

ATOMS FOR PEACE?

THE ATOMIC WEAPONS
ESTABLISHMENT AND
UK UNIVERSITIES

A collaborative report from
NUCLEAR INFORMATION SERVICE
MEDACT

About the Author

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Contents

Executive summary	5
1. Introduction:AWE’s scientific role.....	8
2. Research approach.....	10
3.AWE and its influence on UK universities.....	11
3.1 Background:An introduction to AWE.....	11
3.2 AWE’s scientific research.....	13
3.3 AWE and UK universities.....	16
3.4 Case study:AWE’s work with Imperial College.....	25
3.5 AWE’s work with National Research Laboratories, Professional Institutes, and Industry Groups.....	27
3.6 Finance.....	28
3.7 AWE and the Research Councils.....	29
3.8 What does AWE get for its money?.....	32
3.9 Key issues arising from this section.....	34
4.AWE and the universities:Addressing dual use and ethical issues.....	35
4.1 Establishing an ethical reference point - our own ethical position.....	35
4.2 Research on controversial topics and dual use concerns.....	38
4.3 Contracts, research management, and ethics.....	41
4.4 Key issues arising from this section.....	44
5. Ethical guidelines and codes of conduct.....	45
5.1 The need for ethical guidelines and codes of conduct in scientific research.....	45
5.2 Use of ethical guidelines and codes.....	50
5.3 Dual use issues,AWE and UK universities.....	54
5.4 Practical issues in developing ethical guidelines or codes of conduct.....	55
6. Conclusions.....	60
7. Recommendations.....	62

Supporting Essay: University research in the modern world: The influences of commercialisation and the military

1. Scientific research in modern universities.....	63
2.The influence of business on science, engineering and technology and universities.....	65
3. University funding from the military sector.....	67
4.The consequences of university commercialisation.....	69

Text boxes

AWE William Penney Fellowships.....	23
Conference sponsorship.....	24
Co-operation between AWE and Imperial College.....	25
AWE and EPSRC Centres.....	30
The aims of AWE’s Technical Outreach programme.....	33
Key international agreements relating to weapons of mass destruction.....	36
The ethical framework at the University of Leeds.....	53
Model ethical guidelines covering research with dual use potential in nuclear weapons science.....	57

Glossary of abbreviations

AWE	Atomic Weapons Establishment
AWE ML	AWE Management Ltd
AWE plc	AWE plc (the company that operates the Atomic Weapons Establishment)
AWRE	Atomic Weapons Research Establishment
BNFL	British Nuclear Fuels Ltd
CASE	Collaborative Award in Science and Engineering
CIFS	Centre for Inertial Fusion Studies (Imperial College)
COMEST	Commission on the Ethics of Scientific Knowledge and Technology (UNESCO)
COPE	Committee on Publications Ethics
CTBT	Comprehensive Test-Ban Treaty
DERA	Defence Evaluation and Research Agency
DSTL	Defence Science and Technology Laboratory
DTC	Defence Technology Centre
EPSRC	Engineering and Physical Sciences Research Council
FOI	Freedom of Information
GEObs	Global Ethics Observatory (UNESCO)
GOCO	Government Owned Contractor Operated
IAEA	International Atomic Energy Agency
INES	International Network of Engineers and Scientists for Global Responsibility
INSEN	International Nuclear Security Education programme (IAEA)
IPR	Intellectual Property Right
ISP	Institute of Shock Physics (Imperial College)
JSP	Joint Services Publication
MoD	Ministry of Defence
NIF	National Ignition Facility
NNL	National Nuclear Laboratory
NPT	Non-Proliferation Treaty
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Development
RA	Research Assistant
ROF	Royal Ordnance Factory
SET	Science, Engineering, and Technology
STFC	Science and Technology Facilities Council
UKRIO	UK Research Integrity Office
UNESCO	United Nations Educational, Scientific, and Cultural Organisation
UTC	University Technology Centre (Rolls-Royce)
WMA	World Medical Association

Executive summary

This report examines the relationships the Atomic Weapons Establishment (AWE) has with the scientific, engineering, and technology community in British universities through its Technical Outreach programme of scientific research and collaboration. This is the first time to our knowledge that information on this topic has been collected and subjected to open scrutiny. The first part of the report documents AWE's involvement with universities and research institutes and the second part of the report explores the ethical issues associated with such collaboration and proposes a model ethical code of conduct intended to help in addressing such issues.

