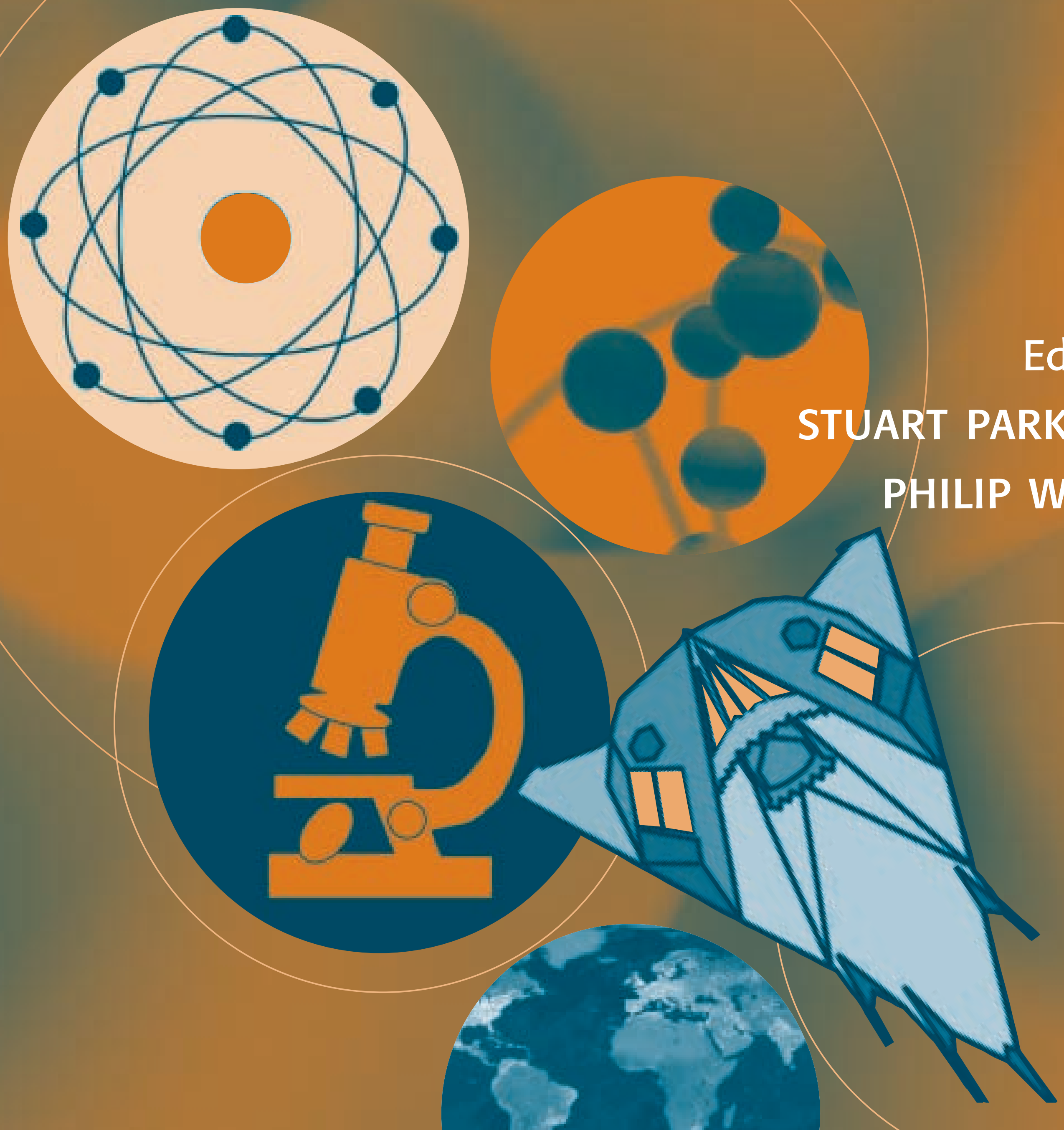
Scientists for Global Responsibility

SGR
Promoting ethical science and technology

Soldiers in the Laboratory

Military involvement in science and technology –and some alternatives

by CHRIS LANGLEY



Edited by
STUART PARKINSON
PHILIP WEBBER

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SGR
PO Box 473
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Chris Langley
Stuart Parkinson
Philip Webber

October 2004

CONTENTS

Acknowledgements 3

About the author and editors 7

Executive Summary 8

INTRODUCTION 11

A brief history of military science and technology 11
The military science and technology sector today 11
The changing face of conflict 12
Global social and environmental issues 13
Change of goals—corporate influence in science and technology 13
Raising ethical questions 13
Growing public concern 13
Structure of the Report 14
References and further reading 14

CHAPTER ONE: Science, engineering & technology—a background 15

KEY POINTS 15
1.1 Introduction 15
1.2 Science, engineering & technology—which way to go? 16
1.2.1 Science in action—tools and methods 16
1.2.2 A loss of freedom 17
1.2.3 Science in the park 17
1.2.4 Science parks—a question of culture 18
1.3 The pace of change quickens 18
1.3.1 A question of Foresight 19
1.4 Privatising the universities—its impact 20
1.4.1 Corporate involvement– some examples 20
1.4.2 Universities and Intellectual Property Rights 21
1.5 Military interests & national priorities 22
References and further reading 22

CHAPTER TWO: The military machine—some facts & figures 24

KEY POINTS 24
2.1 Introduction 24
2.2 Some facts & figures 25
2.3 The role of the military machine 26
2.4 The pursuit of peace 26
2.5 The military & power 27
2.6 Military power and the role of science & technology 28
2.7 The military world—the human cost 28
2.8 Weapons—a global business 29
2.9 Environmental impact of the military 29
2.10 The military world—some future prospects 30
2.11 The ultimate security 30
References and further reading 31

CHAPTER THREE: The military investment and presence in science, engineering and technology ... 33
KEY POINTS ... 33
3.1 Introduction ... 33
3.1.1 A changing landscape ... 34
3.2 UK government military spending and SET ... 34
3.3 The UK military industry and SET ... 37
3.3.1 Military interest groups and the SET agenda ... 38
3.4 Military sector R&D and 'spin-out' ... 39
3.5 The changing face of government military R&D ... 41
3.6 The military sector and university collaboration ... 42
3.6.1 The Joint Grants Scheme ... 42
3.6.2 Consortia and partnerships ... 43
3.6.3 Military corporations and the universities ... 45
3.7 Military influence and SET–the international dimension ... 46
3.7.1 European Union and SET research ... 46
3.7.2 The NATO Science Programme ... 47
3.7.3 US Government funding of UK SET ... 48
3.8 The influence of the military–a complex terrain ... 48
References and further reading ... 48

CHAPTER FOUR: Case studies of military science and technology ... 50
KEY POINTS ... 50
4.1 Introduction ... 50
4.2 The influence of US military policy ... 50
4.3 Case studies ... 51
4.3.1 Case Study 1: Biological sciences and the military ... 51
4.3.2 Case Study 2: Nanotechnology - from nanotubes to the battlefield ... 54
4.3.3 Case Study 3: Missile Defense and the securing of dominance ... 56
4.3.4. Case Study 4: A new generation of nuclear weapons ... 60
4.4 The need for a paradigm shift towards global security ... 61
References and further reading ... 62

CHAPTER FIVE: Science and technology and a broad global security agenda ... 64
KEY POINTS ... 64
5.1 Introduction ... 64
5.2 Some examples of new approaches to security ... 65
5.2.1 Peace and disarmament–some initiatives ... 66
5.3 Poverty and security ... 66
5.4 Global climate change ... 67
5.4.1 Health and climate change ... 67
5.4.2 Mitigating climate change–the role of science & technology ... 68
5.4.3 Climate change–a call to action ... 70
5.5 Investing in the future–a shift in perspective ... 70
References and further reading ... 70

CHAPTER SIX: Conclusions and recommendations ... 73
6.1 The main arguments ... 73
6.2 What would be appropriate military involvement in SET? ... 73
6.3 Responsibility and the individual scientist or engineer ... 74
6.4 Recommendations ... 75
References and further reading ... 76
Abbreviations and Acronyms ... 79
About SGR ... 81

About the author

Chris Langley holds degrees from University College London and the University of Cambridge. After post-doctoral research in neurobiology at Cambridge he has spent more than twenty years in science policy and the communication of science and medicine. He currently runs ScienceSources, an independent consultancy, which provides access to science, engineering and technology to the non-profit sector. He has produced a number of critiques of current science and medicine for lay and professional audiences.

About the editors

Stuart Parkinson is Director of Scientists for Global Responsibility (SGR). He started his career as an electronic engineer working for a military corporation, before ethical concerns led him to return to university to do a PhD in climate science. He has since carried out scientific research and education work across a range of areas including climate change policy, energy and the environment, science and ethics, environmental inequality, and science policy. He has been an expert reviewer for the Intergovernmental Panel on Climate Change, and is co-author of the book '*Flexibility in Climate Policy*' and the booklet '*An Ethical Career in Science and Technology?*'

Philip Webber has written widely on defence and ethical issues in relation to science and technology. His publications include the books '*London After the Bomb*', '*Crisis over Cruise*' (both co-authored) and '*New Defence Strategies for the 1990s*', and several pamphlets and scientific papers. Dr Webber has been Chair of SGR for ten of the last twelve years and is head of a leading environment unit in Kirklees, West Yorkshire. His career also includes a spell as Deputy Director of Emergency Planning, South Yorkshire, and 12 years as a research scientist at Imperial College, London, where he gained his PhD.

EXECUTIVE SUMMARY

Overview

Military technology has contributed centrally to the shaping of the world in which we live. The economic and political dominance of the industrialised countries is in part the legacy of innovations in military technology in Europe and later in the USA. The power and range of military activities is, in a variety of ways, closely linked with the expertise of scientists, engineers and technologists engaged in or funded by the military sector.

The main purpose of this Report is to document the power and influence of the military in the governance and direction of science, engineering and technology in the UK over the past fifteen years. A great deal of the discussion is concerned with the implications for research and development (R&D). We find, however, that teaching, including at the postgraduate level, and public attitudes are also both influenced in various ways by military involvement with, and support of science, engineering and technology (SET).

The report also examines whether some reallocation of the resources that the military currently devotes to weapons-related SET would contribute better to the goals of peace, social justice and environmental sustainability. In exploring this issue, we consider the argument that the concept of security can be more broadly defined, so as to include measures to forestall many of the pressing challenges facing the world today, such as climate change and a range of poverty-related issues.

It should be noted that a lack of openness in this area, often unrelated to national security concerns, has hampered attempts to gather information in some areas.

Background—the science world and the military world

During the last fifteen years, wealth creation has become the major driving force for investment in science, engineering and technology (SET), as exemplified by the UK's ten year science and innovation investment strategy published in 2004. This commercial agenda has led to a plethora of R&D partnerships and funding initiatives, which in turn frame the directions and priorities of the research itself. This agenda also underpins significant involvement from the military sector.

Profound global changes have affected military and security issues over this period. The advent of the 'War on Terror' has reversed the drop in military expenditure that followed the end of the Cold War. Global military expenditure in 2003 stood at a massive US$956 billion, with the USA accounting for over 40 per cent of this. The UK is also a major military power, and is the world's third largest military spender.

An increasing emphasis on high technology weaponry among the wealthier countries is contributing to a narrow approach to dealing with security issues. Currently, the Ministry of Defence (MoD) only spends approximately 6 per cent of its budget on conflict prevention. Meanwhile, there is growing evidence that the international arms trade is contributing to conflict and exacerbating human rights problems and poverty.

Military involvement with science, engineering and technology

Our investigation has uncovered a wide range of information about military involvement with SET. Such involvement is concentrated in a fairly small number of countries, with the USA dominating. For example, in the European Union, the UK, France, Spain and Germany accounted for 97 per cent of the total government military research budget in 2000. The UK itself is the world's second largest funder of military SET. In 2003/04, the military spent approximately £2.7 billion on UK R&D. £2.6 billion of this finance came from the MoD - 30 per cent of the total public R&D budget. Furthermore 40 per cent of government R&D personnel are employed by the MoD. The procurement of advanced weapons technology is also a major component of state expenditure, with the UK Defence Procurement Agency spending approximately £6 billion a year on military equipment.

A small number of military corporations in the UK exert a largely invisible influence on the government. Through a complex array of advisory committees and lobby groups, they have a significant voice in the funding and shaping of the research agenda. Lockheed Martin and BAE Systems - two of the largest military corporations in the world - have a major presence in the weapons laboratories of the UK and USA. They also support work across many disciplines and fields within science, engineering and technology for military objectives.

In addition, the military sector supports emerging technologies such as space technology and the nanotechnologies, enjoying a large-scale effect on the direction of their development.

A number of new multi-million pound collaborations between the military sector and the universities have been created in the UK in the last few years. The three main initiatives are Defence Technology Centres, Towers of Excellence, and Defence and Aerospace Research Partnerships. All reflect a narrow technological approach to security issues.

Science and technology and a broad global security agenda

The world today faces a range of social and environmental problems, many of which have an impact on security. Poverty, lack of access to basic resources such as clean water and sanitation, and global climate change represent urgent problems. Furthermore, unsustainable levels of resource consumption by the industrialised world can contribute to a range of international problems, at times including conflict.

Our investigations show that SET programmes in conflict prevention, poverty alleviation, and environmental protection often yield clear benefits for relatively little cost, yet these areas get a fraction of the budget allocated to military technology. Disarmament and peacebuilding initiatives also tend to be smaller scale. Equally, R&D budgets for renewable energy technologies, essential to tackle the threat of climate change, are dwarfed by budgets for the development of weapons technology.

Principal conclusions

There are seven main conclusions which have arisen as a result of the research undertaken for this Report concerning the military influences on SET. These can be summarised as:

1. The military sector, especially in the UK and USA, has a very large and disproportionate effect on science, engineering and technology. The UK-US 'special relationship' (largely based on a 1958 treaty, which was renewed in 2004) further drives military R&D which has profound social and ethical implications.

2. Current military thinking is based predominantly upon the idea of security through the superiority of military force, and marginalises broader concepts of security based on social justice and environmental sustainability. This affects which areas in SET are funded by the military.

3. The UK government policies which have shaped SET over recent decades have moved commercial priorities centre stage, and military corporations have played a large part in this process.

4. Military and commercial pressures compromise openness and accountability in SET, for example, through the use and overuse of commercial confidentially and national security arguments. This can stifle debate and dissent over ethical issues in SET. In general, public scrutiny of SET in the UK, including its funding and direction, is weak.

5. Military support of emerging technologies such as the nanotechnologies is high (especially in the USA). This imposes barriers to full public scrutiny of these technologies and colours the public perception of the potential usefulness of such technologies.

6. Technology transfer from military-supported R&D to civilian use is a complex and expensive route which has, to a large extent, been disappointing in view of the massive investments involved.

7. Areas such as peace-building and sustainable development are currently underfunded, and would benefit substantially from an expansion of SET expertise paid for by a reallocation of proportions of military budgets.

Furthermore, we make eight additional conclusions:

8. Global security today faces more challenges from terrorist groups than from nation states. However, the use of essentially Cold War-type strategies and technologies (and the R&D that supports them) in the industrialised countries does not significantly address these needs.

9. Globally, military spending on equipment procurement and R&D not only can divert resources from, for example, health or poverty alleviation programmes, but can also contribute to arms proliferation and refugee crises globally.

10. A broader interpretation of security is called for which takes account of global issues such as climate change, resource depletion, loss of biodiversity and an array of human health problems. Some redirection of the global 'defence' burden to underfunded areas (many with a SET component) such as renewable energy and climate change mitigation would significantly assist in the development of these areas.

11. The development of a new generation of nuclear weapons, by US and probably UK weapons laboratories, is likely to compromise security through the undermining of the Nuclear Non-Proliferation Treaty. Nuclear weapons create a climate of fear and send a strong message to other countries who do not yet have them that possession of nuclear weapons is a desirable and acceptable security objective. Furthermore, new, so-called 'bunker-buster', low-yield nuclear weapons are likely to blur the distinction between conventional and nuclear war.

12. Areas such as space science and the biosciences have become 'militarised' in the USA. This has influenced, and potentially downgraded, the priority given to other areas such as research to produce low cost therapeutic agents, energy efficiency and strategies for urgent climate change amelioration. These effects originating within the USA ramify across the world essentially because of the country's pivotal role in SET.

13. A number of consortia have been launched over the past three years in the UK which involve the military corporations, government departments and the universities. These forms of collaboration have a largely military agenda for research. Such an agenda has not been sufficiently scrutinised for its social and ethical implications.

14. Intellectual property rights and patents are highly contentious areas within university-industry collaboration, especially given the new consortia involving the military corporations, and clear guidelines need to be implemented to safeguard individual and public utility.

15. There is a pressing need for a much wider public debate over the direction which science, engineering and technology is taking in the UK (as currently laid out in the 2004-2014 investment strategy), taking particular account of the role of the military sector.

Recommendations

Based on the extensive evidence which we have assembled in this Report, we make a series of recommendations which address the concerns we have identified. They are divided into three groups according to the audience to which they are addressed: the UK government; professional scientific and engineering institutions and publishers; and individual scientists and engineers.

Recommendations to the UK government

1. Divert a large fraction of current UK military R&D funds to addressing wider issues. To redress the disproportionate involvement of the military in publicly-funded SET, the government should begin a rapid and significant shift of funding from military R&D to civil R&D which contributes to peacebuilding, addressing environmental problems and alleviating poverty at a national and international level. A public review should be conducted to decide on exact levels and timescales but, as a first estimate, we recommend a shift in funds of the order of one-third to one-half of the current military R&D budget in the near term. Such a review should be part of a re-examination of current priorities in UK SET - with widespread public involvement - which was broadly lacking in the drawing up of the recent ten year science and innovation investment strategy.

2. Restrict military involvement with R&D of emerging technologies. Ministry of Defence funding for emerging technologies such as nanotechnology should be less than ten per cent of that from civil public funds. Military involvement should not restrict full public scrutiny of such areas. The UK government should call on the USA and others to follow suit.

3. Enact procedures to make Ministry of Defence funding of R&D far more transparent and open to public scrutiny. Organisations receiving MoD funding whether directly or indirectly (eg through the Defence Science and Technology Laboratory or QinetiQ) should be required to publicly acknowledge the source, its extent and purpose.

4. Devote more resources to implementing a far more inclusive concept of security within policy. Such a broadened concept would place social justice, peace and environmental sustainability at the centre of considerations of security. Such an approach would lead to the Ministry of Defence relying to a much lesser extent on the development and implementation of military technology and the use of force, and a much greater support where SET and other activities can contribute to peacebuilding and non-violent conflict resolution.

5. Conduct a full and transparent review of the 1958 Agreement for Co-operation on the Uses of Atomic Energy for Mutual Defence Purposes (renewed in 2004) and all other military agreements between the USA and the UK. Such agreements are a powerful driver of new nuclear and other military technologies and have not received full Parliamentary scrutiny or public discussion.

6. Cease all scientific and technical work related to the design and development of new nuclear weapons. Call on the USA and other nuclear powers to do the same. As a signatory to the Nuclear Non-Proliferation Treaty, the UK has agreed to pursue global nuclear disarmament, yet it is making little effort to do so. The UK government should be leading international efforts to make rapid progress in this area.

Recommendations to professional bodies, scientific and engineering institutions and publishers

7. Require all academic papers and reports based on work funded by the military (whether government or corporate) to publicly acknowledge this funding and its scale.

8. Strengthen or initiate professional ethical codes to encompass the problems of professional involvement with the military and its current narrow interpretation of the concept of security.

9. Reduce or eliminate financial ties with the military at least until the adoption of the policies recommended above (1 to 6).

10. Lobby for the above changes in government policy.

Recommendations to individual scientists and engineers

11. Educate yourself about any military interest in your field of work and in your institution. Examine whether it is more likely to encourage security policies focused on the use of military force, or security policies based on, for example, the tackling of the root causes of conflict.

Either

12. Engage with military interests to try to encourage a shift in the way they use the work to a more holistic security perspective.

Or

13. Avoid working with the military altogether and choose a scientific/ engineering post which provides civil benefits to society, for example, by helping to address social and/ or environmental problems.

14. Support lobbying for the above changes in government policy.

15. Encourage discussion of these issues in your institution and within the appropriate committees or boards of your professional associations.

The open society, the unrestricted access to knowledge, the unplanned and uninhibited association of men for its furtherance - these are what may make a vast, complex, ever growing, ever changing, ever more specialized and expert technological world, nevertheless a world of human community

from Oppenheimer (1953)

INTRODUCTION

The main purpose of this Report is to document the power and influence of the military in the governance and direction of science, engineering and technology in the UK. A great deal of the discussion is concerned with research and development (R&D). We find however that teaching, including at the postgraduate level, and public attitudes are also both influenced in various ways by military involvement with and support of science, engineering and technology (SET).[1]

The Report also examines whether some reallocation of the resources that the military currently devotes to weapons-related SET would contribute better to the goals of peace, social justice and environmental sustainability. In exploring this issue, we consider the argument that the concept of security can be more broadly defined, so as to include measures to forestall many of the pressing challenges facing the world today, such as climate change and a range of poverty-related issues.

The main focus of this Report is the UK situation since the end of the Cold War in 1989. We put the position of military funding in the UK into a global context and refer to other countries, especially the USA, where appropriate. Military involvement in and influence on science, engineering and technology is complicated but extensive. We attempt to identify the main concerns, in detail where possible, over the past fifteen years or so. Collaboration between the military sector and those engaged in research and development has a far longer history. The sweeping socioeconomic changes which have occurred in global society, especially over the last century, have impacted both upon the nature and practice of SET and the military and security agenda, which in turn also influence each other.

What will be clear from even the most casual reading of the Report is that this area is both complex and at times difficult to unravel. A lack of openness has hampered our attempts to gather information. We should also point out that the influence of the military on SET in the UK has not been the object of sustained investigation for many years - indeed this was one of the motivating reasons for undertaking this study - and so, to set the scene, we have included extensive background material, so that the reader may gain a greater understanding of the issues as a result of a better appreciation of their context.

In addition, the report makes a number of conclusions and recommendations about the role of SET in today's world, especially commenting on its direction and funding. We also raise a number of points about security in the 21st Century.

A brief history of military science and technology

Military technology has contributed centrally to the shaping of the world in which we live. One of its central features, the dominance of the industrialised countries of the 'North' over the developing countries of the 'South', is in part the legacy of innovations in military technology in Europe and later in the USA (MacKenzie and Wajcman 1999). Such an imbalance of power is still present.

Interactions between scientists and the military have a long history. Both Galileo and Da Vinci, for instance, contributed to military technology in their time. The First World War boosted SET, particularly in the fields of aviation, medicine and radio, which all had peaceful as well as military applications. Industrial research in chemicals and other science-based industries also benefited from the government's wartime support (Hartcup 2000). In Britain the Department of Scientific and Industrial Research was set up in 1915 to advance trade and industry. It included the Radio Research Board, which supported the First World War development of radar. In the USA the National Advisory Committee for Aeronautics was founded in 1915 before the USA entered the war. In 1918 the National Research Council was created to support research in both military and peaceful uses of science.

Closer collaboration between scientists, engineers, technologists and the military really began in earnest during the Second World War (Hartcup 2000). From 1939 onwards, achieving technological 'improvements' in weaponry became an abiding concern in the majority of the industrialised countries of the world. MacKenzie and Wajcman (1999) point out that at the height of the Cold War arms race as much as 40 per cent of research and development effort worldwide was devoted to military technology.

The military science and technology sector today

The Cold War 'victory' of the West has left the USA with global supremacy in economic and military terms. As we will see in Chapter two, the US spends over 40 per cent of the world's military budget, is home to five of the top six military corporations and is by far the largest government spender on military R&D. However, the terrorist attacks of September 11th, 2001 brought home a stark reminder that security is not just about the strength of military forces or the advanced nature of weapons systems. Nevertheless, with the declaration of the 'War on Terror', world military spending rose for the first time since the end of the Cold War to reach a massive $956 billion in 2003 (SIPRI 2004).

The UK, with its 'special relationship' with the USA, has mirrored some of the military trends of its larger compatriot, albeit on a more modest scale. It is the world's third largest military spender (see section 2.2), is home to the largest military corporation outside the USA (BAE Systems), and has the world's second highest level of government spending on military R&D (Smith 2003).

In 2003/04, approximately £2.7 billion was spent by the military on UK R&D: £2.6 billion coming from the Ministry of Defence (MoD) - this being 30 per cent of the total public R&D budget for that period - and in the region of £100 million from military corporations (see Chapter three). The government employed 29,677 R&D personnel in 1999-2000 of which 12,047 (40 per cent) were employed by the MoD (www.ost.gov.uk/setstats). The procurement of advanced weaponry is also a major component of state expenditure, with the UK Defence Procurement Agency spending approximately £6 billion a year on military equipment. It is also noteworthy that in 2003 the MoD overspent £3.1 billion on major projects (www.nao.gov.uk).

The Box gives some comparative information on military R&D for selected industrialised countries.

–Government military R&D spending in industrialised countries

Total European Union government military R&D expenditure is largely represented by a small group of countries. In 2000 for example the UK, France, Spain and Germany accounted for 97 per cent of the total government military research budget for the EU (Euros 8.9 billion in 2003 values). The 'defence' R&D as a proportion of the total government R&D was highest in the UK (33 per cent) followed by France (23 per cent); this proportion is less than 0.5 per cent in Austria and just over 1 per cent in Finland and Portugal (www.oecd.org - November 2003).

To put these figures into context the US government spends more than half its total R&D budget on the military. In the 2004 Department of Defense Budget allocations, the Department received the second-largest increase in history for its R&D budget to US$62.8 billion which represents an increase of US$4.2 billion, with all of the increase going to the development of weapons systems (Koizumi 2004).

Together with the USA, France and some others, the UK government retains a strong commitment to supporting industry at the forefront of military technological development (Molas-Gallart 1999). The resultant corporations are powerful and significant employers, especially of scientists and technologists. BAE Systems in the UK is the fourth largest military contractor in the world with annual sales across 130 countries of £15 billion (see section 2.8). Such industries have a marked influence on government and the framing of security debates as is described in Chapter three.

One of the concerns we examine in this Report is the way in which close collaboration between military industry, government and researchers can lead to a narrow security agenda, with too great an emphasis on military technology. For example, some have warned that overemphasis on technology like 'smart' weapons may lead the public and policy makers to have overly high expectations about the ability to 'win advantage' without incurring loss of life in one's own armed forces or the civilians in the conflict area. A further assertion is that such technologies could also lead to less attention being paid to diplomacy and political factors that could have an influence on how international disputes are tackled (see Byman and Waxman 2002).

These concerns have become especially pertinent since the election of President George W. Bush in 2000. The neo-conservative policies pursued by Bush's administration since coming to power, and especially after the September 11th attacks, have focussed on a unilateralist security agenda with the use of military force playing a very prominent role. SET budgets in the US have reflected this with large increases in military R&D and cuts in, for example, environmental work (Brumfiel 2004). We discuss the effects of US policies on UK SET on several occasions in the Report, especially in sections 4.2 and 4.3.

The changing face of conflict

The basic rationale for military forces is that they play a key role in insuring against armed threats facing nations. Increasingly, however, the majority of such threats are within rather than between nations. Following the end of the Cold War the number of major armed conflicts (such as civil war and inter-state conflict) declined from 37 in 1990 to 21 in 2002, with the hostility between India and Pakistan being the only remaining inter-state hotspot. In total, between 1989 and 2002 there were 58 different major armed conflicts in 46 different locations across the globe (SIPRI 2003). The post-September 11th changes to military policy appear to have had a direct impact on most of the conflicts which occurred in 2002 and 2003.

It has been estimated that just over three million people were killed by war between 1997 and 2002 (Smith 2003). Due to the shift from inter-state conflicts, which generally involve regular armed forces, to civil wars, which more often involve irregular forces, there has been a major increase in the proportion of civilian casualties. Around 75 percent of those killed in wars today are civilians - there being no reliable data on how many are wounded and disabled by war. In addition famine and economic dislocation after conflict also disproportionately affect civilians (*ibid*).

The nature of international warfare is relevant to those working in military SET due to the globalised nature of the industry. Despite a range of treaties and codes of conduct, many weapons manufactured in the UK and other industrialised nations still find their way (both legally and illegally) to conflict zones, and there is concern that international sales drive weapons proliferation more generally. We discuss this issue further in Chapter two.

The predominant armed threats today to industrialised countries such as the UK and USA are terrorism and disruption of resource flow such as oil. The extent to which these security threats can be dealt with using military force dependent on high technology is a moot point, and an issue that recurs throughout the Report.

Global social and environmental issues

The world today faces a range of social and environmental problems. As well as being pressing issues in their own right, many of them can be seen in terms of a broader concept of security as we discuss in Chapters two and five.

The United Nations Development Programme statistics of poverty and deprivation highlight the extent of the problem. In 1999 the share of the income of the poorest 20 per cent of the world's population had halved since 1960. The numbers of those who have incomes of less than US$1 a day, who lack access to clean water, and who die before they reach the age of 40, each exceeds one billion. Nearly as many, around 800 million people, suffer from various degrees of malnourishment (UNDP, 1999). In 2000, the developing countries' debt amounted to almost US$2,000 billion. As a comparison, world military spending that year was approximately US$810 billion (Smith 2003).

In addition, environmental problems are becoming increasingly urgent, with serious impacts on human populations (UNEP, 2002). Local and regional damage from industrial expansion, mining and deforestation are affecting greater numbers of people and ecosystems. Meanwhile, emissions of greenhouse gases are causing global climate change. The impacts of this, which include increased flooding and other severe weather events and disruption to water supplies and agriculture, will particularly affect the most vulnerable, i.e. those in poverty and endangered wildlife. Environmental problems create refugees, which causes yet further problems.

As we discuss in Chapter two, these effects can be contributing factors to conflict, including terrorist activities. The expansion of the traditional concept of security such that it encompasses security of access to basic resources (eg food, water, shelter, a clean environment) can affect policy responses to these problems. This can be especially important in countries where military demands for resources are prioritised over social needs. The policy approach to security can also change how scientific research and technological development is directed and used. We study examples of SET being used to tackle security problems in a broader way in Chapter five.

Change of goals—corporate influence in science and technology

An important dimension of the discussion presented in this Report is the radical change which has occurred over at least the last fifteen years in the way research worldwide is funded and directed, especially as a result of increasing economic globalisation. As we outline in Chapter one, commercial interests have increasingly penetrated all areas of SET, with industrial representatives now occupying positions of influence in the governance of research and teaching within universities. Many of the world's science and technological research programmes are directed and funded, or are influenced by, major corporations (Senker 2003).

This change has shifted the priorities within SET. Wealth creation is now accepted as a major goal, as demonstrated in the UK's recently released ten year science and innovation strategy (HM Treasury *et al* 2004). There is concern that these interests focus SET too narrowly, sidelining work which has wider social and environmental goals. Moreover, when corporations have military interests, this can have a significant impact on the type of security-related SET which is prioritised.

Raising ethical questions

Military involvement poses a unique ethical question for scientists and engineers. It is the only situation in which their skills will have a central role in developing technologies whose aim is to kill others, or otherwise support a war-fighting capability. Given the controversy over recent conflicts, such as that in Iraq, and the international arms trade, the question as to whether to be involved with military work goes beyond the simple issue of 'defence of the realm', as we shall see throughout the Report, especially in Chapter six.

Another query hanging over military SET is the extent to which it can lead to civilian 'spin-out' technologies. There are some cases where civilian use has followed from military investment, for example, radar and flat screen technology. However, one must balance the value and usefulness of the civilian products against the level of the original military funding and the costs and complexity of 'spin-out' (see section 3.4), as well as wider concerns about military technology. Related to this is the issue of dual-use technology, i.e. that which has both military and civil applications, and can potentially allow the proliferation of weapons-related know-how. There are further related issues concerning the military's major involvement in cutting-edge technology such as nanotechnology (see Chapter four).

A further important consideration is the way in which SET is viewed by the public. To have too close an association with the military, and more specifically weapon technologies, may harm science's public image. This is especially pertinent given growing concerns about the negative aspects of SET, including situations where it contributes to environmental damage and ill-health, which may have impacts on the recruitment of new scientists or engineers, already markedly down in recent years.

Growing public concern

Between the end of the Cold War and the September 11th attacks, there was only limited sustained public or media debate about the general desirability and effects of weapons technology. While the impact of, for example, land mines on civilian populations and especially children had considerable coverage at times (and led to the Ottawa Treaty banning them), issues such as the UK's nuclear weapons or our high military spending received much less attention. Attempts by campaign groups to get the government to address ethical concerns about, for example, the UK role in the international arms trade have had only limited success (Wheeler and Dunne 2004).

However, with the declaration of the 'War on Terror', and especially the US government's pursuit of a pre-emptive military policy over Iraq (supported by the UK government), public concern about our military and security policies has been heightened. As yet the influence on and role of SET in these issues has received little direct attention. This Report is an attempt to fill such a gap.

Structure of the Report

Chapter one gives background on the contemporary UK science and engineering base: how it operates; its structure; and the various changes in policy and funding which have occurred over the last fifteen years. It highlights the growing role of industry and business within SET, and the consequent effects.

Chapter two offers an overview of the 'military machine', its costs and various examples of armed intervention. It examines the concern that a weapons-based agenda is too influential within military and security thinking, and discusses broader interpretations of 'security'.

Chapter three deals with the involvement of the military sector in research and development and the structures that result from or support that involvement. It describes the changes which have resulted in a drive toward privatisation of Ministry of Defence in-house R&D establishments. It also examines the role of the military corporations, and their associated lobby groups as well as critically assessing recent attempts to 'spin-out' military technology into civilian sectors.

