help define the scope of a research project. The Study Team considered that further granularity should be provided on these areas of research, such as sustaining and developing existing capabilities (para 3.4), the requirement for more basic, innovative research, and modelling.

Conclusions and Recommendations

3.13 The review has demonstrated that the vast majority of MOD's research programme is aligned to Departmental requirements. In a number of cases alignment could be further improved if these requirements were articulated in greater detail.

3.14 The Study Team's work to define the programme in terms of outcomes, and to analyse in detail the extent to which Departmental research priorities are being met by the current programme has produced a large volume of data in a form not previously available. While the precise determination of outcomes involved a degree of judgement on the Team's part and may require further analysis, this information, if maintained, can provide a much needed guide to future balance of investment decisions. However, this will require a determined effort to maintain and update the data provided by the study.

3.15 The Study Team made a number of recommendations on the basis of its alignment review. These included the need for further analysis of low scoring projects with a view to re-aligning or stopping the research; the need for future versions of high level Departmental strategies to present a more coherent, comprehensive and specific set of required capabilities and technologies; and, in the light of the study's analysis, that the present balance of investment in research be reviewed.

RE-ALIGNMENT OF BRIMSTONE RESEARCH

Firing of Brimstone © MBDA

MOD originally based the Brimstone missile system on the requirement to attack large columns of massed armour. During procurement, the end of the Cold War reduced the massed armour threat; research enabled Brimstone to be re-aligned to emerging threats. As conventional upgrade and disassembly of the missile is difficult due to its novel construction, this research focused on improved discrimination, lethality and insensitive munitions compliance.

MBDA, the UK design authority for Brimstone, developed a dual mode/dual role sensor to improve target discrimination. This allows effective discrimination between armoured vehicles in hides or open environments and civilian vehicles. The sensor, in conjunction with improvements to the warhead, motor and targeting algorithms, will reduce potential collateral damage and allow greater use of Brimstone in engaging targets of opportunity under restrictive rules of engagement. This capability allows all-weather, autonomous discrimination in a design that is simpler and more effective than equivalent capability developed by other nations.

In the course of this research, MBDA supplemented its expertise in leading-edge missile seeker technology by forming a strong collaborative team with QinetiQ (algorithm design), SELEX (sensors) and ROXEL (warheads and motors), while Dstl provided support during testing and through the provision of data collection. Through this collaborative work, the team successfully re-aligned its research efforts to meet changing requirements and created an internationally leading capability. Brimstone is planned to be integrated into the Joint Strike Fighter, allowing potential export opportunities.

Detail of the Brimstone dual mode/dual role seeker © MBDA

The vast majority of MOD's research is of high quality and in some areas it is world-leading

"Although the nature of conflict remains dirty, dangerous and deeply personal often with no substitute for 'boots on the ground', the UK needs to stay ahead in technology against both conventional and novel threats, such that we can quickly develop counter measures and solutions as new threats emerge. A strong and innovative science and engineering base in UK Government research agencies, industry and universities is essential to meet this need. [19]"

Key Findings

- External peer reviewers assessed a third of the projects in MOD's current research programme; over 90% were judged to be of acceptable quality or better.
- 22% of projects were classed as world-leading and providing the UK with a competitive edge internationally.
- Nearly half the sample was deemed good quality research that would have merited publication in a top-tier research journal.
- A small number of projects were found to be of poor quality; earlier independent peer review might have helped steer these projects towards a higher quality output.
- The study has demonstrated that external peer review of MOD research is practicable. In future, it is proposed to establish regular external peer review of all research projects at formation and on completion. A wide pool of external reviewers will be established and regularly refreshed to this end.

Process and scope

4.1 The Study Team selected a representative sample of projects, amounting to 34% of the research programme identified in the Alignment part of the study, and including all projects valued over £5M. Post-April 2005 projects were excluded because their output would be insufficiently mature for meaningful evaluation. The sample was otherwise selected at random and the Study Team was confident that there was no bias towards any supplier or technology area.

4.2 While most of MOD's research programme already undergoes internal peer review, with some elements subjected to external peer review, this was the first extensive review of research quality using external peer reviewers for a significant proportion of the programme. The peer review panel comprised 5 Fellows of the Royal Society (FRS) and Royal Academy of Engineering

19 Defence Industrial Strategy Cm 6697 Dec 2005 A5.1 p38

(FREng) recruited specifically to the Defence Scientific Advisory Council [20] for this study. They were supplemented by further 38 FRS and FREng qualified members of the Council. Since all Council members hold security clearance, project classification did not constrain the review sample Projects were assigned to reviewers according to their areas of expertise.

4.3 Most projects were marked by a single peer reviewer. The lead researchers from each project team presented their work directly to the peer reviewer, followed by detailed questioning. For a small number of projects where this was impractical, assessment was through published reports and research papers.

4.4 Peer reviewers were given general guidance including common indicators of quality that they should consider, according to whether the project was traditional scientific research or engineering-orientated. Two scores on a scale of one to five were awarded for each project. The first related to the scientific (or engineering) methodology adopted by the research team; the second to the quality of research output (or anticipated output).

4.5 The Study Team also scored project management by the suppliers; this reflected factors such as clearly stated research objectives, achievement of deliverables, and project risk. This assessment also captured a project's fitness for purpose for its stated objectives.

Main findings

4.6 Figure 5 summarises the results. There was no significant difference between the scores relating to output and approach. The 22% of projects scoring the maximum mark for output were judged as world-leading and providing the UK with a competitive edge internationally. A more detailed analysis showed these projects to be a mix of successful "high-risk high-reward" projects, truly innovative research, and collaborative projects where the overall quality was assisted by good gearing. Just under half the sample (47%) scored a 'four' for output, signifying good quality research that would have merited publication in a top-tier research journal if publication were possible.