Nuclear Information Service and Medact undertook this study with input from Scientists for Global Responsibility between January 2012 and May 2013. Data was collected using requests for information under the Freedom of Information Act, a desk study of literature and information published on the internet, and interviews with key informants at universities and research institutes.

Our investigations indicated that university funding from the Ministry of Defence through AWE is widespread and its extent is not made openly available in the public domain. More than fifty UK universities receive funding from AWE. That is roughly half the number of all UK universities. Limited information is publicly available on research funded by AWE in UK universities, and the Ministry of Defence did not provide detail (for instance, about publications or departments undertaking research) in response to requests about the universities that obtain funding from AWE. Five universities have agreed 'Strategic Alliances' with AWE (Bristol, Cambridge, Cranfield, Heriot-Watt and Imperial College) and receive long-term funding for wider research programmes. These partnerships enable both parties to collaborate in areas of science and engineering, including the use of the other party's facilities and the development of staff.

AWE's Technical Outreach programme supports unclassified research in the physics, materials science, high performance computing, modelling, and manufacturing disciplines. AWE also commissions academic involvement in the areas of nuclear detection techniques and nuclear forensics. The study provides case studies of examples where AWE has provided significant funding to universities to create a concentration of expertise to address areas of interest to AWE.

AWE provides support to UK universities through a variety of routes – direct financial payments for research, financial support for academic posts and studentships, and support for conferences and training. Money from AWE is often supplemented by support from other partners with overlapping interests. As well as universities, AWE also has academic partnerships with other research laboratories and professional institutions and works jointly with the Engineering and Physical Sciences Research Council and the Science and Technology Facilities Council.

AWE's academic collaboration helps increase AWE's reputability, allows AWE to draw on expertise from universities to support its work, provides a pool of potential recruits for staff posts at AWE, and enables AWE to maintain a broader scientific and technological awareness. The published aims of AWE's Technical Outreach programme clearly show that academic collaboration is directly intended to allow AWE to maintain its position as the UK's centre of expertise for military nuclear science.

Many aspects of AWE's scientific research work are conducted in sensitive and controversial areas, raising complex ethical and legal issues. There are international norms against the use and possession

of weapons of mass destruction, recognised by a number of international legal treaties, including the nuclear Non-Proliferation Treaty and the Comprehensive Test-Ban Treaty, which require states holding nuclear weapons to take steps towards disarmament. It is important that relationships between AWE and universities recognise the aims of these treaties and, consequently, the ethical issues relating to work funded by AWE.

Applied research conducted at universities with support from AWE may well have dual use applications – the capability to be used for benign, peaceful purposes and / or military purposes contributing to the development of weapons of mass destruction. Valuable work conducted by universities on nuclear threat reduction and other areas of public benefit may be countered by research which may potentially undermine treaties aimed at controlling weapons of mass destruction.

Ethical guidelines or codes – which have increasingly become an important part of research and teaching activities in science, engineering, medicine and technology – are particularly important in guiding research in which security or military work is involved. The report presents a set of model guidelines which could be used to manage research work funded by AWE in UK universities and help in addressing the associated ethical issues.

Three general issues of potential concern are identified in relation to collaboration between AWE and universities:

- The need for increased transparency;
- The impact upon the research environment;
- A weak framework for considering ethical implications.

We recommend that AWE adopts a set of ethical guidelines (based on the model guidelines which we propose) to manage relationships under its Technical Outreach programme, and require universities and institutes with which it collaborates to adopt code of conducts similar to the model guidelines. Ethical committees in universities and AWE itself should be more pro-active in advising all who receive funds from AWE that they have personal responsibility for the research which they undertake and the outcomes of their investigations. AWE should publish an annual report detailing the programmes it has funded in universities, and an independent audit of the impact of AWE funding on research in universities should be periodically undertaken to assess the results, effectiveness, and value for money resulting from such funding.