Chapter four details four case studies in which significant links between the military sector and R&D can be demonstrated: biological sciences; nanotechnology; Missile Defense; and new nuclear weapons. It looks at how the research agenda has been affected, and highlights concerns. The case studies demonstrate the degree to which US military SET policy influences that of the UK.

Chapter five presents a number of examples of where SET funding has been used and/ or is needed to provide a broad-ranging response to security needs. The examples include disarmament and conflict prevention, access to clean water and sanitation, and global climate change mitigation. Comparisons are made between the funding available for this work and military budgets.

Chapter six summarises the Report's conclusions and presents recommendations. It examines some of the key arguments about what might be an 'appropriate' level of military involvement in science, engineering and technology, and discusses the importance of SET's broader contribution to society. It also briefly examines the role of the individual scientist or engineer. Three sets of recommendations are presented for three audiences: policy-makers; professional scientific institutions; and individual scientists and engineers.

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NOTES

1. In this Report we use the official term of 'science, engineering and technology' or SET.
2. For a relative comparison of the military and social expenditure of different countries, see web.sipri.org.

CHAPTER ONE

Science, engineering and technology—a background

"A just and healthy society must include forces within it which provide alternatives to the state's provisions and which may contradict its policies . . ."

from Mullin (2000)

KEY POINTS

- Science, engineering and technology (SET) are powerful knowledge-based systems with a complex culture and their products are moulded by the society in which they are located. Funders of research can influence the research direction in often significant ways.
- SET has undergone marked changes in the last twenty years especially in how funds are provided and the rationale for research funding. Commercial objectives now occupy centre stage. Although some commercial components with directed goals have featured in SET research for many years, the pace and extent of industrial involvement is now intense.
- The increasing commercialisation of SET has had a profound impact on the enterprise of science with less openness, more of the research agenda focussed on economic goals, and questions about intellectual property rights and other contractual obligations looming large.
- Commercial partnerships have a marked tendency to import a skein of commercial values including secrecy, poor public accountability and a less open attitude to inquiry in universities and other public institutes.
- The military sector is a major player in the commercial partnerships in SET supported by government.
- Support of scientific research by the military may reduce the diversity of research approaches and/ or impact negatively on innovation.
- The reduction in diversity of impartial advice from public research institutes including the universities in areas such as energy, security, transport and communication compromises an open and democratic society.

1.1 Introduction

In order to understand the possible influences of the military on science, engineering and technology (SET)[1] it is necessary to look, in detail, at the contemporary worlds of both SET and the military sectors. This chapter explores the ways in which SET has changed and its funding has altered over the recent past, and includes a brief description of the role of science and allied disciplines in our modern world. The next two chapters go on to describe the military sector and its interactions with SET.

SET are very powerful knowledge-based systems, possessing a highly complex 'culture' and embedded within a much wider social structure. They are backed by powerful and influential professional organisations - such as the Royal Society in the UK and the National Science Foundation in the United States, which tend to support a conservative set of values and methods. The products of SET may be seen all around us. SET and its processes of discovery leave no aspect of our lives untouched (Webster 1991, Richards 1987).

The products of SET are potentially capable of negative or positive effects, from nuclear weapons, landmines and the production of climate-changing greenhouse gases to medical interventions, clean water and low pollution sources of energy. Technology and engineering are assumed to make use of the knowledge which 'trickles' down from science.

Science and technology also play a significant part in forming our attitudes to the world. In a less obvious way, these attitudes can have effects just as powerful as the products themselves. Scientific 'facts' are often regarded as being completely objective, the result of presumed value-free investigation, and it is forgotten that such facts come wrapped in a social and often quite personal garb (Richards 1987). The world of scientific investigation has changed greatly over the past twenty years. The nature of research undertaken has changed too but so have the funding policies which have supported it, and the institutions in which it is practised. During this same period the expectations of the public and policy makers towards SET have also altered in radical ways. John Ziman in his seminal book *Prometheus bound: science in a dynamic steady state* has shown what these changes consist of and says:

> *"Science is going through a radical structural transition to a much more tightly organised, rationalized and managed social institution; knowledge-creation, the acme of individual enterprise, is being collectivised"* (Ziman 1994).

This process of collectivisation - where often very large teams of scientists and engineers work together on a joint project - whilst not new is to be found increasingly within SET. It is a theme running through this Report, especially in the creation of various consortia and centres discussed in Chapter three. The objectives of such collectivised groups include space science, materials and nanotechnology.

Collectivisation has also called for changes in the apparatus of funding in order to support such endeavours. And during the last twenty years a spectrum of 'partnerships' has evolved comprising university staff and industrial players. Such groups can be either formal or very informal - exchange of ideas, methodologies and material being open or limited (Stewart 1999) - and are not novel; the Manhattan Project which created the first atomic bomb involved such collaborations with defined research goals.

Furthermore, by the 1990s most major OECD countries had entered an era of 'steady state' science, an environment in which government funding was reduced (Ziman 1994).

Great debate has raged over the past fifteen years about the precise nature of the scientific process and the place within our society of science and to some extent technology. Some argue that such products and approaches are the result of a 'higher', more rigorous process, towards a world filled with concrete objective 'things'. Others maintain that science is merely *one* of a variety of alternative approaches to the world based on human agency and does not need to be treated in ways which differ from literature or the arts. Such heated debate has been dubbed the 'Science Wars' and is discussed in a number of volumes including those of Mulkay (1979), Gilbert and Mulkay (1984) and Ziman (2000). But regardless of one's point of view on the issue of the exact nature of science, it is inescapable that SET possesses significant power for social and environmental change, and such power can be profoundly influenced by an array of external factors not least of which is the funding source and its objectives.

1.2 Science, engineering and technology —which way to go?

The direction of science and technology is big business and resides in the hands of powerful players including governments and, as we will see later, industry. John Ziman has discussed how the way science is undertaken has radically changed in the recent past, and he paints a very vivid picture in his book *Real science: what it is, and what it means* (2000) of the various pressures and ethical conundrums which face those who carry out research in modern society. His broadly drawn landscape of modern SET also captures the other, more practical difficulties of those who collaborate with government or industry and the rise of 'post-academic science' (Ziman 2000, p.65- 66). Those in science, engineering and technology are involved in an undertaking which is value laden, and the practitioners of these disciplines are responsible in large measure for the products and insights of their research.

1.2.1 Science in action—tools and methods

The prevailing scientific culture in the early twentieth century based its activity, in part, on the Enlightenment ideal of freedom to explore the material world without too close a connection with industry. Since Victorian times there was a divide between the academic and the industrial species of science - the latter being heavily dominated by practical issues. It was therefore felt that industrial liaisons would tempt the scientist to concentrate too much on immediate technological concerns rather than more basic and 'pure' scientific issues (Webster 1991). Since the 1970s there has been a move in both the industrial and academic worlds towards a culture in which SET is far more actively directed to meet the needs of business and to assist in the creation of wealth.

There were, so the enthusiasts remarked, a string of examples of the UK's scientific and technological breakthroughs which led to little in the way of economic successes. It was clear to the enthusiasts that such discoveries fell to other countries to exploit economically. Thus, the argument goes, the UK lost out. Much of the drive for closer ties to industrial needs was based on the idea that our global economic position needed the input from those in the universities who were pursuing both 'pure' and 'applied' research goals and in possession of specific expertise.

Obviously there is some truth in such assertions - for instance, the industrial revolution in Europe was firmly based on SET discoveries, and the electronic revolution of the recent past depended on the science of the silicon chip and the resultant technology. But it is also clear that many 'breakthroughs' in science and technology depend upon the disinterested pursuit of fundamental questions - for instance knowledge about the material universe. In addition, the location of the universities – which accommodate the majority of fundamental SET research – within a business culture centred on obvious commercial end-points, has the potential to make the research subjects under study ever more narrowly focused and the methods of research ever more conservative. Enlarging the commercial component of SET at the expense of disinterested research introduces a raft of ethical and practical questions. Issues related to these questions arise – and are addressed – repeatedly throughout this report.

As Ziman has pointed out the freedom to explore fundamental questions in science, the humanities and arts, and to a lesser extent engineering and technology, in a disinterested fashion is a key component of 'academic freedom' - embodied within the idea of the liberal university and the *sine qua non* of academic life for many (Krimsky 2003). Ziman has pointed out that such freedom has been enshrined in the liberal financial patronage of institutions and by tenured employment - a situation which has now almost vanished in the UK. Historically such financial support has not been from a commercial sponsor expecting a profit. Of course, everyone in science, technology or engineering comes with some form of pre-existing agenda, seeking to join a socially structured research community, where even those engaged in 'pure' research will have professional interests (Ziman 2000). 'Academic freedom' has always been subjected to, at times, a rather shaky compromise between 'truth', career and research direction (Ziman 2000). However, the essence of science has been openness with free exchange of ideas, interpretations and a willingness to have ideas and hypotheses challenged (see Krimsky 2003).

Broadly defined, academic freedom is also a key to society's much wider freedoms and liberties. Public engagement with the various practitioners of SET, its products and methods is now more important than ever since science is becoming increasingly powerful in its ability to change the physical world and impact on our lives in often profound ways. Such engagement calls upon all within and outside the SET endeavour to speak openly and without fear of reprisals from a sponsor (Krimsky 2003). Even the Royal Society, up to now a bastion of the scientific status quo, has recently invited public comment on scientific issues (www.royalsoc.ac.uk). Similarly in the area of bioweapons the Society has called for an independent body to give teeth to the international Biological and Toxic Weapons Convention, discussed in Chapter four (Anon 2004).

1.2.2 A loss of freedom

As we will see later, corporate interest in the expertise located within universities and higher education institutes frequently has more to do with enhancing and then protecting profits than with the support of blue skies research or with unravelling the 'truth'. Such corporate support of research raises serious ethical and practical concerns, especially where weapons, human behavioural control technology and surveillance systems are concerned, in particular where they 'spill' over into everyday life. Corporate interests are often felt to be best served by secrecy, a monopoly of intellectual property rights and the removal of those who appear to be dissidents - a world view very different from that of the traditional liberal university and its associated research culture (Krimsky 2003 and Monbiot 2000).

Save British Science, the pro-science pressure group, has in response to the Treasury's Lambert Review of Business-University Collaboration (2003) suggested that "business-oriented research is and should be a relatively minor part of the overall portfolio of university research" (www.savebritish-science.org.uk - accessed 2003).

Monbiot (Monbiot 2000 *op cit &* 2003) has argued that 'academic freedom' has been eroded and compromised in the UK by the spread of business interests and subsequent goals, in particular in the last 20 years. Scarcely any SET department in a UK or US university is now free from some form of corporate presence. The boards and committees of the research councils and government advisory panels often have senior corporate membership. Major corporate interest, especially representing the biotechnology, engineering and the military industries, can be found on the governing and executive committees of various research councils (see especially the recent Annual Reports of the Engineering and Physical Sciences Research Council and the Biotechnology and Biological Sciences Research Council).

1.2.3 Science in the park

The creation of science and technology parks together with university-business partnerships frequently involving foreign corporations may be found throughout the UK. The UK attracts the greatest proportion of US and Japanese research and development facilities in Europe according to the Invest in Britain Bureau, which was set up by the UK government to co-ordinate efforts to gain investment from outside the country (Invest in Britain Bureau 1998).

An example of this is Microsoft's decision to site its first overseas basic research laboratory outside the USA at Cambridge University in the UK. Similarly Hitachi opened a semiconductor device centre at the University's Cavendish Laboratory in 1989 - here the company owns the intellectual property rights enshrined within a formal agreement covering all work done at the Hitachi Cambridge Laboratory and pays royalties to those involved (Christodoulou 1998). A number of reasons have been suggested for this investment trend including the fact that English is widely spoken in the SET community, the low cost of research skills and the high quality of the UK science base (Christodoulou 1998).

Science parks and 'innovation centres' are not new. Heriot Watt and Cambridge set up out-of-town science parks in the 1970s in order to exploit research-intensive companies, to transfer new technology to the marketplace and to forge strong links with publicly funded research centres such as those of the research councils and universities. Such parks have sprung up in two waves. The first, in the 1970s were carbon-copies of the US pattern of innovative firms funding parks in and around academic hot spots such as the Massachusetts Institute of Technology (MIT). These parks often had strong links with the military sector (corporate and government) and the growth of military technology helped to provide a solid platform for the new venture. Segal Quince's major study of such science parks entitled *The Cambridge Phenomenon* (Segal 1985) points out how important was the general growth of national and international advanced electronics and telecommunications companies, within and around the city of Cambridge in the UK, in forming strong but often informal links with researchers in the university.

Such advanced science-based companies are frequently part and parcel of both civilian and military undertakings in aerospace or manufacturing industrial programmes. The University of Cambridge has had and continues to have major investment from military industries such as GKN, Rolls Royce and BAE Systems over many years, despite strong opposition from both students and staff. The Cambridge-Massachusetts Institute of Technology partnership was primarily arranged in order to capitalise on business opportunities and not to enrich and expand research portfolios.

Cambridge science park is still going strong with small but innovative pharmaceutical companies now predominating. The second wave of science parks came in the 1980s and tended to be set up in response to a series of cuts in government funding of higher education. Wield has noted (Wield 1986) that the cuts, which were as much as 40 per cent in places such as Salford, forced the universities to find other ways of raising income. Many of these ways set the scene for the changes which have rendered many departments in universities little more than outposts of government or industrial R&D. Wield lists the selling of 'surplus' land to attract technology companies; the search for local or industrial sponsorship for a host of activities including science parks; and the attraction of private capital to commercialise their R&D, as being amongst the means of attracting much needed funds (Wield 1986).

1.2.4 Science parks–a question of culture

Unemployment during the 1980s helped to foster the view that such science parks would help overcome job losses in the local community.

Science parks have a culture of individualism and high status, of long hours of work and the absence of trade unionism - a set of values enshrined in the Thatcher view of the industrialised university, driven by 'economic advancement'. They are places where SET and its methods interact with the 'real' world – havens for 'spin-out' activities which facilitate technology transfer between universities and commercial companies.

A recent study, sponsored by Turnberry Consulting, questions the assumed benefits flowing back to universities from their involvement with science parks. The study found that 40 per cent of the park tenants interviewed described themselves as service firms, with only 30 per cent claiming a pure research and development function. Furthermore, there was little evidence of strong linkages back to the university. Around 50 per cent of firms had some link to the local higher education institution. Of those, only half agreed that technology transfer had taken place. In fact, the authors of the report point out that most knowledge transfer was from the university to the participating company rather than two-way. Only 15 per cent of firms had employees who worked part-time with the university or had seconded staff (Lizieri 2004).

The active reshaping of public sector SET within academic and government research establishments which is discussed in detail later in this Report has been part of a far wider set of changes, in the funding, planning and management of higher education as well as research activities throughout the OECD countries. Webster (Webster 1991) discusses three major elements as characterising this global change:

1. sustained cuts in state support across Europe, including the UK, during the early 1980s forcing the closure and 'rationalisation' of academic departments, with redundancies, the relocation of teaching and research staff. We know that calls for ever more 'relevant' and 'useful' research and teaching are today enshrined in the Research Assessment Exercise which has been widely criticised;

2. the pressure to remove the more traditional discipline boundaries in both teaching and research, and to forge new support measures for interdisciplinary work - this led to the Interdisciplinary Research Centres and their various incarnations including the Defence Technology Centres and similar partnerships described in Chapter three. Allied with this emphasis on interdisciplinarity has been the launch of a range of strategic research programmes with industry over the last decade - where the military corporations have been major players;

3. the broad and again sustained changes in the contractual relationships between public-sector academics and their employers, with increasing emphasis on more 'industrial', 'entrepreneurial' and 'efficient' patterns of work relations overseen by a new regime of management. This style of management - hands-on, directive and outcome driven - has overseen the virtual disappearance of tenure, and the growth of short-term contracts as a target of successive governments. These elements have totally changed the landscape of life in the university for all disciplines including science, engineering and technology.

A range of causes have been articulated to explain how these changes came about and have been sustained, but detailed consideration lies outside the focus of this Report. Interested readers can find more details in John Ziman's books and those listed in the References and Further Reading section at the end of this chapter. For the purpose of this Report it is clear that they have set in train a series of processes which opened the universities to the influence of industrial partnership and various forms of corporate financial incentives, and where such industries are powerful and influential (such as the pharmaceutical, military and biotechnology sectors) the agenda for large areas within SET becomes increasingly an industrial one. The disproportionately represented voice of such interests can influence government support of SET.

1.3 The pace of change quickens

In 1993 the Tory government published a White paper on science called *Realizing our potential* (Office of Science and Technology, 1993) which proposed that there should be "a better match between publicly funded strategic research and the needs of industry" (see: Monbiot 2000, page 285). The research councils were obliged to develop "more extensive and deeper links..... with industry". They were also required to seek "more of their senior staff from industry". Each council was to have a chair who would "bring in relevant experience from the industrial and commercial sectors" (Monbiot, 2000). Following this paper came a number of policy measures which strengthened collaborative activities, such as:

- ❑ Faraday Partnerships
- ❑ University Challenge Fund
- ❑ Science Enterprise Challenge
- ❑ Higher Education Reach-out to Business and the Community (HEROBAC)
- ❑ Joint Research Equipment Initiative (JREI)
- ❑ University of Industry

Some of these are discussed below with a timeline of major milestones given in Box 1.1.

Box 1.1
–Major milestones in the commercialisation of the university

1991 The Faraday Partnerships set up
1993 *Realizing our potential* White paper
1994 Foresight panels set up
1995 Office of Science and Technology moved from the Cabinet Office to the Department of Trade and Industry
1997 Report of the National Committee of Inquiry into Higher Education: *Higher education in the learning society*
1998 Relaunch of the Council for Science and Technology
1998 *Our competitive future* White paper
1999 The University of Cambridge/MIT Initiative launched with government and industrial backing
2000 *Excellence and opportunity* - the Department of Trade and Industry publication stresses the knowledge economy
2003 Lambert Review of Business-University Collaboration
2004 Ten year science and innovation investment framework launched putting science at the centre of future economic success

1.3.1 A question of Foresight

In 1994 the Thatcher government set up the Foresight Panels which represent "a national capacity to think ahead....revised regularly to ensure that it is positioned to meet new challenges" (www.foresight.gov.uk). The Foresight programme hosted by the Department of Trade and Industry, which is still going strong, brings together people from industry and the universities and at present comprises 13 Panels, one of which was the Defence, Aerospace and Systems, more details of which are to be found in Chapter three. The output of the Panels, which are heavily dominated by industry, is to guide the allocation of government money into areas which "make the most of the potential of science and technology and deliver decisions by research funders, business, government or others to make the most of science and technology" (Monbiot 2000). Chapter three discusses the various initiatives set in train as a result of Foresight panel recommendations.

The 1995 decision to move the Office of Science and Technology to the Department of Trade and Industry from its previous location at the Cabinet Office also sent further signals that SET were subjects firmly wedded to wealth creation and industrial targets.

The Blair government in its White paper of 1998, *Our competitive future: building the knowledge-driven economy* (Department of Trade and Industry 1998) on competitiveness, launched a fund to encourage universities to work more 'effectively' with business. The role of the higher education funding councils, which provide core support to the universities, also embraced the business ethic, in that they were to "ensure that higher education is responsive to the needs of business and industry" (Department of Trade and Industry 1998 and Monbiot 2000). In addition the LINK programme, originally launched in 1986 and given a face-lift and relaunch in 1995, was expanded and more funds from government were diverted into joint business ventures. LINK programmes take account of the Foresight panel recommendations and their industrial direction (Stewart 1999).

Also in 1998 the Council for Science and Technology, a vital source of scientific advice, was brought back from the dead. The membership has a very strong industrial voice and is appointed by the Prime Minister. In 2003 it included Euan Baird, Chairman of Rolls Royce; Alec Broers, former Vice-Chancellor of Cambridge and advisor to the BAE Virtual University Strategy; and Chris Evans, founder and director of 12 biotechnology companies (www.cst.gov.uk). Following a five year review in 2003 changes were made to the composition of the Council's membership with some recognition that wealth creation is not the sole role of science and technology - the Council now includes members with interests in sustainability issues and in public engagement with science.

As Monbiot points out (Monbiot 2000) the science budgets over the period 1983 to 1999 had been cut and the Research Assessment Exercise has forced all universities to compete on narrow criteria, thereby ignoring their diversity (see also www.savebritishscience.org).

In 2000, the Department of Trade and Industry paper *Excellence and opportunity* again stressed the importance of the so-called 'knowledge economy' and the need to build ever more links with industry. The large increases in science funding which followed the release of this paper were again tied to economic priorities. The Department's Innovation Report of December 2003 (DTI 2003) also highlighted knowledge transfer to assist business innovation. The Blair government started to address the problem of the industrial exploitation of university expertise on the cheap with its 'full cost accounting' for all research projects, and the Science Review of 2003 underlined the need for salaries and contracts to be improved.

The ten-year science and innovation investment framework (announced as part of the Treasury's 2004 Spending Review) continues the increases in funding. The SET spending administered by the Department of Trade and Industry (DTI) will grow by around 5.6 per cent per year in real terms over the three year period of the Spending Review. However, such increases (which include the stipend for PhD students announced in the Science Budget 2003/4 to 2005/6 allocations from DTI following the recommendations of the Roberts Review in this area) will be firmly wedded to the idea that the science base is 'for innovation in UK business and public services' (HM Treasury et al 2004).

DTI will inject at least £178 million per year by 2007-8 for collaborative R&D and knowledge transfer networks. The 2004 Spending Review puts science firmly at the centre of future economic success and so consolidates the view that industry targets are firmly embedded in the research culture. The Review also wishes to "shape the science base to be more responsive to the research and skills needs of the economy" (HM Treasury *et al*

2004). The Wellcome Trust, a major supporter of medical research, has pledged to at least match government by investing £1.5 billion on science projects thus taking overall increases in science spending between 2004/05 and 2007/08 to £2.5 billion.

Faraday Partnerships were established to encourage a closer relationship between various members of the EPSRC research community and industry by involving intermediate organisations who have strong connections with both parties. This includes small to medium enterprises, certain research and technology organisations, universities, government agencies or private sector laboratories. The intention of such partnerships, which began in 1991, was to provide post-graduate training of industrial relevance and hence to stimulate two-way flow of industrial technology and skilled people between the SET base and companies. The Faraday Partnerships involve military players such as QinetiQ and Rolls Royce (especially in the materials field) and those universities such as Cranfield, Oxford and Birmingham who are in receipt of a range of funding from the military (see Faraday Partnerships Annual Report 2002/2003). Since 1997 to the time of writing this Report 24 Faraday Partnerships have been funded throughout the UK (www.faradaypartnerships.org.uk).

Thus through the combination of first cuts and then specifically directed initiatives and inducements universities have increasingly turned to the commercially focused area which includes both the industrial corporations and various kinds of public-private partnerships.

In addition to altering the objectives, culture and products of SET such a change also impacts on those disciplines and topics which are not easily fitted within an industrial approach to funding - languages, the humanities and the social sciences for instance. This creation of disciplines which are 'less well endowed' in financial terms has important consequences for the intellectual life of a nation and the culture of informed and broadly-based debate of contentious issues, which is so necessary in the face of the rapid pace of scientific and technological innovations and their impact on us all.

1.4 Privatising the universities - its impact

A variety of complex and interlocking changes which have occurred in the UK and elsewhere in the industrialised world in the last fifteen to twenty years have set the stage for the privatised university. Here research portfolios are increasingly dominated by industrial liaison of various kinds and commercial agendas are often imported wholesale into the university domain (Monbiot 2000, Scott 2003 and Spier 1995).

The commercialisation of the campus has been happening across the globe and is one of the perhaps unexpected forms of economic globalisation. Some countries however, like Sweden and Germany, fund science on the basis of advancing knowledge *for its own sake* (Calvert and Martin 2001). Many would argue that increased reliance on industry; the redirection of research effort towards practical or applied subjects in both teaching and research; the proprietary treatment of research outcome with commercial interest in secrecy overriding the public interest in free, accessible and shared knowledge; all compromise 'academic freedom' (Brown 2000) and there are many examples of how corporate sponsorship can limit the traditional freedoms.

Some analyses point to the dangers of overemphasising knowledge transfer and the commercialisation of universities. Some have argued that the public research sector, especially the universities should be seen as the generator of expertise not 'technology' narrowly defined (Florida 1999). Geuna (1999) has argued that knowledge transfer is optimal when the universities pursue high quality research, and that drives toward commercialising technology can be counterproductive by diverting resources away from research. Some have pointed out that the success in the USA in the 1990s of innovation and technology transfer was stimulated by research excellence in the universities and not by measures to stimulate liaison with industry (Pavitt 2000). Again, many have pointed to the fact that the benefits of public research extend well beyond commercially useful knowledge (Salter and Martin 2001, Scott *et al* 2001). These concerns about university-industry collaboration recur throughout the Report and should warn us about the health of science within a commercial environment.

Furthermore, where military issues are concerned, there must be grave doubts as to how open collaboration, with agreed sharing of data and methodology, is likely to be a part of the working practice in those consortia discussed later, comprising government, industrial and universities 'partners'. It is not only commercial interests which insist on secrecy. In the UK we all witnessed how the Ministry of Agriculture, Fisheries and Food kept research findings on BSE hidden during the media scare in 2000. And so it was difficult at the time to put events into context and in addition there was little possibility of evaluating the risk by weighing up evidence from expert sources. The Ministry of Defence in its present form will always be limited in its commitment to openness by considerations of national security.

1.4.1 Corporate involvement - some examples

Brown (2000) points to a study (Shulman 1999) which found that more than one-third of recently published articles produced by University of Massachusetts scientists had one or more authors who stood to make money from the reported results - they were patent holders, or had some financial interest in the results. However, the pecuniary interests of the authors were not declared.

In an article in the Journal of the American Medical Association a study is presented which collected the outcomes of 370 randomised drug trials using a detailed meta-analysis, adjusted for a range of possible confounding influences (Als-Nielsen *et al* 2003). The article clearly showed that the conclusions of drug trials were seen to be more in favour of the drug intervention when financially supported by the companies in comparison to trials funded by non-profit organisations. The authors of this, one of the most detailed analyses to date, cited eight other large scale studies which supported this same conclusion. One is forced to question whether the multinational pharmaceutical industry and the scientists receiving their support value scientific rigour, objectivity and reliability over the commercial ethic. Might this also be a problem in other university-industry liaisons?

In an article in the journal Nature entitled "Is the university-industry complex out of control?" (Anon 2001), the anonymous author points out the dangers in one specific case of a close liaison between big business and a prestigious university. The case involved the Novartis Corporation (in the form of the Novartis Agricultural Discovery Institute - NADI) and the University of California at Berkeley, where a US$25 million 5-year grant was provided by Novartis in order to fund plant research in the university. The chancellor at Berkeley, Robert Berdahl, voiced disquiet over this arrangement. He cited the stimulation of the industrial-university complex by forces which lead to a variety of damaging changes in academic life including the loss of decent salaries at universities, a burgeoning of ethical and social problems stemming from fast technological change and the loss of intellectual objectivity. The agreement set restrictions on all members of the Department of Plant and Microbial Biology at the University who were co-signers to the agreement. NADI would ultimately be financing 20 per cent of the departmental budget. Participating faculty members would have the opportunity to sign a confidentiality agreement that would give them access to NADI's proprietary genetic database. However, it was later disclosed that faculty were effectively gagged from speaking out about any perceived dangers to the environment and public which might arise during the course of their research. Studies like this have shown that secrecy and commercial protection are the key elements in all those situations investigated where industry and the universities are involved in a 'partnership'. Krimsky details many more such instances in his book *Science in the private interest* (Krimsky 2003).

Stephen in a review of university-industrial collaboration points out that university-industrial partnerships could have profound negative effects on education, including the content and quality of teaching. In addition the relationship between staff and students might also be compromised (Stephen 2001). Industrial involvement with university research may also shift attention away from fundamental research questions which do not appear to lead to a commercial pay-off. There have been very few studies of the impact of industry-university collaboration in terms of the effect on quantity and quality of research, faculty behaviour, openness, teaching and questions of intellectual property rights (Poyago-Theotoky *et al* 2002).

How much more difficult would such an arrangement be when the active partners are part of the military sector (military corporations and government defence ministries). One's unease is increased with announcements accompanying the various consortia now being supported by the military corporations and the Ministry of Defence - the Towers of Excellence and the Defence Technology Centres - described later in this Report, that intellectual property rights and openness are to be "considered on a case by case basis" (www.mod.gov.uk). It is not clear from publicly available material what safeguards will be in place for good practice, how researchers who are concerned by breaches of contract or safety matters will be able to respond and how the public will benefit from tax funds being used to support this endeavour.

Muttitt (2003) has studied the role of the oil corporations in British science and the picture is very similar to that where other powerful multinational corporations are in 'partnership' with research and teaching faculties. They found that nearly 1000 research projects were being conducted for oil and gas companies in UK universities in 2000. Some university facilities were wholly dependent on oil company funding - one such being at the University of Aberdeen. In many higher education institutions such funding is used to support undergraduate and postgraduate studies as well as research programmes. For instance BP sponsors a range of university positions including professorships, fellowships or lectureships at seven universities including Oxford and Cambridge (Monbiot 2003).

National Science Week - the showcase of UK science which attracts a vast audience - has both obvious and more subtle industrial sponsorship from corporate sources including the oil and military industries.

1.4.2 Universities and Intellectual Property Rights

The question of intellectual property rights (IPR) and patents looms large in the new world of university-industrial liaisons. In a recent Royal Society report entitled *Keeping science open: the effects of intellectual property policy on the conduct of science* (Royal Society 2003) it was recognised that "We do not know whether, overall, the disadvantages of widespread patenting of publicly funded research outweigh the benefits, but the potential disadvantages are sufficient to be worth minimising by a carefully thought out IP (*intellectual property*) policy". They conclude that "commercial forces are leading in some areas to legislation and case law that unreasonably and unnecessarily restrict freedom to access and use information and to carry out research" (Royal Society 2003, page 30). At the time of writing many universities are grappling with the thorny issues of IPR and whether staff or the university should be the recipient of the financial return from patents.

In gathering material for this Report, we have become acutely aware of the barriers which prevent the universities being fully open about the scope and nature of the research in which they are involved. In particular, many of those universities know to have military sector funding (government or commercial) simply refuse to supply details of such funding and how it is used.

In addition to these practical issues, what place will there be for the dissenting or challenging voices, questioning the ethical and social implications of military involvement on the campus and in the research laboratories? Do university members know about the scale of military funding that their universities accept?

1.5 Military interests and national priorities

Close relationships between the best SET expertise and the perceived needs of the military establishment have always loomed large in countries like the UK, France and the USA, married to advanced military technology. Military spending on research and development, described in Chapter three involves the support of a large cross-section of science, engineering and technology, and as Freeman has pointed out "the scale and complexity of technology have been carried to extreme limits in research, design and development for military aircraft, missiles and nuclear weapons" (Freeman 1974). The products of such support can be found in the pages of Jane's Defence Weekly or the Global Defence Review. Nations where many of the population have no access to clean water, satisfactory sanitation or education still manage to have military forces equipped with the latest in information technology, armour, weapons and transportation. For example, in 2001 Tanzania purchased a military air traffic control system from BAE Systems in the UK for US$40 million, when this developing country has only eight military planes and would secure US$77 million in debt relief (www.worldpress.org).

As any government has relatively limited funds available for research and development the funding of military objectives can reduce the monies available to other areas such as health care and environmental sustainability which is discussed in Chapter five.

This chapter has provided a glimpse of the various forces which have changed the face of SET in the UK. The following chapter describes the military sector and its structure and activities and compares military expenditure with other nations in order to put into perspective the power, influence and pursuit of military objectives.

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NOTES

1 In this Report we use the official term of 'science, engineering and technology' or SET.

CHAPTER TWO

The military machine —some facts and figures

"The world establishment is firmly entrenched in the business of war: the Permanent Members of the Security Council of the United Nations were together responsible for 81% of world arms exports from 1996-2000. The G8 countries sold 87% of the total supply of arms exported in the entire world, and the US share alone has reached almost 50% of this figure".

from Sen 2004

KEY POINTS

- The UK is a major military power, ranked third in the world in terms of spending. It continues to deploy about two hundred nuclear weapons.
- Globally, the military use of resources is huge. Spending in 2003 reached US$956 billion and approximately 54 million people make up the world's regular armed forces.
- The distinction between military power and security is a major issue in the current global situation.
- Conventional military thinking focuses on the strength of military forces, weapons and related equipment which leads to a narrow approach when addressing security problems. The focus on high technology weapons in the USA, UK and other wealthier countries contributes to this.
- The development of weapons and other high technology military equipment is critically dependent on workers in science, engineering and technology (SET).
- Current global increases in military spending, including those in the UK, mean a lessening of funds available for other purposes. The impact of such spending increases is especially damaging in developing countries, which already have high levels of poverty.
- Global arms sales and distribution can decrease security - this is especially the case where arms are sold into areas of ongoing conflict or find their way to terrorist groups. There is growing evidence of some UK arms exports fuelling conflict and undermining human rights.
- War causes widespread human suffering and environmental damage. The UN estimates 35 people are killed each hour as a direct result of armed conflict.
- The use of a weapons-based 'defence' posture is unlikely to reduce the incentive for terrorism. Peacebuilding and positive responses to conflict are more likely to lessen the *raison d'etre* for terrorist activities. In areas where peace-keeping and armed intervention have been undertaken there is a post-conflict need, largely unfulfilled, for 'good will' such as removal of cluster bombs and mines in order to support the growth of peace.
- Building long-term security needs a broader approach than is currently being pursued. At its heart must be the tackling of the roots of conflict. This covers a complex set of issues such as social inequity, poverty, ethnic differences, and environmental problems. Peacebuilding work is generally under-resourced, and would benefit from greater input from those working in SET.