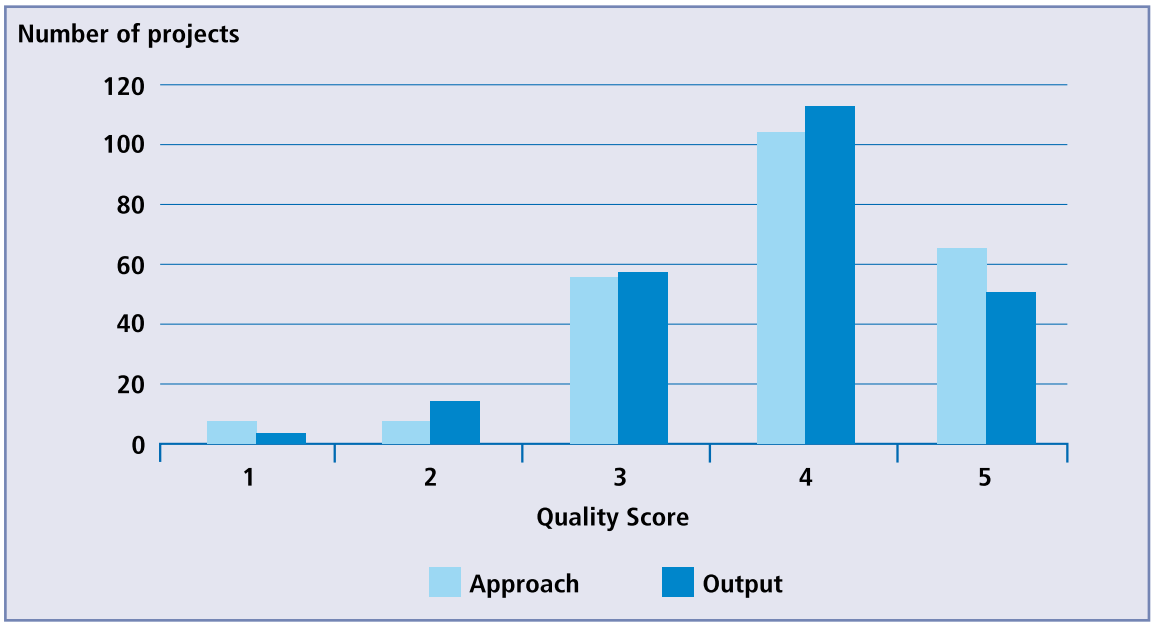


Figure 5: Analysis of research approach and quality of output across the research programme

20 The Defence Scientific Advisory Council (DSAC) provides independent advice to the Secretary of State for Defence on matters of concern to the Ministry of Defence in the fields of science, engineering and technology. DSAC is a Non-Departmental Public Body (NDPB) i.e. a body which has a role in the process of national government but is not a Government department or part of one, and which accordingly operates to a greater or lesser extent at arm's length from Ministers. As an Advisory NDPB it does not employ staff or incur expenditure on its own account.

4.7 Projects scoring a "three" (24%) were considered good but not of a standard which could be published in a top-tier journal, or were judged on a par with similar projects in the field but not world-leading. In several cases, the reviewer remarked that a project could have been re-directed to improve the quality of the end product had it been peer reviewed at an earlier stage. In some instances, reviewers also remarked that science projects in this category had not considered publishing work, even though this would have been appropriate. Several engineering projects were awarded this score because the reviewer was aware of other research being conducted internationally which was more advanced and therefore felt unable to award a higher mark. There are of course reasons why the Department may still wish to conduct research in these areas, e.g. to retain an industrial capability, or to try and close a current gap with another nation's capability. However, such considerations were beyond the scope of the reviewer and these projects, although of an acceptable quality, did not achieve top marks.

4.8 18 projects (7%) scored either a 'one' or a 'two' and were considered to be of poor quality. A variety of factors were cited by reviewers, some of which were beyond the control of the research teams. Often the reviewer felt projects had been unable to achieve their objectives through a lack of funding or were constrained by the terms of the requirement they were seeking to meet. Occasionally low scores were awarded on value for money grounds, particularly in areas where similar work had been conducted outside MOD. Again, some reviewers remarked that such issues might have been identified earlier had the research proposal been subjected to external peer review.

4.9 The Study Team's assessment of research suppliers' project management is shown in Figure 6. The average score of 'four' indicates that the majority of research is well-managed using best practice project management techniques. This reflects a number of initiatives designed to improve research project management such as ISO 9001. However, the Team found cases where project milestones were used more to facilitate stage payments for work done than as genuine milestones of project achievement. For example, many milestones were simply reports summarising the previous six months' work, rather than a critical decision point or stakeholder demonstration.