“I believe that every citizen must be accountable for her or his deeds; this applies particularly to scientists” .

– Joseph Rotblat, Nuclear physicist and Nobel prize winner.¹

¹ In 'Social Responsibility of Scientists'. Editorial, Newsletter of the Marie Curie Fellowship Association, February 2000, Vol. 2 No. 1. Online at: http://www.mariecurie.org/newsletter/news2000/news_winter_2000.pdf (Accessed 13 May 2013).

I. Introduction: AWE's scientific role

Scientific research has always been at the very core of the essence and ethos of the Atomic Weapons Establishment (AWE). AWE's predecessor organisation, the Atomic Weapons Research Establishment (AWRE) opened in 1950 to bring together some of the nation's most talented scientists and engineers to work on Britain's atomic bomb programme. By the end of the 1950s AWRE scientists had developed Britain's first thermonuclear bomb, and for the remainder of the twentieth century the Establishment's main roles were to design, manufacture, and maintain the weapons in the UK's nuclear arsenal².

Ever since its inception, AWE's scientific role has developed in response to different political contexts. In 1987 AWRE merged with Royal Ordnance Factories involved in the UK nuclear weapons programme to become the Atomic Weapons Establishment (AWE), and not long afterwards the Establishment was contractorised, with management and operation of AWE sites being handed over to the private sector³. Over the next two decades both the management culture and scope of scientific work at the Establishment changed significantly. As a result of a halt in underground nuclear weapons testing, the Establishment moved towards a stockpile management approach based on scientific theory and modelling at the same time as a series of progressive reductions in the size of the UK's nuclear arsenal reduced the emphasis on design and manufacturing. Revelations about the sale of nuclear weapons secrets by Abdul Qadeer Khan and growing realisation of the risks posed by the proliferation of nuclear technology, together with fears that terrorists might gain the knowledge and ability necessary to launch a radiological or nuclear attack, have provided new responsibilities for AWE. AWE's work nowadays is increasingly focused on stockpile stewardship, disarmament verification, and nuclear threat reduction, with AWE scientists working in close collaboration with partners from universities and institutes outside the traditional boundaries of AWE's barbed wire fences. If in future the government decides to begin work to design and manufacture a new generation of nuclear weapon, the work undertaken by the Establishment's scientists can be expected to evolve further.

AWE's role as a laboratory undertaking research into the development of nuclear weapons raises a number of questions about the nature of its scientific work, including its compatibility with international treaties intended to limit the spread of nuclear weapons such as the Non-Proliferation Treaty (NPT) and the Comprehensive Test-Ban Treaty (CTBT); the value for money the public receive from spending at AWE; the context set by AWE's commercial character; and the nature of university involvement with the Establishment. Although the research work undertaken by AWE with universities is not security classified, much of it has 'dual use' dimensions – possessing the capacity for both military and peaceful purposes – making decisions on whether or how to proceed with such research complex. To date there has been little examination of the ways in which AWE interacts with the UK's university research community and the significant practical and ethical questions that such interactions create. Nuclear Information Service and Medact feel that it is important to map out the relationships between AWE and the UK's universities and suggest ways in which these relationships should be organised to increase openness and transparency.

This report addresses questions relating to AWE's involvement in UK universities, and considers how AWE and universities might ensure that research partnerships are based on sound ethical principles

² 'What We Do'. Atomic Weapons Establishment website. http://www.awe.co.uk/aboutus/what_we_do_27815.html (Accessed 13 May 2013).

³ AWE is used throughout this report to refer to the Establishment itself, comprising facilities at Aldermaston (the main site), Burghfield, and Blacknest. AWE plc is used to identify the private company which, since 2000, has managed the Establishment and its facilities.

and best practice, supporting the spirit of international treaties controlling the development of weapons of mass destruction and allowing AWE to use the world-class scientific resources and talent that it undoubtedly has at its disposal to advance the role of the UK as a “disarmament laboratory” – as envisaged by the former Foreign Secretary Margaret Beckett in 2007⁴.