2.1 Introduction

This chapter examines in detail the costs and implications of maintaining a military machine and its impact on the world, especially in terms of security and peace. We also briefly trace the changes to global security which followed from the end of the Cold War.

The UK is a major military power. Recent spending is shown in Table 2.1, while Table 2.2 shows that the UK military budget is the third highest in the world. It is the fourth largest consumer of taxpayers' money after social security, health and education. The UK Ministry of Defence spends around £12 billion per year on the procurement of goods and services, of which about £6 billion is spent by the Defence Procurement Agency on weapons and other military equipment (HM Treasury 2004: Chapter 13). British forces have been deployed in Afghanistan and Iraq and between 2001-02 and 2004-5 the Government has provided £4.4 billion of taxpayers' money to meet the costs of these conflicts (HM Treasury 2004: Chapter 6).

Two recent documents are of immense importance to the military, the security of the UK and the wellbeing of the science base - the 2004 Spending Review (HM Treasury 2004) and the Ministry of Defence's Defence Command paper entitled *Delivering security in a changing world: future capabilities* (Ministry of Defence 2004). Both publications signal a change in the support and structure of the UK armed forces, which will be further discussed in the following section.

2.2 Some facts and figures

Table 2.1
–Defence expenditure in real terms in the UK (1997-2004)

1997/98:	£24,268 million
1998/99:	£25,319 million
1999/2000:	£24,878 million
2000/01:	£25,660 million
2001/02:	£25,966 million
2002/03:	£27,198 million
2003/04:	£29,242 million

Sources: UK Defence Statistics 2003, Defence Analytical Services Agency. All figures quoted make use of the HM Treasury GDP Deflator of 30.06.2004. Subsequent increases in the defence budget are described below.

Box 2.1
–A note on military economic statistics

Throughout this Report we have used figures for both procurement and research and development which have been obtained from the Ministry of Defence website and numerous publications such as the Defence Statistics and various Policy Papers. In addition data from the National Audit Office, Office of National Statistics, Office of Science and Technology, Defence Analytical Services Agency and Stockholm International Peace Research Institute have been used extensively throughout the Report. All government budgetary figures are now provided in private sector terms. For instance, 'out-run' figures are now used rather than costs at constant prices. Hence comparisons with other countries over time can be problematic.

The UK has been involved in armed conflict of one kind or another recently in: Northern Ireland (1969 -1994); Kuwait and Iraq (1991 and the subsequent aerial patrol of airspace and the economic sanctions); former Yugoslavia (1999); Sierra Leone (2000); Afghanistan (2001 to the present day); Iraq (2003 to the present day). Armed force has been used in both peacekeeping (as in former Yugoslavia and Sierra Leone) as well as open warfare in joint operations (such as in Iraq and Afghanistan). The total personnel in UK forces numbers 316,100. This comprises 213,500 full-time service and 102,600 civilian men and women, there are a further 3,500 staff in the Royal Irish (Home Service) in 2003 (UK Defence Statistics 2003). However the 2004 Spending Review and the Ministry of Defence paper *Delivering security in a changing world: future capabilities*, point to some significant changes in the UK Armed forces to have been achieved by April 2008. The major changes in staff are:

❑ the Royal Navy's size to be reduced by 1,500
❑ the Army to comprise around 102,000
❑ the Royal Air Force to fall from 48,000 to around 41,000
❑ civilian staff to fall by over 10,000
❑ planned increases on 'defence' of 1.4 per cent per year in real terms with total spending to be £3.7 billion higher in 2007/8 than in 2004/5. The 'defence' budget for 2007/8 would be £6.5 billion higher (in present day terms). This increase is on top of the increased budget agreed for in the 2000 and 2002 Spending Reviews.

These increases are despite the Ministry's declaration that "there is no longer a major conventional threat in Europe, but more frequent crises over a wider geographic area..." (Ministry of Defence 2004). Accordingly the budget for counter-terrorism and 'resilience' will rise from £923 million in 2001/3 to £2,115 million in 2007/8, and although the 2004 Spending Review underscores the importance of "tackling its [terrorisms's] underlying causes" (HM Treasury 2004: Chapter 6) it is unclear how it is envisaged that this will be done.

The UK also continues to deploy approximately two hundred nuclear weapons on four Trident submarines (see section 4.3.4).

Globally around 54 million men and women comprise the regular and reserve armed forces. This is about 10 per cent less than in the mid 1980s, at the height of the Cold War (Smith 2003). Children are also used by some irregular militias. One should not think however that human numbers in the military tell the whole story about power since small numbers of highly trained personnel can operate sophisticated weaponry with massive fire power.

There are marked regional disparities in the share of economic resources devoted to military expenditure (the 'defence burden'). In 2001, for instance, North America spent 3 per cent of its GDP whilst the Middle East spent 6.3 per cent and Latin America spent 1.3 per cent.

Globally military spending reached a massive US$956 billion in 2003 (SIPRI 2004). In Western Europe the defence burden fell slightly in real terms during both 2001 and 2002, after a short period of increase since 1997, when the post-Cold War decline ended. In the UK and France there have been substantial increases since 2002 which seem likely to continue (see Hagelin and Skons 2003 and Table 2.1). Germany has capped its military spending in nominal terms at present levels up to 2006, which suggests a fall in real terms. The so-called 'war on terror' is one factor behind some planned increases and some suggest the use of expeditionary forces to those countries from which terrorists are thought to originate. This will lead to more rapid reaction forces together with communications and intelligence systems which are part and parcel of the Ministry of Defence areas of interest - see Chapters three and four. However, outside the ranks of the American neo-conservatives many policy analysts question whether, for example, war and the military machine is a valid means of dealing with international terrorism (Heymann 2003). In the long term such analysts agree that the use of force does nothing to deal with the political nature and driver of international terrorism (see Halper and Clarke 2004, for a recent treatment of the issue).

Other major spenders increased their military expenditures in 2002 for a number of reasons. Table 2.2 shows the top countries in terms of military spending.

Table 2.2
–Top 10 military spending countries (2002)

Rank	Country	Size (US$billion)	World share (%)
1	USA	335.6	43
2	Japan	46.7	6
3	UK	36.0	5
4	France	33.6	4
5	China	31.1	4
6	Germany	27.7	4
7	Saudi Arabia	21.6	3
8	Italy	21.1	3
9	Iran*	17.5	2
10	South Korea	13.5	2
Total spending		584.4	77%

** the figure for Iran is 2001* *From web.sipri.org*

2.3 The role of the military machine

The military sector represents a part of the economy that is to a large extent protected from public scrutiny and any real economic competition. The Centre of Defence Information estimates that every billion dollars spent on military procurement produces 25,000 jobs (Harigel 1997). The same billion would create 30,000 jobs in public transport, 36,000 in housing, 41,000 in education or 47,000 in health care. Harigel quotes a figure of 6,395 being employed by the US Department of Defence in promoting and servicing foreign arms sales by US companies at a cost of more than US$450 million to the American taxpayer (Harigel 1997).

The military machine is paid for on the assumption that it forms a large part of the cost of insuring against perceived threats, that is, to provide for national 'defence' and hence maintain security. But the majority of threats are now within rather than between states. The 'war on terror' has also dramatically changed the whole concept of security, which was already shifting as a result of the end of the Cold War (see above).

Today military power and national security are very different things - security cannot be guaranteed by increasing weaponry and ever larger defence budgets. Increasingly the military sector internationally has less to do with security than it has to do with power and the complex and pervasive projection of that power. But in the face of international terrorism even the most powerful nations on the planet are surprisingly vulnerable. International terrorism calls for international solutions. This includes the pursuit of diplomatic, investigative and global police operations to identify and locate, arrest and then bring to justice members of terrorist groups who have carried out acts of violence. Some analysts argue that military action as has been undertaken in Afghanistan and Iraq is unlikely to reduce the terrorist 'threat' and is far more likely to inflame existing anti-Western feelings (Zunes 2002, Barnett 2001).

However, military analysts in the West still maintain that there are basic rivalries existing between nation-states which continue to underlie both military planning and, as this Report indicates, require further investment in the expertise residing in science, engineering and technology. Whilst the picture is complex and multilayered there are security issues which are raised by the growing gulf between ethnic groups, and the rich and poor, producing powerful conflict areas where the legitimacy of governments are challenged. Both environmental problems and broader security issues have social and political causes, which may be independent of one another and one should exercise some caution in assuming that poverty and disadvantage necessarily lead to conflict. In certain situations violent conflict is focussed around resource wealth in poorer countries - such as minerals, timber and diamonds (Leach 2000).

Governmental instability and religious fundamentalism are also seen to seriously threaten Western interests (Lewer and Schofield 1997, and for a slightly different view of the engine of conflict see Blum 2003 and Jenkins 2002). Such highly charged situations call for a nuanced and holistic approach rather than ones based simply on power, weapons and standing forces.

2.4 The pursuit of peace

The pursuit of peace in the face of conflict is currently undertaken in various ways, involving governments and other groups, some from the voluntary non-governmental sector.

At the governmental level firstly, peacekeeping, especially that which involves the United Nations, is based on an agreement reached between parties to seek some form of peaceful settlement, but is brokered with the threat of using force. In 2002/3 the UK spent £1.6 billion on peacekeeping. The post-Cold War security agenda has involved a clear shift towards UN peacekeeping and the UK has made a major contribution, ranging from small-scale policing using military personnel to complex peace enforcement in which all three armed services have been involved. This role was acknowledged in the 2004 Spending Review discussed earlier. A recent Parliamentary Question tabled on behalf of the Peace Tax Campaign group Conscience by Adam Price MP showed that only 6 per cent of the Ministry of Defence budget is spent on conflict prevention (Conscience Update, 123, Winter 2004). It is clear that more can be achieved in avoiding conflict (further discussed in Chapter five). Secondly, peace enforcement is where the UN Security Council intends to impose peace on conflict zones. Thirdly, there is peacebuilding, which is a long-term, relatively expensive and complex process, but is closely linked to considerations of social justice and the need to avoid open conflict. It comprises socio-economic development, security, forming political infrastructure and reconciliation. Far more expensive however are the costs of maintaining large standing armed forces and developing new military technologies. Peacebuilding is not about power. Peacebuilding does not necessarily depend upon sophisticated technology and science, but tries to address the real causes of tension and defuse potential flash points.

The spread of weapons and their associated technologies across the world frustrates peace and the non-violent resolution of conflict. There is a desperate need for international conflict prevention and resolution along the lines suggested for Europe by Plesch and Seymour where a strong civilian capacity is built to support crisis management and peacebuilding (Plesch and Seymour 2000).

The development of weapons and related systems is, of course, heavily dependent on the expertise residing in science, engineering and technology, and enthusiasm for technological devices in the military, especially in the USA (Clark and Lilley 1989, Gray 1989), is an important driver of the arms agenda. The governments and military corporations who fund military R&D play a significant role in making peace more fragile by this focus on an offensive means to address conflict resolution. We discuss this further later in this Report.

The confrontation between the USA and the USSR from the end of World War Two until 1989 was always both military and political. The extent of US-Soviet rivalry was global even though the main military area of engagement was European and north-east Asian.[1] The Cold War ended not by military means but by social and economic factors. In the main the Soviet bloc was unable to sustain its economic system and as it fell apart the political system could not continue. In this way the perceived military power of the Soviet bloc diminished in the eyes of those in the West (Smith 2003). Since the end of the Cold War, conflicts globally have changed in many ways and it is clear that long-lasting security depends upon economic prosperity, co-operation and the addressing of global issues such as climate change, clean water, secure food supply and social justice.

Like the Cold War, the international arms race today involves the production of weapons systems which are not simply collections of warheads, bombs and missile launchers, but they provide countries with a sense of prestige and give other nations signals that speak of intentions and capabilities. Such weapons systems are often made available to regimes who have poor human rights records and environmental credentials, with the active involvement of government. Indeed, the arms trade is a very profitable aspect of the arms race with the major arms suppliers being based in the USA, Russia, France and the UK. Like so much else in the military world, there is little available information in the public domain but, for instance, the small arms trade is very lucrative and amounts to more than US$5 billion. Around 500,000 people are killed yearly by small arms in wars, internecine conflict and in the pursuit of various crimes (Smith 2003). The selling of weapons can also lead to unexpected problems in the future - examples include Iraq, Indonesia and Iran. Section 2.8 discusses the arms trade in more detail.

Clearly there is a pressing need for a major shift towards a more broadly based security agenda. Some constructive approaches to broadly defined ideas of security are discussed in more detail in Chapter five.

2.5 The military and power

For the most powerful, armed force gives political advantage. The massive ownership of military hardware by the USA underpins both its current influence and its drive for expansionism across the world. The USA has the most sophisticated and newest weapons and military technology, brought to market by scientists and technologists. Thus the USA can, with the help of its current allies when it wants them there, project devastating power to virtually any part of the world. Chapter four explores the intention by the Bush administration to further militarise space and to develop new nuclear weapons, with help from the UK.

The mobilization of American 'defence' and security after the terrorist attacks of 11 September 2001 led to massively increased military spending and the deployment of American forces across the globe (see Smith 2003 and Skons *et al* 2002). The US returned to the Philippines, increased their numbers in the Gulf region, and sent expeditionary forces to Afghanistan, Iraq and Central Asia for the first time. An important factor behind the US worldwide presence is its need for oil. The consumption of oil in the USA is a quarter of the world total, and it imports 60 per cent, much of it from the Middle East (Smith 2003). During the time of the Bush administration this figure has been rising. This energy consumption is linked to the low priority generally given within the USA to energy efficiency and energy conservation. Greater security for the American citizen at least in part lies with a change in energy consumption patterns, with more renewables and increased efficiency of existing modes of energy use.

The USA has intervened in various ways in countries pursuing in one form or another policies of self-determination, from China to Nicaragua (Blum 2003). And American forces have stepped into sovereign states where American interests have been felt to be threatened, in countries including Mexico, China, Egypt, Honduras and Nicaragua (Blum 2003).

In those countries where military spending is highest, such as the USA, UK and France, vast sums are used to develop ever more advanced weapons and their support technologies, as well as subsidiary systems involving surveillance and security clearance. The military-industrial sector is complex and is described at length in this Report; the sector's role in producing military technology is profoundly influenced by the institutions in which it is produced as well as by those in which it is used (MacKenzie and Wajcman 1999). Mary Kaldor in her 1982 book The Baroque Arsenal together with the work of other writers such as Fallows (1981), and Gansler (1982) pointed out the nature of the driver of increasing military budgets.

The armament sector of Western economies, suggests Kaldor, has one customer, the state, and a small but powerful number of military suppliers. Kaldor argues that competition between the military corporations together with the political desire to justify new weapons by various nations dictate that the performance characteristics of new systems be superior to their predecessor. However, the military sector is basically conservative and demands a narrow band of acceptable performance characteristics and this in turn stifles innovation where different approaches might result in simpler and cheaper systems being more appropriate.

As a result of the situation described by Kaldor, the weapons systems found in the UK and the USA are very complex, elaborate and immensely expensive. In addition to the innate conservatism of the military sector, military contractors' representatives have found their way into various advisory bodies, and research committees and hence are well placed to markedly influence both the military and many areas within the SET R&D agenda. Added to this situation is the international aspect of arms development which supplies global markets and provides profits to such military corporations. Chapter three describes the military research and development situation which is central to the creation of such weapons. It is also noteworthy that there is an increasing overspill from military uses to the civilian sphere, especially in the area of crowd control, surveillance and the so called 'non-lethal weapons' (see Rappert 2003 and 2004).

2.6 Military power and the role of science and technology

Scientific research has long been central to the national defence policies of Western nations like the USA and the UK (Brumfiel 2002). During the Cold War US researchers strove to develop better weapons and intelligence-gathering devices than their Soviet counterparts. But where terrorism is concerned the perceived threats are diffuse and hard to identify, and it is more difficult to set specific research priorities - this topic is taken up in more detail in Chapter three. It is clear however that more monies for military purposes means a drop in the available funds for other areas; for instance the Bush administration has cut the budgets of various research programmes and redirected funds to military and homeland security (Check 2003, Brumfiel 2004).

Many believe that an overemphasis on the latest technology has led to a decrease in national security, because national security essentially depends upon political rather than technological solutions. As Wheeler and Booth say "We are inundated by technological changes...future international security is at root a political problem" and "technology rarely deserves the centrality which it usually is accorded" (Wheeler and Booth 1987).

The Gulf War of 1991 helps to shed some light on the importance of advanced technologies in military affairs - a vital consideration in the light of the various partnerships described in the following chapter. A vast array of technologies were used in the war and the Coalition overwhelmed the Iraqi forces without themselves incurring many casualties.

This war has been used by some as an example of the value of advanced weaponry and support systems. A number of analyses however have taken issue with the idea that this war was won by advanced technology. In particular a report by the US General Accounting Office (GAO) has cast doubt on the usefulness of technology in the Gulf War and pointed out that claims for the pinpoint precision of the advanced technologies were "overstated, misleading, inconsistent with the best available data, or unverifiable " (Schroeer 1997). The report slams the effectiveness of the Stealth bomber, the Tomahawk cruise missiles and much of the smart weaponry used by the USA. In addition the destruction wrought by the war had massive impact on civilians during and after the conflict.

It is sobering that in the 2003 Iraq invasion by the USA and the UK, using a new generation of high technology weaponry, there were more deaths of non-Iraqis caused by 'friendly fire' than by the Iraqi forces themselves. The use of local knowledge and guerrilla tactics by the Iraqi 'insurgents' created advantages over the most sophisticated technology - which continues today. This lesson, shown starkly in Vietnam in the face of American occupation, is perhaps now being learned again by the current Bush regime.

2.7 The military world - the human cost

Whilst the bulk of the expenditure on the military is spent by Western industrial nations, the heaviest economic burden is in those countries considered as 'developing', those with the highest levels of poverty. As we noted earlier about 1.2 billion people, around 25 per cent of the developing world, subsist on just US$1 a day (UNDP 2001). Under these situations, even a world defence burden of 2.6 per cent constitutes a massive diversion of resources from the basic needs of people (Skons *et al* 2002). Some of the poorest countries in the world have substantial defence burdens - these include Burundi, Eritrea, Ethiopia, Rwanda, Serbia and Montenegro, Bosnia-Herzegovina, and Croatia. It is likely that there are serious underestimates of the defence burdens in many poor countries because official expenditure data are severely underreported in those places suffering from armed conflict (Skons *et al* 2002).

Furthermore, the sale of weapons worldwide and the subsequent maintenance of conflict also sustains a massive refugee population.

Campaign Against Arms Trade (CAAT) in their report *Fanning the flames* (CAAT 2004) have clearly shown that UK arms sales not only maintain conflict, but also that arms transfers across the globe significantly contribute to the creation of refugees (Craft and Smaldone 2003, quoted in CAAT 2004). Using a variety of independent literature sources *Fanning the flames* describes recent cases in Algeria, Colombia, Kenya, Nepal, and the Phillipines where UK military equipment has been supplied to governments involved in internal conflicts with the loss of thousands of lives. It also highlights a number of other suspect UK arms deals (see the next section).

The World Health Organisation estimates that around 35 people are killed each hour as a direct result of armed conflict (WHO 2002). Present day warfare, using either advanced or simple weaponry has increased the numbers of displaced individuals from 2.5 million in 1970 to more than 23 million in the latter part of the 1990s (Zunes 2002, WHO 2002). In addition, there are some 22 million people who are displaced from their homes and families within national borders (Hampton 1998). Research undertaken at the Refugee Studies Centre at the University of Oxford (www.rsc.ox.ac.uk) show that out of ten countries sending the most refugees to Europe, seven experienced war in the decade up to 2000, whilst the other three have a history of repression.

There is no reliable data on the more indirect effects of conflict and its aftermath such as how many of those in conflict zones are wounded, psychologically disabled and driven into despair.

2.8 Weapons—a global business

Chapter three details the complex world of the UK military sector comprising successive governments and their departments, the military corporations, lobby groups and advisory bodies and their role in setting the 'defence' agenda. Also described is their participation in the research agenda of science and engineering. As we have mentioned, this web is also involved in the global weapons market. The Oxford Research Group, Campaign Against Arms Trade and CorporateWatch have all described the UK arms business and the export of weapons to regimes waging war on their citizens and those in neighbouring states.

A major player in developing and supplying weapons and their support technology is BAE Systems, the largest military corporation in Europe, which features in many of the consortia described in the next chapter. In February 2000 BAE Systems had supplied under licence from the Blair government spare parts for Zimbabwe Hawk aircraft even though there were frequent outbreaks of violence in the country. In 2002, despite outbreaks of violence between India and Pakistan (both now nuclear nations) over Kashmir, BAE Systems was granted 160 licences to ship various armaments to the two countries over the course of two months. Moreover, the UK government's arms promotion agency, the Defence Export Services Organisation (DESO), was lobbying India to buy 60 BAE Systems Hawk aircraft (CAAT 2004).

Furthermore, BAE Systems has been exporting military components for the US-produced F-16 aircraft destined for use by the Israeli airforce (CAAT 2004). These advanced war planes have been used to attack refugee camps occupied by Palestinians. In July 2002 a government report disclosed that sales of weapons to Israel almost doubled since 2001 to a figure of £22.5 million. Since the outbreak of Intifada in September 2000 more than 23,000 people have been injured in Palestinian and Israeli-occupied areas, with 300 Israelis and 1,300 Palestinians killed.

Despite various codes of conduct and repeated pledges to act in an ethical way, the UK is still exporting huge amounts of weaponry and support systems to countries many of whom are actively engaged in conflict. Indeed DESO and the UK government's sales missions promote such sales and threaten widespread war even in areas of potential nuclear conflagration like the Middle East. Finally, like so many other positions in the military web, the present head of DESO was previously with BAE Systems.

Table 2.3 lists the world's top ten military corporations, all heavily involved in the international arms trade.

Table 2.3
—World top 10 military companies (2002)

Rank	Company	Country	Military Sales (US$ million)	Total Sales (US$ million)	Military Sales as percentage of Total Sales
1	Lockheed Martin	USA	23,337	26,578	88
2	Boeing	USA	22,033	54,000	41
3	Raytheon	USA	15,291	16,760	91
4	BAE Systems	UK	15,036	19,485	77
5	Northrup Grumman	USA	12,278	17,206	71
6	General Dynamics	USA	9,800	13,800	71
7	Thales	France	7,653	11,636	66
8	EADS	Netherlands	6,290	31,344	20
9	Finmeccanica	Italy	3,894	8,132	48
10	Honeywell	USA	3,800	4,000	16

From Defense News 21.7.03

2.9 Environmental impact of the military

As well as the ultimate environmental degradation which is part and parcel of armed conflict, the preparation for military operations causes an almost continuous low-level 'war' to be fought. Training produces cumulative damage to the environment. These include the use and degradation of land (including UK National Parks); the pollution and use of airspace and the noise generated by low-flying aircraft, again often in National Parks; the use of energy sources and the production of various waste material (Renner 1991, Barnett 2001).

Globally vast tracts of land are given over to training and testing of weapon systems. The US Department of Defense controls around 25 million acres of land (Perry 1995, Barnett 2001) and the increasing demand for land follows from ever more powerful weapons and the use of live ammunition by troops. It is ironical that the military use of land, especially in the UK National Parks and other open spaces in the guise of defending a country's 'freedoms' effectively withdraws the public's access to those areas. The US uses other countries to train and test their weapons. In the Cold War period the US military was the largest holder of agricultural land in the Philippines (Renner 1991). Seager has estimated that there were 3,000 military bases situated on foreign lands in the early 1990s and that such foreign occupation exerted far greater environmental damage than would occur in the domestic locations (Seager 1993).

Huge environmental damage has been caused by weapons testing, including nuclear and conventional systems. In addition, the use of weapons in times of war or in more limited conflict damages the environment in a host of ways. The use of Agent Orange and similar defoliants in the Vietnam war and the burning of Kuwaiti oil-wells in the 1991 Gulf war illustrates the forms of environmental damage which accompany conflict (Ramachandran 1991, Barnett 2001). The consequences of war last for decades after the initial conflict.

2.10 The military world—some future prospects

A number of worrying trends have emerged over the past five years which have the potential to further reduce peace globally, exacerbate human and environmental damage and increase the likelihood of further conflicts arising. In addition higher military spending will also impact on other issues relating to security such as poverty, the creation of refugee populations and the further erosion of support for open science.

Prior to September 11 2001 there were very few instances of heavy military operations against terrorist threats and incidents. The US-led wars in Afghanistan and Iraq changed all that. This strategic change will influence the perception held of the West by the rest of the world. In addition the security clamp-down on foreign visits to and from the USA will damage the whole enterprise of science, which thrives on the free exchange of both people and ideas (see Chapter one).

There are a number of security issues which are not only not addressed by the 'War on terror' but are actually worsened by it. These include the diversion of funding from civilian R&D into military R&D in many countries (these already include the USA and Canada - Skons *et al* 2002); increasing resentment, especially in Islamic countries, of the attitude of the Bush administration and the anomalous attitude toward Israel's treatment of Palestine and the Palestinian population in the occupied areas; the failure to address the potential for use of nuclear and chemical facilities in the West for the construction of, for instance, 'dirty bombs'. Huge repositories exist in Russia, the USA and the UK of chemical and radioactive materials stored on-site at chemical and nuclear plants (including those involved with the manufacture and storage of nuclear warheads). Such material could be used or targeted by terrorists.

The Bush administration's still secret December 2001 *Nuclear posture review* complained about the "limitations in the present nuclear force" and felt that "new capabilities must be developed to defeat emerging threats". In the USA a number of multibillion dollar preparations are being set in train to make limited nuclear strikes possible (Paine 2004). The lack of any real dissenting voice in the political scene in the USA, coupled with the support of the Blair government, makes pre-emptive strikes and first-use part of future military planning, especially following the pre-emptive invasion and subsequent activities in Iraq. In addition the Coalition used many new and refined weapons such as earth-penetrating bombs, area-impact munitions and so-called precision guided missiles, some of which may be of doubtful legality (Medact 2003).

Such earth-penetrating and low yield nuclear devices (discussed in more detail in Chapter four) may well involve research at Aldermaston and other facilities in the UK, perhaps including certain universities. The development of these weapons threatens to start a new nuclear arms race.

2.11 The ultimate security

Many have written about the need for a more inclusive understanding of the means of securing peace and stability in the years after the end of the Cold War. The end of the Cold War and the growing threat of terrorism across the world has led many to question the importance of military power in comparison with other, non-military goals of public policy (for instance Zunes 2002, Cairns 2003, Hagelin and Skons 2003). Many in government and in science have shifted their attention toward non-military threats to security such as domestic poverty, educational crises, the impact in human and environmental terms of economic globalisation, drug trafficking, crime, migration (including the refugee crisis), environmental degradation, global climate change, resource shortage and dwindling biodiversity (Baldwin 1995) - and we discuss examples of this work in more depth in Chapter five. This change in perspective calls for an increased focus on the intimate and at times complex relationship between military power and domestic issues, such as the economy, civil liberties and the apparatus of civic society. These issues are now being thrown into relief following the various contraventions of human rights and freedoms in many countries (including Iraq and Afghanistan) following the atrocities on September 11.

Others have written about the growth of modernization and globalisation leading to a number of 'societal risks' which themselves give rise to hazards and risks which reduce social justice and inflame conflict (Beck 1992). Few societies can sustain classic warfare today especially in light of the growing complex structure of cities and the loss of autonomy that accompanies modernisation. In addition war is the ultimate assault on sustainability. What is needed today, more than ever before, is to make a choice between military power with the possibility of a devastating nuclear event, and a shift to a far more sustainable future. It is pivotal that those living in poverty are given the opportunity to improve their standard of living without adding to the West's destruction of the planet's life-support systems.

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NOTES

1. The role of science and technology in support of the Cold War lies outside the scope of this Report but has been described by historians elsewhere - for example to Hartcup (2000).

CHAPTER THREE

The military investment and presence in science, engineering and technology

"One of the great values of higher education to society is that it provides a body of authoritative opinion . . . which is deemed to be trustworthy in terms of the independence of its judgement"

from SURPC (1997)

KEY POINTS

- ❑ The military has a very powerful role in UK government spending on science, engineering and technology (SET). The Ministry of Defence spends approximately 30 per cent of the UK government R&D budget.
- ❑ The military sector comprises a complex web of industrial, government and academic players who all have significant roles in influencing the SET agenda. Such influence rarely is subject to public scrutiny.
- ❑ The restructuring within both the military and university sectors, together with the political agenda shared by UK governments over the past decade, have created a climate conducive to the military support of research and development across universities and similar institutions. Recent joint initiatives have included the Defence Technology Centres, the Towers of Excellence, and the Defence and Aerospace Research Partnerships.
- ❑ There have been a swathe of changes to the arms procurement process and the military research and development effort which has created a broad alliance between the universities, the military corporations and the government.
- ❑ Military R&D comprises a narrow focus on a high-technology weapons-based agenda. This is especially so in the case of the Defence Technology Centres, the Towers of Excellence and the Defence and Aerospace Research Partnerships.
- ❑ A small number of powerful military corporations tend to have a disproportionate voice within decision-making groups and government committees and tend to drive the research towards narrowly focussed goals.
- ❑ The influence of the military corporations is very extensive within the university sector and pervades teaching, research and public relations. Again, such influence tends to narrow research goals. Similarly the agenda for security tends to be focused on a simplistic view based on weapons and other means of force.
- ❑ Technology transfer from military-supported R&D to civilian use is a complex and expensive route which has in the last twenty years been disappointing in view of the massive investments involved.
- ❑ The widespread presence of military interests within SET means that dissent and ethical concerns are stifled or at best difficult to articulate. This move away from openness also means that information is difficult to obtain and secrecy prevails. This builds a climate where independent expert opinion is scarce.
- ❑ The extent and full impact of the military on the UK's SET research programme is hidden. Secrecy and evasion prevail throughout the universities where funding or sponsorship is concerned. Full public accountability and scrutiny is largely missing, even in those areas carrying little security risk.
- ❑ The NATO 'Science for Peace' programme is a small but promising example of how SET can be driven by a broader security agenda.

3.1 Introduction

This Chapter brings together many of the themes which have been mentioned earlier in this Report and describes the often complex and multilayered world of 'defence'. Here we pay particular attention to the military sector's engagement with science, engineering and technology (SET) in UK universities in research, teaching and public relations, as well as the changes wrought in various research laboratories funded, now in part, by the government. Included within this is a broad overview of the various initiatives which have been launched over the past decade to link various aspects of university research with the military sector.

In the pages that follow the UK military sector is regarded as comprising the Ministry of Defence (MoD), the military corporations and some of the activities of the Foreign and Commonwealth Office and the Department of Trade and Industry (DTI), including the latter's Aerospace and Defence Directorate.

This Chapter explores the extensive presence both in government and within the research communities of the military sector, their representatives and their agenda. Some figures will set the scene. In 2003/04, approximately £2.7 billion was spent by the military on UK R&D: £2.6 billion coming from the Ministry of Defence (OST 2003), and in the region of £100 million from military corporations.[1] The argument we develop further in this chapter, following on from the discussion in earlier chapters, is that this presence not only marginalises alternative views of security within SET, but also drives a narrowly focused, commercial agenda. The potential which this has to lead to a reduction of independent expertise has been highlighted earlier in the Report.

The 'defence' burden pays for weapons and their support technology, various kinds of equipment designed for conflict and the employment of staff. Powerful weapons systems, including the nuclear arsenal, depend upon sophisticated technology and scientific expertise and have been a fact of life in the 20th Century, with their threatened use being a feature of the Cold War. The early part of the 21st Century, especially given current US military policy, shows little sign of a reduction in the risk of their use.

The global military expenditure is huge. In 2000 it was US$810 billion annually - around two-thirds of its level at the peak of the Cold War (in 1985), and rose to US$956 billion in 2003 (SIPRI 2004). Spending accelerated sharply in 2002 increasing by around 6 per cent (see Smith 2003 and SIPRI 2003). Military spending accounted for 2.5 per cent of world GDP in 2002. The current level of world military spending is 14 per cent higher than at the post-Cold War low of 1998. More details of the military sector may be found in earlier chapters of this Report.

3.1.1 A changing landscape

There have been a number of profound changes in the UK over the past decade which include the socioeconomic reshaping of life and a markedly altered research and teaching landscape in public sector institutes. These changes were discussed in Chapter one. The global political situation has also altered dramatically, and the ways in which the military operate and the equipment they use has been transformed. Even before the 'War on terror', countries in the North replaced their doctrine of 'engagement' in disputes or offensive operations where land-, sea- and air-based forces were previously large, with smaller, highly sophisticated rapid deployment forces to bring about desired ends in the battlefield. Support of such strategies involves cutting edge offensive weaponry such as robot vehicles and drones, guided missiles, cluster bombs and perhaps one day even 'mini-nukes' (see section 4.3.4), and largely depends upon the expertise residing in the SET world.

At the same time space has been increasingly considered as potentially a stage for the deployment of weapons in ways we discuss in Chapter four. Defence postures across the world are increasingly unilateralist (a view championed by the USA - see section 4.2) and challenge the assumption that all human beings are of equal importance. There have been serious reductions in the rights of individuals in the wake of the 'War on terror' (Global Civil Society Yearbook 2002) and this adds to the erosion of academic freedom discussed in Chapter one.

Successive governments in the UK have wrestled, in the main with only marginal success, with both the spiralling costs of armaments (weapons procurement) and the desire of military corporations to sell their latest and ever more sophisticated technology. We discussed earlier the driver of such expensive weaponry (Kaldor 1982). It is important to realise that there is a complex interaction between the Ministry of Defence procurement 'needs' and the military corporations' desire for increasing profits. This interaction comprises a number of competing elements: value for money, the potential for civilian take-up of military technology (especially in view of dual use and technology transfer) and the changing landscape of security needs. This is often a complex and changing interaction and the pages which follow will trace the various strands in this involved landscape at the time of writing.