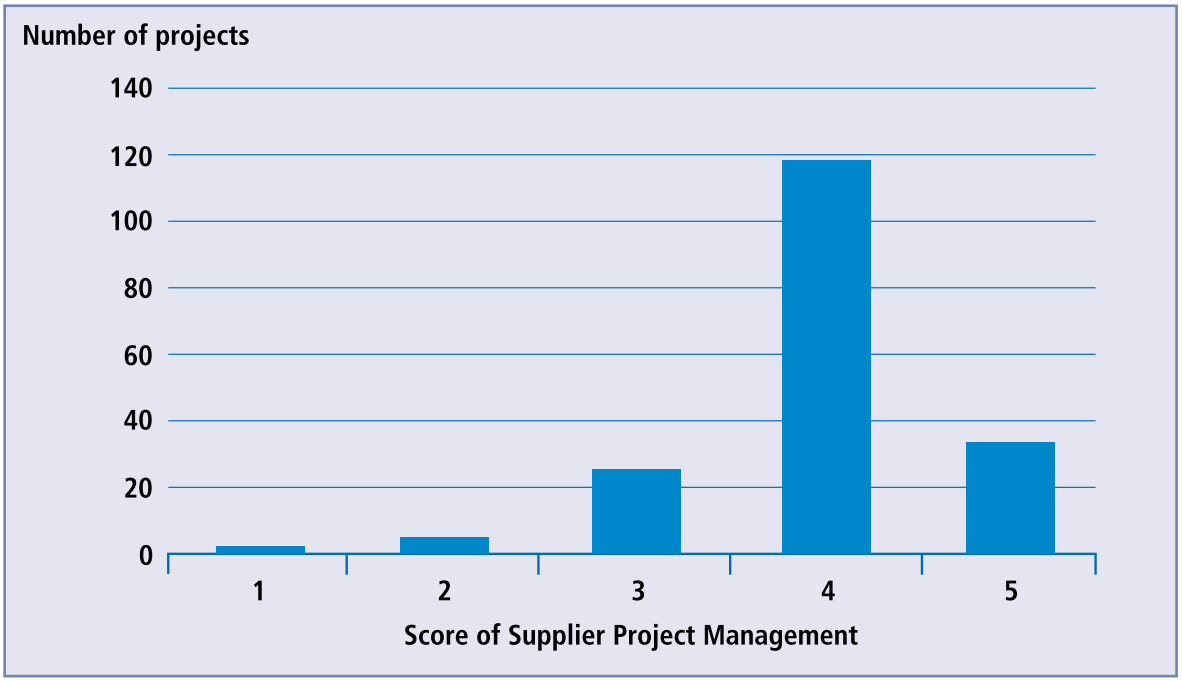


Figure 6: Analysis of research project management across the research programme

Conclusions and recommendations

4.10 Over 90% of the sample of MOD's current research was assessed by external peer review as being of acceptable quality or higher and fit for purpose. The majority of this was found to be very good, while 22% was considered world-leading. This provides confidence that the Department's research investment is sound, and that its main suppliers are meeting the requirements placed on them. Nevertheless there remains scope for further improvement in research quality. The introduction of greater competition should help in this context.

4.11 A small number of projects (less than 8%) were found to be of poor quality, although no common factors were identified. These will be subjected to further scrutiny with a view to stopping the research where appropriate. As recommended by the Study Team, the introduction of more thorough peer review of initial research proposals and of the research itself as it is carried out will help improve technical quality in future. The Research Acquisition Organisation has strengthened its review process in this respect during the study. In particular it now uses independent reviewers during its assessment of research bids and has plans for wider peer review on contract completion. The Study Team also suggested that greater publication of research results in learned journals would help increase external benchmarking; this will be encouraged.

HIGH QUALITY ARMOUR RESEARCH

Novel lightweight armour being tested at Lulworth

Effective armour is crucial to the protection of mobile forces. The move to smaller and lighter forces has increased the challenge. MOD research in this area supports both existing platforms such as Challenger-2 and future platforms such as the Future Rapid Effects System against current and evolving threats. Since the development of Chobham Armour, the UK has held a world-wide lead in the development of armour. The Dstl armour team has demonstrated a number of advances in lightweight armours, details of which must remain highly classified. In the course of its research, Dstl developed strong international collaborations in order to maintain peer review and to provide a benchmark of its work.

Besides developing novel armours, the Dstl research team played a key role in providing a number of successful upgrades for Challenger-2, Warrior and CVR(T) through Urgent Operational Requirements during Operation TELIC.

Exploitation is acceptable and there are a number of initiatives in place further to improve performance

"The Department has recognised many of the key exploitation issues and has developed new commercial conditions and processes to enable the exploitation of the technology development it funds both for Defence and for wider civil uses. There is more the Department can do … to bridge the gap between work funded from the research and equipment programme budgets [21] "

Key Findings

- In the medium-term, exploitation of research has been good.
- There is increasingly widespread use of exploitation planning for current research and growing use of technology roadmaps to improve exploitation of capability-related research.
- End-user engagement from the outset of a project greatly increases the chances of successful exploitation.

5.1 In accordance with its Terms of Reference, the Study Team interpreted 'exploitation' as ´effective use of research`. Depending on the intended outcomes of individual research projects, this could range from sustaining the science and technology base or use of research in decision-making to pull-through of research into equipment and Front Line use.

5.2 The timescales from initiation of a defence research project through to final exploitation can be very long; in the case of equipment, this can take up to 15 years or more. This makes any assessment of exploitation performance difficult, not least in establishing an audit trail from laboratory to Front Line. The study accordingly adopted a two-pronged approach, using samples of both current and old research projects.

Exploitation of current work

5.3 The Study Team selected a random 10% sample of projects from the current research programme and interviewed project customers to assess their awareness of the output of the research and plans for its exploitation. Each project was given a score from 1 to 5 for both exploitation plan quality and expected impact.

21 NAO Report – The Management of Defence Research and Technology – 10 Mar 04 (Executive Summary para 8)

Plans

5.4 Figure 7 provides an assessment of exploitation planning and impact. Most projects had an exploitation plan and 85% of projects with such plans were assessed as good value-for-money. A key factor in determining how well plans were executed was the involvement of the anticipated end-user of the research; if engaged in their formulation, exploitation plans were considerably more likely to be carried out.