The objectives of this report are to:

- Examine and document the involvement of AWE with the scientific, engineering, and technology community in UK universities.
- Investigate the potential impact this interaction has on AWE’s partner universities, especially on their openness and independence in light of the increasingly commercialised nature of the UK’s universities.
- Raise questions about the openness and accountability of research undertaken and funded by AWE and suggest how this might be improved.
- Assemble a set of practical ethical guidelines capable of helping to safeguard professional standards in university research which is funded by or involves collaboration with AWE. Such guidelines should help build a more critical and accountable environment to ensure that research undertaken jointly by AWE and universities is in the overarching public interest.

⁴ ‘Keynote Address: A World Free of Nuclear Weapons?’ Margaret Beckett. Carnegie Endowment for International Peace. 25 June 2007. <http://carnegieendowment.org/2007/06/25/keynote-address-world-free-of-nuclear-weapons/kc0> (Accessed 13 May 2013).

2. Research approach

The research for this study was conducted between January 2012 and May 2013 by Nuclear Information Service and Medact, with input from Scientists for Global Responsibility. Research work was conducted and the report was authored by Dr Chris Langley on behalf of Nuclear Information Service and Medact.

Data was collected for this study using the following means:

- Requests for information under the Freedom of Information Act were made to the Ministry of Defence and AWE⁵ and five universities which are engaged in Strategic Alliances with AWE (Bristol, Cambridge, Cranfield, Heriot-Watt and Imperial College).
- A desk study of literature and information published on the internet was undertaken.
- A series of individual interviews was undertaken with key informants at universities and research institutes, including academics with a special interest and expertise in ethical aspects of scientific research. We also spoke to those who were supported by funds from AWE. Interviews were conducted in a personal capacity and with a guarantee that the identity of the interviewee would not be disclosed. Informants were selected on the basis of a literature search for those active in the area, the knowledge of project board members, and suggestions from other informants.
- The ethical guidelines which are presented later in the report were drawn up in consultation with a number of academics in the field, selected on the basis of literature searches, the author's knowledge from previous work on ethical aspects of research, and suggestions from project board members. The guidelines also drew on recent literature from the field of science ethics.

Limitations of the study:

- Information provided by universities and the Ministry of Defence in response to our requests was sometimes patchy and lacking in detail.
- Time and budget constraints and, in some cases, reluctance to participate in the study limited the number of informants that were interviewed during the research.
- Names of individual researchers were not provided by some of AWE's Strategic Alliance universities when responding to our requests, so we were unable to identify trends in publishing patterns for departments undertaking work funded by AWE.

⁵ Although AWE plc, as a private company, is not currently bound by the terms of the Freedom of Information Act 2000, the company will forward requests for information to the Ministry of Defence for response.

3. AWE and its influence on UK universities

3.1 Background: An introduction to AWE

The Atomic Weapons Research Establishment (AWRE) was set up on 1 April 1950 by the UK government's Ministry of Supply at the former RAF Aldermaston airfield with the task of designing and developing an atomic weapon for the UK. From the outset the Establishment set out to draw together the cream of the UK's physicists and nuclear scientists, as required by the cutting-edge nature of the work. AWRE's first Director was William Penney, who had previously worked on the Manhattan Project – the US-led project to develop the atomic bomb during World War II – and other British scientists involved in the Manhattan Project also contributed their expertise⁶.

After a programme of atmospheric tests in the 1950s, when AWRE built and tested first fission (atomic) and then fission-fusion (thermonuclear or 'hydrogen') weapons, Harold Wilson's Labour government decided in 1965 that the UK would no longer undertake nuclear warhead design and would cease testing weapons. A hiatus in weapon testing followed, and the UK conducted no nuclear tests from 1965 through to 1974. Although the UK's nuclear weapons programme was less active and some civilian work was undertaken at AWRE over this period, AWRE scientists were also working in secret on the controversial Chevaline warhead programme⁷.