The UK like any industrialised nation is motivated by the desire to 'improve' its 'defence' position but it is clear from the history of the nuclear weapons strategy during the Cold War that "a good defense is not good enough" (see Kaplan 1983). The growth of more and more sophisticated technology, especially that comprising the Missile Defense programme clearly shows that this approach is still leading the military sector, especially in the West.

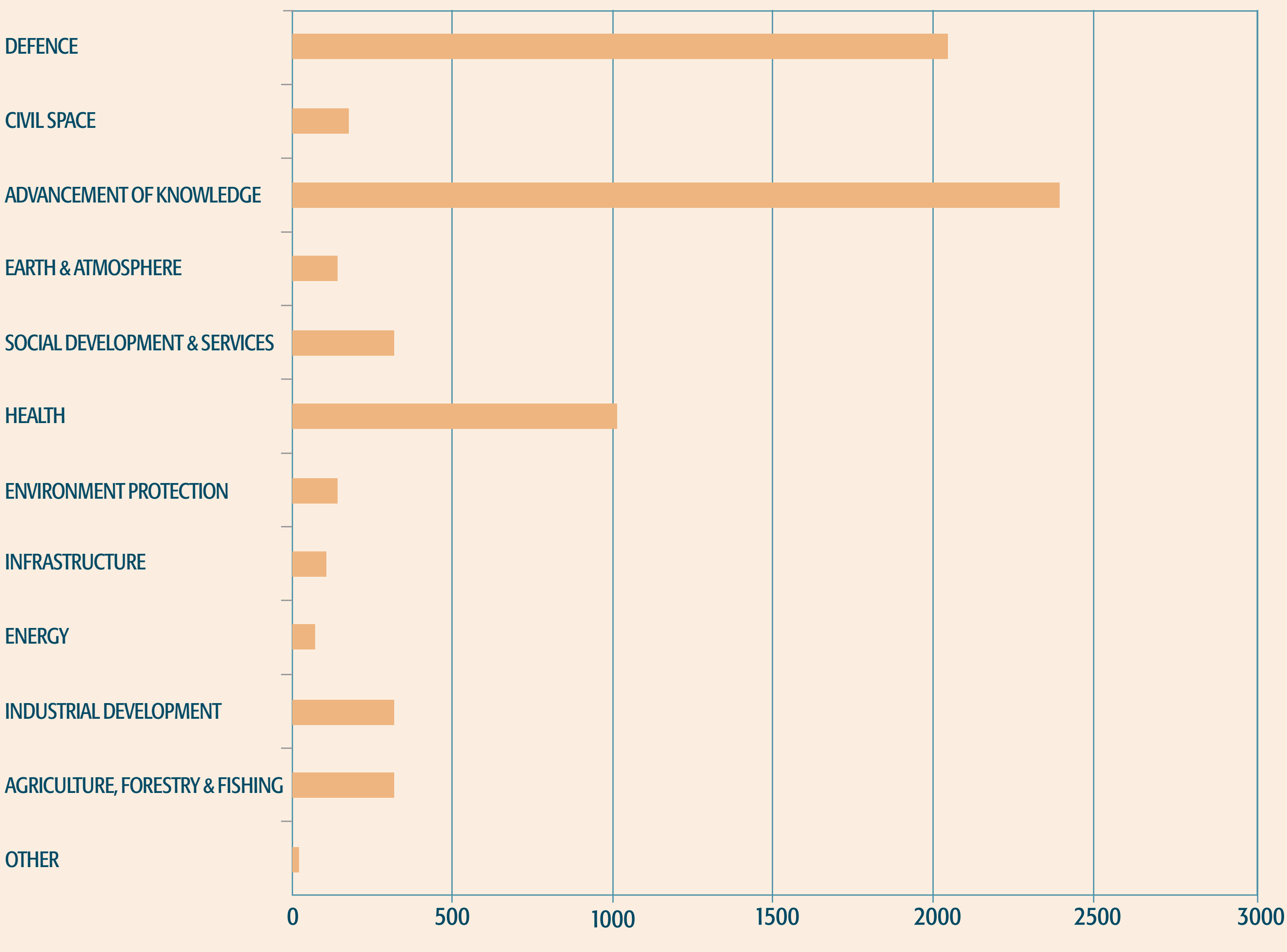
Weapons influence our behaviour and our expectations in innumerable ways. SET has not only provided advanced battleground technology but has also delivered a varied range of surveillance and control systems, as well as increasingly sophisticated weapons to governments across the world. Such equipment has been used to gain ascendancy in a conflict, to police borders, to verify people's access to specific environments and to monitor movement. Thanks to 'dual use' technology, which is discussed later, urban policing and control at times look very similar to urban warfare. Indeed, it is often difficult to distinguish between policing and battlefield situations in the many advertisements to be found in Jane's Defence Weekly, the showcase of the military world.

3.2 UK Government military spending and SET

Figure 3.1 shows UK government R&D expenditure by end-use in 2001/02 (the latest year for which these figures are available - see www.ost.gov.uk/setstats Table 3.8). It shows clearly that 'defence' enjoys a very prominent position within UK publicly-funded SET. The most recent figures available at the time of writing show that R&D spending by the MoD was planned to reach £2.6 billion in 2004/05 (OST 2003), about 30 per cent of the total public funds for UK R&D.

Strictly speaking the Ministry of Defence does not carry out basic or curiosity-based research itself (but see OECD 2002 concerning the problems associated with definitions of R&D). However, the Ministry has a research budget and separately a huge budget for the acquisition (procurement) of military equipment, which includes development, that is, the design and testing (normally in industry with the MoD as customer) of specific equipment.

Figure 3.1 **UK Government R&D expediture (2001-02)**



from www.ost.gov.uk/setstats

Despite the claims made by the MoD about its support of research, its non-nuclear research budget - the Research Building Block (RBB) - held by the Chief Scientific Adviser is used to undertake corporate and applied research.

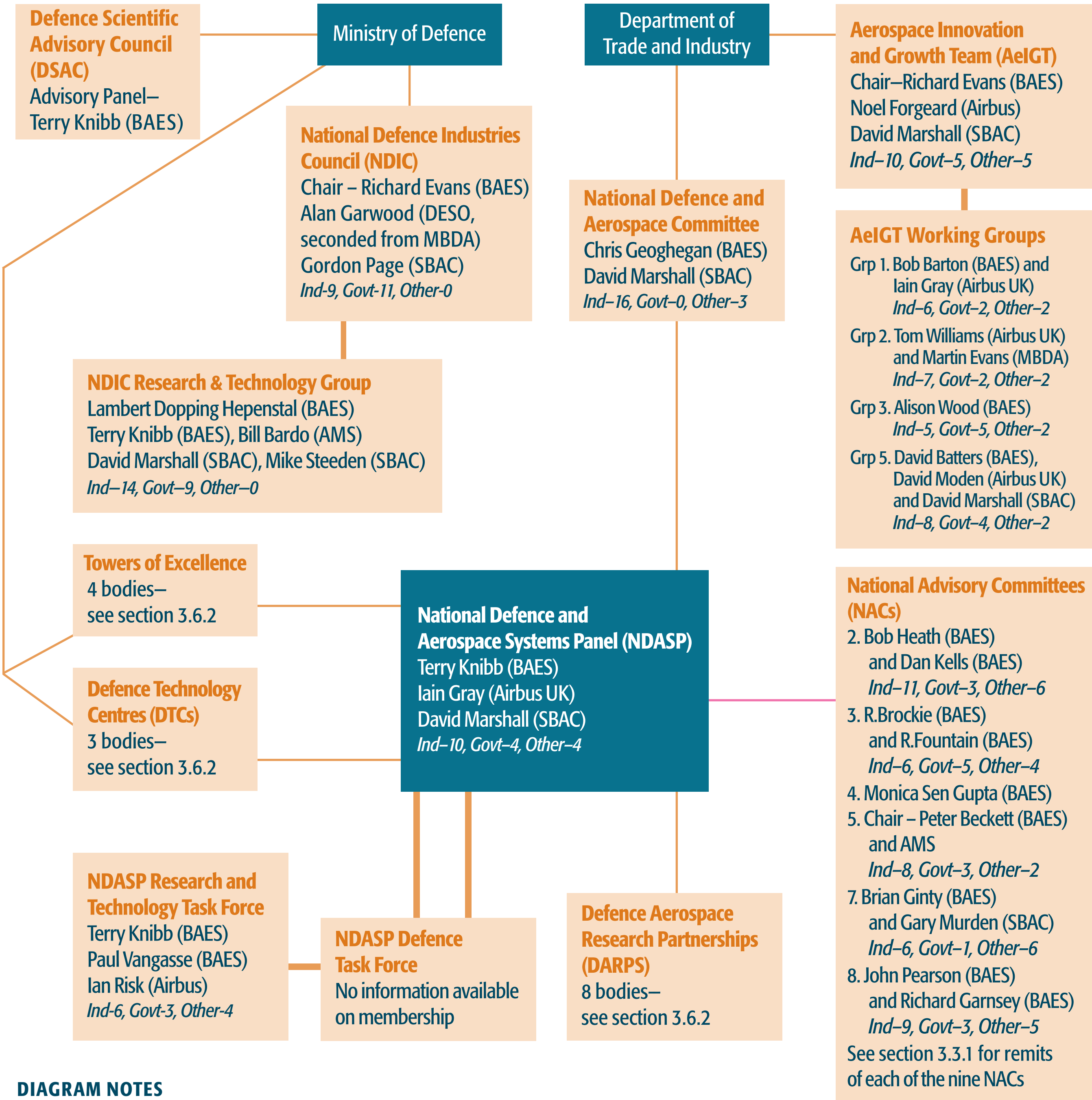
RBB expenditure in 2004/05 is expected to be £463 million (www.mod.uk). There has been little change in this figure over the past five years. The RBB consists of two major categories. The first is the Applied Research Programme (ARP), which is used to develop specific 'solutions' to current military needs and also to scope options for future military equipment. The second area is the Corporate Research Programme (CRP). About one-third of this Programme (10 per cent of the whole RBB) is spent on inventive and novel research with obvious military potential but as yet no defined need (Ministry of Defence 2002a). The remainder of the CRP is research which aims to address a whole array of known military needs. Other than the ARP and the CRP, the remaining significant elements in the RBB are the funding of the setting up of international research collaborative endeavours and the Joint Grants Scheme (jointly with the Research Councils, see section 3.6.1). These have clear defence-related goals in a range of disciplines and involve scientists, technologists and engineers in addition to others with a science background.

For forward planning purposes the RBB also includes around £25 million to fund the technology demonstrator programme (TDP) which is intended to reduce the areas of high technical risk following from a novel 'project' or technology associated with future military equipment. More detailed discussion of the Ministry of Defence research interests will be found later when the new consortia involving the universities, the Ministry and the military corporations are described.

A complex web, involving advisory and industrial lobbying groups as well as favoured 'spokespersons' for various interest sectors, plays a key role in setting the agenda for military-supported SET activities (see figure 3.2). The web comprises a plethora of inputs to government decision making and the opportunities for informed challenge are few and far between. The secretive and Byzantine pathways which characterise the military sector are not open to public scrutiny.

Central to this military sector web appears to be the National Defence Aerospace and Systems Panel (NDASP). This panel has conduits to government through the Ministry of Defence and the Department of Trade and Industry (DTI). In carrying out research for this Report, we found that the amount of detailed information available on the relationship between the NDASP and the lobbying groups representing the UK and European aerospace and military corporations (such as the Society for British Aerospace Companies) was very limited. However, it is clear from literature in the public domain that BAE Systems plays a key role across the military web in the various advisory groups including NDASP (see section 3.3.1 for more information on NDASP).

Figure 3.2
–The web of the major military advisory groups



Based on a diagram from CAAT (2003). Used with permission.

DIAGRAM NOTES

- ❒ A thick line indicates a sub-group or committee. Other lines indicate a relationship but the nature of this relationship may vary. See the following text for details of each relationship as far as it is known.
- ❒ A number of the boxes contain a description of the make up of each body: 'Ind' for Industry covers companies and industry associations; 'Govt' represents all branches of government; and 'Other' covers academics, the occasional union representation and those for whom no description is given. BAES is BAE Systems; DESO is Defence Export Services Organisation; SBAC is Society of British Aerospace Companies; AMS and MBDA are military companies

The Ministry of Defence spends taxpayers' money on R&D in the main to assist its various contractors to develop and hence make available what is later bought by the Ministry. In the late 1990s around one-third of the defence R&D budget was spent in the Ministry of Defence's own research establishments. These comprised the Defence Evaluation Research Agency (DERA) laboratories (see section 3.5) and the Atomic Weapons Establishment at Aldermaston (see Chapter four).

In a written reply to a question about research contracts placed by the Ministry of Defence with universities and other academic research centres Lewis Moonie, Parliamentary Under Secretary of State for Defence and the man responsible for science and technology at the Ministry of Defence, said that from 1998 to 2003 almost all of the Ministry's research work had been placed with DERA, and since July 2001, with the newly created Defence Science and

Technology Laboratory (DSTL) and QinetiQ. The latter offers contracts to academia and industry for military-related research projects, as well as offering access to in-house specialist knowledge (see section 3.5).

He pointed out that in turn these organisations had sub-contracted with academia in "a manner which ensures that the Department's needs are met in an integrated and cost-effective manner. MoD does not hold centrally information about the number of sub-contracts placed by our contractors with either academia or industry and this could be provided only at disproportionate cost" (Hansard 18 March 2003). This surprising lack of centrally located information, available for public scrutiny, has also been encountered in various quarters during the preparation of this Report. In many cases it has proved impossible to obtain details of the extent and level of funding by the military sector in UK universities.

Moonie went on to say that the MoD had placed contracts directly (from 1999 to 2003) with three (unnamed) universities to the tune of £591,000. In addition ten universities in the UK (again unnamed) had received £2.6 million for "their role in successful consortia bidding into research programmes" (Hansard 2003) - these are likely to be the universities involved with the Defence Technology Centres (DTCs) and the Towers of Excellence mentioned later in this chapter.

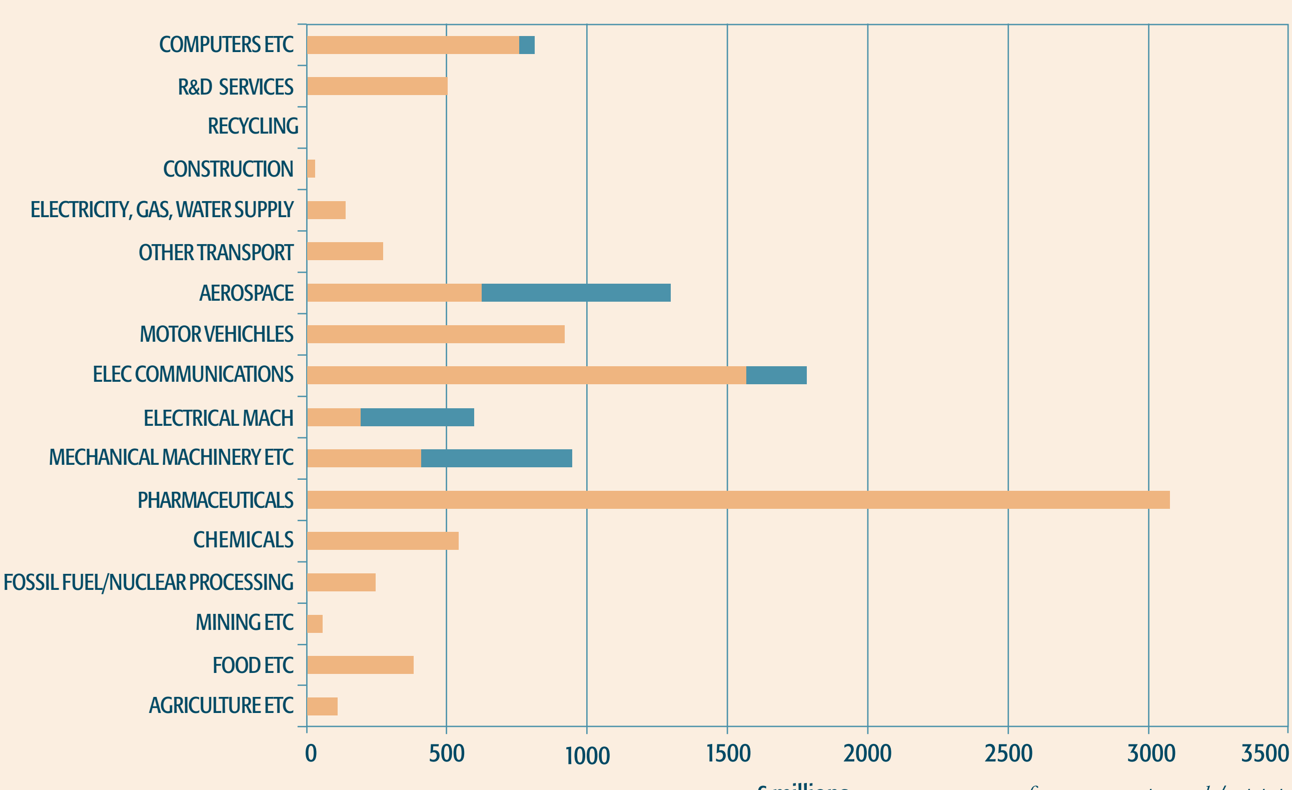
3.3 The UK military industry and SET

The military industry, which is one of the most powerful in the OECD, has been undergoing change in the last twenty years. In the UK, military and aerospace companies like BAE Systems and Rolls Royce have dominated the procurement process, and by take-overs and 'consolidations' such corporations have expanded and become even more influential. They are also to be found on a variety of panels, committees and government advisory groups which set a research agenda that strongly reflects the interests and economic wellbeing of the military corporations (see figure 3.2).

In the UK successive governments have responded to these changes in ways which are detailed in various Strategic Defence Reviews. The latest of which (HM Treasury 2004) also calls for a more slim-lined armed force with increasing use of sophisticated technology. The Smart Acquisition reforms also seek to reduce the costs of procurement and to build an even more technologically advanced R&D effort. Major military corporations have themselves changed by having Integrated Project Teams for each MoD programme with various streamlining initiatives which call for loss of jobs and outsourcing to be used (Schofield 2002). Such a drive actively taps into expertise residing in the universities in order to form commercial 'partnerships' such as are described in Chapter one.

The military industry in the UK is a large component of the manufacturing sector, with a turnover of around £15 billion per year and employs around 345,000 people. This includes scientists and engineers in various capacities over and above R&D (see Ministry of Defence 2002b). In 2003, of the top 3000 international corporations, the aerospace (including civil) and 'defence' sector accounted for 4 per cent of the world R&D spend - in the UK this figure is 9 per cent (Financial Times 20 October 2003). More details on the share of the military in UK and global industrial R&D may be in found in Figure 3.3 and at www.statistics.gov.uk

Figure 3.3 UK business R&D expenditure 2000-01 (selected)



from www.ost.gov.uk/setstats

It is worth reiterating here the concerns raised in Chapter two that the military industry is a major driver of the international arms trade and currently sells its products to many regimes guilty of serious environmental and human abuse. Clearly the employment and economic benefits to the UK of these industries should be considered in this context.

The military industries depend heavily on UK government support for weapon development and research and the means of delivery. For example, the Joint Strike Fighter aircraft (JSF) programme has £1.4 billion of UK taxpayers' money invested in its collaborative development. Procurement of military equipment is the preserve of the government's Defence Procurement Agency (DPA). This agency currently has an annual budget of £6 billion, employing around 4,300 people of whom 1,800 are scientists and engineers. Over 13,000 contracts with industry are managed by DPA.

3.3.1 Military interest groups and the SET agenda

The Foresight programme which was discussed in Chapter one comprises a variety of panels, claiming now to have refocused on 'improving the quality of life' rather than solely on wealth creation. As was discussed earlier the second round of Foresight ran from 1999-2002. In this second round the military sector was covered by the Defence Aerospace and Systems Panel and the Defence Task Force. Both these groups were heavily freighted with military industry representatives including BAE Systems (www.foresight.gov.uk).

The next round of the Foresight exercise began in April 2002 and the military interest was removed from the broad remit of the Foresight programme to become a free-standing programme - the National Defence Aerospace and Systems Panel (NDASP). Funding is from the Ministry of Defence (to whom the Panel reports) and DTI (reporting is here through the Aerospace Committee). At the time of writing the NDASP consists of sixteen panel members of whom two are from universities and the remainder comprise governmental and non-government representatives, the latter include those from GKN, BAE Systems and Rolls Royce. The role of the NDASP is to achieve a 'better fit' between the MoD funding of SET and industrial and research council's investments.

There are also powerful lobby groups within the UK and European military sector, which largely comprise of the aerospace companies. Such groups have the ear of both national governments and many within the European Union. In the UK the Society of British Aerospace Companies (SBAC) represents the interests of the aerospace and airport development industries and is the voice of 600 companies. SBAC represents the UK aerospace industry at European, national and international levels and has a well cultivated relationship with government. A sustained and developed programme of Parliamentary events and lobbying ensures that SBAC gains access to those in Parliament and government who maintain the military industry's interests.

National Advisory Committees (NACs)

These Committees have been created to act as the "national fora for defence and aerospace research and technology (R&T) development" within a set of specific areas (www.foresight.gov.uk). Some have arisen from previous bodies, such as the Aerospace Advisory Group of the Innovative Manufacturing Initiative (which itself led to various military corporation and university 'partnerships'), others are newly created.

The NACs are expected to "advise the National Defence Aerospace and Systems Foresight Panel of key themes and directions for the national defence effort in research and technology development, taking account of European and international initiatives". Thus a role in shaping many areas within the national SET agenda, especially in engineering and similar disciplines, falls to the NACs.

At the time of writing nine NACs have been established:

- ❑ Aerodynamics
- ❑ Aerospace manufacturing
- ❑ Avionics and flight systems
- ❑ Electronic material and devices
- ❑ Human factors
- ❑ Materials and structures
- ❑ Mechanical systems
- ❑ Synthetic environments
- ❑ Systems engineering

Each of the NACs is supposed to develop and communicate a "shared understanding of priorities for research and technology development between all stakeholders". Needless to say, given the climate discussed in Chapter one, the NACs are also charged with maintaining an overview of UK competitiveness. And again BAE Systems has a very strong presence on all those NACs for which there is publicly available information. Many of the NAC interest areas have been expanded in the programmes of the Defence Technology Centres which are discussed later.

The NACs are expected to focus the research activity in each of the nine areas listed above. Doubtless more areas will become identified as technology advances and 'needs' are identified. As is pointed out in the Foresight website "it is important to ensure that they [the NACs] are kept informed of developments in the national scene in military and aerospace, of the driving and constraining factors within funding bodies and of changing market opportunities". Clearly this will impact on R&D priorities and the involvement of those within SET in universities, especially where funds are limited, and industry. In publicly available information the NACs appear to have only marginal interest in issues of energy efficiency, sustainable transport or the possible amelioration of global climate change.

Defence Scientific Advisory Council (DSAC)

In ways which are very similar to the Council for Science and Technology which was mentioned in Chapter one, the Defence Scientific Advisory Council advises at a ministerial level. DSAC advises the Secretary of State on matters of concern in the area of SET, including R&D. The Council has representatives from the military corporations as well as those from an academic background. Julia King who is now the chair of the Council was previously with Rolls Royce before she became the Chief Executive of the Institute of Physics (the Institute interestingly has a representative of QinetiQ on its business interest committee). The movement from industry to academia and to senior posts in government has been described previously and is very common. As we discuss later such a process will tend to strengthen an increasingly industrial agenda for SET with little room for dissent, and with serious limitations on the availability of independent expertise.

At the time of writing the Council is supported by four Boards: the Chemical, Biological Defence and Human Sciences Board; the Information Superiority Board; the Precision Attack Systems Board; and the Battlespace Manoeuvre Systems Board. In addition there are three groups which cover operational analysis, sensors and materials which feed into the DSAC. To further aid in the information flow there are 180 'independent' experts who can be called upon for specific tasks. All DSAC groupings such as the Boards and Working Bodies have Defence Science and Technology Laboratory (DSTL) and MoD members as well as those from other government departments and the MoD Chief Scientific Advisor (who until recently was Professor Sir Keith O'Nions, now Director General of the Research Councils, and thus plays a key role in the allocation of funds for SET). DSAC members are security vetted and the meetings are not usually open to public scrutiny.

Aerospace Committee
The DTI also plays a role in many areas of 'defence' policy and liaison with the military corporations. The Aerospace Committee facilitates the work of the Department of Trade and Industry (DTI) in providing fora for the UK aerospace industry to influence the officials and Ministers in the DTI on issues concerning military R&D.

Defence Industries Council (DIC)
The Defence Industries Council is a forum for senior figures from the military industries and trade associations to discuss and press ahead with issues of strategic importance to the UK military industry. The Chairman of DIC is currently Ralph Robins who is chairman of Rolls Royce and the secretary is David Marshall the Director-General of SBAC (see above). As would be expected DIC has 'dialogue' with the Ministry of Defence and will be instrumental in consolidating the position of military corporation interests in R&D.

National Defence Industries Council (NDIC)
Another link between the military industry and the government is provided by the NDIC which also advises on matters of strategy relating to 'defence' concerns and identifies and commissions work of strategic interest to government and the military industries. The NDIC is chaired by a Minister from the MoD and is attended by senior officials from the relevant parts of MoD and its R&D Directorate.

The NDIC has various sub-groups and committees and these include the Technology Working Group, an NDIC R&D group as well as human resources and support policies groups.

Aerospace Innovation and Growth Team (AeIGT)
This Team was set up by Patricia Hewitt, Secretary of State for the DTI, in May 2002, with the chairmanship of Richard Evans from BAE Systems and 140 senior military corporation representatives as well as representatives from government, the universities, the trades unions and research organisations (www.aeigt.co.uk). Interestingly this team was anticipated in the SBAC's 2002 campaign '*Winning the global aerospace competition*' document.

The remit of the AeIGT was to provide, in 2003, recommendations to the Prime Minister on a range of issues directly of interest to the aerospace industry including competitiveness and R&D.

The AeIGT has a number of working parties containing BAE Systems and SBAC lobbyists who 'advise' on technology, engineering and environment and safety (surprisingly the latter does not have a BAE Systems member).

Other non-military commercial bodies, such as the Office of Government Commerce and the Competitiveness Council, also have military corporation representatives and will influence the SET agenda and prioritise military interests rather than those relating to other less lobby-driven areas such as sustainability and the broader security issues, discussed at various points in this Report.

3.4 Military sector R&D and 'spin-out'

Despite the changes in the fortunes of some of the global 'defence' markets, and the lower profile given before 11th September 2001 to military-industrial issues following the end of the Cold War, the effort invested in defence-related R&D in the UK has been significant for the past 20 years (Molas-Gallart 1999). Such R&D effort, as we saw earlier, is a principal feature of countries wedded to sustained military technology development like the UK, France and of course the USA. For instance in 2001 the USA accounted for more than 75 per cent of the overall OECD-area budget for 'defence' R&D, or more than 4 times that of the European Union total (OECD 2003). See Box 3.1 for further discussion of R&D economic statistics. The USA also has the largest share of government outlay for R&D devoted to military objectives, 57 per cent of its total R&D budget in 2004 (www.nsf.org). Spain and the UK were the only other OECD nations to commit more than a quarter of their R&D outlay in defence R&D (OECD 2003). The overall military budget for the USA was US$345 billion in 2002 and is expected to rise to an average of US$387 billion per year from 2003 to 2007 in inflation-adjusted dollars (Jane's Defence Weekly, 29 January 2003, page 18).

'Spin-out' is the term given to attempts to convert military technologies for civilian use. However, the broad usefulness of the products of the significant military R&D investment to civil needs is frequently far from clear. Military needs shape the form a product takes (nuclear power and microelectronics being examples, Slovomic 1991, quoted in Mort and Spinardi 2004) and in order for such products to be taken up in non-military manufacturing industries a long and often expensive innovative process has to be in place.

Box 3.1
–A note on R&D economic statistics

Some care should be used in comparing R&D budgets of different countries because defence R&D is often defined by reference to who does the research and who funds it rather than the objectives of the research. Differences in the origin of 'government' funding in Spain may explain how it gets to be up in the front of the R&D race with the UK and the USA who have occupied this unenviable position for decades. In addition there are problems with 'dual-use' technologies. The results of a great deal of R&D can be applied to both military and civilian goals, regardless of the origin of funds. Within large diversified aerospace corporations much R&D work is conducted for both civilian and military objectives, but especially in the UK many firms with military contracts are loathe to diversify into civilian markets (see Mort and Spinardi 2004 , Stewart 1989). With the constantly changing nature of technology it is highly problematic to derive a clearly defined boundary for the types of technology which have potential military applications (Cuthbertson 1983). This creates long recognised problems for defining and evaluating 'defence' R&D.

Commenting on these shortcomings in both the quality and availability of the data on defence R&D (which was also a serious problem in gathering material for this Report) Molas-Gallart (1999) suggested that use should be made of the R&D spending patterns of defence agencies and public programmes earmarked for defence purposes. We have used such an approach, where possible, in this Report and have also given those estimates of research and development budgets which are publicly available.

Indeed those who claim that the funding of military R&D will result in spin-out of products into the civilian market - technology transfer - are taking an overly simplistic view of the innovation process and the possibilities for civilian value from military investment. The Defence Diversification Agency, set up in 1998 (see Box 3.2), is charged with two-way technology transfer between the civil and military sectors. It is not clear what, if any, real impact this Agency has had.

For spin-out from military investment to be of benefit to national economic wellbeing those industries involved with military contracts must be willing and able to develop the product further for its civil use. In their study of the engineering company Vickers at Barrow, Mort and Spinardi (2004) have shown that although there are various examples of successful spin-out from military investment into civilian-use technology - such as radar, liquid crystals and certain kinds of semiconductors (Spinadi 1999, quoted in Mort and Spinardi 2004) - the process is complex. The authors point out that there is a great deal of evidence that UK manufacturing companies with potentially both military and civilian markets tend to favour military over civilian work.

These authors show that not only Vickers but also Ferranti decided to drop civilian work despite their highly successful civil operations. Likewise GEC did not build upon its 'defence' contracts for the production of liquid crystal displays for civilian markets despite the chance afforded it by work undertaken at the then Ministry of Defence signals research establishment at Malvern (Spinardi 1999). Although the reasons for lack of diversification within the electronics and engineering industries from military to civil markets are complex, it is nonetheless instructive when considering the non-defence value of the potential products expected to arise from the consortia discussed later in this chapter.

Furthermore, it is increasingly difficult to trace the relationship today between the civil and military R&D operations within those companies that supply to both markets. Lockheed Martin and Raytheon are around 90 per cent military, BAE Systems, Northrop and General Dynamics are all between 70 and 80 per cent (see section 2.8). In a number of key areas such as electronics and information technologies the pace of civilian led innovation is well ahead of that undertaken in the military sector (Molas-Gallart 2000). Many off-the-shelf commercial products are used by the military even though historically such products were the subject of military R&D.

Alic *et al* (1992) have also shown that the relationship between military investment and the corresponding spin-out is far from simple and the claims that the civil benefits from military investment are automatic, straightforward or simple are misleading. They show that there are costly downstream technical efforts and the and that complementary assets are vital to create a viable commercial product. They add: "Concerns regarding the propriety of allowing federal investments to benefit private parties complicate technology transfer policies" (Alic *et al* 1992). These various caveats feature in the critique of the commercial outcome of the various consortia discussed later in this chapter.

Over a number of years the opportunities for exploitation of the capabilities of the UK defence research establishments for civilian objectives have been the subject of a swathe of reports and studies. In 1989 it was proposed that National Technology Research Centres be set up in order to drive through benefits from research carried out within the defence research faculties at significant cost to the tax payer (Advisory Council on Science and Technology 1989 and Molas-Gallart and Sinclair 1999). But the suggestion was dismissed by the then government because it was felt that there would be a gulf between the actual research and the military application. However, as a result of the discussions which followed a number of Dual-Use Technology Centres (DUTCs) were set up from around 1994 onwards. It was thought, especially by the Lords Select Committee on Science and Technology, that DUTCs potentially might be a powerful way of bringing industry and the research community together with the Defence Research Agency (the forerunner of DERA) to work on projects of mutual interest (Molas-Gallart and Sinclair 1999) and to produce both civilian and military innovations.[2]

In a detailed discussion of the DUTC concept and the various working practices which were found, Molas-Gallart and Sinclair pointed out that conflicts in priorities and potential conflicts of interest made it difficult for the DUTCs to fulfil their intended objective of focusing the defence research establishments on technology transfer and diversification into non-military contexts. The latter is an important point when we discuss how wider issues of security might be addressed in the future. It is unclear just what has happened to the DUTCs following the break-up of DERA in the Defence Science and Technology Laboratory (DSTL) and QinetiQ. (This break-up is discussed in the next section.)

The question of how best to make use of the expertise within the DERA research programmes was also addressed in the 'Pathfinder' conference scheme, launched in 1992. The intention was to enable industry to access research areas in DERA and to contribute at an early stage, ideas which might link with their own possibly civilian research direction. Funding support was mixed and could consist of complete funding from industry, or by use being made of DERA research facilities or for funding to be of a collaborative nature. Pathfinder intended to give military industries a voice in determining the research agenda and also to encourage spin-in from civilian to military research areas. But like the DUTCs the Pathfinder scheme appears to have been dropped. The problems of commercialisation that the DUTCs faced are as important now for QinetiQ as they were in the 1990s.

3.5 The changing face of government military R&D

From the mid-1980s the UK government supported or launched several high profile initiatives to transfer technologies generated through military funding to other, civilian, applications. The tide of privatisation discussed in Chapter one, which sped the demise of the traditional role of the university, was during this same period. A broad range of initiatives to reorganise government military research facilities and their relationship with the users of their research - the military corporations and the armed forces - to derive savings and create a more commercial agenda, also occurred during this time.