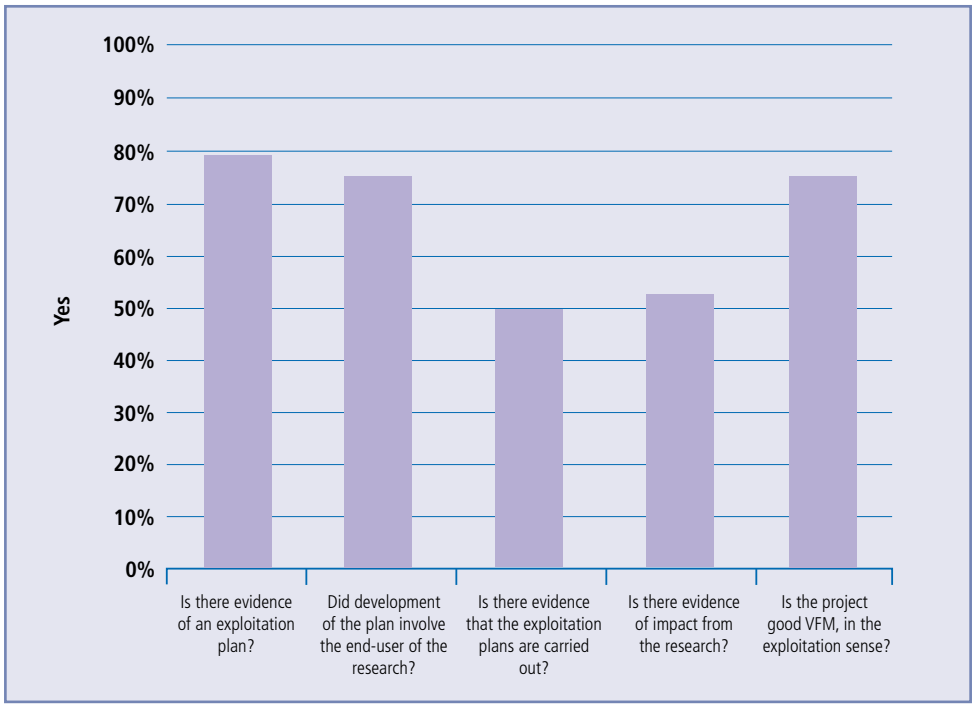


Figure 7: Exploitation Performance of a 10% Sample of Current Projects

Impact

5.5 Just over half of the projects showed evidence that they had had an impact or were likely to in the future. This was significantly higher for capability-related research projects than other projects, an expected finding given the differences in the nature of the work. Projects with an exploitation plan were over three times as likely to show evidence of impact. Involvement of the end-user also significantly increased the likelihood of project impact.

5.6 The Study Team also analysed examples of projects that Research Directors considered represented good exploitation and projects which did not meet expectations, in order to identify any common factors underlying exploitation success. The clear common characteristic of successful projects was the extent and variety of collaborative and stakeholder links. Technical success may depend on an ability to analyse and incorporate advances in related work into the programme. Formal and informal links into academic and industrial research are the most effective means to optimise that process. Such links were specifically highlighted by Research Directors in nearly half their chosen successful projects. Successful exploitation also depends on understanding end-users' requirements and tailoring the research accordingly.

5.7 An indicator of an ambitious research programme is that not all projects succeed. However, technical success does not by itself guarantee successful exploitation. Nearly half the low scoring projects in the sample reviewed were described as technical successes, but were not exploited either for budgetary reasons or because they did not match the corresponding capability need.

Outcomes of completed work

5.8 The Study Team also assessed the exploitation of a random 10% sample of projects from the 1995/96 research programme [22]. Project Managers or lead researchers from over 70 projects were asked about the technical success and subsequent exploitation of their work. The results need to be treated with some caution given the small sample size.

5.9 Overall, 77% of the projects were judged successful [23]. Figure 8 shows that a significant number of technically successful projects led to follow-on research. Even when there had been no exploitation of the research, over half of respondents assessed the work as good value-for-money. The overall level of exploitation was 64%.

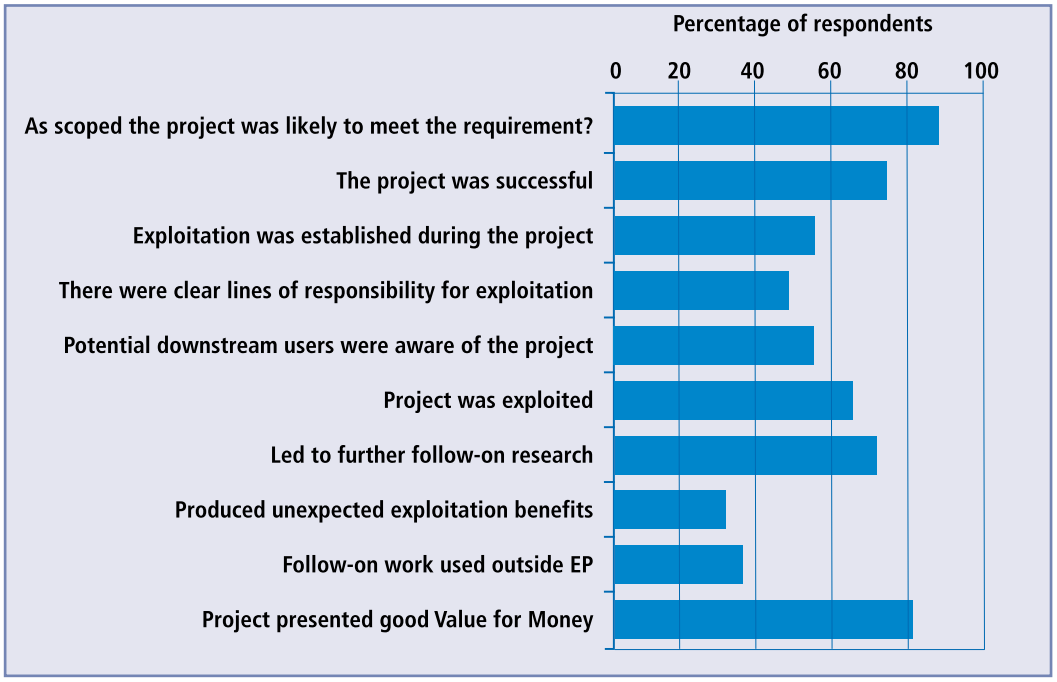


Figure 8: Exploitation Performance of a 10% Sample of 1995/96 Research Projects

In the case of projects intended to provide innovative solutions, nearly half were assessed as having led to a new or improved capability. Over two thirds of such work subsequently had an unexpected exploitation route within Defence, or led to "spin-off" into the wider civil sector. The replies suggest good transfer of technology into the private sector, with 50% of innovative projects having provided Intellectual Property Rights that were taken up by industry.