In 1987 AWRE was combined with the Royal Ordnance Factory (ROF) Burghfield and ROF Cardiff (now closed), both also involved in the manufacturing of nuclear weapons, to form the Atomic Weapons Establishment (AWE), bringing the key sites involved in the production of the UK's nuclear weapons together into the same management structure to commence production of a new 'Trident' nuclear warhead. Towards the end of the 1980s pressure for privatisation of government-owned facilities, together with a series of high-profile safety failures at AWE and major delays in the construction of new facilities for the production of Trident warheads, led to a decision to appoint private contractors to run AWE under a Government Owned Contractor Operated (GOCO) arrangement – a model used by some of the US nuclear weapons laboratories. In 1993 the management of AWE became the responsibility of the Hunting-BRAE consortium, comprising Hunting Engineering Ltd, Brown and Root Ltd and the AEA Technology Ltd⁸. From 2000 the contract has been held by AWE Management Ltd (AWE ML), which, through its subsidiary company AWE plc, has a contract to manage and operate the Atomic Weapons Establishment until 2025.

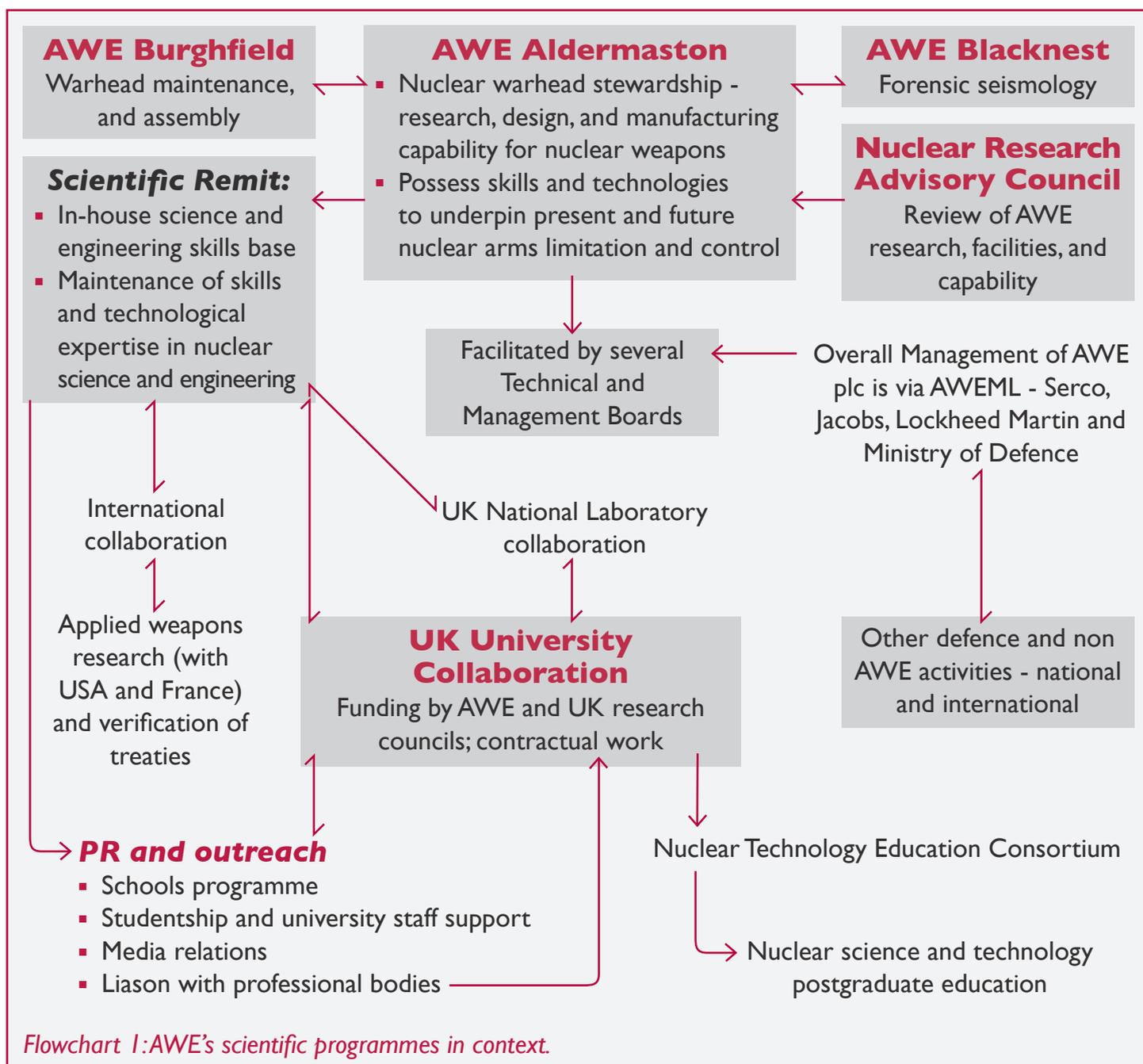
The AWE ML consortium comprises three commercial partners (Serco, Lockheed Martin UK and Jacobs Engineering⁹) together with the Ministry of Defence, which holds a special share as a contingency against unforeseen circumstances (see Flowchart 1).