A medley of thirty fragmented laboratories and other establishments like those at Porton Down (the chemical and biological weapons research centre - see the next chapter) and Malvern (the radar and signals research establishment) was merged into a single operation, the Defence Evaluation Research Agency (DERA), which was the largest Government Defence Research Establishment (GDRE) of its kind in Europe (see Box 3.2). Only Los Alamos, the weapons research facility in the USA, was of comparable size. In 1993-4 management of the Atomic Weapons Establishment (AWE) became the responsibility of a private contractor, Hunting-BRAE. AWE is now a partnership with British Nuclear Fuels, Lockheed Martin and Serco (see the following chapter for more details).

The 1998 Strategic Defence Review showed that the Blair government was determined to create some form of privatised structure for DERA. The original plan to wholly privatise DERA was scrapped after strong objections from the USA government, concerned about questions of competition and sensitive information, likely to harm US profits. As a result, beginning in 2001, DERA was split, under intense and at times acrimonious debate, into the Defence Science and Technology Laboratory (DSTL; www.dstl.gov.uk) which has the highest concentration of scientists and engineers in any public service and the oddly-named QinetiQ (Watson 2001).

Box 3.2
–Government Defence Research Establishments - all change

1993 MoD creates an Executive Agency the Defence Research Agency (DRA)

1995 Defence Research Agency plus a range of Defence Establishments form the Defence Evaluation Research Agency (DERA) which comprised:

1. DRA - retention of former activities
2. DTEO - test and evaluation
3. CBDE - mainly chemical and biological defence
4. Centre for Defence Analysis

1998 DERA set up Defence Diversification Agency (DDA) - aims of which were threefold:

1. Exploit widely as possible military technology within civil markets.
2. Stimulate MoD expertise transfer for future needs - database of expertise for industries other than defence
3. Encourage civil technology to be taken up by the defence industries.

2001-2003
DERA becomes Defence Science and Technology Laboratory (DSTL) and the part-privatised QinetiQ

Similar reorganisation has also been happening throughout Europe, as the drive to redefine, privatise and slim down Government Defence Research Establishments (GDREs) took hold elsewhere. The GDREs have played a central role in the national SET programmes across Europe in the last fifty years (Molas-Gallart 2001).

Historically the various establishments comprising DERA have been the major suppliers of research to the MoD, although about 25 per cent of the work has, in the past, been put out by DERA to contract for industrial and academic bidding. Research supported in this way included projects in biological, social and the physical sciences. QinetiQ now offers research contracts to bidders from both industry and academia, and is a partner in some of the DTCs discussed later. DSTL have a number of links with UK universities through co-operative research centres and intend to further develop this theme. Also around half of DSTL's collaborative R&D work is with the USA (www.dstl.gov.uk - accessed September 2003).

The creation of DSTL and QinetiQ has changed not only the relationship with government but also with military corporations. Downsizing during the process also meant the loss of jobs for many with SET expertise. There was and is a great deal of opposition, not least from Parliament, to the creation of such privatised defence research organisations which was first being discussed in the 1990s (Masood 1998, Loder 1999). More recently, a spokesperson from Rolls Royce told the House of Commons Select Committee on Science and Technology that the creation and sale of QinetiQ would compromise the ability of QinetiQ to fully participate in the EU Framework Six Programme (see later in this chapter for more about EU support of military R&D) (Research Fortnight 26 February 2003).

The changes which have been undertaken to create DSTL and QinetiQ have also been followed by other government research establishments such as the Building Research Establishment - all of which affect those with SET expertise. As was discussed in Chapter one governments in the UK in the past twenty years have applied the so-called New Public Management theories to public science and technology establishments. This approach lays great emphasis on output controls, a suite of performance 'indicators', accounting-led management and a 'robust' marketisation. To see the effects of such a drive the reader should glance through the pages of the Annual Reports for DSTL and QinetiQ.

As has been described for the universities, government research establishments have been pressured into linking up with industrial partners and users. The needs of customer and provider have sometimes come into conflict here especially in the sell-off of DERA. The environment in which DSTL and QinetiQ operate is not only one in which the ever rising costs of new military technology must be controlled, but also one in which competition is fierce and 'dual use' technology complicates issues. At the time of writing QinetiQ is partly owned by the MoD and around one-third is in the hands of the Carlyle Group, a venture capital outfit, which is involved with a number of military companies in the US including Vinnell, United Defense and Vought Aircraft.

The privatisation of the former DERA is set, once complete, to reduce the numbers of professional scientists and engineers in DSTL and QinetiQ to around 10,000 from the previous 17,000 (Ministry of Defence 2001).

The privatisation of DERA is intended, at least in part, to allow the SET workforce to move away from its military paymaster, who reduced research budgets by 50 per cent between 1990 and 2000 (Watson 2001). A variety of novel technologies had arisen from DERA researchers including carbon fibre, tank armour design, and ground-penetrating synthetic aperture radar (which has grown into a number of medical imaging devices) and also various computer software applications. However, it is clear that QinetiQ is firmly located in military technology and will be so for the foreseeable future.

3.6 The military sector and university collaboration

As is detailed in Chapter one the universities are increasingly supported by commercial contracts and partnerships. This is in addition to the major research support provided by the seven research councils. Funds are dispersed to these councils on the basis of their remit. The Ministry of Defence is actively engaged through the Joint Grants Scheme with a number of the research councils.

3.6.1 The Joint Grants Scheme

The UK research councils, such as the Medical Research Council (MRC), the Engineering and Physical Sciences Research Council (EPSRC) and the Particle Physics and Astronomy Research Council (PPARC), together with the Ministry of Defence, offer a Joint Grants Scheme (JGS) to support research which has 'defence relevance'. The JGS provides funding for science in a variety of areas including: materials, DNA pathogen sequencing (see Chapter four for a discussion of biological warfare issues), smart materials and a wide range of nanotechnology and 'cutting edge' research (for a full listing of areas of MoD interest see www.dstl.gov.uk). The JGS strongly encourages reporting and open publication of results and the scheme is envisaged as providing long-term links within many of the large government funded research programmes.

Representatives of the interests both of government and of the MoD are linked to the JGS. These representatives come from bodies such as the Defence Science and Technology Laboratories (DSTL), the Atomic Weapons Establishment (AWE Aldermaston) and the Meteorological Office. Research projects supported under the JGS are 'sponsored' by a staff liaison officer from one of these organisations. Examples of past projects supported by the JGS can be found in the EPSRC Annual Reports for instance. Lewis Moonie, Minister responsible for SET at the MoD, has stated (Hansard 18 March 2003) that the scheme had made the awards that are listed in Table 3.1.

The Ministry of Defence also undertakes a number of collaborations which include the co-funding of aeronautical research by the MoD and Department of Trade and Industry (DTI) where identified dual-use technologies exist. Collaborative research has been undertaken at the former DERA under the DTI's Civil Aircraft Research and Technology Demonstration programme (CARAD) and the MoD's Corporate and Applied Research Programmes.

Table 3.1
–Funding provided by the Joint Grants Scheme to UK universities

	Number of grants	Value in £,000
1999	43	5,100
2000	61	4,600
2001	41	4,650
2002	34	4,780
2003	31	5,600

From Hansard 18 March 2003

Table 3.2
–Military sector-university consortia
–who was involved in 2004

	UTC	DTC	DARPS	TOE
Bath				✓
Birmingham	✓	✓✓	✓	✓
Bristol		✓	✓✓✓	
Brunel		✓		
Cambridge	✓✓	✓	✓✓✓	
Cardiff		✓		
City			✓	
Cranfield	✓	✓✓	✓✓✓	✓✓✓
De Montfort		✓		
Edinburgh		✓		
Glasgow		✓	✓✓	
Glasgow Caledonian			✓	
Heriot Watt		✓		
Imperial College London	✓	✓	✓✓✓✓	✓✓✓
Leeds		✓		
Leicester			✓	
Loughborough	✓		✓✓	✓
Manchester	✓		✓✓✓	
Nottingham	✓✓			
Oxford	✓✓		✓✓	
Sheffield	✓✓✓	✓		✓
Southampton	✓✓	✓✓	✓✓✓	✓
St Andrews		✓		
Strathclyde	✓	✓		
Surrey	✓	✓	✓	✓
Sussex	✓		✓	
Swansea	✓		✓	
University College London		✓		✓✓
York	✓		✓	

Notes

At the time of writing there are three Defence Technology Centres (DTCs), described in this chapter, and each has more than one participating university, each ✓ represents participation in one of the DTCs.

The Rolls Royce University Technology Centres (UTCs) have been single centres, covering the company's major businesses (civil and military aerospace, marine and energy) and are found at 15 UK universities, with some universities having more than one UTC. The UTCs have attracted funding from other military and non-military sources (see section 3.6.3).

Currently there are seven Defence and Aerospace Research Partnerships (DARPS) and like the DTCs more than one university participates in each of the individual centres. Each ✓ represents participation in by a university.

At present there are four Towers of Excellence (TOE) and again each ✓ represents participation in one of the four.

It should be reiterated that an unknown number of other university projects are funded by the military, but are not listed here due to a lack of accessible data

Sources are provided in the main text.

3.6.2 Consortia and partnerships

A number of new partnerships which draw on and support the expertise located in the universities and military corporations have been set up in the last five years - largely as a result of the DTI's Foresight programme mentioned earlier. Three such partnerships which tend to be complementary to one another are currently underway:

- ❑ The Defence and Aerospace Research Partnerships
- ❑ Towers of Excellence
- ❑ Defence Technology Centres

Table 3.2 summarises the universities which are involved in these collaborations.

Before discussing them it is worth briefly mentioning here that there are other, less obvious, examples of the ways in which the military sector collaborate with the university sector and exert an influence on the SET agenda in a variety of ways. Two are worth further discussion.

First are the collaborations between one or more military companies and the universities, these include the University Technology Centres which were set up by Rolls Royce, and also other funding initiatives such as those of Boeing in manufacturing.[3]

Secondly is the extensive public relations programme that is undertaken by both the Ministry of Defence and the military corporations. It is not immediately obvious in the glossy brochures and booklets detailing the science behind various projects that the aim of the technologies is often to kill, incapacitate and destroy enemy 'targets' and thus win an advantage. These programmes include outreach to schools and to undergraduates, to the public through mechanisms such as the National Science Week and at the annual British Association Festival of Science. We return to these areas in section 3.6.3.

Defence and Aerospace Research Partnerships (DARPS)
DARPS are industry-led university partnerships which encompass not only 'national need' but also alignment with the Foresight priorities (see Chapter one). The partnerships are funded by the Engineering and Physical Sciences Research Council (EPSRC), Department of Trade and Industry and Ministry of Defence as well as industry (see www.esprc.ac.uk and www.dti.gov.uk). By 2002, 12 partnerships had been set up to bid for the available DARPS finance. Of these, 6 are active with a further 2 under discussion. These 8 are:

❑ Rotocraft aerodynamics led by GKN/Westland Helicopters. Involves the City University and those of: Glasgow; Bristol; Southampton; Imperial College, London; Leicester; and Glasgow Caledonian.

❑ Advanced metallic airframes led by BAE Systems/Airbus/Filton.

❑ High integrity real time systems led by the University of York and the industrial partners include Rolls Royce (through the UTC based at the University of York), BAE Systems, Marconi and former DERA laboratories.

- ❑ Modelling and simulation of turbulence and transition for aerospace led by the Sowerby Research Centre (the BAE Systems corporate research and technology facility at Filton). The universities involved are Cranfield; Manchester; Imperial College, London; Loughborough; Southampton and Cambridge.

- ❑ Design led by University of Cambridge. Located in the Department of Engineering this DARP is based upon the Rolls Royce/BAE university technology partnership and will include not only Cambridge but also Sheffield and Southampton universities.

- ❑ Advanced aeroengine materials led by Rolls Royce and involves collaboration between the company's UTCs based at the universities of Birmingham; Swansea; Manchester; Cranfield; Cambridge; Oxford and the former DERA Structural Materials Centre (this centre was at one time a Dual Use Technology Centre discussed earlier in this chapter).

- ❑ Research in data and sensory fusion led by BAE Systems will involve the universities of Manchester; Oxford; Southampton and Swansea. In addition former DERA laboratories will be involved.

- ❑ Unsteady modelling for aerodynamics led by BAE Systems. This also involves the universities of Manchester; Bristol; Glasgow; Surrey; Sussex and Cambridge.

The total value of the DARPS research programme for 2002-03 was around £18 million (www.epsrc.ac.uk). Announcing these DARPS, millionaire science minister Lord Sainsbury said that "....we need to build effective partnerships between industry and academia - partnerships that will stimulate and focus research, provide a framework for technology transfer and the effective exploitation of results, and help to maintain and develop the UK's world-class science and technology base" (www.ost.gov.uk). In March 2003 a new partnership between BAE Systems and the EPSRC was announced - its aims to address the long-term needs of the civil and military aerospace industries (www.epsrc.ac.uk), the first phase was funded in 2003-04 and resulted in a joint investment of £4.5 million to Cranfield University and the second phase is currently being developed with Loughborough University.

It has proved quite difficult to find out more about the existing DARPS and these new partnerships, but they cover areas already involving liaison between the military sector and universities and the payoff of such collaboration will benefit military objectives, including the design of advanced weapons and launch platforms. Because of the 'dual-use' nature of such research there may be potential for some civilian benefit later, but as we discussed in section 3.4, the path to the civilian market is often difficult and requires an innovative drive that is not always forthcoming even in the most successful companies.

Towers of Excellence

This form of collaboration is between researchers in the former DERA research establishments, universities and the military industries and was launched at the Farnborough Air Show in July 2002. The 'Towers' are "generally created at the level of the major sub-systems technology" (www.mod.uk/toe). Six priority areas were identified: guided weapons; radar; electro-optic sensors; underwater sensors; synthetic environments and commercially available software for use in human-machine interface. (This last area has been a priority within the various programmes at the Defense Advanced Research Projects Agency (DARPA) in the USA, which is discussed in the next Chapter). The vigorous development of the Towers is actively supported by SBAC.

The Towers of Excellence will mirror the various 'innovative' research areas that DARPA supports in the USA. It is assumed that Towers will have the capability of underpinning a new military industrial strategy in the UK, which was proposed by Baroness Symons, the former UK minister for 'defence' procurement in 2001 (Jane's Defence Weekly, 27 February 2003). The view taken by some 'senior sources in the defence industry' is that the Towers and the complementary Defence Technology Centres will change the landscape not only for the Ministry of Defence procurement process but also for the DTI and the Foreign Office (Jane's Defence Weekly, 2003, ibid).

It is envisaged that up to 25 Towers could be created and the thrust of each will be in areas where there are seen to be particular commercial strengths and where government/industry teams can pursue 'world-beating products' with a positive disincentive for the pursuit of technology for its own sake. Possible peaceful objectives for emerging technology or methods are thus relegated. Current participants include BAE Systems, Alenia Marconi, Thales, DSTL, QinetiQ, DTI, and DPA. Once again there is limited room for independent expert input.

A Tower focused on guided weapons technology was announced in February 2003 and comprises various UK military industrial partners, the MoD, DTI and QinetiQ, together with Cranfield University and Imperial College London.

In 2004 there were a total of four Towers:

- ❑ the guided weapons Tower discussed above
- ❑ radar involving the following universities: Cranfield; Birmingham; Sheffield; Surrey; and Imperial College, London
- ❑ underwater sensors which involves the following universities: Heriot Watt; Imperial College, London; Southampton; Loughborough; Bath; University College, London
- ❑ synthetic environments which at present has Cranfield as the university component.

Some analysts point out that the Towers scheme could come into conflict with existing UK procurement strategy since non-UK companies would be unwilling to bid for those MoD projects with clear links to a Tower. Although intellectual property rights issues have been discussed, and 'official sources' say that such concerns are now resolved, it is not clear how this might impact on technology transfer into civilian, non-military areas and just what commercial deal is likely to be in place for those within Tower-collaborating universities.

What is obvious is that such Towers and even more so the Defence Technology Centres discussed below will in many ways impact on defence and security strategy. Such high technology 'incubators' help create reductionist, high technology solutions to what are complex conflicts and make it more difficult for governments to use a more long-term, holistic and non-offensive approach to conflict resolution (see Chapter two).

In addition certain SET research priorities are likely to be influenced by the military research agenda and focus, and possibly redirect the academic partners in the DTCs and Towers to more commercial and military-related directions.

Defence Technology Centres

Defence Technology Centres (DTCs) are envisaged as a major element in developing advanced technology for 'meeting the MoD's science and technology priorities' (www.mod.uk/dtc). The DTC programme was launched in February 2002 to extend the collaboration between industry and the universities and thereby to develop new technologies conceived as 'solutions' to defence 'problems'. The Ministry of Defence will provide each DTC with funding of up to £5 million per annum for between 3 and 5 years. Each consortium is expected to meet up to 50 per cent of the overall contribution. Each DTC will have a director appointed but other staff details are apparently down to local needs and are not spelt out in detail.

The preferred bidders for the first three DTCs were announced in November 2002. BAE Systems leads the group for the Electromagnetic Remote Sensing DTC and a BAE Systems-GKN joint group, Aerosystems International, leads the consortium for the Human Factors Integration DTC. A General Dynamics-led consortium made a successful bid for the Data and Information Fusion DTC - a description of which is to be found in section 4.3.3. At the time of writing the following universities are involved with the three DTCs so far established:

Data and Information Fusion (DIF-DTC): Bristol, Cambridge, Cardiff, De Montfort, Imperial College London, Southampton and Surrey

Human Factors Integration (HFI-DTC): Birmingham, Brunel, and Cranfield

Electromagnetic Remote Sensing (EMRS-DTC): Birmingham, Edinburgh, Glasgow, Heriot Watt, Imperial College London, Leeds, Cranfield, St Andrews, Sheffield, Strathclyde and Southampton

As in the Towers initiative, intellectual property rights are also a vital issue. As we discussed in Chapter one the area of patents and intellectual property rights (IPR) is an increasingly important one within the commercial environment in which university researchers find themselves. In the MoD's DTC website there is the following mention of IPR:

"*...no prescription on handling of Intellectual Property Rights - IPR arrangements to be proposed by the consortia and negotiated on a case-by-case basis.*." (www.mod.uk/dtc/intro_dtcs2.htm)

Again, one wonders where and how useful technology might be made available to the wider, non-military world from the DTCs? Moreover, how will competing claims over IPR involving the university, researcher and commercial partner be settled? One should keep in mind at this point the difficulties discussed in Chapter one where university-industry collaborations are ones in which industrial voices tend to predominate over other areas of concern such as objectivity, free exchange of ideas, methods and personnel, between research groups and the voicing of dissent.

3.6.3 Military corporations and the universities

In addition to these partnerships of academic, industrial and government stakeholders, there have been a number of other initiatives which we briefly mentioned earlier and need to revisit here. Military corporations have, since the Cold War period, pursued R&D and educational opportunities within universities. With the advent of the Public Understanding of Science (PUS) programme in the mid-1980s in the UK the major military and other science-based corporations have been eager to present an acceptable face to the public. For example Rolls Royce (www.rolls-royce.com) and BAE Systems (www.baesystems.com) have taken active roles in the University of Cambridge National Science Week held each year, showcasing to the public their investment in engineering and related technology through the University's Engineering Department.

Rolls Royce at present supports over 20 University Technology Centres which are embedded in 15 universities throughout the UK, including Sheffield, Oxford, Cambridge and Imperial College London. Rolls Royce also has similar centres in Italy, Germany, Scandinavia and the USA. A primary role of such Centres is both short-term and long-term research supporting the company's business aims through "improving the product, improving productivity and reducing cost-of-ownership" (www.shef.ac.uk/acse/utc/). Other military corporations, like Boeing (www.boeing.com) and GKN, also enter into a variety of arrangements with universities, deals often being supported by local authority agencies keen to be seen to be creating employment opportunities, especially in the North of England where for many years manufacturing industries have been in serious decline.

Rolls Royce and other military corporations also financially support posts in universities across the UK together with provision of undergraduate and postgraduate funds and career support. Such career and training support will also be part of the Defence Technology Centres' structure where various post-graduate opportunities are to be offered. Once an individual is part of a team which is supported by the military sector it is likely that they will continue within that sector and may well be lost to other SET activities. Military corporations are powerful and their influence is often pervasive. For example, the University of Cranfield enjoys massive support from many such companies and the University has its own military-related spin-out company, Cranfield Aerospace. It is extremely difficult to obtain any information on who funds such liaisons, especially at Cranfield. Thanks to 'commercial sensitivity', universities do not publish details of their corporate sponsorship and indeed during the compilation of this Report it has become obvious that in the UK, open universities are a threatened species. The Press Office at Cranfield University, for instance, said that sponsors would not want it known who they were or what they supported.

BAE Systems, the largest military corporation in the UK, is keen to maintain its future recruitment of SET personnel and its public relations by moving into the educational sector. For the last twenty years military and other potential recruiters of SET undergraduates had an obvious, if rather low key, presence at the careers fairs and freshers' days at the universities. BAE Systems in 1998 went a step further by setting up a 'virtual university', which awards certificates in management, supported by the Open and Lancaster Universities. The former Vice Chancellor of the University of Cambridge also appeared to be on the Board of this virtual university as well as that of the Engineering and Physical Sciences Research Council (EPSRC) (Evans and Packham 2003). BAE Systems has also managed to gain support from the EPSRC. (One will recall that the MoD also part funds the Joint Grant Scheme - see section 3.6.1 - of which the EPSRC is one partner.) It is unclear how the EPSRC, as an autonomous non-departmental body, can justify its support of a BAE Systems enterprise.

BAE Systems has also supported the UK Department for Education and Skills Specialist Schools Programme for many years and has around 40 specialist schools, most of which are Technology Colleges. In 2001 BAE Systems announced that it was to form Engineering Colleges to focus on systems engineering which is a major theme for the company and which features in the various university consortia in which the company plays a role.

BAE Systems in addition has a variety of partnerships with other UK universities including Sheffield Hallam, Cambridge, Sheffield and Southampton; universities which are also involved in the Rolls Royce University Technology Centres and the DTCs.

BAE, like many multinational businesses, deliberately links its name with scientific excellence and make little of the fact that it produces weapons systems, military aircraft and a variety of support equipment, often sold to regimes with poor human rights and environmental credentials (see section 2.8).

QinetiQ also provides funding and support to SET students through scholarships and a placement scheme for the 'Year in Industry' programme (QinetiQ 2003).

Curriculum support materials and displays in museums and university contributions to National Science Week are all part of the public relations exercise undertaken by many corporations including those in the military sector.

As will be obvious from the case studies in the next Chapter - the widespread presence and influence of such corporations together with their financial power make the SET research and teaching agenda, especially in the physical sciences and engineering, heavily biased toward military issues. In addition, the ethical acceptability of military funding for SET research is rarely openly discussed on university campuses. Where it is, opposition can frequently be strong from both staff and students. For example, during the discussions pertaining to the establishment of the GKN Professorship of Manufacturing Engineering at Cambridge in 2000, the local MP urged the vice-chancellor to accept student demands for stringent safeguards to be attached to academic sponsorship from weapons companies.

3.7 Military influence and SET —the international dimension

The picture so far described is that of the UK, but there are other significant players in the research landscape who are in various ways involved with the military sector. They also influence the ways in which scientists and technologists are trained, funded, exchange their expertise and employed. Although detailed description is outside the scope of this Report mention must be made of the principal non-UK bodies involved in supporting research in UK SET and their involvement with the military sector - namely the European Union, NATO, and various Offices of the US government.

3.7.1 European Union and SET research

Until relatively recently the European Commission has kept at arm's length both European military research issues and other military-related problems. It was widely felt that defence was an area which lay outside the remit of the European Union. This view was supported by Article 223 of the Treaty of Rome (the Treaty established the European Community in March 1957 and has been amended by subsequent treaties). Although it does not expressly prevent all actions by the European Communities that could impact on military industries, most Member States have tended to think that Commission action would not be directed toward 'defence'-related areas.

All this changed significantly with the signing of the Maastricht Treaty on 7 February 1992 (Molas-Gallart 2002). The Maastricht Treaty included both a security and a foreign policy for the European Union as a whole. In the latter part of 2003 there was a great deal of media coverage of the idea of a strictly European defence posture - one which is hotly contested by the Bush administration in the USA, claiming it was a contender to NATO.

Collaboration is part of the European Framework research programmes. They are currently worth about £9.5 billion over four years, and represent 5 per cent of the total public R&D expenditure across the EU. Over the years, the Framework programmes have provided funds for a very broad spectrum of SET research with many of those participating being in the UK.

There were a number of discussions which took place while the Fifth Framework Programme for Research and Technological Development (1998-2002) was being prepared, concerning the military-related and dual-use SET research agenda. It has been long recognised that dual-use SET research has been undertaken within the Framework programme. Molas-Gallart (2000) drew attention to the fact that officials in what was DG-XII (now Directorate General Research) noted that more than 8 per cent of the total number of participants in EU-funded BRITE, EURAM, ESPRIT, ACTS and TRANSPORT research programmes were military organisations. Whilst it was clear that the projects in which these military organisations were involved complied with the civilian objectives of the Framework programme, yet the active participation of companies and research groups with a marked dependence on military markets, suggested that there was clear dual-use direction in action.

In Framework Five QinetiQ was a key partner with Rolls Royce in a variety of European SET research projects. It participated in 34 aeronautics projects, 13 of which also involved Rolls Royce (Research Fortnight 26 February 2003).

The European Parliament has underscored the view that national governments within Europe should agree on long-term R&D projects, and in particular the EUCLID[4] defence research programme and the Community R&D programmes should be 'strengthened' and better co-ordinated (Molas-Gallart 2000, and Titley 1997). *Inter alia* it is noteworthy that EUCLID is a Europe-wide military R&D effort managed by the Western European Armaments Group (Molas-Gallart 2000). More recently EU ministers in the Competitiveness Council decided unanimously to fund research on identifying Europe's 'defence' and security needs. It appears that both military R&D targeted to an EU military posture and a EU military equipment policy is now on the EU agenda (see www.researchresearch.com).

During 2004 Erkki Liikanen, commissioner for enterprise, and Philippe Busquin, commissioner for research at the European Commission have agreed to try to broaden the remit for Framework Seven to include, in a more obvious way, military R&D. A proposal for a dedicated 1 billion Euro military R&D programme came from a 27-member high-level group, chaired by Liikanen and Busquin. A report from the group maintains that there are "...structural deficiencies at the institutional and political level [which] hinder Europe in the exploitation of its scientific, technological and industrial strength" (Research Fortnight 2004). The group proposes that a European 'security' research programme would assist in bridging this supposed gulf.

The difficulties of dual-use may mean that many of those applying for funds through the Sixth Framework (2002-2006) will be unaware that a growing proportion of the bidders will come from organisations pursuing military projects and applications. Thus many scientists will find themselves participating in projects with military partners.

This change of Framework direction may well have an impact on innovation and research strategy which addresses goals other than military ones. Furthermore, research aiming at sustainable or socially responsible goals ideally set within a collaborative framework across Europe will have to compete with powerful military-related organisations who will import a range of military objectives.

3.7.2 The NATO Science programme

The North Atlantic Treaty Organisation (NATO) is a pact set up between some of the nations of Europe and the USA as a result of the post-Second World War period. The Treaty, signed in April 1949 at Washington DC by the USA, UK, Canada, France, Belgium, the Netherlands, Norway, Luxembourg, Iceland, Denmark, Italy and Portugal initiated a security partnership to ensure mutual or common 'defence' against a perceived aggressor. The primary impetus for NATO was fear of and failure to come to terms with the Soviet Union and their satellites.

The NATO Science Programme was set up in 1958 with the establishment of the NATO Science Committee which arose from the recommendations of a group on Non-Military Co-operation within NATO. A variety of science support vehicles were soon put in place, which continue to this day and include Advanced Study Institutes, Collaborative Research Grants and Science Fellowships. The portfolio of programmes has changed and grown over the years but throughout the last fifty years the NATO Science Programme has supported non-military aspects of SET.

In 1999 the Science Programme was altered again in order to provide more support to NATO partner countries and to facilitate exchange of scientists across the world. In many ways NATO Science Programmes have provided the access to open science with public accountability and full discussion of pressing concerns that are recommended later in this Report.

In 2003 a further transformation was undertaken, which in many ways addresses the various security issues which are drawn out in Chapters two and five of this Report, namely the fully nuanced understanding and countering of 21st Century security threats such as climate change, deteriorating health and growth in poverty in many parts of the world which do not respond to posturing with ever more complex weaponry. The new NATO programme is entitled *Security though science* and involves collaborative activities in the following ways:

- ❑ Collaborative linkage grants
- ❑ Expert visits
- ❑ Advanced study institutes
- ❑ Advanced research workshops
- ❑ 'Science for Peace' R&D projects

The 'Science for Peace' programme was set up in 1997 with the aim of funding R&D projects which contribute to 'overall stability and peace', especially including collaboration with eastern Europe and former Soviet states. Since then it has funded over 120 projects including, at the time of writing, earthquake remediation; building protection in earthquake zones; and the technological needs of the farming communities in eastern Europe. Projects vary in size from a few ten of thousands of euros to a few hundred thousand euros. The programme is exemplary in the way it aims to use high quality scientific and technical expertise in effective and timely work to address broadly defined security problems. It also places strong emphasis on the free exchange of ideas and researchers. It contrasts sharply with the approach of many other programmes examined in this Chapter (www.nato.int/science/sfp/index.htm).

3.7.3 US Government funding of UK SET

Research in UK universities has been and continues to be supported by various agencies of the US government, especially the Departments of Defense and Energy. Many disciplines are covered from biochemistry to mathematically modelling. The major agencies are the Office of Naval Research and the Defense Advanced Research Projects Agency (DARPA) mentioned earlier in this chapter. More detail of the influence of the USA on SET across the world is to be found in Chapter four.

3.8 The influence of the military —a complex terrain

The picture painted in this chapter is of a complex and pervasive influence of the military sector in SET R&D in the UK and increasingly in the European Union. It is one in which the various players frequently change, their role is difficult to unravel and the extent of their funding and influence rarely open to public scrutiny and debate. As we suggested earlier such a terrain offers little room for alternative points of view or dissent or the openness which has been a feature of science in the recent past. In the next Chapter, through the use of four case studies, we discuss these issues in more depth.

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NOTES

1. Much of the expenditure on R&D by the military corporations is paid for by the Ministry of Defence. The figure of £100 million is our estimate based on data from the situation in 2000/01 (www.ost.gov.uk/setstats) and discussions with statisticians at the Office of Science and Technology. The problems of statistics in this whole area are discussed in Boxes 2.1 and 3.1

2. In 1998 there were six DUTCs in operation: the Structural Materials Centre, which was the first such centre, the Farnborough Superconducting Centre; the Centre for Marine Technology; the Telecommunications and Information Technology Centre; the GEC/DRA Uncooled Imaging Project and the Software Engineering Centre

3. Boeing has had for many years collaborative relationships with universities in the USA to tap into their expertise. In 2002 the corporation announced three R&D initiatives with Cambridge, Cranfield and Sheffield Universities to the tune of many millions of dollars. An Advanced Manufacturing Research Centre at Sheffield is a £15 million partnership with Boeing (see amrc.co.uk).

4. EUCLID is a research training network funded by the European Commission's Fifth Framework Improving Human Potential programme and facilitates collaboration and movement of research staff across Europe.

CHAPTER FOUR

Case studies of military science and technology

"It is time to stop pretending that Europeans and Americans share a common view of the world, or even that they occupy the same world. On the all-important question of power - the efficacy of power, the morality of power, the desirability of power — American and European perspectives are diverging".

from Kagen 2003

KEY POINTS

- In the four areas of science chosen for the case studies in this chapter there has been inadequate discussion, especially by the lay community, of the social and ethical dimension of novel and potentially powerful technologies - all of which have the potential to damage progress towards global disarmament.
- In each case study it is clear that the novel technology often attracts large-scale military funding despite the claims made in its support for civilian usefulness. Such military support has the effect of limiting the openness of debate and compromising future civilian use and public acceptance.
- Military utility of emerging technology tends to militarise those areas of science from which the technology arises and calls for high security regulatory mechanisms to be put in place.
- High public sector funding of novel technologies can lead to 'lock-in' with a corresponding limitation of the range of options available to tackle world problems. Within the security agenda, it can drive a weapons-based approach to dealing with complex disputes.
- US military policy has a major influence on US research and development and on UK military policy, the latter especially through the US-UK 'special relationship'. Both factors in turn strongly influence UK science, engineering and technology. The cornerstone of the special relationship is the 1958 Agreement for Co-operation on the Uses of Atomic Energy for Mutual Defence Purposes, which has been extended until 2014, and to date has been subject to little public debate.
- There has been a profound change in military policy to first-use of nuclear weapons in the face of non-nuclear attack in both the USA and the UK. This change has been supported by active funding of new, and in the case of Missile Defense, largely untested technologies. Furthermore, the UK is currently expanding its nuclear weapons laboratories at Aldermaston which may contribute to the development of a new generation of nuclear weapons.
- The military is a major funder of R&D in nanotechnologies.
- Current biodefence research may be crossing the thin line between defence and offense. Furthermore, military involvement in this area may be leading to a diversion of some expertise away from work on the more pressing problems of naturally occurring diseases.
- Detailed critiques within each of the four case studies (biological sciences, nanotechnology, Missile Defense and new nuclear weapons) are to be found in the relevant sections.

4.1 Introduction

In the previous chapter we examined in some detail the ways in which the military sector, including government agencies and private corporations, exerts influence over science, engineering and technology in the UK. It is the purpose of this chapter to shed further light on the extent of military influence by the use of a number of case studies, which pull together many of the themes developed so far in the Report.