Exploitation Planning and Responsibilities

5.10 The study revealed evidence of increasing use of exploitation plans (80% of current projects had a plan compared with less than 60% of old projects) and that these clearly improve the chances of exploiting research output. The increasing use of technology road maps to improve the prospects of successful exploitation of capability-related research projects was also apparent. In some areas, particularly in projects related to placing technology in the supplier base, there were examples of very well-constructed and effective exploitation plans and roadmaps.

22 Prior to the introduction of the present Output system, the research programme was divided into the Applied Research Programme and the Corporate Research Programme.

23 That is, the work successfully achieved its technical objectives.

5.11 The Study Team concluded that this best practice should be adopted across the research programme through improved exploitation plans and a closer and more thorough stakeholder management process. The Study Team noted the need to enhance visibility of the research programme as a whole, especially visibility within the Defence Procurement Agency of more basic research which might have future relevance to their work. There was also scope for greater cohesion between different research funding areas in order to improve pull-through from basic research to capability-related research and ultimately, the supplier base.

Spin-Out

5.12 The Study Team collated examples from Dstl and QinetiQ of spin-out companies formed to exploit Defence research. These include:

From Dstl	From QinetiQ
P2i	Psimedica (psivida)
Remo Technologies	ZBD Displays Ltd
Enigma Diagnostics Ltd	NXT (licences) (see vignette below)
Acolyte Biomedica Ltd	Quintel Technology Ltd
Lucigen	Aurix Limited
Alaska Food Diagnostics	Sybard
Enigma Diagnostics	Sepura sGPS (Partnership with QinetiQ)

Further details on these companies are at Annex E.

SPIN-OUT TECHNOLOGY: NXT FLAT PANEL SPEAKERS

NEC LaVie T Laptop. Technology developed by NXT allows the lens screen in front of the LCD display to act as the loudspeaker.

In the late 1980s a well-known helicopter manufacturer asked the Defence Evaluation and Research Agency (DERA) to help reduce noise in the cabin of one of their aircraft. Initial attempts were unsuccessful but an interesting discovery was made along the way: a roof panel inside the cabin was actually amplifying the sound produced by the aircraft.

The research team realised that this phenomenon could be used by loudspeaker manufacturers to create new, marketable products. After further work the technology was patented by DERA in 1991 and a number of loudspeaker manufacturers were approached to gauge interest in taking it further.

In 1994 the technology was licensed to NXT Plc, which built on the initial discovery with a series of additional inventions to create a system that can be applied to a range of commercial situations. The company has since withdrawn from the manufacturing process to focus its efforts on research and development, with revenues coming from royalties, licence fees and consultancy work.

NXT's Distributed Mode Loudspeakers (DML) operate under the principle of bending wave physics to induce random surface vibration in a panel. The technology allows sound reproduction from a wide range of materials that are flat and thin. There is almost no limit to size and so DML technology offers greater versatility in application than traditional loudspeakers.

NXT now has more than 250 licensees in over 50 countries for its patented flat panel loudspeaker technology. Products on the market that incorporate NXT systems include mobile phones, televisions, PCs, and portable, home, commercial and automotive audio equipment. QinetiQ is NXT's exclusive aerospace licensee and has so far, through a partnership with Lufthansa Technik, fitted two Boeing 737s with NXT-based audio systems. So, ironically, a technology that was discovered while trying to reduce noise in an aircraft is now achieving the opposite goal.

Conclusions and Recommendations

5.13 The Study Team concluded that all projects should, as a minimum, have an exploitation plan with clear lead responsibility for its delivery. Projects aimed at a particular capability should also have a roadmap that identifies its capability connections, in particular to the Equipment Plan and any key links and dependencies both within and outside the technology under study that will help achieve successful output from the work.

5.14 The Study Team proposed that Head Office staff, with the Research Acquisition Organisation, should take responsibility for facilitating the spread of best practice, noting that Dstl staff also have an important role in developing this within their capability areas. End-users should be responsible for exploitation, so it can be monitored and clear lines of accountability established, ultimately to the Defence Science and Technology Board. [24]

5.15 The Study Team concluded that an appropriate forum both to construct requirements and assume responsibility for exploitation would be the Capability Working Group or an equivalent body which brings together all Front Line customers to work towards building a particular capability. By including Research Acquisition Organisation and Dstl representatives, the Capability Working Group can take responsibility for all but the most basic research, and by enjoying control of both requirements and exploitation, maximise the output of their research. This would also help improve visibility of the research programme for those who would benefit from it. Such an arrangement has already been shown to work well in the Equipment Capability Customer organisation.

5.16 The Study Team considered such an approach would also be appropriate to more basic research that can be linked to a particular capability, however long-term the final exploitation might be. For basic research with several potential applications, the Study Team proposed that a group analogous to a Capability Working Group be created to be responsible for such research and its exploitation. Such "Research Working Groups" would need to draw in appropriate likely end-users of research where necessary, but would be led from within the Science Innovation and Technology Top Level Budget.