⁶ 'Our History'. Atomic Weapons Establishment website. http://www.awe.co.uk/aboutus/our_history_f77a4.html (Accessed 13 May 2013).

⁷ Tom Milne and Henrietta Wilson: 'Verifying nuclear disarmament: A role for AWE Aldermaston'. British Pugwash Group, 1999.

⁸ 'Atomic Weapons Establishment'. Wikipedia. http://en.wikipedia.org/wiki/Atomic_Weapons_Establishment (Accessed 13 May 2013).

⁹ Serco is a global company undertaking a wide array of activities, including, in the UK, management of military installations especially for the Royal Air Force, transport, detention centres and the tagging of convicted offenders, and immigration control. Lockheed Martin, the world's largest military corporation, has its headquarters in the USA. It has a huge portfolio of military and aviation interests and since 1993 has been involved in the management of the Sandia National Laboratories US nuclear weapons laboratory. Lockheed Martin manufactures and provides technical support for the Trident II D-5 missile. Jacobs Engineering is also based in the USA and provides advanced technology in aerospace, construction, mining, biotechnology and other technology markets. Jacobs took over a share of AWE Management Ltd previously held by British Nuclear Fuels Ltd (BNFL) in December 2008.



A further piece in the mosaic of government and former government laboratories which undertake research and development of specific interest to the military sector should be briefly mentioned here. Around thirty government laboratories and similar establishments, such as those at Porton Down (the UK's chemical and biological weapons research centre), and at Malvern (radar and signals research establishment) were merged in 1995 to form the Defence Evaluation Research Agency (DERA) – the largest such government defence research establishment of its kind in Europe¹⁰. DERA was part of the Ministry of Defence until 2001 when it was split into the Defence Science and Technology Laboratory¹¹ (DSTL) and Qinetiq, a private company. We will meet these entities again later in the report when we examine the involvement of universities in military research.

¹⁰ Defence Evaluation and Research Agency. Wikipedia. http://en.wikipedia.org/wiki/Defence_Evaluation_and_Research_Agency (Accessed 13 May 2013).

¹¹ For an overview of how this tranche of government research establishments was privatised, see M Sharp, 'Cavalier: How Britain discarded many of its strongest institutions – and why it needs to rebuild'. Research Fortnight, 9 March 2005.

3.2 AWE's scientific research

Peter Luff, former Minister for Defence Equipment, Support, and Technology has described AWE as 'a centre of scientific and technological excellence, with some of the most advanced research, design and production facilities in the world...a key capability, which is essential for our national security'¹². AWE requires highly sophisticated scientific and technological capabilities to design and produce nuclear warheads. As well as manufacturing and maintaining warheads, AWE is also responsible for guaranteeing their reliability (ensuring that they explode with the full destructive power they are designed to release) and their safety (ensuring that they will not explode unless signalled to do so). AWE's current work involves maintaining the UK's arsenal of Trident nuclear warheads, upgrading existing warheads with a new arming, fusing, and firing system and other modifications designed to improve their destructive capability¹³, and undertaking early stages of optioneering and design work for a successor warhead to replace the current Trident warhead, should the government decide to give the go-ahead for production of a new warhead¹⁴.