One particular aspect which we briefly highlight is the role and position of individual scientists, especially when they hold a dissenting or alternative view. At the time of writing, such concerns are prominent in the wake of the sad death of UK biological weapons expert David Kelly. He revealed his concerns to a journalist about the evidence on biological weapons used to justify the Iraq war, and the resulting political pressure led to his suicide. In the case studies, we briefly mention two other contrasting cases.

Before tackling the case studies, however, we shall discuss further one particular key aspect: the influence of US military policy.

4.2 The influence of US military policy

The end of the Cold War essentially left the USA as sole global 'superpower'. It has the world's largest economy, and as we have seen the world's largest military, dependent in part on scientists and technologists. This allows it enormous political influence, which in turn affects SET policies across the world.

US military policy in recent years has been increasingly driven by a unilateralist stance towards security. The neo-conservative administration of George W. Bush has actively pursued the military doctrine of 'full spectrum dominance', which calls for overwhelming superiority of military forces on land, sea, air and most recently space (US Department of Defense 2000, Project for the New American Century 2000). In the wake of the September 11th attacks, military policy has been hardened and now explicitly includes pre-emptive attack towards those who are considered to threaten broadly defined American interests (Byman and Waxman 2002, Halper and Clarke 2004). This agenda is also promoted by the influential corporate-backed think tanks such as the Center for Security Policy, the National Institute for Public Policy and the Project for the New American Century.

This unilateralist defence posture drives a high-technology military programme, including the US$141 million appropriation for pilot-less drones capable of carrying missiles, and US$300 million to counter biological weapons attacks and US$9.2 billion for Missile Defense research (Rogers 2004). Such an overemphasis on technology may lead many, including policy makers in the USA and Europe in particular, to pay less attention to political and diplomatic factors in those areas where conflict has begun or where the West's interests may be perceived as under threat (Byman and Waxman 2002).

These policies not only profoundly influence SET in the USA, but also have a global effect, as the case studies will discuss. In particular, the US-UK 'special relationship' (see Box 4.3 later) reinforces this effect on UK SET. Some figures will set the scene. For example, since 1994, SET-dependent research and development in the United States has risen sharply, from US$169 billion to around US$265 billion (Science & Engineering Indicators 2002, 2004). The US Department of Defense is a major funder among Federal agencies for R&D support, its contributions amounting to 57 per cent of all Federal R&D in 2004 - up from 53 per cent in 2001 (www.nsf.org). In addition the US Department of Energy, which also supports many military objectives, provides a further US$7 billion. There is also Federal US funding of research and development in other countries, including the UK. In 2001 for example the Department of Defense supported UK researchers to the tune of over US$85 million and the Department of Energy a further US$11.6 million (National Science Foundation/Division of Science Resource Statistics 2003). There is no publicly available detail as to the research that this funding supported. The USA accounts for about 44 per cent of total R&D expenditures of all Organisation for Economic Co-operation and Development (OECD) countries combined. R&D investments in the USA are 2.7 times greater than R&D investments made by Japan, the second largest spender (Science and Engineering Indicators 2003). In addition there have been continuing increases in the US defence budget. The projected defence budget for 2005 is set to be 28 per cent higher than 2004, which was itself above previous post-Cold War levels (DeFrancesco 2003).

The American unilateralist stance results in many contentious scientific and technological activities around the globe. For example, in Europe some governments have become involved in US Missile Defense (MD) plans. The Czech Republic is in discussions about missile siting on their territory. In the UK, the government's compliance has already led to the continuing expansion and use of the RAF/USAIA Menwith Hill eavesdropping base and the upgrade of Fylingdales' radar station in North Yorkshire. Work to enable Fylingdales to support the small missile interceptor batteries situated in Fort Greely and Vandenburg Air Force Base in the USA is being undertaken by Boeing who were awarded a US$111 million contract (Chamberlain and Davis 2004). We revisit Missile Defense later in this chapter.

4.3 Case studies

Here we present four case studies on: biological sciences; nanotechnology; Missile Defense; and new nuclear weapons. In each we examine the background, military influences, and key issues arising.

4.3.1 Case study 1: Biological sciences and the military

Current concerns

Historically, naturally occurring micro-organisms and toxins have been considered for bioweapons. But over the past decade genetic manipulation and other sophisticated genetic and biotechnology methods (together with genomic commercialisation) have opened the way for a growing range of potential new bioweapons to emerge (Royal Society 2000).

During 2001-2 two prominent experiments were widely reported. The first was the insertion of the interleukin-4 gene into the mousepox virus which increased its virulence and vaccine resistance. It was felt that this experiment might be used to manipulate smallpox to render it resistant to current vaccines. The second was the artificial synthesis of poliovirus by reconfiguring DNA. Of particular concern here was that the artificial poliovirus was made available by mail order, while its DNA sequence data was published on the world-wide web. Such high profile cases and others in the security-conscious environment of post-September 11 science raises profound questions concerning the openness of science and whether some areas within science are simply too problematic to pursue at present (Rappert 2003).

In addition the concept of dual use, mentioned earlier in this Report, means that many of the technologies needed for the development and production of bioweapons are common to both hostile and peaceful objectives. The military sector supports both basic and peaceful uses of biotechnology such as vaccine development and the engineering of protective environments for handling dangerous pathogens. Clearly the issue of such dual use has important implications for safeguarding legitimate access to methods and protocols which are fundamental to science.

Considerations of security and the influence of the military perspective are shown in stark relief in the mutually interconnecting worlds of biotechnology, genetics and bioweapons. The Biological and Toxic Weapons Convention (BWC) intended to prevent the developing, testing, production and stockpiling of bioweapons, was agreed in 1972. Most, but not all, nations have signed this, and/or the 1925 Geneva Protocol which prohibits the *use* of bioweapons. Although terrorist use of bioweapons is uppermost in many people's minds, dangers can arise from offensive state-sponsored programmes, such as the illegal and secret Soviet biological weapons programme, which persisted into the 1990s despite being banned under the BWC. Some current US programmes in biodefence, by potentially stimulating offensive capabilities across the world can be seen to cross the line and violate the BWC (see www.pugwash.org/reports/). This impression is strengthened by the fact that in 2001 the USA blocked the draft verification protocol at the BWC Review Conference.

A number of reactions in the USA to the fear of bioterror have been reported in the scientific press, including the trial and vilification of the respected plague researcher Thomas Butler (see Box 4.1). This and other cases clearly show that the massive funds being handed out for biodefence are doing little to reduce tension either within or outside the scientific community.

Box 4.1

–The Butler case

The Butler case represents an extreme example of the various pressures to which researchers working in the area of potential bioweapons can be subject. It also illustrates the complicated issues surrounding the university-industry interactions. Butler, an acknowledged researcher, was arrested in January 2003 after being accused by the FBI of illegally transporting vials of the plague bacteria *Yersinia pestis*, from Tanzania to his laboratory and then to Army research laboratories. The rules about the transportation and holding of so-called Category A pathogens like the plague bacterium have become complicated and onerous in the environment of bioterror scares in the USA. Butler had originally reported that the samples of the bacteria had gone missing but investigators who quizzed him concluded that he had destroyed the samples and then lied about it. He apparently took steps to also conceal from his employer, Texas Tech University, a number of contracts which he held with drug companies like Hoffman-LaRoche, Chiron and Pharmacia. He was paid to test various drugs on patients who were enrolled in trials at the University's Medical Center. The transportation of the plague samples into the USA, which was paid for by funds which Butler obtained from drug companies, was to test the efficacy of certain antibiotics. The complex interactions between Butler's employer and the contracts held by him with pharmaceutical corporations and the transportation of Category A pathogens, in the highly charged atmosphere of a country fearful of bioterror, are highly indicative of the current ethical dilemmas faced by those in science. Butler has been found guilty of fraud and improper shipping of dangerous pathogens - at the time of writing Butler has not been sentenced (Check 2003, Miller 2004).

Many researchers feel that not only had Butler been made a scapegoat but that he had been subjected to entirely disproportionate treatment by the Bush government (Check 2003). A number of researchers who have a reputation in plague research have stopped their research.

In fact many believe that the biodefence bonanza will severely distort the priorities in infectious disease research, diverting funds away from understanding and countering natural disease outbreaks which pose a greater threat to public health, especially given the impact of climate change. A Report in 2003 in Nature suggests that experts in weapons proliferation consider that laboratories working on potential bioweapons agents will increase the risk of these agents getting into the hands of potential terrorists because the number and amount of agents which are available could be increased (Check 2003).

A recent article by three prominent arms-control experts from the USA has criticised the Department of Homeland Security's plans to start a new programme of biodefence research. The authors point out that activities at the proposed National Biodefense Analysis and Countermeasures Centre could breach the Biological Weapons Convention by crossing the line from defensive to offensive measures (Check 2004).

Many researchers in microbiology are confused and concerned by the complex and lengthy regulatory machinery put in place to reduce this risk - especially after the case of Thomas Butler (Check 2003). Such regulations, which increase the scrutiny of established researchers and their laboratories, tend to create 'militarised zones' for certain areas in science and medicine and this impacts in many ways on the research agenda both in the USA and internationally.

Many researchers have recently decided to discontinue or not pursue research on regulated biological agents, rather than implement the new security regulations in the USA, and bear the associated financial burdens (Gaudioso and Salerno 2004). These kinds of actions will tend to suffocate potentially valuable research into public health and biodefence, which could mean that outbreaks of serious infectious disease like SARS will be difficult to deal with effectively (Gaudioso and Salerno 2004). Additionally, some argue that diseases like influenza and other common respiratory-tract infections routinely kill far more people than would die in a bioterrorist attack and hence more priority should be given to work in these areas. (Check 2003, Glass 2004).

Biological weapons—a glimpse into the UK scene

A large part of the research on biological and chemical weapons in the UK has centred on Porton Down in Wiltshire. The Porton Down chemical warfare establishment was set up in May 1916 in order to counter the German use of chemical weapons in 1915. Since its inception, Porton Down has undergone a number of changes listed in Box 4.2. Despite Britain's ratification of the 1925 Geneva Protocol in 1930, Porton Down undertook research and development of chemical weapons. This situation changed in 1955-56 when Britain abandoned plans to modernise its chemical warfare facilities. Instead work focused on the assessment of chemical weapons and 'defensive requirements' and this apparently continues today. However, Porton Down was involved with research and development of CS gas, a 'riot control agent', and took an interest in trauma and wound research (all of which involved animal experiments which brought significant criticism from animal protection bodies in the UK). In addition CS gas was used in the 1960s by the US Army in Vietnam in massive quantities (almost 16 million pounds of the gas was procured for operations between 1964 and 1970 - Rappert 2004) and was used to 'control' both civilian and military personnel. Interest at Porton Down in chemical warfare and associated agents continued through the 1980s especially in light of abuses of Iraqi Kurds by the Saddam Hussein regime.

From the 1940s Porton Down was also the centre of British interest in biological warfare and measures against this mode of warfare. In 1979 the Centre for Applied Microbiology and Research was set up, concentrating on the previous biological research at Porton Down, under the aegis of the Public Health Laboratory Service. This Centre is now part of the Health Protection Agency. As discussed earlier in this Report the DERA research laboratories were split into QinetiQ and the Defence Science and Technology Laboratory (DSTL) in 2001 and Porton Down is now one of the laboratories comprising DSTL[1]. The history of Porton Down, especially its activities using UK 'volunteers', has had a great deal of adverse media coverage and discussions of the role of service personnel in testing various agents continues today. Like all former DERA establishments Porton Down is expected to create lucrative spin-offs but interest from British investors has been fairly low key to date (Stewart 2004).

Box 4.2
–A brief history of Porton Down

1916–1929	Royal Engineers Experimental Station
1929–1930	Chemical Warfare Experimental Station
1930–1948	Chemical Defence Experimental Station
1948–1970	Chemical Defence Experimental Establishment
1950s	Development of CS riot control gas
1970–1991	Chemical Defence Establishment
1991–1995	Chemical & Biological Defence Establishment
1995–2001	Chemical & Biological Defence Sector of DERA
2001	Creation of Defence Science & Technology Laboratory (DSTL) Porton Down

Adapted from: Carter 2000

In the UK the Royal Society has published position papers over the past four years addressing the difficulties of containing the development of bioweapons and the potential for offensive use of such agents. Most recently a joint Royal Society and United Nations Foundation Discussion Paper suggests that "there is a need for the scientific community, governments and relevant agencies to be fully aware of the potential of scientific advances both in enabling the illegal development of more lethal weapons and in developing more effective counter measures..." - in other words there is a need for individuals to act in responsible ways to achieve the most desired, non-offensive outcome for their research. They add that international collaboration and agreements backed by access to the latest science and a fully operational verification programme is the best way forward (Royal Society 2004). The British Medical Association (BMA 2004) echoes these recommendations. Unfortunately such an approach has been thwarted by several countries including the USA.

Biosciences—key issues for security

In the preceding discussion, we have highlighted three key concerns regarding the relationship between biological sciences and military issues:

- that cutting edge civil R&D in the biological sciences can increase the potential availability of biological weapons;
- that military involvement in the biological sciences through a major biodefence programme (as currently in the USA) can blur the line between defence and offense, again increasing the potential availability of biological weapons; and
- that, in order to prevent such potentially dangerous knowledge being misused or falling into the hands of 'states of concern' or terrorists, very strict controls are necessary which can both stifle transparency in science and undermine more pressing research on e.g. naturally occurring diseases.

Tackling these problems is complex and requires actions by governments, professional scientific bodies, individual scientists and others. For example, the recent discussion paper from the Royal Society and the United Nations Foundation (Royal Society 2004) on the role that the individual scientist can play in averting bioterrorism sets clear guidelines for addressing such security threats. Individual responsibility and the various ethical dilemmas faced by all in the scientific community are further discussed in the last Chapter of this Report. The following recommendations draw upon those in the above discussion paper:

- International agreements on limiting the production and use of both biological and chemical agents must be supported at a senior level within the scientific community. International scientific advisory panels would be a pivotal way of keeping abreast of the technological advances in the various sciences involved and would provide advice to policy makers.
- Members of the research community should exercise judgement in the publication of their work and raise awareness through various fora about the ethical and legal dimensions of the research they undertake (Nixdorff and Bender 2002). There must be a balance between the necessary open nature of scientific discourse, of researcher and student movement across the globe to pursue research objectives and the security needs of countries. The vetting of researchers and students must be undertaken in an internationally agreed way with protocols in place which recognise the value to science of collaboration (Rappert 2003). Military goals should not overwhelm other issues of importance to human rights and the integrity of science. In countries like the USA and UK, which depend upon non-national scientists in areas like biodefence, such research will be severely inhibited if scientific isolationism is pursued (May 2004).
- There should be an internationally agreed consensus on good practice, especially in combating the misuse of scientific advances in ways which could pose a threat to global security and peace.
- Full examination should be undertaken, as a matter of priority, of legal constraints on biological weapons

development nationally and internationally in order to strengthen these constraints and build an enforceable code of practice, especially in light of the many advances being made in the biosciences. Some form of expert-based verification system should be built to oversee this process (Nixdorff and Bender 2002) and, of necessity, this should be under the auspices of the Biological Weapons Convention.

- Military biodefence programmes should not be allowed to undermine pressing research on naturally occurring diseases.

4.3.2 Case study 2: Nanotechnology –from nanotubes to the battlefield

Background

The nanotechnologies are a cluster of innovations that will have a major impact in many fields over the next ten years. A number of authors have pointed out the potential for the nanotechnologies to be used to augment and deliver a range of chemical, biological or nuclear weapons. Some of the problems that this situation will create are likely to impact on the various biological, chemical and nuclear weapons treaties discussed elsewhere in this chapter.

This section is necessarily brief as nanotechnology is a vast and fast-moving research area and our intention is to illustrate specific examples where material on funding by the military sector is openly available.

Nanotechnology comprises a range of techniques which can measure, manipulate and structure material on the nanoscale (one nanometre is one thousandth of one millionth of a metre). Matter at the single atom level can now be fabricated and manipulated and the range of potential research programmes encompasses most areas in science, engineering and technology. Nanotechnology represents not simply the ability to miniaturise but is a radically new approach to research questions in science, engineering and technology.

Nanotechnologies, like other emerging or fairly recent technologies such as pervasive computing, artificial intelligence and virtual reality, will throw up novel and challenging ethical, social and political conundrums. All these technologies are supported to various degrees by the military sector, and feature in the consortia described in Chapter three and below.

The forerunner of nanotechnology, microelectromechanical systems (MEMS), was born several decades ago in nuclear weapons laboratories. Sandia National Laboratories in the USA are world leaders in bringing MEMS engineering into practice (Amato 1998). They also have an abiding interest in nanotechnology. Sandia National Laboratories have since 1993 been 'managed' by Lockheed Martin, the world's largest military contractor[2].

Expecting future markets of significant scale, governments and businesses have greatly increased their nanotechnology R&D effort. Transnational bodies like the European Commission have also become important stakeholders in nanotechnology (the technology being one of the major themes in its Sixth Framework Programme for Research and Technological Development - see fp6uk.ost.gov.uk).

In 2003 global government spending on nanotechnology represented US$650 to US$800 million in each of the following four sectors: Western Europe; the USA; Japan; and the rest of the industrialised nations which have nanotechnology R&D programmes, such as Israel, Australia and Canada (Roco 2003, 2004). Expected benefits include many that have the potential for sustainable development, such as reduced energy consumption, reduction of resource use and lowered pollution levels, and lighter and 'smarter' materials. Many of the visions for future use of the nanoscale, which are currently being discussed in the scientific press, are highly hypothetical and involve nanorobots, self-replication and self-assembly as well as human-machine interface (an area of abiding interest to those supported by the US military body, DARPA). The convergence of nanotechnology with other growing research areas such as information technology, cognitive science and biotechnology adds to issues of human and environmental concern and the potential for military uses of such technological 'blends' (Roco and Bainbridge 2002, Roco 2003).

In the USA the National Nanotechnology Initiative was unveiled by President Clinton in January 2000. This initiative is built around five funding themes distributed among the agencies currently funding nanoscale SET research, and funding has increased year by year to over US$800 million in 2004. The Department of Defense is a major sponsor of nanotechnology (US$322 million) and other high spenders in 2003 included the National Science Foundation (US$221 million), the Department of Energy (US$134 million) and the National Institutes of Health (US$78 million). The Institute for Soldier Nanotechnologies (web.mit.edu/isn/) was set up in 2002 using a $50 million grant from the US Army to develop military applications using nanotechnologies. Its main aim is 'to create a 21st century battlesuit'. It is hosted by the Massachusetts Institute of Technology (MIT) which interestingly is partnered by the University of Cambridge in the UK in a programme of commercial projects. Readers will see later that Cambridge is a major centre of expertise in nanotechnologies and also enjoys considerable military funding (see also Table 3.3). Hence it is possible that future collaboration between MIT and Cambridge University may involve military work on nanotechnology.

In addition to Federal funding there are also individual US states who are dedicating considerable funds to nanotechnology. At the time of writing there are 250 companies in the USA heavily involved in nanoscale R&D (compiled from a variety of sources including www.ostp.gov , www.nano.gov and Altmann 2004). Some commentators have noted that the National Nanotechnology Initiative has stimulated other countries to pursue military R&D in nanotechnology (Roco 2001, Altmann 2004, Altmann and Gubrud 2002).

The USA National Nanotechnology Initiative has referred to the possibility of information dominance through nanoelectronics, information systems, a wide range of monitoring platforms (for biological, chemical and nuclear sensing) and control devices for weapon systems. Fourth generation nuclear weapons, for instance, that make use of nanotechnology can be developed using inertial confinement fusion facilities such as can be found in the USA, Germany and Japan in full compliance with the Comprehensive Test Ban Treaty (CTBT) but not the Nuclear Non-Proliferation Treaty,[3] (Gsponer and Hurni 2000).

Support for nanotechnology in the UK

Major research effort in nanotechnology is underway in the university and corporate sectors in the UK, supported by the various research councils and government departments including the Ministry of Defence, as well as at QinetiQ, the former DERA research laboratory. The Department of Trade and Industry supports nanotechnology through its Manufacturing Initiative. Wide ranging research efforts on nanoscale science can be found at Oxford, Cambridge and Glasgow Universities in particular. Cambridge and Oxford have formed a number of nanotechnology spin-out companies. The Institute of Nanotechnology estimates that there are over 1500 researchers in the UK involved in nanotechnology (for up to date information see www.nano.org.uk).

In the past three years there has been a significant increase in government funding of nanotechnology in the UK - without full public consultation. Initiatives include the University Innovation Centre in Microsystems and Nanotechnology at the Universities of Durham and Newcastle, and the Interdisciplinary Research Collaborations (IRCs), comprising the Universities of Bristol, Cambridge and University College London. The IRCs are supported by the Medical Research Council, Engineering and Physical Sciences Research Council, Biotechnology and Biological Sciences Research Council and Ministry of Defence, with funding of around £18 million divided between the IRCs.

In 2003, Science Minister Lord Sainsbury announced a cash injection of £90 million over the following six years to "help industry harness the commercial opportunities offered by nanotechnology". The Department of Trade and Industry has allocated £50 million within this generous cash injection for an applied research programme supporting collaborative research and development projects and technology transfer initiatives. The remaining £40 million is to be used for Capital Projects for a Micro and Nanotechnology Network.

Seen from the narrow military perspective, nanotechnology fits with a range of potential defence options, including those described in Chapter three. The Defence Technology Centres and the Defence Aerospace Research Partnerships in particular embrace several Ministry of Defence objectives in which nanoscale methods have potential applications. It is envisaged that nano-solar cells and nanorobots, for instance, could be used in a variety of purposes including human-machine interfaces and microplatforms for battlefield reconnaissance (Altmann 2004).

In addition to the range of potential military uses to which UK nanotechnology R&D could be put, QinetiQ (with funding from the UK Ministry of Defence and Tetronics, a major plasma torch manufacturer) has developed a plasma process capable of increasing the production of nanomaterials by several orders of magnitude. QinetiQ intends to establish itself as one of the world's leading suppliers of nanomaterials using advanced fabrication techniques for a range of new materials (QinetiQ 2002). It is not clear from information in the public domain what consultation, if any, was undertaken with the communities in Farnborough (where QinetiQ is based) about its intentions.

As we have discussed throughout this Report the difficulties implicit in dual use mean that within many areas of science and technology there are no longer clear distinctions between their possible or actual military or civilian uses. Potential problems with nanotechnology may arise from either current military or civilian applications - including impact on human health and the environment and the possibilities for weapon development. This is especially so in areas such as nanotechnology-genetics based agents, autonomous fighting systems and microrobots (Altman and Gubrud 2002). Many of the military nanotechnology applications could arrive five to fifteen years from now. Some might be solely for defensive purposes, whilst others would be more offensive or invasive, including miniature anti-satellite weapons, various robotic vehicles and body implants (Altmann 2004). Such applications are currently being researched in the UK and the USA. In a Royal Society/Royal Academy of Engineering report published in July 2004 attention was drawn to potential benefits but the authors also noted that public debate is needed about the direction of development of nanotechnologies, and stressed the urgent need for research into health and environmental effects of nanoparticles. The report also says of the potential military uses for nanotechnologies, that the manipulation of biological and chemical agents using nanotechnologies could "result in entirely new threats that might prove hard to detect and counter" (RS/RAE 2004). In addition the authors of the report commented that the ease with which individuals can make use of nanotechnologies makes proliferation of weapons development programmes much harder to detect and further blurs the distinction between military and non-military industrial activity. The report warned that if R&D on nanotechnologies has too close a relationship with the military, public willingness to accept that benefits may arise from this area are likely to be undermined (RS/RAE 2004, page 56).

Nanotechnology—the key issues

As we have mentioned, the nanotechnologies are likely to have wide-ranging implications. Recently a range of concerns about the toxicology of nanoparticles have been raised within the scientific community. Mason Tomson at the Center for Biological and Environmental Nanotechnology at Rice University in Texas has shown that cages of carbon-60 'buckyballs' travel through the soil in unexpected ways and may traverse the food chain in a manner not previously envisaged. In addition research has shown that rats exposed to a mist of nanometre-sized Teflon particles experienced lung irritation. Such particles can also pass from the tissues into the blood stream with ease (Brumfiel 2003). Therefore certain nanoparticles or nanotubes could have the potential to inflict a variety of human health problems including those of the heart and lungs in ways which may be similar to those now traced to small particulates released from combustion sources (PM10).

What is needed now is transparency and wide-ranging public debate on nanotechnology, neither of which is easy when funding involves military or commercial players, as we have seen earlier in this Report. In addition the research and development funding across the world for nanotechnology is already well advanced and this will tend toward technological 'lock-in' where considerable momentum within one area of technology may deny other, possibly more desirable, approaches proper consideration. Such lock-in is fairly common and is especially obvious in the development of nuclear power reactors in the USA (Cowan 1990). As Robin Grove-White has noted:

"*Industrial innovation plunges ahead in areas of relative scientific ignorance. Regulators and ministerial advisory committees stumble along behind, discovering by trial and error the implicit pitfalls, seeking to contain and mitigate them. Meanwhile, Ministers lean on the absence of conclusive proof or evidence of harm....to keep the show on the road*" (Grove-White 1998, quoted in Willis and Wilsdon 2004).

As Willis and Wilsdon point out in their Demos essay, *From bio to nano and beyond*, what is called for is a new approach to discussing and assessing the potential of the nanotechnologies. Such an approach should explicitly acknowledge uncertainty of risk and ensure that the public (not just the scientifically literate) are involved in a much wider debate than that which surrounded GM food, leading to proper account being taken of public feeling and concerns. Most importantly, the headlong rush into nanotechnology must be capable of being put 'on hold' whilst the range of risks, benefits and impacts are fully and openly examined.

There are some encouraging signs that senior experts in nanotechnology and science policy in the USA and UK, including at the Royal Society and Royal Academy of Engineering (see above), might be taking the human and environmental safety issues seriously. However, the NanoBusiness Alliance, a group based in New York representing the interests of the nanotechnology companies, are reported as being uninterested in addressing the concerns of various groups both inside and outside science. It is also worrying that military support of nanotechnology may well call upon 'national security' considerations as a means of limiting public scrutiny of their funding and the areas of research supported. The following are needed:

1. Full and transparent discussions by the public and independent experts in open fora across Europe in order to put in place institutions and regulatory regimes for nanotechnology. Such a process would not simply rely on an assessment of the established science but would look at potential social, security and environmental impacts (Willis and Wilsdon 2004).
2. Governments of industrialised countries acting and *being seen* to be acting in the interests of all society members rather than simply participating in the delivery of a commercial agenda for nanotechnology. The role of the World Trade Organisation, which uses science as the sole arbiter, must be offset by more holistic means of assessment. Willis and Wilsdon suggest that a possible approach might emulate that of the Swedish proposal for an "International Convention for Socio-economic and Environmental Evaluation of New Technologies". Here the United Nations, for instance, would ensure that there was independent assessment of emerging technologies through processes which ensured full public participation (Ministry for the Environment, Sweden 2002, miljo.regeringen.se quoted in Willis and Wilsdon 2004).
3. The potential impacts of nanotechnology on various weapons systems should be covered within the terms of such treaties as: the Outer Space Treaty, the Sea-Bed Treaty, the Biological Weapons Convention, Chemical Weapons Convention and the Threshold Test Ban Treaty. This is a matter of great urgency in order to limit weapons proliferation and misuse. This concern was mentioned in detail in the Royal Society/Royal Academy of Engineering Report (RS/RAE 2004).
4. An interdisciplinary research programme should be funded to investigate the social and ethical issues expected to emerge from the nanotechnologies.
5. There is also an important question concerning patents and nanotechnologies which has been touched upon earlier in this Report. Patents, especially broadly defined ones, granted on specific processes or techniques and products, can hinder innovation and access to information which might be valuable in many areas including economically sustainable technologies. In addition patents held by the military sector could impede transfer of potentially useful technologies into the civilian sphere (RS/RAE 2004).

4.3.3. Case Study 3: Missile Defense and the securing of dominance

Introduction

The final two case studies, the Missile Defense (MD) programme[4] and the new generation of nuclear weapons, illustrate the ways in which SET and military policy interact. As we shall see, they involve the major military corporations, governments and SET expertise, including that in the UK. They are driven by the current unilateralist view of security issues prevalent in US political circles.

Both of these programmes have been heavily criticised by many within the scientific community and by military analysts on the basis of high costs, speculative technology and the potential to undermine international security.

Box 4.3
–The nature of the US-UK special relationship

The special relationship which is claimed to be enjoyed equally by both the USA and UK is primarily based on the 1958 Agreement for Co-operation on the Uses of Atomic Energy for Mutual Defence Purposes. This agreement provides the basis for secret collaboration between the USA and Britain on all aspects of nuclear weapons development. The Agreement also allows the two countries to 'exchange' information about the improvement of their weapons, delivery systems and other areas pertinent to weaponry - this now includes the Missile Defense systems and undoubtedly the new generation of nuclear devices being actively discussed in the USA, as it has in the past (see Giles 2004). The 2003 UK Defence White Paper 'Delivering security in a changing world' appears to tacitly assume that the major thrust behind the development by the UK of a flexible military response involves a mechanism of inter-operability with US command and control structures. This will greatly increase the dependence of the UK on the USA in military areas, and may well compromise our own security. The 1958 Agreement has recently been extended until 2014, despite the British American Security Information Council (BASIC) securing a legal opinion arguing that the Agreement was in breach of the Nuclear Non Proliferation Treaty (www.basicint.org). To date there has been little in the way of discussion by Parliament or by the scientific community despite being covered in the scientific press (see for instance Edwards 2004).

Missile Defense and global communication

Many in the scientific community felt that Bush's choice of Defense Secretary Donald Rumsfeld signalled a push by the USA for the establishment of military supremacy in space. Commentators pointed out that Rumsfeld was not only a long-standing champion of the MD programme but also of the US efforts to control space and access to it. Rumsfield's views are deeply embedded in the neo-conservative agenda of 'full spectrum dominance' (see section 4.2). Rumsfeld, who was in President Gerald Ford's White House staff almost 30 years ago, chaired a bipartisan committee that helped to build support in 1998 for MD.

While there are many space-related activities with a military component, for the purposes of this section we will concentrate on narrower issues relating to the influence of the military sector, especially in the UK, on the technology capable of supporting MD.

It is instructive here to recall that activities in space have had a political and military dimension since the early 1950s (see, for example, the Scientists for Global Responsibility briefing on this issue - Webb 2004). Space exploration and the use of satellites played an important role in the 'space race', the Cold War competition between the United States and the Soviet Union for exploration and exploitation of space. Space technology not only underpinned military strength but also demonstrated national pre-eminence in science, engineering and technology as a means of asserting 'global leadership'. Many of the satellites currently in use serve civilian, military or both purposes. After the withdrawal of the USA from the Anti-Ballistic Missiles (ABM) Treaty in December 2001 many saw this as a first step in cranking up the weaponisation of space (Mean and Wilsdon 2004).

The Global Positioning System (GPS) launched by the Navstar satellite in 1978 was designed primarily to allow an estimated 40,000 military users to navigate with high precision. Civilian advantage came in the 1980s, with further expansion arriving in the 1990s, when 24 GPS satellites began their orbit of the Earth. The next US version of GPS will still have primarily military objectives although the commercial success will undoubtedly continue (the GPS equipment market having reached US$3.5 billion worldwide). Although civilian use far outweighs the armed forces' use of GPS across the globe, in times of conflict the USA has the capability to block or switch off high resolution GPS transmission - priority being given to military use as occurred during the 2001 invasion of Iraq (Enge 2004). The European version of GPS - Galileo - has after four years of discussion been accepted by the US administration, following earlier claims by them that it might compromise the US and NATO operations.

The present MD system is the latest in a family of high-cost and science fiction-like programmes which aim to create a defensive shield to protect the USA. The current version is reminiscent in some ways of that of President Reagan's 1983 dream of the impenetrable Strategic Defense Initiative - 'Star Wars' - in its use of space weapons (some of which may be nuclear - Brumfiel 2002, Zimmerman and Ferguson 2003).

The MD programme is a high priority for the Bush administration - the development budget for which jumped by 22 per cent to US$8.3 billion for Fiscal Year 2004. Much of this increase went to the Missile Defense Agency, in preparation for deploying a test system as soon as possible. By contrast the Department of Defense support for basic research declined steeply by almost 8 per cent to US$1.3 billion in 2004 (Koizumi 2003).

The major US military companies also have a large stake in MD. Lockheed Martin, Raytheon, Boeing and TRW (see section 2.8) are the primary industrial contractors on the programme. It will be of little surprise that these companies have lobbied heavily in support of MD. For example, Lockheed Martin also spent US$9.7 million in 2002 on lobbying US Congress.

Against this backdrop there is a discernable shift in relations between the US Department of Defense and the National Aeronautics and Space Administration (NASA). Until the last few years the missions of these two players in the space arena have been very different - a recent European Space Agency survey notes "new modes of co-operation between America's civilian and military space programmes are currently being explored" (European Space Agency 2002). In November 2002 a new agreement was signed to formalise the closer working arrangements between NASA and DoD (Mean and Wilsdon 2004). At the time of writing NASA is poised to undertake a massive reorganisation and this will, among other changes, involve the combination of the Earth- and space-sciences operations in a single science directorate. Many in the space science community see these changes as signalling the marginalisation of NASA's involvement in the politically contentious sphere of climate change (Reichhardt 2004). It is unclear at this time where and how NASA will be involved in MD activities.