5.17 This proposed approach of delegated responsibility for exploitation would ensure that end-users are involved in exploitation plans and that these plans are followed through. It would

24 Chaired by the Chief Scientific Adviser with 3-star representatives from other research budget areas

provide a clear route by which research suppliers can engage the end-user, as well as improving cohesion between funding sources as technology matures. It would create a capability focus for most research, while, given an outcome-based Balance of Investment, still ensuring the balance between fundamental and applied research.

HIGH ALTITUDE LONG ENDURANCE UNMANNED AERIAL VEHICLE

THE REQUIREMENT

There is a need for a persistent and repeatable surveillance capability of areas deep in enemy territory, providing both strategic and tactical situational awareness in a responsive and timely fashion. This requires an air platform which can operate at altitudes that enable both greater reach and greater survivability.

This role has previously been catered for by space-based systems and manned aerial vehicles. However, low earth orbiting space surveillance systems are limited in revisit and dwell capability, longer-dwell space systems are limited by the extended range, reducing the achievable resolution, and manned aerial vehicles are costly and prone to attack, resulting in unacceptable loss in both human and financial terms. A High Altitude Long Endurance (HALE) Unmanned Aerial Vehicle (UAV) could provide an affordable alternative.

THE SOLUTION

Innovative, world-leading technology. To minimise design requirements such as propulsion, flight loads and operational and weather constraints, the UAV is designed to be launched by its wingtip whilst suspended below a balloon. The aircraft spins around its tether to the balloon prior to release into free-flight. The research demonstrates the design and construction of a lightweight carbon-fibre UAV capable of electro-optic (EO) sensor payloads. On flight trials to assess stability and flight characteristics, the video camera payload remained operational throughout the entire mission in temperatures of -30°C and demonstrating good robustness. HALE uses a regenerative power storage system which achieves almost twice the performance of present Lithium-polymer batteries. This project has achieved many world firsts, including first HALE UAV flight outside the US.

Pull-through from basic research. This project utilises previous QinetiQ private venture funding and involves collaboration with many other suppliers. To achieve the aim of free flight at high altitude, the project has exploited and integrated a number of technologies including: light-weight carbon fibre composite structures (single skin construction), miniature GPS guidance, micro-engineered sensors and actuators, and thin film solar cells on flexible substrates. The project is also addressing issues such as UAV launch and recovery, high altitude environmental effects, autonomous guidance and control free-flight performance assessment, safety cases and operations, and extended operability.

Clear plans for exploitation. Exploitation will be through the Equipment Capability Customer organisation and other stakeholders. There is also potential civil spin-off into European Pegasus HALE UAV project being conducted by VITO, the Flemish Institute for Technological Research.

THE IMPACT

This project has attracted significant attention within MOD and has led directly to two further applied research contracts placed to address the potential application of HALE UAVs for provision of a deep, persistent, ISTAR capability. Further work addressing requirements and early risk reduction for a possible future Technology Demonstrator Programme has been funded.

It is too early to quantify the financial benefits from the research, but there is the potential for an unmanned vehicle at a unit cost of some £1.5M to replace manned aircraft or satellites costing significantly more. Additional benefits will include removing the risk to personnel and not having to divert satellite tracks.

The HALE UAV

© QinetiQ

Conclusions and recommendations

"Well targeted investment in R&T is a critical enabler of our national defence capability. [25] "

6.1 This was an objective, impartial and robust review of MOD's research programme. The Study Team conducted extensive consultations within and outside MOD to ensure the study methodology embraced best practice for reviewing research. Throughout the study, the Team enjoyed good cooperation - notably from research suppliers - without which its work would have been impossible. In the assessment of research quality in particular, the Team noted that many researchers welcomed the opportunity to present their work to external peer reviewers. Overall, the Study Team achieved a sufficiently comprehensive and in depth analysis of the present research programme to enable reliable conclusions to be drawn.

6.2 The review has demonstrated that a high proportion of the research programme is satisfactorily aligned to MOD's needs, and that the research product is mostly high quality; indeed, in some areas it is world-class. Exploitation of research in its broadest sense has been acceptable and there is an increasing focus on exploitation planning and road-mapping which should help improve performance in future. Finally, there is a high degree of customer and stakeholder satisfaction with the programme.

6.3 The study identified a number of areas where there is still room for improvement. In terms of research alignment, there is scope to rationalise Departmental strategies which drive the research programme and to improve their coverage. There are differences in the funding allocated to research priorities, and balance of investment across the programme could usefully be reviewed. There is scope for re-aligning some current work. In terms of research quality, there is a small number of projects, and some particular areas of research, where the quality is not as high. Having established the precedent for widespread external review of Defence research during this study, it is planned to make this part of the normal management process for research projects in future. In terms of exploitation of research, there is evidence that "process" issues can and do inhibit effective pull through. The present increased emphasis on exploitation planning and road-mapping represents best practice which will be adopted across the research programme. Further improvement in exploitation performance will be achieved though clearer ownership of exploitation responsibility, improved end-user engagement and better visibility across the Department of the research programme. The Study Team made a number of suggestions for improvement which will now be progressed.

6.4 This study has set a benchmark for future regular reviews of the research programme in a number of ways. It has demonstrated that widespread external peer review of MOD research is achievable, even in the case of highly classified projects. This has paved the way to introduce regular and systematic use of peer review at key points throughout the life of research projects. The Team gathered comprehensive data on the balance of MOD funding of its main research priorities which, if maintained and updated, should help inform future balance of investment decisions. It has established the extent to which the present research programme is aligned to Departmental needs, analysed the quality of a third of the programme and the exploitation performance of a significant number of current and old projects. This has set a clear standard in terms of how to conduct future reviews of MOD research, whether as part of a routine review process or less frequent, large scale reviews such as this one, and a baseline for measuring improvements in performance in future such reviews.