The UK Trident warhead – believed to be based closely on the design of the USA's W-76 warhead – was designed and built using information derived from underground nuclear testing in the 1970s. However, in 1992 President George H.W. Bush announced a moratorium on nuclear testing at the Nevada Test Site, where UK weapons tests had taken place, and in 1998 the UK ratified the Comprehensive Test-Ban Treaty, giving a commitment not to undertake any further nuclear weapon tests. AWE's current nuclear weapons programme therefore relies on a much more theoretical approach centred on using high performance computers to model the behaviour of warhead materials and components at extreme temperatures and pressures. Scientific disciplines which are central to AWE's work are plasma physics, design physics, supercomputing, hydrodynamics, materials science, and systems engineering¹⁵. Knowledge and expertise in these areas are maintained through close co-operation and peer review arrangements with US nuclear weapons laboratories – principally Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories – under the auspices of the 1958 US-UK Mutual Defence Agreement¹⁶. In addition to co-operation with American nuclear weapons laboratories on warhead science, in future years co-operation between AWE and French nuclear scientists is expected to take place through the 'Project Teutates' hydrodynamics research programme¹⁷. A variety of technical and management boards oversee the portfolio of science-based activities undertaken at the Establishment, with input from the Ministry of Defence. AWE's Science and Technology Advisory Committee plays an important role in setting priorities for research co-operation and determining which fields of research are suitable for external collaboration.

¹² 'MOD announces investment in nuclear facilities'. Ministry of Defence press announcement. 15 May 2012. <https://www.gov.uk/government/news/mod-announces-investment-in-nuclear-facilities> (Accessed 13 May 2013).

¹³ 'Trident upgrade underway, MoD admits'. Richard Norton-Taylor, Guardian, 14 March 2007. <http://www.guardian.co.uk/politics/2007/mar/14/greenpolitics.military> (Accessed 13 May 2013).

¹⁴ 'Nuclear weapons'. Written Parliamentary Answer by Nick Harvey MP. Official Report (Hansard), 13 July 2012, c412W. <http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm120713/text/120713w0001.htm> (Accessed 13 May 2013).

¹⁵ 'Science, Engineering, and Technology'. Atomic Weapons Establishment website. http://www.awe.co.uk/set/science_engineering_technology_3f641.html (Accessed 13 May 2013).

¹⁶ For a full account of the scope of the US – UK Mutual Defence Agreement see 'U.S. – UK Nuclear Co-operation After Fifty Years' Edited by Jenifer Mackby and Paul Cornish. 2008, Center for Strategic and International Studies, Washington D.C.

¹⁷ For further information please see 'Anglo-French nuclear co-operation and the 'Teutates' programme'. Nuclear Information Service, November 2010. <http://nuclearinfo.org/article/government-awe-aldermaston-development/anglo-french-nuclear-co-operation-agreement-new> (Accessed 13 May 2013).

To equip AWE for delivering a stockpile management programme for the UK's nuclear arsenal the government announced in 2005 a major programme of investment aimed at sustaining key skills and facilities at AWE, including a substantial infrastructure construction programme¹⁸. Spending annually at AWE is currently around £1 billion per year, of which around half is committed to capital expenditure, and is expected to remain at this level for the rest of this decade.

The AWE capital programme includes the following research facilities:

- Orion, a new powerful laser facility which can be used to heat and compress materials to millions of degrees Celsius in nanoseconds. Experimental conditions created in Orion will complement those available in the National Ignition Facility (NIF) laser at the Lawrence Livermore National Laboratory in California. The NIF runs collaborative programmes with the international academic community¹⁹.
- A Technology Development Centre for developing instrumentation for monitoring hydrodynamics tests, during which warhead materials and components are exposed to intense pressures. AWE currently has its own hydrodynamics research capability and from 2015 will also have access to the joint French – UK 'EPURE' hydrodynamics test facility which is being constructed in France as part of Project Teutates.
- New laboratories to investigate materials used within nuclear warheads²⁰.
- Provision of enhanced supercomputing capacity to build models of warhead performance using experimental data²¹.