In the USA almost all MD funds go to advanced development, testing, manufacture and the evaluation of various systems with a further US$774 million provided from elsewhere in the Department of Defense budget for the procurement of completed systems. It is also likely that some of the associated technology for MD is developed under the auspices of the Defense Advanced Research Projects Agency (DARPA). This agency has also had an increase in its R&D budget to US$3.0 billion for 2004 (an increase of almost 10 per cent from 2003). The US Air Force began work on the Airborne Laser which was to be instrumental in stopping ballistic missile launch by the 'enemy' a decade ago. To date US$2 billion has been spent on this laser and yet little progress seems to have been made (Hecht 2004).

In July 2003 the Ministry of Defence in the UK launched its own Missile Defence Centre (MDC). Like the various consortia mentioned in the previous chapter the UK MDC will be a 'virtual' centre supported by government and the military corporations. The 2003 UK Defence White Paper *Delivering security in a changing world* claims that there is growing interest in MD following the US abrogation of the Anti-Ballistic Missile Treaty, but such interest was stimulated by an already existing drive by the Bush and previous administrations to develop MD (referred to above - see Wilkening 2001). In the 2003 UK Defence White Paper '*Delivering security in a changing world*' there is a claim that there is growing interest in MD following the US abrogation of the Anti-Ballistic Missile Treaty, but such interest was stimulated by an already existing drive, referred to above by the Bush and previous administrations, to develop MD (see Wilkening 2001). In the same White Paper there is a hint that interceptor missile batteries would be deployed on UK territory - such propositions have not been open to any public scrutiny or debate.

At the time of writing the UK MDC comprises five founders from the military sector, including BAE Systems and QinetiQ. Players in the military sector actively involved in the Defence Technology Centres (DTCs) are described in section 3.6. Universities and other UK companies are being invited to become involved in the UK MDC and, like the various consortia-supported DTCs, the government is putting £5 million per annum for up to 6 years into the MDC. The Memorandum of Understanding signed by the USA and UK in June 2003, which puts in place this link-up of the MD programmes of the military sectors in the two countries, was apparently undertaken without public discussion or advice from anyone outside the military web described in Chapter three. Furthermore, the UK government has been collaborating on research on MD with the USA since at least the 1980s (James and Gummett 1998). In response to a Parliamentary Question in January 2004 the Defence Minister, Geoff Hoon, said that the UK government had spent £12.5 million from 1998 to 2002 on the Technology Readiness and Risk Assessment Programme focussed on MD.

Missile Defense—the technological imperative

We have described in the earlier pages of this Report how advancing technology supports new military postures and how the complex interaction between SET, weapons and their support technology depends upon funding from the military sector. And it is instructive here to recall that the Towers of Excellence, discussed in Chapter three, pursue goals which have potential for application to MD. In fact a Tower announced in February 2003 comprising various 'defence' partners including QinetiQ will focus on guided weapons technology, which is part and parcel of MD. Also the first Defence Technology Centre, announced in February 2003, which is to be involved with Data and Information Fusion (DIF-DTC), could be instrumental in technological support of the MD.

The DIF-DTC comprises a consortium led by General Dynamics UK (a subsidiary of the world's sixth largest military corporation, which had sales of US$14 billion in 2002 - see Table 2.3) in conjunction with British Telecommunications (BT), QinetiQ and the Universities of Bristol, Cardiff, Cambridge, Cranfield, De Montfort, Southampton, Surrey and Imperial College London. The participating universities will interact with research teams at QinetiQ and DSTL.

There are planned to be around 40 full-time researchers and 25 post-graduate students in the DIF-DTC graduate school. Phase 1 is envisaged to cover data and information research in areas which include multisensor management, tracking and target classification, situational assessment and various data architectures. The themes will also relate to other potential uses, both military and civilian, many of which raise profound questions of privacy and human rights. It is clear from discussions with anonymous sources during the preparation of this Report that there has been little debate on the ethical or social implications of the DIF-DTC by members of the university campuses involved, and certainly not by the public.

Although the major thrust of the DIF-DTC is military it is clear that many of the technologies being funded could also be used - for example - in urban surveillance and crowd control, especially the themes of 'situation awareness and human factors'. This could impact not only on civilian populations in time of war but also become easily modified to further erode privacy and human rights by the expansion of an 'enhanced' CCTV network, a technology which has been questioned by a number of human rights groups in Europe. Information supplied by General Dynamics for this Report also hint that commercial links could be established with other military corporations including Lockheed Martin which is a major contractor for MD (see earlier footnote).

Missile Defense—some of the key issues

The idea of fabricating a defensive shield using a sophisticated web of ground/sea/air/satellite-based technology with the deployment of missiles to intercept incoming intercontinental ballistic missiles (ICBMs) has been discussed for more than thirty years. In the face of international terrorism and the various global threats to security which we have described, ICBMs are not a primary threat to the either the UK or USA, in the short to medium term (Wilkening 2001). Some strategists and neo-conservative politicians comment that some day, somewhere, someone of a 'rogue nature' may acquire ICBMs and launch them (Wilkening 2001). However, many have pointed out that multilateral diplomatic efforts can limit the spread of such weapons and deterrence can dissuade their use (Wilkening 2001). Indeed the stalled Nuclear Non-Proliferation Treaty expressly addresses the need for international disarmament.

There are a variety of MD options which have been discussed in both the lay and professional press, all of which are immensely expensive and most of which have attracted significant criticism within the scientific and military communities. Public opinion in the UK, when canvassed by the British American Security Information Council (BASIC), was that the MD plans of the USA would lead to a new arms race (70 per cent of those questioned), and 62 per cent thought that the National Missile Defence version of MD programme would make disarmament more difficult to achieve (www.basicint.org). Some governments in Europe also feel either ambivalent or deeply sceptical about MD and feel that other more conventional approaches, including multilateral diplomacy, would be far more cost effective and appropriate, especially in these times of international terrorism.

MD has demonstrated very little success despite its massive funding over the recent past. MD can also weaken global security rather than strengthen it, as technology is sold to other nations through the international arms trade (eg Dupont 2004). In addition high levels of MD research and investment diverts funds away from more broadly defined global security objectives.

It worth noting here that scientists criticising the military can find themselves victimised. MIT physicist Ted Postol has been a leading critic of US 'defensive' missile use over several decades - especially the science of specific guided weapons and their testing. For his trouble, he has been the target of numerous attempts at gagging and intimidation. Postol's many critiques of MD have used only non-classified material and are thus in the public domain and should be open to scientific debate (Marshall 2001).

Readers should access the websites listed in Box 4.4 for detailed critiques of MD and the impact of this technology on security and peace but the salient issues are:

1. Massively expensive - US$130 billion has been quoted by the Center for Arms Control and Non-Proliferation as being spent in the USA to date on MD.
2. No workable system ready. Expert opinion points to a number of serious design faults in the various forms of MD.
3. The assessment of a ballistic missile threat has been overstated.
4. MD forms part of a trend toward the USA weaponisation of space and if nuclear weapons are envisaged as part of the MD system it will abrogate the Nuclear Non-Proliferation Treaty as well as the Outer Space Treaty. MD is directed toward a strategic rather than a physical defence.
5. Preparation and installation of MD will stimulate weapons proliferation and endanger international peaceful use of space. Those countries such as the UK who actively participate in the US-led plans for MD compromise their own security.
6. There are far more urgent needs for funding which address issues such as global climate change, international terrorism and alleviation of poverty.
7. There is considerable potential for the scientific, engineering and technological expertise currently invested in research for MD or the new generation of nuclear devices to be used for weapons verification, monitoring and other peaceful purposes.
8. Testing and eventual use of the interceptor missiles will cause significant levels of pollution and 'fall out' in countries away from the conflict zones.
9. The launch and detonation of nuclear-armed missiles in low earth orbit could disrupt the critical system of commercial and civil satellites for considerable periods and hence destabilise high-technology economies in nations far from the conflict zone for an extended period of time. It could also result in considerable amounts of space debris which is hazardous to space craft attempting to travel through it.

Box 4.4

–Websites containing details and critiques of Missile Defense

American Physical Society - a resume of the technical facts but not policy arguments - www.aps.org

Bulletin of the Atomic Scientists - a range of views including those relating to science, technology and policy issues - www.thebulletin.org

Union of Concerned Scientists - another range of science and technology views on the MD programme and also discussions of the claim that the Bush administration has systematically manipulated science to suit its political objectives - www.ucsusa.org

BASIC - detailed policy and scientific critiques - www.basicint.org

Yorkshire Campaign For Nuclear Disarmament - for details of the Fylingdales and Menwith Hill plans - www.yorkshirecnd.ork.uk

The Campaign for Accountability of American Bases (CAAB) - for a UK view of the issue of MD planning and the use of the UK - www.caab.org.uk

Pugwash Conference on Science and World Affairs - various defence issues, especially nuclear proliferation and MD - www.pugwash.org

Federation of American Scientists - wide ranging discussions of MD and the use of space by the USA - www.fas.org/spp/starwars/program

UK Ministry of Defence - various press releases relating to the UK Missile Defence Centre - news.mod.uk/news/press/

Center for Arms Control and Non-Proliferation which contains information on both MD and the new nuclear weapons research - www.armscontrolcenter.org

Scientists for Global Responsibility - www.sgr.org.uk/arms.html

10. Access to information and parliamentary scrutiny has become more difficult in the Blair governments since 1997. Until 1995 the Trident nuclear weapons programme was subjected to detailed scrutiny by the Defence Select Committee on an annual basis - no such regular process is currently in place for informed inquiry and discussion of issues like MD or the successor, if there is to be one, to Trident.
11. Globally there is a great deal of public opposition, including from senior members of the military establishment (see Center for Arms Control and Non-Proliferation) and from members of the scientific community - see Box 4.4.

4.3.4 Case study 4: A new generation of nuclear weapons

Like MD, this case study illustrates the development of sophisticated and largely speculative technologies which have attracted a great deal of criticism from the scientific community and many military analysts. In addition, both case studies concern new military technologies that lead to a weakening of the drive for global nuclear disarmament.

The US government's Nuclear Posture Review which was leaked to the media in 2002 allows for the use of nuclear weapons in three scenarios: against targets able to withstand attacks by non-nuclear weapons (the 'bunker busters'); in retaliation for attacks with nuclear, biological or chemical weapons; and in the event of 'unexpected military development' - such as an Iraqi attack on Israel (Paine 2004). The Review has significantly broadened the circumstances in which nuclear weapons might be used, and clearly underpins the Bush unilateralist position detailed earlier in this Chapter.

UK Defence Secretary Geoff Hoon appeared, after the leaking of the Review, to give tacit support to such disproportionate and indiscriminate 'pre-emptive' action, suggesting that in light of "new emerging threats" it is right that "all possible elements of a comprehensive strategy be examined" (Oppenheimer 2003). This easing of the threshold for nuclear strikes is a major shift from previous UK policy. In addition, the UK government has a newly adopted nuclear first-use policy in the face of an attack from biological or chemical weapons despite the massive and catastrophic death toll and destruction of the environment that would result from such use.

A new generation of nuclear weapons has been keenly supported not only by the major defence corporations but also by the US weapons laboratories such as Sandia, Lawrence Livermore and the Los Alamos national laboratories. In November 2003 Bush signed into law the Defense bill that authorized research into new low-yield nuclear weapons and set up 'advanced concept teams' at the US weapons laboratories (Siegel 2004).
It emerged in June 2002 that the UK government was investing more than £2 billion in 'upgrading' the Atomic Weapons Establishment (AWE) at Aldermaston. The special facilities would include:

- ❑ Orion, a new powerful laser
- ❑ new hydrodynamic testing facility which would allow weapons test data to be assembled without recourse to underground tests
- ❑ new materials laboratories which could provide underground-test-quality data on weapons material
- ❑ the provision of supercomputing to build mathematical models of warhead performance

Apart from supporting the routine maintenance of the UK's Trident nuclear weapons, Aldermaston has in the past carried out computer simulations of nuclear tests which replace the underground tests banned under the Comprehensive Test Ban Treaty. It is thus feasible, given the expertise at Aldermaston, that the planned expansion could make possible the design and production of low yield nuclear weapons, designed to destroy underground targets - such as command bunkers and storage facilities suspected of containing weapons of mass destruction.

The AWE expansion plan not only coincides with an apparent decision to radically alter the UK nuclear doctrine, but also with an impending government decision on whether to development a replacement for the UK's Trident nuclear weapons which are due to be decommissioned in about 20 years (Milne et al 2002). It is possible that the AWE expansion signals that the decision has already been taken. As such it would conflict with UK commitments under the Nuclear Non-Proliferation Treaty (see later).

Of further concern is reports of increased visits of AWE scientists to the USA (Oppenheimer 2003). Visits from AWE to the nuclear test site in Nevada rose from nine in 1999 to 40 in 2001, and in 2002 more than 300 scientists from Aldermaston visited 25 sites in the US including the weapons laboratories at Sandia, Lawrence Livermore and Los Alamos (Edwards 2004). Such movement of nuclear research personnel given the security lapses at Los Alamos and Sandia does tend to give some cause for concern.

There are now 16 joint UK/USA working groups on weapon issues including warhead physics, nuclear counter-terrorism technology, and nuclear weapon code development. Everet Beckner who is in charge of the US nuclear weapons programme at the Department of Energy was the deputy chief executive at Aldermaston (Edwards 2004).

The Orion laser facility will be more powerful that the existing HELEN laser and will be capable of generating conditions which more closely resemble those found in the centre of stars or within a nuclear detonation. Orion is also intended for use in inertial confinement fusion experiments long associated with research and testing of nuclear weapons (see section 4.3.2 and www.acronym.org.uk). It is thus possible to test, design and build not only a strategic successor to the Trident system but also to drive forward the new generation of tactical low yield nuclear weapons.

Box 4.5

–Aldermaston at a glance

The UK's Atomic Weapons Establishment (AWE) consists of Aldermaston and the smaller facility at Burghfield Common which is responsible for final assembly, in-service maintenance and the decommissioning of the UK's two hundred nuclear warheads. AWE is run on a Government-owned, contractor-operated basis with the present contractor (AWE in partnership with British Nuclear Fuels, Lockheed Martin and Serco). The contract runs until 2025. Aldermaston has been the subject of a number of Reviews from the 1970s to the 1990s which have pointed to several serious management errors and contamination episodes. Aldermaston has on-site expertise in high performance supercomputing, hydrodynamics, explosives technology and nuclear physics. At the time of writing around 3,600 people are employed at the two sites - these include those with SET expertise. Annual running costs are about £300 million and the intention was that the nuclear programme budget would fall by around 30 per cent over the next ten years. But major investment has been agreed which includes the Orion laser facility. This facility was temporarily withdrawn as a result of complaints raised by local residents, the West Berkshire Council and the Nuclear Free Local Authorities (www.awe.co.uk), but was given the go-ahead in July 2004.

The UK-USA special relationship discussed in the context of the MD (see section 4.3.3) is also to be found operating in the nuclear collaboration concerning the Trident system which is on lease to this country from the USA. The UK Trident warhead is closely based on the W76 US weapon, and a pool of Trident II D-5 missiles is manufactured by Lockheed Martin (Oppenheimer 2003). For a full discussion of the UK nuclear weapons strategy readers are referred to the British Pugwash Group publication, entitled *An end to UK nuclear weapons* (Milne et al 2002). For the purpose of this chapter the critique of the new US nuclear posture also applies to the UK's involvement.

The new generation of nuclear weapons —some of the key issues

1. The research and development budgets needed for the new nuclear weapons are very large.
2. Many military strategists point out that new low-yield nuclear weapons do not in fact significantly increase military advantage (Levi 2003 and 2004c).
3. Development of pre-emptive low-yield nuclear weapons would drive weapons proliferation. It would subvert the Comprehensive Test Ban Treaty (CTBT) and further weaken the Nuclear Non-Proliferation Treaty (NPT) - both signed and ratified by the UK government. As such, the authority of nuclear states to seek the end of nuclear proliferation in other countries would be undercut. In many ways the USA, UK and other nuclear states are already in contravention of the NPT since Article VI of this treaty requires the negotiation of total nuclear disarmament. Given these arguments, the active co-operation of SET personnel in warhead programmes is especially ethically problematic. Work in this area could however be ethically justified if there were a wholehearted commitment to decommissioning and destroying warheads (see Nicholls 2002) and the use of new technologies to strengthen verification and improve decommissioning processes.
4. Radioactive fallout from the so-called low yield mini-nukes is substantial and is seldom discussed by those who regard the system as a potential answer to strategic problems (Levi 2004a, 2004b and 2004c). The data used to support these weapons as bunker busters are based on Nevada Tests undertaken during the Cold War and systematically under-represent the levels of radioactive fallout which would result from a new generation of earth-penetrating nuclear devices.
5. Several commentators have described how conventional weapon systems can provide sufficient power and are not adequately discussed in those scenarios in which nuclear bunker buster weapons are suggested as appropriate (Levi 2004a).
6. The latest claims for undertaking research into low-yield nuclear devices - from the Defense Science Board of the US Department of Defense (www.fas.org) clearly shows that the deployment of the new nuclear devices would supercharge USA military ambitions and thereby reduce the effectiveness of the NPT and CTBT, stimulating proliferation and a new nuclear arms race.
7. If the UK government decides to commission a replacement for the Trident nuclear weapons system, it would further undermine international attempts at nuclear disarmament, including the NPT negotiations, for the reasons specified in point (3) above.

4.4 The need for a paradigm shift towards global security

The case studies described in this chapter have charted in some detail how significant funds have been used to support narrow, weapons-based military strategies, driven by R&D investment in the countries of the North, especially the UK and USA. Such investment owes much to political ambition and the projection of power reminiscent of the Cold War. As we have stressed at several points in this Report, what is desperately needed for a secure world is a fundamental shift in focus toward an inclusive understanding of security - including the prevention of conflict - which gives salience to social justice, sustainability and a central role for addressing the effects of global problems such as climate change and degradation of the environment. The following Chapter will describe some of the urgent issues facing the world today and illustrate ways in which the SET community are helping to tackle these issues.

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NOTES

1. Currently DSTL works with a number of countries in their military programmes and research agreements with the US account for around half of DSTL's collaborative research and development work.

2. See sections 2.8 and 4.3.3 for more details of Lockheed Martin and its activities.

3. In June 1968, Nuclear Non-Proliferation Treaty (NPT) signed in Washington, London, and Moscow. Among other obligations, the NPT requires parties to the Treaty to "seek to achieve the discontinuance of all test explosions of nuclear weapons for all time and to continue negotiations to this end," and under Article VI, to "pursue negotiations in good faith on effective measures relating to the cessation of the nuclear arms race at an early date and to nuclear disarmament ...."

4. Various terms have been used for the Missile Defense programme over the recent past, including Ballistic Missile Defense and National Missile Defense. Throughout this Report Missile Defense is used to describe the complex space-based system of missile interception.

CHAPTER FIVE

Science and technology and a broad global security agenda

"The scientific enterprise is now largely involved in the creation of novelty - in the design of objects that never existed before....And precisely because we create those objects and representations we must assume moral responsibility for them..."

from Schweber (1993)

KEY POINTS

- ❑ International action on broad security-related issues such as disarmament, poverty, environmental degradation, and resource depletion is seriously inadequate. Multi-lateral initiatives to tackle these problems need much greater resources and much wider support.
- ❑ Unsustainable use of resources by wealthier nations can contribute to conflict. Nations which move towards more environmentally sustainable practices can lessen such a contribution.
- ❑ The UK academic community (amongst others) has launched a number of initiatives which attempt to address concepts of security in broadly inclusive ways.
- ❑ There needs to be a greater emphasis on non-violent intervention in settling disputes worldwide. SET expertise can be a vital element in helping to moves towards disarmament and peace.
- ❑ SET expertise is an important aspect of poverty alleviation programmes. Providing access to clean water is an example.
- ❑ The evidence that global climate change is happening and is caused by human emissions of greenhouse gases (GHGs) is very strong and has widespread acceptance amongst the scientific community. The likely effects (eg sea-level rise and increased flooding, increased severe weather, and changes in disease patterns) will cause serious and long-term damage to human health and natural ecosystems unless much more action is taken to reduce GHG emissions. Increasing conflict due to, for example, increasing numbers of environmental refugees is a significant possibility.
- ❑ The main source of GHG emissions is the combustion of fossil fuels. Large scale reductions require major investment in and deployment of renewable energy technologies and energy efficiency measures, as well as other measures as part of the wider move towards a more sustainable society. While some progress has been made recently in the UK and a few other countries to reduce emissions, much more effort is needed. Engineers and scientists have a key role to play here.
- ❑ A redirection of some of the resources currently used by the military in the UK and elsewhere (especially the USA) to pressing social and environmental problems is likely to have clear benefits, not least in terms of security. Such a redirection of resources would include a change in R&D priorities and the redeployment of many scientists and engineers.

5.1 Introduction

Addressing the threats to global security will demand changes in national governments' policies. In the majority of cases science, engineering and technology will all play pivotal roles in facilitating such change.

This chapter describes some innovative examples, mainly with a UK component, of modest funding being used to address issues which have a security dimension. We look at how the SET community is involved and how these initiatives might be further developed to secure peace, justice and sustainability. It is our contention that policy makers and others in positions of influence should place more emphasis on an integrated agenda of positive global security. Such an agenda would recognise the links between seemingly disparate areas such as energy policy, resource conflict, poverty, climate change and global inequalities which can stimulate conflict. Furthermore, in taking forward this agenda use could be made of some of the funds which presently are used by the military.

As we highlighted in the previous chapter, US policy can be very influential on the way SET funding is spent internationally. Hence, it is worth noting current spending priorities there. Despite being the world's largest emitter of the greenhouse gases responsible for climate change, environmental science research programmes have been hard hit in the budget proposals of the Bush administration, especially those for 2005. Such programmes have the potential to address, for example, what kinds of action need to be taken to at least slow down the effects of climate change. However, the budget for science and technology at the Environmental Protection Agency (EPA) has been cut from its 2004 level by 12 per cent to US$577 million. Research at the National Oceanic and Atmospheric Administration is down 3 per cent to US$350 million, and the US Geological Survey is down by 2 per cent to US$920 million. As we pointed out earlier (Chapter four) changes at NASA (especially the merger of the Earth and Science Directorates) will mean that climate change studies will also be severely reduced at NASA. At the same time, the Department of Defense's overall budget for military objectives is boosted to US$400 *billion*. As one of the members of the House subcommittee overseeing the research on environmental areas said "This is a budget lacking vision" (Brumfiel 2004).

In order to bring about a more just and peaceful world, it is vital that the leading nations forge a truly multi-lateral approach to international issues. Unfortunately, the USA (with some other countries) has chosen to eschew such a route in a whole range of areas. They will not implement the Kyoto Protocol on climate change (see Luterbacher and Sprinz 2003) nor ratify international treaties on land mines, the international criminal court, biological weapons, and nuclear proliferation. This makes it very difficult to bring about international accountability by national governments and thereby reduce potential areas of conflict.

Despite the UK showing much greater willingness than the USA to follow a multi-lateral agenda, there is still much room for progress. As we have argued in earlier chapters, the prevalence of a narrow 'world view' in military circles leads, essentially, to a bias within UK SET towards weapons and their support systems. Furthermore, the fact that claims that major civilian utility results from the huge military funding of SET are at best overstated (see section 3.4 and also Alic *et al* 1992, and Sarewitz 1996) reinforces the case that at least some SET expertise could and should be redeployed from the military.

By forging an agenda with a much wider interpretation of security issues, new strategies and roles for SET can be seen. For example, global economic factors can have important linkages with conflict, although the relationship is often complex. Space does not permit anything but the briefest of glances at this area, but it is worth a little examination of ways in which changes in a nation's economic behaviour may influence the potential for conflict. An issue especially relevant to SET workers is the reliance of Western countries on mainly imported fossil fuels, especially oil. Not only do many oil-exporting nations have human rights problems or suffer from internal conflict in which control of oil revenues is a factor, but growing global demand for oil at a time when stocks are becoming depleted leads to pressure for military strategies to protect access to sufficient sources of the fuel. Furthermore, oil consumption is a major contributor to climate change whose global impacts could contribute to conflict through, eg, the creation of large number of environmental refugees. Clearly, national strategies which lead to more sustainable energy consumption patterns (eg through expansion of renewable energy) offer an alternative security strategy by not only reducing the damaging effects of climate change but also reducing the potential for resource conflict.

The UK government has taken the first steps towards a sustainable society through the publication in 1999 of its sustainable development strategy for the UK, entitled *A Better Quality of Life*. However, as is clear from the title of the recent independent review of the effectiveness of this strategy, *Shows promise - But must try harder* (SDC 2004), the UK's progress towards environmental sustainability is patchy at best, with much stronger action required especially in areas such as transport, waste and sustainable consumption.[1] Clearly, more urgency must be injected into the UK's drive for environmental sustainability.

We now want to describe a number of pressing issues which endanger global security and which call for not only significant funding but also a vision of pursuing peace by means other than superiority of force.

5.2 Some examples of new approaches to security

The New Security Challenges Programme of the UK Economic and Social Research Council (ESRC) is an example of a research programme based on a broad interpretation of the concept of security. With modest funding of £4 million the programme has been launched under the Direction of Professor Stuart Croft from Birmingham University. Professor Croft comments, in an interview in the ESRC Newsletter, that "Today ....threats to security are recognised to vary greatly in their causes and manifestations. Our objective ...[is] to promote research into security which transcends the traditional pre-occupation with military conflict between states." (Social Sciences 2003). Some of the studies which address threats to security being undertaken by leading researchers throughout the UK within this programme include: the impact of the media, issues of gender, and the impact of technological development. In addition the programme seeks to explore three factors pivotal to concepts of security: the environment, economic issues and human interactions. Professor Croft points out that damage to the ozone layer is a marked threat and one which will impact across the world but it has not been perceived widely as 'an enemy'. He argues that security is much more than just the threat of military force, it is about making the world safer, more tolerant, open and just for all.

The ESRC also funds a number of other research programmes which have immediate implications for framing and understanding the concept of security. For instance a £3 million programme is being undertaken at the University of Sussex to understand the social and economic processes that shape, foster or deter sustainable technology development. Also at Sussex, with ESRC funding of almost £150,000 is a project which addresses the various factors which either facilitate or hinder the development of 'appropriate technology' (see section 5.4.2). With ESRC funding several research teams are also teasing apart the psychological and societal aspects of terrorism, with a total budget of less than £750,000.

There are also other individuals within the UK research community who are undertaking research into conflict and environmental change and trying to seek funding, which is potentially more difficult in the climate of commercial 'relevance' which we described in Chapter one.

These various initiatives to understand security help give rise to effective ways of, for example, tackling the roots of conflict. They are all to be warmly welcomed but it is clear, simply from the size of the military budget as against other claims such as those described above, that these issues are not centre-stage in considerations of what must be done to secure a safe world for all its inhabitants.

5.2.1 Peace and disarmament–some initiatives

There are a number of initiatives with a science and technology component which are examining disarmament and alternatives to the use of military force.

One example is the University of Bradford Department of Peace Studies, which is a key player in providing the intellectual and research base for peace, conflict resolution and security studies. The Department was established in the early 1970s with support from the Society of Friends (Quakers), who were keen to create a centre for peace studies along the lines of several successful endeavours in North America and Scandinavia. At present the Department has three major research groups which cover social change, conflict resolution, mediation and peacekeeping set within the context of international relations. Research published by the Department has been drawn upon for this Report.

There are many initiatives across the world that address non-violent means of intervening in conflict. The Oxford Research Group examined 280 non-violent interventions in conflict across the globe and published details of fifty of the most effective of those initiatives with costs (Oxford Research Group 2001). The overwhelming finding was how cheap non-violent intervention could be and indeed how effective. One of the most impressive examples was the setting up of a task force to help forge effective united democratic opposition to Milosevic in Serbia in 1999. It was by comparison with the other examples in the study, quite expensive - US$240,000 - but set in the context of the UK military budget, for example, extremely cheap. Elworthy has calculated that the UK spends £550 million on conflict resolution, peacekeeping and enforcement which amounts to less than 2 per cent of the government's military budget[2] (www.oxfordresearchgroup.org.uk - June 2004 and Elworthy 2004). The combined total requested for Office of Conflict Management and Mitigation of the US Agency for International Development (USAID) for financial years 2004 and 2005 was $22 million, again a tiny fraction of the country's total military budget (www.usaid.gov/our_work/cross-cutting_programs/conflict/).

In the UK, one example of seeking non-violent paths in conflict resolution is the UK Global Conflict Prevention Pool, a project of the Ministry of Defence, the Foreign Office, and the Department for International Development. Together with the Africa Conflict Prevention Pool, the Joint Pools represent a small but very valuable development in conflict prevention. The Pools have a budget of £124 million, which although small by Ministry of Defence funding standards (about 0.03 per cent of UK military spending and a vanishingly small proportion of the USA DoD budget) it is at least a start.

What specific place is there in non-violent conflict resolution for the scientific and engineering expertise of those who wish to contribute to global security? We mentioned earlier the proliferation of weapons and their consequences remaining long after conflict. Landmines are a particularly devastating weapon in post-conflict communities. United Nations estimates that landmines kill around 20,000 civilians each year (Smith 2003). Globally there are 8 to 9 million mines owned by those states that are party to the Mine Ban Treaty of 1997[3] and 220 million are owned by states that have not signed the Treaty (this includes 11 million mines owned by the USA).

Although the production of anti-personnel mines has fallen since the Mine Ban Treaty was agreed, the effort put into mine clearance and related R&D is still very limited. For example in 2000 only US$20 million went to each of Angola, Afghanistan and Cambodia for mine clearance. Many governments claim that part of their military budget is to be spent on demining. In 1997 the European Commission's Joint Research Centre identified the need for further R&D to develop and test improved methods for mine detection, identification and removal. The USA has targeted itself to increase global spending on finding effective ways to demine to US$1 billion per year by 2010. However, a major problem is that military funding tends to produce demining devices for military needs - namely ones that can be used by armed forces in combat situations and hence can be too specialised and expensive for developing countries to implement for civilian populations. The UK company Redbus LMDS (www.lmds.redbus.co.uk) has produced robot landmine clearing machines which not only clear the area containing possible landmines but also returns the soil duly filtered and free of all ordinance. Redbus LMDS machines have been used in Bosnia and the company is not part of the military sector. A range of customisations of the machines has been undertaken relatively cheaply using SET expertise to pursue humanitarian objectives without military support.

5.3 Poverty and security

Poverty and the access to food and clean water are pressing issues across the world. Disparities of wealth and resource access within and across countries can be potential contributing factors to conflict - as we mentioned in Chapter two. Indeed, it is worth noting that 45 million people are estimated to live in poverty in the USA despite the economic and military position of the nation (Smith 2003).

Water has been described as the emergent global resource crisis of the 21st century. Around 1 billion people do not currently have access to safe clean water and 2.4 billion lack adequate sanitary systems (WHO and United Nations Children's Fund 2000). Around 80 per cent of all diseases in the developing world are water-related, and water is also central to managing agriculture. Water is thus pivotal in meeting Millennium Development Goals (see Box 5.1). Changes in climate, accelerated soil erosion and the use of agrochemicals further endanger water quality and its supply.

Box 5.1
–The UN Millennium Development Goals

1. Eradicate extreme poverty & hunger
2. Achieve universal primary education
3. Promote gender equality & empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria & other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

See www.developmentgoals.org for further information

About 40 per cent of humanity depends upon the 260 major international water basins shared by more than two countries. Hence growth in population and water demand in these regions is a potential source of conflict. The World Panel on Financing Water Infrastructure estimated that the US$80 billion spent annually on water systems for developing and transition nations could reach US$120 billion in 20 to 25 years time. The WorldWatch Institute estimates that universal access to around fifty litres of water per person per day by 2015 would require less than 1 per cent of current global water withdrawal (www.worldwatch.org).

Clearly some minor reallocation of spending from the global military budget (which stood at US$956 billion in 2003) could make a major contribution to tackling this water insecurity and, at the same time, reduce the potential for conflict.

Examples of ways of tackling water insecurity which make use of SET expertise, and which could benefit greatly from a boost in funding include:[4]

- development of new storage systems for water - and also improved ecological sustainability of water sources
- a focus on better integrated water management (including irrigation, small local hydropower plants and waste management)
- promotion of the development of local solutions for meeting safe drinking water and sanitation goals
- development of emergency planning for floods and droughts
- restoration of degraded aquatic habitats and ecosystems

5.4 Global climate change

There is now widespread scientific acceptance that the threat of serious climate change is real, and that human emissions of greenhouse gases (from fossil fuel consumption and deforestation) are the main culprit (see for instance Hardy 2003 and Houghton *et al* 2001).

A number of signals have been cited in the scientific literature that show the magnitude of the change. For instance the ten hottest years on record have occurred since 1991, while in the past century average temperatures have risen by around 0.6 degrees Celsius (King 2004). New measurements indicate that the increase in temperatures in the 20th Century is likely to have been the largest of any century during the past 1,000 years. Tide gauge data indicates that global sea level rose between 0.1 and 0.2 metres during the 20th Century. Furthermore, atmospheric levels of the main greenhouse gas (GHG), carbon dioxide, are at their highest level for at least 430,000 years (see: www.ipcc.w2g.org and also Hardy 2003).

A range of marked geographical indicators of climate change have been described including: the retreat of ice caps and the disappearance of some glaciers across the world (Houghton et al 2001, McCarthy *et al* 2001); the thinning of summer and autumn Arctic Sea ice by up to 40 per cent in recent decades (Wadhams 1997); and an increase in both severity and frequency of storms. Without action to reduce GHG emissions, the Intergovernmental Panel on Climate Change (IPCC) projects that global temperature will increase by between 1.4 and 5.8 degrees Celsius by the end of this century, relative to the 1990 level (Houghton *et al* 2001). If we continue along the present global development scenario the change will be towards the upper end of the range. Such a change would be as large as that between a glacial period (ice age) and an interglacial period. The adverse effects would be profound, including large rises in sea level and resultant massive flooding, increases in severe weather events, massive loss of wildlife, as well as changing patterns of human disease and illness which we will examine further below (www.ipcc.w2g.org).