---

25 Defence Industrial Strategy Cm 6697 Dec 2005 A5.1 p38

Annex A Terms of Reference
The Science and Technology Capability and Alignment Study

AIM

1. To assess the quality and relevance of the Defence research programme funded by the Science Innovation and Technology Top Level Budget (SIT TLB) and establish a benchmark for future regular reviews of the programme.

SCOPE

2. The study will consider the non-nuclear research programme. It will not address MOD research funded by other Top Level Budgets such as the Defence Procurement Agency, nor nuclear-related research.

COMPOSITION

3. The Study Team will comprise:

1 x 1* Senior Civil Servant;
1 x Band B (or equivalent);
2 x Band C (Fast stream or equivalent).

STEERING GROUP

4. A Steering Group will be formed to oversee the review and provide strategic guidance to the Team. The Steering Group will be chaired by the Chief Scientific Adviser and will include a mixture of Defence Science and Technology Board members and external scientists.

METHODOLOGY

5. The Study will address three key areas:

a. Relevance/Alignment:

i. Is the research programme meeting the needs of its Customers [26] ?
ii. Are there areas where more should be done?
iii. Are there areas where less should be done?
iv. Are there gaps?

26 'Customers' include Output owners (and their staff), Ministers, Front Line Commanders and wider stakeholders as appropriate.

This assessment will be conducted by reference to MOD strategic documentation, and relevant other Government Department strategic documentation.

b. Technical Quality:

i. In which areas of research do research suppliers [27] excel?
ii. In which areas are they less effective?
iii. Are there any gaps in research capability?

This analysis will be conducted through the formation of Technical Working Groups that will include Defence Scientific Advisory Council/other external scientific expertise.

c. Exploitation:

Is SIT TLB-funded research pulled through to:

i. Meet operational needs?
ii. Provide timely and analytical advice to decision-makers?
iii. Reduce project risk?
iv. Capitalise on innovation?
v. Develop specific equipment?
vi. The civil sector?

In addressing these areas, the Study Team should evaluate the ability of the TLB and its suppliers both to identify and to access for Defence purposes research available in the wider commercial and global science and technology base.

CONSULTATION

6. The Study Team will consult widely with key customers and stakeholders for research within the Department and with MOD's major research suppliers. The Team will seek out best practice in the review of research within Government and UK industry and key Allies/other Governments.

TIMING

7. The Study Team will deliver its final report and an implementation plan by December 2005. [28] Any deviations from this timetable will be subject to approval by the Steering Group.

27 `Suppliers` include both in-house and extramural organisations.

28 The timescale for completion of the study was extended to allow a larger sample of projects to be reviewed for quality.

Annex B

Composition of Science and Technology Capability and Alignment Study Steering Group

Chief Scientific Adviser	Chairman
Science and Technology Director	
Deputy Chief of the Defence Staff (Equipment Capability)	
Deputy Chief Executive, Defence Procurement Agency	
Finance Director	

Prof Frank Kelly FRS	CSA, Dept for Transport
Prof Julia King CBE FREng	Imperial College, London
Prof Dame Julia Higgins FRS FREng	Imperial College, London
Mr Paul Stein FREng	Managing Director, Roke Manor Research Ltd
Prof Sir Mike Brady FRS	University of Oxford
Mr Alex Dorrian CBE FREng	Chief Executive Thales UK plc
Prof Sir Peter Knight FRS	Imperial College, London

Annex C
Individuals and organisations consulted

BAE Systems
British National Space Centre
Department for Environment Food and Rural Affairs
Department for Trade and Industry
Department for Transport
Department of Health
National Audit Office
Engineering and Physical Sciences Research Council (EPSRC)
Government Communications Headquarters (GCHQ)
Office of Science and Technology
Dstl
QinetiQ
Roke Manor Research Ltd
Rolls-Royce plc
Secret Intelligence Service
The Wellcome Trust

Délégation Générale pour l'Armement, France
FOI, Sweden
US Army Research Laboratory
US Department of Army Research and Technology
US Los Alamos National Laboratory
US National Science Foundation
US Naval Research Laboratory
US Navy Department, N607 OpNav
US Office of Management Budget
US Office of Naval Research
US Office of the Secretary of Defense Deputy Under Secretary Defense Science and Technology
US Sandia National Laboratories

Annex D
Science and Technology Programme Taxonomy

Class	Sub-class	Description
Development of S&T competence and expertise	Low maturity S&T – research suppliers and universities / wider UK	Develop and maintain underpinning expertise within the UK or other accessible research suppliers to enable understanding and future development of a range of fundamental and emerging S+T areas
	System Integration level maturity, core Dstl KI and TW	Develop a core technical expertise to allow system integration, support to equipment projects (new and existing systems) & the Front Line/head office; and assessment of third party and contracted research
	Application level maturity - industry	Develop expertise and familiarity in the application of technologies for specific equipments within the prime and sub-contractors, eg. maintain essential, niche and core expertise between major procurements
S&T evidence and support to planning, decision making and the Front Line	Front Line	Model development and analysis to support decision making in the commands and various deployed HQ and PJHQ
	HLOA	Development and use of models to support force development and other HLOA
	OA for ECC business decisions	Development and use of OA to support COIEA and COA for specific equipment options within the EP
	Conceptual and technical development for ECC decisions	Development of equipment concepts, modelling of concepts and development of technological solutions to demonstrate equipment concepts
S&T innovative solutions and technology development	Emerging technology understanding and development	Development of emerging technology for a specific military problem or sub-set of problems or threats, eg. materials for thermal imaging
	Solution demonstration	Technological solution to a specific problem or sub-set of problems, eg. Explosive Ordnance Detection (EOD) or Chemical Agent Monitoring (CAM)
	Solutions to the Front Line	Technological solutions (equipment and processes) which directly feed into Front Line activities, Front Line commands & PJHQ
	Equipment de-risk and demonstration	System demonstrators, directly linked to an EP line or IPT, which reduce areas of technical risk for equipment, eg. FRES TDP

Annex E
Spin-out companies

Dstl

The technology transfer unit of Dstl has been responsible for creating new ventures over several years. These include both spin-out companies as well as strategic joint ventures. These new companies benefit local economic development and they have created many new jobs in the region. Examples of companies specifically created to commercialise Dstl technology are listed below.

Acolyte Biomedica Ltd

Acolyte Biomedica develops proprietary diagnostic systems primarily for clinical microbiology using the Dstl's adenylate kinase (AK) bioluminescence technology. Its first product, the BacLite® MRSA test, is now in use at a number of hospitals and other products are coming on stream. The newly launched "BacLite® RapiTECT™" kit brings the AK technology for accurate quantification of bacteria into the research laboratory markets.

Alaska Food Diagnostics Ltd

Alaska is developing an ultra-rapid diagnostic technology to protect food retailers, distributors and manufacturers and, most importantly, the general public against bacterial contamination of food and drink. By using Dstl's adenylate kinase bioluminescence AK technology, together with Defra's bacteriophage technology, the presence of pathogenic bacteria can be tested throughout the food distribution chain in a timely fashion.

Enigma Diagnostics Ltd

Enigma's mission is to become a world leader in the rapid detection and identification of bacteria and viruses in environmental and biological samples at the point of sampling. Enigma's polymerase chain reaction (PCR) technology has wide applications especially in the biothreat, veterinary and point of care diagnostic markets.

Lucigen Ltd

Lucigen, a strategic joint venture with Biotrace International plc., manufactures high grade firefly luciferase. This material is a critical reagent for rapid hygiene testing and microbial detection systems based on luciferase and is a requirement for fielded MOD detection systems. Lucigen also satisfies international commercial demand for modified luciferase.

Porton Plasma Innovations Ltd

P2i Ltd's plasma surface coating process gives everyday products extraordinary levels of oil and water repellency. An ultra-thin P2i plasma surface enhancement can be applied to fully assembled products, even complex 3-D structures made of different materials. The P2i followed on from targeted government research in using pulsed radio frequency energy to activate chemicals for them to deposit on articles. The surface of the object gains the properties of the plasma (eg. water-repellence) leaving the other, desirable properties of the object unchanged.

QinetiQ

pSiMedica

Established by QinetiQ to exploit BioSilicon™. The company has since come under the ownership of the global pSivida company. DERA developed BioSilicon™ through MOD-funded work to produce light emitting devices in silicon material. The work focused on creating porous nano-structures in the material and achieved considerable success, although not as a usable device. However, the biocompatibility and biodegradability properties of the material were recognised and the material has significant applications in the medical and pharmaceuticals industries. Its first application, which is in advanced stages of clinical testing, is in silicon-based brachytherapy for the treatment of liver cancers and many more uses are envisaged.

ZBD Displays

ZBD spun-out from the DERA in July 2000. It has developed a novel bi-stable Liquid Crystal Display (LCD) that offers very low power, which coupled with improved optical performance can be used in a range of devices such as mobile phones, PDAs, electronic books, smart cards or labels (picture shows a battery-less price display similar to those being trialled by John Lewis and Tesco). The first LCD was invented at the Royal Signals and Radar Establishment (RSRE) Malvern site in 1972 (the forerunner of DERA & QinetiQ) and each important development in LCD technology has been pioneered in Malvern.

Quintel Technology

A joint venture between QinetiQ and the Consensus Business Group. It exploits technology, again developed at QinetiQ Malvern and its forerunners like the Royal Signals and Radar Establishment (RSRE), to allow mobile phone operators to share antennas allowing operators to roll out 3G and limiting the size and number of new antenna masts. The solution also allows operators to take advantage of new optimisation freedoms. For example, an operator can optimise different service layers through the use of independent tilts for each service, all from one antenna. O2 has recently replaced its 3G antenna at Trentham in Staffordshire with the Quintel solution to enable coverage for 3 and Vodafone as well as itself.

Aurix

aurix experts in speech

Established as a joint venture between QinetiQ and NXT to exploit speech recognition techniques and concepts originally developed under MOD funding by DERA and its predecessors for voice activated control in defence systems. The technology is now being exploited in a variety of legal, security and defence markets as well as commercial call-centre type scenarios.

Sybard

QinetiQ SyBard::®

A group of software products developed by QinetiQ that provide management support for securing the Microsoft Windows™ desktop environment by controlling the release of information from an IT system. A large number of customers now use it in securing IT systems. The technology is based on QinetiQ's expertise in secure network and software development, built up over years of investment by MOD in DERA and its forerunners.

Sepura sGPS

Sepura is not a spin-out company but an independent company that has exploited QinetiQ's high-sensitivity Global Positioning System technology for the new Police TETRA radio system. QinetiQ's expertise in GPS was developed through years of MOD funded research and has enabled receivers to be produced that are a 1000 times more sensitive than existing systems. These can gather position data in areas that were problematic with standard GPS, such as built-up urban areas and offer a fast time-to-fix capability, a critical factor when dealing with such defence issues as missile tracking. The characteristics of the QinetiQ GPS technology has led to a focus on civil defence, and Sepura's TETRA hand-held police radios now incorporate the QinetiQ low signal strength GPS module. Over 90,000 QinetiQ GPS units are now deployed in TETRA radios used by UK police forces and other international public safety organisations.

Produced by DGMC DEF PR Publicity on behalf of
The Science and Technology Capability and Alignment Study Team
Published by Ministry of Defence UK
© Crown Copyright 09/06 c3