As we will see later, the UK has taken important first steps to reduce its GHG emissions and the government has argued for strong international action on climate change. Indeed, the Chief Scientific Advisor, Professor David King, wrote in a brief but broad-ranging review of the need for action, specifically that "climate change is the most severe problem that we face today - more serious even than the threat of terrorism" (King 2004). The behind-the-scenes response of the Blair government to this statement, however, reveals some of the tension between conventional military thinking and the broader security agenda. King was sent a memo by a senior civil servant criticising his use of the terrorism/climate change comparison, probably concerned about antagonising the Bush government which remains unconvinced of the need for major reductions in GHG emissions (Connor and Grice 2004).

5.4.1 Health and climate change

The historical role of the climate in conflict has been well documented (see especially Lamb 1988) but climate change will also impact on human health in ways which could be both abrupt and longer lasting. The prospect of increasing numbers of extreme weather events and their relationship with human ill-health has been discussed in the medical press. The devastating heat wave of 2003 was implicated in the deaths of an estimated 15,000 people in France alone in a matter of weeks. In an editorial in the British Medical Journal, Patz described the range of health effects which are brought about by global climate change, especially by the extreme events such as heat waves, droughts, floods and severe storms. For every one person killed in a 'natural disaster' 1000 people are affected either physically or through loss of property or livelihood (Patz 2004). Furthermore, climate-related disasters cause much greater loss of life in developing countries indicating that poorer communities are particularly vulnerable to climate change (World Disasters Report 2003).

Climate-related disasters are on the increase rising from 200 such events per year in 1993-97 to 331 per year in the period 1998 to 2002 (World Disasters Report 2003). The World Health Organisation estimated that globally around 150,000 people died due to various aspects of climate change in 2000 alone (www.who.int). Climate change is also likely lead to an increase in insect-carrying diseases such as malaria. In addition, other mosquito-borne diseases such as dengue fever and encephalitis, which are generally more prone to being influenced by local climate, are likely to spread to new corners of the world. There will therefore be an increase in the incidence of certain diseases globally (Patz *et al* 1996).

Climate change can also lead to excessive rainfall and runoff in some areas. This can lead to increases in pathogens entering the water supply, and increases in waterborne disease have been traced to heavy rainfall in the USA (Patz 2004).

Sixteen of the world's so-called mega-cities (in countries such as China, Egypt, Nigeria, Bangladesh and India) are on coastlines with low lying river deltas where even a small rise in sea level or shifts in weather patterns would have a devastating effect (New Economics Foundation 2004).

Hence, if left unchecked, climate change is likely to increase the burden of human disease globally, especially amongst poorer communities and in those parts of the world having less than well-developed disease prevention and treatment programmes. Concern has also been expressed in the scientific community that the large scale funding of the biodefence programme in the USA might obscure the fact that what is needed internationally is more support for research into the diseases affecting the poorer countries, especially those likely to increase in the wake of climate change (see section 4.3.1 and Fraser 2004).

5.4.2 Mitigating climate change –the role of science and technology

In 1997 the Kyoto Protocol was agreed, setting targets for the reduction of GHG emissions by the industrialised countries. In combination, if the targets were met, GHG emissions during the period 2008-12 would be 5 per cent lower than their 1990 levels (UN FCCC 1997). Since then the withdrawal of the USA and Australia from the Protocol, coupled with a 'watering down' of the rules on emissions trading and forestry, mean that the total emissions of industrialised countries by 2012 will be very much higher than that laid out in the treaty. This is against a backdrop of the need for global GHG emissions to reduce by between 30 to 70 per cent by the end of the century, and the emissions of industrialised countries to reduce (assuming a convergence to equal emissions per head across the world) by at least 80%[6]. Clearly a substantial global effort is needed to tackle the problem, and scientists and technologists have a critical role.

In contrast to US antipathy, the UK government has been far more pro-active on the issue of climate change. Under the Kyoto Protocol the UK has a target of a 12.5 per cent cut in GHG emissions. In addition, the government has also set a voluntary target of a 20 per cent cut in carbon dioxide emissions by 2010 and, in the 2003 Energy White paper (DTI 2003), set an 'aspirational' target of a 60 per cent cut by 2050. However, to put this in perspective, achieving the 20 per cent target would only bring UK carbon dioxide emissions per head of population down to a level similar to that of, for example, Austria and still a long way behind Sweden[6]. Furthermore, without much stronger action to curb the current rise in emissions from road transport, there is a real danger this target will not be met (see, for example, SDC 2004).

In the following sub-sections, we discuss first energy and then some other climate-related R&D initiatives in the UK and overseas in this context.

Energy and climate change

Fossil fuel combustion is responsible for about 80% of the emissions of carbon dioxide, the main greenhouse gas. Hence there is a pressing need for expansion of technologies for harnessing renewable energy and improving end-use energy efficiency. Examples include wind turbines, solar photovoltaic panels, building insulation, bio-fuels, hybrid electric cars, wave turbines, combined heat and power plants and eventually hydrogen fuel cells. In addition carbon capture and storage technologies, which could remove carbon dioxide from the exhaust gases of power stations and deposit it underground, could make it possible to continue with some limited use of fossil fuels in a carbon constrained world. Using such technologies could make a profound difference to GHG emissions levels across the world, especially if used in combination with measures to encourage more environmentally-friendly behaviour, eg taxation to encourage a shift from car travel to train travel.

In addition to the targets for total GHG emissions set under the Kyoto Protocol above, several have been set or advocated for changes in energy use. For example, the UK has a target of generating 10 per cent of its electricity from renewable energy by 2010. Meanwhile, the Task Force on Renewable Energy set up by the G8 nations[7] called in 2001 for the adoption of renewable energy targets to serve at least one billion people with renewable energy by 2010. The task force also called for the phasing-out of G8 government subsidies for fossil fuels and nuclear energy, while increasing research and development for renewables, in order to level the playing field and allow the energy markets to function in a balanced fashion (see www.renewabletaskforce.org).

It is worth examining in more detail the issue of fossil fuel subsidies. Levels of fossil fuel energy subsidies in the OECD (industrialised) nations ran at about US$73 billion per annum between 1995 and 1998; with a further US$162 billion of subsidies to fossil fuels in non-OECD nations -

a total of US$235 billion every year in this period (Pershing and Mackenzie 2004). Others put this figure higher, at between US$250 and US$300 billion (Ottinger and Jayne 2000). Subsidies also heavily influence the propagation of fossil fuel technologies within the international development programmes. According to a study by the World Resources Institute over 90 per cent of the US$90 billion in public and private capital flows directed towards new power plants in poorer countries between 1994 and 2001 went to large-scale coal and natural gas projects, while a mere 1.5 per cent went to renewable power supplies (Philpott 2004). In the report entitled *Striking a better balance* the authors suggested that the World Bank Group should: "...devote its limited scarce resources to investment in renewable energy resource development, emissions-reducing projects, clean energy technology, energy efficiency and conservation, and other efforts that delink energy use from greenhouse gas emissions" (World Bank 2004).

A further energy problem related to climate change is that 2.4 billion people (about 40% of the world's population) regularly use biomass, much of which is unsustainably harvested wood, for some or all of their cooking and heating needs. Indeed 1.6 billion of these people have no access at all to electricity. Such harvesting of wood causes deforestation and makes a significant contribution to climate change. In addition, the pollutants from the burning of biomass can lead to severe health problems often resulting in death. It is estimated that around 2.2 million people, mainly women and children, die each year from fuel-related (especially from biomass powered stoves) diseases (UNEP, UNICEF & WHO 2002). Hence there is further need to improve energy provision in developing countries, using a combination of forest conservation measures with renewable energy technologies, including cleaner more efficient biomass burners.

So is energy R&D funding reflecting the need to tackle climate change and other related problems? There are few positive signs. Firstly, publicly funded energy R&D has dropped considerably in recent years. For example, between 1985 and 1998 the USA, the European Union and the UK collectively reduced their public sector investments in all areas of energy R&D by 35 per cent in real terms (Hardy 2003). Some of the drop has been due to increased privatisation of energy infrastructure, but private companies are often not making up the shortfall. Indeed, in the US between 1985 and 1998 the private sector cut energy R&D investment even more than in the public sector: by 53 per cent (Hardy 2003). And with fossil fuel subsidies remaining high, the incentive for private companies to invest in renewable energy R&D has not been great. Secondly, government energy R&D devoted to renewable energy has often lagged behind that devoted to fossil fuels and, in the UK, even the rather more speculative nuclear fusion. For example, in 1998 the UK government spent US$5.2 million on fossil fuel R&D and US$13.6 million for nuclear fusion R&D, whilst committing only US$4.6 million to renewables (from www.iea.org). That same year the UK government spent US$4 *billion* on military R&D whilst the US government funded military R&D to the tune of US$40 billion (Smith 2003). Whilst the picture for renewables R&D has shown a marked upturn in the UK recently the massive disparity between it and funding for military R&D continues.

Two recent relatively modest initiatives demonstrate some UK R&D into low-carbon energy systems. The Carbon Trust[8] has committed £29.9 million in support of research into low-carbon technologies which draws together researchers from universities and also those in corporate facilities to identify innovative means to reduce carbon emissions. Secondly £28 million funding through the Engineering and Physical Research Council, Economic and Social Research Council and the Natural Environment Research Council will be used to facilitate multidisciplinary research into ways of providing both secure and sustainable sources of energy for the UK. The UK Energy Research Centre was set up with £8 to £12 million from this source. Further information may be found at respectively: www.thecarbontrust.co.uk and www.nerc.ac.uk

More research and appropriate development is needed to explore the range of renewable options and directing some of the funds currently devoted to military spending together with the diversion of research from military goals into low-carbon technologies and sustainability would be a major help. The renewable route to energy production can lead to both clean, cost-effective energy and the alleviation of poverty without further damage to the climate.

Indeed, from a security perspective, it is surprising that investment in alternatives to fossil fuels have not been pursued more strongly. As we mentioned earlier, many have argued that oil has had a not insignificant role in conflict, especially the recent wars in the Middle East. Hence it makes security sense to move to renewable energy sources, which are in general indigenous. The case for diversion of military funds to the transition to renewable energy is thus even stronger.

Other climate change R&D initiatives

In addition to energy-related R&D work, a number of UK universities have research centres which address climate change, sustainability and how mitigation of the adverse effects of climate change might be undertaken most effectively. For instance the £10 million Tyndall Centre for Climate Change Research has recently been opened, where multidisciplinary research teams are studying climate change and designing appropriate ways of responding. The research councils have also funded programmes, for instance, using the Envisat satellite to measure atmospheric and oceanic change. In addition £10 million is being put into flood and coastal defence research. Industry has a large research effort in climate change mitigation too. But overall these figures are small and very modest in the face of the funding of military objectives, such as £1.4 billion invested by the UK government in the development of the Joint Strike Fighter aircraft (see section 3.3) or the annual cost of maintaining the UK's Trident nuclear weapons system which has been estimated to be in the region of £2 billion (Milne *et al* 2002).

Sachs (2004) has also argued that funding for future technologies that could underpin sustainable development is a small fraction of military spending in the West.

5.4.3 Climate change—a call to action

A concerted effort must be made, especially by the wealthier industrialised countries which (per head of population) are the leading greenhouse gas emitters, to step up action to tackle climate change. Increased funding to accelerate the introduction of 'low-carbon' energy infrastructures must be given much greater priority, and this will include a large multidisciplinary research and development effort. While the UK is making more effort than many wealthier countries, there is still room for improvement.

To facilitate this transition to a low-carbon and eventually carbon-neutral society, research and investment must be markedly increased. A report from the House of Commons Science and Technology Committee in April 2003 drew attention to the then "fragmented, poorly co-ordinated and lacking in focus" nature of energy R&D in the UK. The Committee suggested that a renewable energy authority be established in order to fully promote research into this form of sustainable practice (see www.researchresearch.com April 2003). What has not yet been widely recognised is that a significant diversion of funds from the military, especially in the UK and USA, could play a critical role in the transition to a low carbon society.

We have also argued that it is essential that developing countries are not left out in the move to a more sustainable society. As David King pointed out in his Science article, ".....developing countries would need to be brought into the process as part of a North-South science and technology capacity-building exercise embedded in a framework that recognizes that issues of justice and equity lie at the heart of the climate change problem" (King 2004). The diffusion of 'appropriate technologies' are a key aspect of this, whereby technologies are introduced in a manner appropriate to the host country and its population. This often requires so-called intermediate technology, which is cheap and can be effective in meeting the needs of the poor and mitigating their contributions to climate change and other damage to the environment, such as loss of biodiversity. Again a shift from the large scale export of military technology (with the problems highlighted in Chapter two) towards export of, eg, renewable and intermediate technologies is likely to provide many benefits.

5.5 Investing in the future—a shift in perspective

In 1986 Woodhouse argued that society is based on a 'violent economy' (see Box 5.2). The evidence and arguments we have presented in this Report mirror some of those that Woodhouse highlighted nearly two decades later. He made the case for shifting to a 'peaceful economy', and this again parallels the arguments we have laid out in this Report. Such a shift requires the active involvement of scientists, engineers and technologists and it is with this in mind that we move towards a set of recommendations in the concluding chapter.

Box 5.2

–A violent economy

Large scale production, hierarchically and bureaucratically organised (*Chapter one*)

High levels of conflict over possession of the world's resources (*Chapter two*)

A complex of military interests in industry and the economy (*Chapters two and three*)

Mass-production, standardisation and deskilling

A high demand for energy for the industrial machine and consequent pollution and exploitation of the environment (*Chapters two and three*)

–A peaceful economy

Democratic control and co-operative working patterns

A diversity of modes of economic activity - with an emphasis on human-scale activities

Production of arms playing a small part of the economy

Low levels of violence within and between societies

A sustainable attitude to the environment

An awareness of the global consequences of economic activity

Adapted from Woodhouse 1986 and quoted by Dando 1998

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NOTES

1 For a more detailed description of this area the reader is also referred to *A better choice of choice: quality of life, consumption and economic growth* (Levett et al 2003) and also *The meaning of environmental security* (Barnett 2001).

2 The Ministry of Defence claims this figure is closer to 6 per cent (see section 2.4).

3 The Mine Ban Treaty of 1997 covers only anti-personnel devices; many similar weapons are not banned. The Claymore-type of fragmentation mine, for instance, is used against people and vehicles and is not covered by the Treaty.

4 Adapted from State of the Planet 2004 at www.earth.columbia.edu/sop2004

5 Required reductions in global GHG emissions depend on definitions for 'safe' upper limits for the atmospheric concentrations of these gases. For example, for carbon dioxide, debate is focussed on whether the safe level is 550 parts per million or lower (see GCI 1997; RCEP 2000; IPCC 2001 for more detailed discussion of these issues).

6 UK carbon dioxide emissions in 2001 were 9.4 tonnes per head down from 10.3 in 1990. Austrian emissions in 2001 were 8.5 tonnes per head, and Sweden's were 6.2 (geodata.grid.unep.ch).

7 The G8 is the group of the world's eight most economically powerful nations: Canada, France, Germany, Italy, Japan, Russia, UK, USA.

8 The Carbon Trust is an independent company funded by the UK government. Its role is to facilitate the UK's move to a low carbon economy by helping business and the public sector reduce carbon emissions now and capture the commercial opportunities of low carbon technologies.

CHAPTER SIX —Conclusions and recommendations

"In the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex. The potential for the disastrous rise of misplaced power exists and will persist"

President Dwight Eisenhower—17 January 1961

6.1 The main arguments

In his 1961 speech US President Eisenhower (a former General) pointed out the potential problems posed by an overly powerful 'military-industrial complex'. In the wake of the September 11th attacks, the declaration of the 'War on Terror' has led to wars in Afghanistan and Iraq and escalating military budgets especially in the USA, but also in the UK and elsewhere. It seems his concerns still have important resonances today.

In this Report, we have documented the extensive links between UK science, engineering and technology (SET) on the one hand, and the military sector, including government departments and multi-national corporations, on the other. Despite many difficulties in obtaining data, which is itself of concern, we have nevertheless documented how this military involvement pervades research, development, teaching and science communication, and extends across disciplines from engineering and the physical sciences, through the life sciences into the social sciences. The scale of the influence is demonstrated by the fact that nearly one third of public funding of R&D is spent by the Ministry of Defence (MoD), while 40 per cent of government scientists and technologists work for the MoD. Furthermore, representatives from military corporations dominate the official advisory panels on issues of military policy and of military SET. In addition, a swathe of new SET initiatives have been set up in the UK in recent years with the heavy involvement of the military: Defence Technology Centres; Towers of Excellence; Defence and Aerospace Research Partnerships; and University Technology Centres.

But is there any real problem with this level of military involvement in UK SET? Isn't it simply a reflection of resources directed in a way to enhance national security? Throughout this Report, but especially in Chapters two and four, we have discussed how the military sector has a narrow interpretation of security issues, and how this drives a largely weapons-based R&D agenda - critically dependent on the expertise of scientists and technologists - and a corresponding 'defence' posture. We have highlighted the associated problems such as the international arms trade and its current role in conflict. We have argued that a much broader mindset is necessary to tackle the issue of global security, involving much greater emphasis on understanding and addressing the roots of conflict. We contend that this would need greater efforts across areas such as disarmament, peacebuilding and reconciliation activities in war torn regions, measures to tackle social injustice and poverty, and environmental protection. As we outlined in Chapter five, efforts in such areas are generally very under-resourced, especially in terms of access to SET expertise.

Our research has also highlighted that the claimed civilian benefits from military SET are in general overstated. Attempts at technology transfer from military-supported R&D to civilian use have proven to be complex and expensive and have, to a large extent, been disappointing in view of the massive investments involved.

A further concern we have expressed is the impact of the military on openness in SET. Openness is a key aspect of science because of the role it plays in helping to ensure reliability in scientific work, and in allowing public and ethical concerns to be properly dealt with. We have highlighted how extensive military and corporate involvement compromises such openness - another reason for limiting this influence. This lack of openness has also restricted access to information required for the preparation of this Report.

6.2 What would be appropriate military involvement in SET?

We have argued that military involvement in SET is too great, so the key question becomes: what would be an appropriate level of military spending in science, engineering and technology compared with other funding objectives and streams? To answer this in depth would require an extensive analysis of a range of issues such as: global political needs and trends; a given country's particular circumstances; ethical arguments regarding the development and use of arms; and the level of national SET expertise in different disciplines. We do not have the space for such a detailed analysis, and indeed much of the relevant information is not easy to obtain, but there are a few important arguments, which we will briefly highlight.

Obviously, the first question to consider is: what are the main priorities to which SET should be applied? SET is a valuable and relatively scarce resource, so it is critical that it is used to best effect for society. As we discussed in Chapter five and reiterated above, there are a wide range of pressing issues, including poverty alleviation and climate change, for which more SET resources are urgently needed. We could also include needs such as improving the sustainability of agriculture or combating disease. Figure 3.1 (Chapter three) compared the UK's public funding of R&D by end-use, and highlighted how the military spend dwarfed that in several of these other areas. Given also the narrow approach of the military to security issues, there are certainly some grounds for a very significant reallocation of resources.

The second question relevant to this discussion is the military 'posture' adopted by a given country and how it affects the level and type of SET used by the military.

One example is the current posture of the United States which has stated that it seeks total, 'full spectrum' dominance of the military sphere at sea, on land, in the air and in space (see section 4.2). This type of posture depends on a high technology military capable of intervention ('force projection') at speed in virtually any part of the globe. This requires a complex command and control system with global coverage and a huge amount of military equipment, personnel and other resources. SET is a vital component of such a posture and is used to maintain a superiority in high technology weapons systems which in turn requires extremely high levels of spending on R&D (for example Missile Defense networks). This military posture is based on a very wide interpretation of the concept of 'self-defence' as enshrined in the UN Charter.[1]

A very different military posture is 'Non-Offensive Defence' (NOD, also known as 'Defensive Defence' - eg Schofield 2002). Under such a policy, a country's armed forces are capable of providing a 'credible defence' but are 'incapable of offence'. Hence military systems capable of being used to threaten other countries, like nuclear weapons and long-range aircraft/ missile systems/ warships, are decommissioned. Implementation of such a policy, its advocates claim, has major benefits in terms of international arms control and disarmament. The defence policies of countries such as New Zealand and Switzerland have many elements in common with the 'Non-Offensive Defence'. As a result these countries spend significantly less on their respective militaries (as a proportion of GDP - web.sipri.org), demonstrate much less military involvement with their SET, and do not support a large indigenous arms industry.

Another concept worth briefly examining is that of 'Humanitarian Intervention' (HI, eg Roth 2004). This concept, which had its roots in post-Cold War security discussions, involves the limited use of military force to prevent mass killing or genocide. This argument was used by the USA and UK as a partial justification for the removal of the Saddam Hussein regime, but advocates of this concept (which include the international organisation Human Rights Watch) roundly reject this argument (Roth 2004). They argue that a series of minimum criteria must be met to justify HI such as imminent threat of mass killing, approval of the UN Security Council, and exhaustion of alternative measures. Furthermore, such intervention should be a truly multilateral effort.

While there is a whole range of alternative arguments concerning the appropriate level for a nation's military forces, including the pacifist's total rejection of military force, we think the two concepts of NOD and HI are useful starting points for making some ethical judgements about the current UK military sector. Clearly, with the UK's deployment of nuclear weapons,[2] and a large number of long range aircraft, missiles and ships, the UK's military posture is well beyond that necessary for Non-Offensive Defence (see Schofield 2002 for a detailed analysis). And, as the above comments highlight, with its close links to US pre-emptive unilateralist military policy, the UK has moved far beyond the perspective of Humanitarian Intervention. The UK position as a major arms exporter, including to regimes with bad human rights records, further erodes efforts to occupy a moral high ground. There have been some positive initiatives, such as the Global Conflict Prevention Programme, and acknowledgement by some within the UK government of the need for a broader security agenda (eg Hain 2001). However, the strong emphasis on weapons-based approaches within UK security policy, compared with the more limited resources deployed to other areas as discussed earlier, leads us to conclude that much could be done to improve the balance of SET spending priorities.

To return to our main question about an appropriate level of military SET, based on the above discussion, we conclude that there is a strong ethical case for a significant redeployment of both finance and expertise away from the weapons-orientated agenda. With annual UK public spending on military R&D currently standing at £2.6 billion, dwarfing that in other pressing areas, we advocate that in the region of one-third to one-half is, in the near term, reallocated to pressing R&D on areas including, but not limited to, landmine detection and removal, conflict prevention, renewable energy, water and sanitation provision, climate science, sustainable agriculture, and forestry. Equally, it is justifiable to reallocate a very significant fraction of the Defence Procurement Agency's £6 billion budget for military equipment.

6.3 Responsibility and the individual scientist or engineer

Given the criticisms we have made above, where does that leave the individual scientist or engineer? Clearly many factors impact on an individual's decision to work on a given scientific or technological project, with or without military involvement, and grey areas abound. Obviously, based on our criticisms of the military sector throughout this Report, we make a general recommendation that scientists and engineers participate in and support, as far as they can, work which contributes to real human needs and more broadly defined means of obtaining security, rather than simply participating in narrowly focussed weapons-based R&D. What that means on an individual basis will, of course, vary. Some may simply decide to avoid direct involvement with weapons-based work. Others may refuse to work on any military projects until and unless the UK adopts a Non-Offensive Defence policy and/ or an embargo on exports to undemocratic regimes. Still others may choose to focus on areas with broad benefits to society such as energy efficiency or environmental protection. Another option is to choose to continue as an employee of the military but 'work from the inside' to encourage a more broadly-based security agenda within one's field.

There have been a great many publications about the moral and ethical responsibilities of scientists (for instance Evans and Packham 2003, Forge 1998, Nixdorff and Bender 2002, Rappert 2003, Scott 2003). We mentioned briefly in the first Chapter that whilst some maintain that science is neutral or value-free, in fact science is embedded within a societal structure; our actions as scientists or engineers always carry ethical and moral choices about both means and ends. The Manhattan Project, which gave the world the atomic bombs that destroyed Hiroshima and Nagasaki, caused many consciences to be searched among the participatory scientists. Many in SET have voiced troubled feelings over the ethical choices which their work presents, particularly about funding sources and the ends of such support (Spier 1995, Evans and Packham 2003). In a survey undertaken amongst engineers, 80 to 90 per cent thought that current engineering students were likely to encounter significant ethical issues in their future engineering practice (McGinn 2003).

Making ethics a core competency in SET would start to address many of the dilemmas described in this Report. The following activities have been identified as having the potential to help encourage responsible and ethical practice within science, engineering and technology (adapted from Bird 2003):

- Increase awareness and knowledge of professional standards across SET, to assist in the identification of a range of acceptable practices from the preferred to the prohibited;
- Increase awareness of the ethical dimensions (including funding sources) and especially the outcome of research within SET;
- Provide experience in making and defending decisions about ethical issues within one's profession and with the wider public;
- Develop strategies and identify resources for making those decisions.

Providing the beginnings of an 'ethical toolkit' is however only the start of a fully ethical science, responsive to the pressing needs of the world and its inhabitants. As we pointed out in Chapter four (in connection with nanotechnology) it is essential that society as a whole should be far more participatory in decision making, especially concerning emerging technologies or contentious science. The extent and direction of funding and support by vested interests in science, engineering and technology should be open to public scrutiny, with universities mandated to disclose in detail their sources of funding. The disproportionate voice of military and commercial interests in the universities and government will tend to act in the self-interest of such powerful groups (Hancock 2003). In addition this feature has helped produce a situation where there is under funding of R&D in non-military areas such as climate change mitigation, renewable energy and conflict prevention.

Engagement by those with training and expertise in science in the governance of a more open, ethical and accountable practice of SET could help drive a so-called 'peaceful economy' or, to put it another way, change the current culture which routinely associates a huge amount of SET with militarism.

Such an ethical science would also help to assuage the public's profound distrust and 'misunderstanding' of science (Nicholls 2002) and, we argue, would contribute positively to the development of a better, more peaceful and just civil society. Jon Beckwith in his book *Making genes, making waves: a social activist in science* (Beckwith 2002) outlines an example of how to deal with the many questions underpinning an ethical science. Beckwith's impulse was to follow a moral path within science and to suggest, for both science and the wider society, the premise that an enlightened science must not separate means from ends. Beckwith has emerged as an informed and respected voice in exposing the fallacies and abuses of behavioural genetics. Another high-profile example of a socially conscious scientist is nuclear physicist Joseph Rotblat who, since his resignation from the Manhattan Project, has worked tirelessly for ethical science and disarmament. In 1995, he received the Nobel Peace Prize jointly with the Pugwash movement (of which he was President) for his efforts. More such voices are urgently needed now to challenge the role and power of the military in the governance and direction of science, engineering and technology.

There are a growing number of organisations worldwide promoting ethically-based science, engineering and technology. Scientists for Global Responsibility is one such organisation. One of its key programmes, called 'Thinking about an ethical career in science and technology' (www.sgr.org.uk), provides information to scientists and engineers which is often not available from such conventional sources as undergraduate courses, careers offices or professional bodies and institutions.

6.4 Recommendations

Based on the extensive evidence that we have assembled in this Report, we make a series of recommendations which address the concerns we have identified. They are divided into three groups according to the audience to which they are addressed: the UK government; professional scientific and engineering institutions and publishers; and individual scientists and engineers.

Recommendations to the UK government

1. Divert a large fraction of current UK military R&D funds to addressing wider issues. To redress the disproportionate involvement of the military in publicly-funded SET, the government should begin a rapid and significant shift of funding from military R&D to civil R&D which contributes to peacebuilding, addressing environmental problems and alleviating poverty at a national and international level. A public review should be conducted to decide on exact levels and timescales but, as a first estimate, we recommend a shift in funds of the order of one-third to one-half of the current military R&D budget in the near term. Such a review should be part of a re-examination of current priorities in UK SET - with widespread public involvement - which was broadly lacking in the drawing up of the recent ten year science and innovation investment strategy.

2. Restrict military involvement with R&D of emerging technologies. Ministry of Defence funding for emerging technologies such as nanotechnology should be less than ten per cent of that from civil public funds. Military involvement should not restrict full public scrutiny of such areas. The UK government should call on the USA and others to follow suit.

3. Enact procedures to make Ministry of Defence funding of R&D far more transparent and open to public scrutiny. Organisations receiving MoD funding whether directly or indirectly (eg through the Defence Science and Technology Laboratory or QinetiQ) should be required to publicly acknowledge the source, its extent and purpose.

4. Devote more resources to implementing a far more inclusive concept of security. Such a broadened concept would place social justice, peace and environmental sustainability at the centre of considerations of security. Such an approach would lead to the Ministry of Defence relying to a much lesser extent on the development and implementation of military technology and the use of force, and a much greater support where SET and other activities can contribute to peacebuilding and non-violent conflict resolution.

5. Conduct a full and transparent review of the 1958 Agreement for Co-operation on the Uses of Atomic Energy for Mutual Defence Purposes (renewed in 2004) and all other military agreements between the USA and the UK. Such agreements are a powerful driver of new nuclear and other military technologies and have not received full Parliamentary scrutiny or public discussion.

6. Cease all scientific and technical work related to the design and development of new nuclear weapons. Call on the USA and other nuclear powers to do the same. As a signatory to the Nuclear Non-Proliferation Treaty, the UK has agreed to pursue global nuclear disarmament, yet it is making little effort to do so. The UK government should be leading international efforts to make rapid progress in this area.

Recommendations to professional bodies, scientific and engineering institutions and publishers

7. Require all academic papers and reports based on work funded by the military (whether government or corporate) to publicly acknowledge this funding and its scale.

8. Strengthen or initiate professional ethical codes to encompass the problems of professional involvement with the military and its current narrow interpretation of the concept of security.

9. Reduce or eliminate financial ties with the military at least until the adoption of the policies recommended above (1 to 6).

10. Lobby for the above changes in government policy.

Recommendations to individual scientists and engineers

11. Educate yourself about any military interests in your field of work and in your institution. Examine whether it is more likely to support security policies focused on the use of military force, or security policies based on, for example, the tackling of the root causes of conflict.

Either

12. Engage with military interests to try to encourage a shift in the way they use the work to a more holistic security perspective.

Or

13. Avoid working with the military altogether and choose a scientific/ engineering post which provides civil benefits to society, for example, by helping to address social and/ or environmental problems.

14. Support lobbying for the above changes in government policy.

15. Encourage discussion of these issues in your institution and within the appropriate committees or boards of your professional associations.

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NOTES

1. Indeed, the assertion that 'self defence' allows for the unilateral pre-emptive use of military force to bring about 'regime change' to deal with the perceived threat of a 'rogue state' - as in Iraq in 2003 - has been rejected or questioned by many, not least the UN Secretary General (BBC news online, 2004).

2. Hill et al (1995) has demonstrated that not only does the UK not gain significant influence from its possession of nuclear weapons, but also that relinquishing them would not negatively affect the UK's security.

ABBREVIATIONS & ACRONYMS

AeIGT Aerospace Innovation and Growth Team (Department of Trade and Industry)

ARP Applied Research Programme of the Research Building Block budget (Ministry of Defence)

AWE Atomic Weapons Establishment (Aldermaston, UK)

BWC Biological Weapons and Toxins Convention

CAAT Campaign Against Arms Trade (UK)

CND Campaign for Nuclear Disarmament (UK)

CRP Corporate Research Programme of the Research Building Block budget (Ministry of Defence)

CTBT Comprehensive Test Ban Treaty

DARPA Defense Advanced Research Projects Agency (USA)

DARPS Defence and Aerospace Research Partnerships (UK)

DDA Defence Diversification Agency (UK)

DERA Defence Evaluation Research Agency (UK)

DESO Defence Export Services Organisation (UK)

DIC Defence Industries Council (UK)

DIF Data and Information Fusion (a DTC see below)

DoD Department of Defense (USA)

DPA Defence Procurement Agency (UK)

DRA Defence Research Agency (UK)

DSAC Defence Scientific Advisory Council (UK)

DSTL Defence Science and Technology Laboratory (UK)

DTC Defence Technology Centre (UK)

DTI Department of Trade and Industry (UK)

DUTC Dual-Use Technology Centre (UK)

EPSRC Engineering and Physical Sciences Research Council (UK)

ESA European Space Agency

ESRC Economic and Social Research Council

EU European Union

GDP Gross Domestic Product

GDRE Government Defence Research Establishment

GHG Greenhouse gas

GPS Global Positioning System

IPCC Intergovernmental Panel on Climate Change

IPR Intellectual Property Rights

JGS Joint Grant Scheme (UK)

MD Missile Defense

MDC Missile Defence Centre (UK)

MIT Massachusetts Institute of Technology

MoD Ministry of Defence

MRC Medical Research Council (UK)

NAC National Advisory Committees (UK)

NADI Novartis Agricultural Discovery Institute (USA)

NASA National Aeronautics and Space Administration

NATO North Atlantic Treaty Organisation

NDASP National Defence Aerospace and Systems Panel of the Foresight programme (UK)

NDIC National Defence Industries Council (UK)

NPT Nuclear Non-proliferation Treaty

OECD Organisation for Economic Co-operation and Development

OST Office of Science and Technology (UK)

PPARC Particle Physics and Astronomy Research Council (UK)

RBB Research Building Block budget (Ministry of Defence)

R&D Research and Development

SBAC Society of British Aerospace Companies

SET Science, Engineering and Technology

TDP Technology Demonstrator Programme (UK)

TOE Tower of Excellence (UK)

UNDP United Nations Development Programme

UNEP United Nations Environment Programme

UTC University Technology Centre (funded by Rolls Royce)

WHO World Health Organisation

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