In a few cases, these new facilities will allow collaboration between AWE and academic researchers. For example, at the time of writing around 15% of the operating time of the Orion laser facility is planned to be available to UK university researchers for high energy density collaborative investigations in areas of interest to AWE²². The nature of academic co-operation with AWE raises questions about dual use applications which are discussed later in this report: the research technology and findings from experiments could conceivably have both civilian and military uses.

In addition to its work on nuclear warhead development, AWE also plays a leading role in providing a National Nuclear Security capability for the UK government. This programme covers a range of areas aimed at controlling and preventing the spread of nuclear weapons, including nuclear intelligence and counter-terrorism, arms control verification, nuclear forensics and forensic seismology, and the ability

¹⁸ 'Atomic Weapons Establishment'. Written Parliamentary Statement by the Secretary of State for Defence (John Reid), 19 July 2005. Official Report (Hansard), 19 July 2005: c59VWS
http://www.publications.parliament.uk/pa/cm200506/cmhansrd/vo050719/wmstext/50719m03.htm#50719m03.html_sbhd0 (Accessed 13 May 2013).

¹⁹ G Brumfiel, 'Welcome to the Atomic Weapons Establishment'. Nature Vol 464, pp 156-157, 2010 <http://www.nature.com/news/2010/100310/full/464156a.html> (Accessed 13 May 2013).

²⁰ 'AWE'. Written Parliamentary Answer by Peter Luff MP. Official Report (Hansard), 22 November 2011, c271W.
<http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm111122/text/111122w0002.htm#111122114002932> (Accessed 13 May 2013).

²¹ 'AWE'. Written Parliamentary Answer by Peter Luff MP. Official Report (Hansard), 22 November 2011, c271W.
<http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm111122/text/111122w0002.htm#111122114002932> (Accessed 13 May 2013).

²² 'Academic Access'. Atomic Weapons Establishment website. http://www.awe.co.uk/set/Academic_Access.html (Accessed 13 May 2013).

to provide an emergency response to a nuclear incident²³. The programme relies on support from a number of universities and research institutes to supplement AWE's own expertise.

AWE's Threat Reduction Division plays a vital international role in supporting arms control measures and disarmament verification and providing nuclear intelligence²⁴. Much of this work takes place at AWE's Blacknest site²⁵, where research is conducted into techniques for distinguishing the seismic signals generated by underground nuclear explosions.

AWE Blacknest is recognised by many in the scientific community as a leading international research centre in forensic seismology and regularly collaborates with leading university seismologists to address questions of interest to various clients and in issues of public good. Blacknest plays an important role in the international network of monitoring stations which has been set up to monitor compliance with the Comprehensive Test-Ban Treaty²⁶. The Royal Society has commented that AWE's National Nuclear Security Division should be developed on the Blacknest model "so that the wider scientific community, including international partners, can engage effectively with this expertise in a non-classified environment"²⁷. There is thus considerable expertise residing within AWE which represents an important pool of research competence and experience beyond the narrow role of developing nuclear weapons.

In summary, the remit of the in-house engineers and scientists at the Atomic Weapons Establishment is fundamentally to:

- Ensure the safety and reliability of the UK's nuclear weapons, and to develop a new generation of weapons if asked to do so by government.
- Undertake various aspects of arms control and disarmament verification work and co-ordinate a national nuclear forensic science capability.
- Actively participate in a variety of research programmes with US nuclear weapons laboratories, with the aim of maintaining the close relationship on nuclear weapons research which exists between the USA and the UK.

Much of this work has a high security classification, in some cases further compounded by the need to respect confidential information arising from collaboration with US and French laboratories. Nevertheless, universities and other academic institutions are often involved in unclassified research programmes, and the role that they play in assisting AWE to achieve its scientific mission is examined in the next section of the report.

²³ 'Building Capability for the Future'. AWE Annual Review 2012, p47. <http://www.awe.co.uk/Contents/Publication/AWEAnnualReport2012.pdf> (Accessed 13 May 2013).

²⁴ Tom Milne and Henrietta Wilson: 'Verifying nuclear disarmament: A role for AWE Aldermaston'. British Pugwash Group, 1999.

²⁵ AWE Blacknest website. <http://www.blacknest.gov.uk/> (Accessed 13 May 2013).

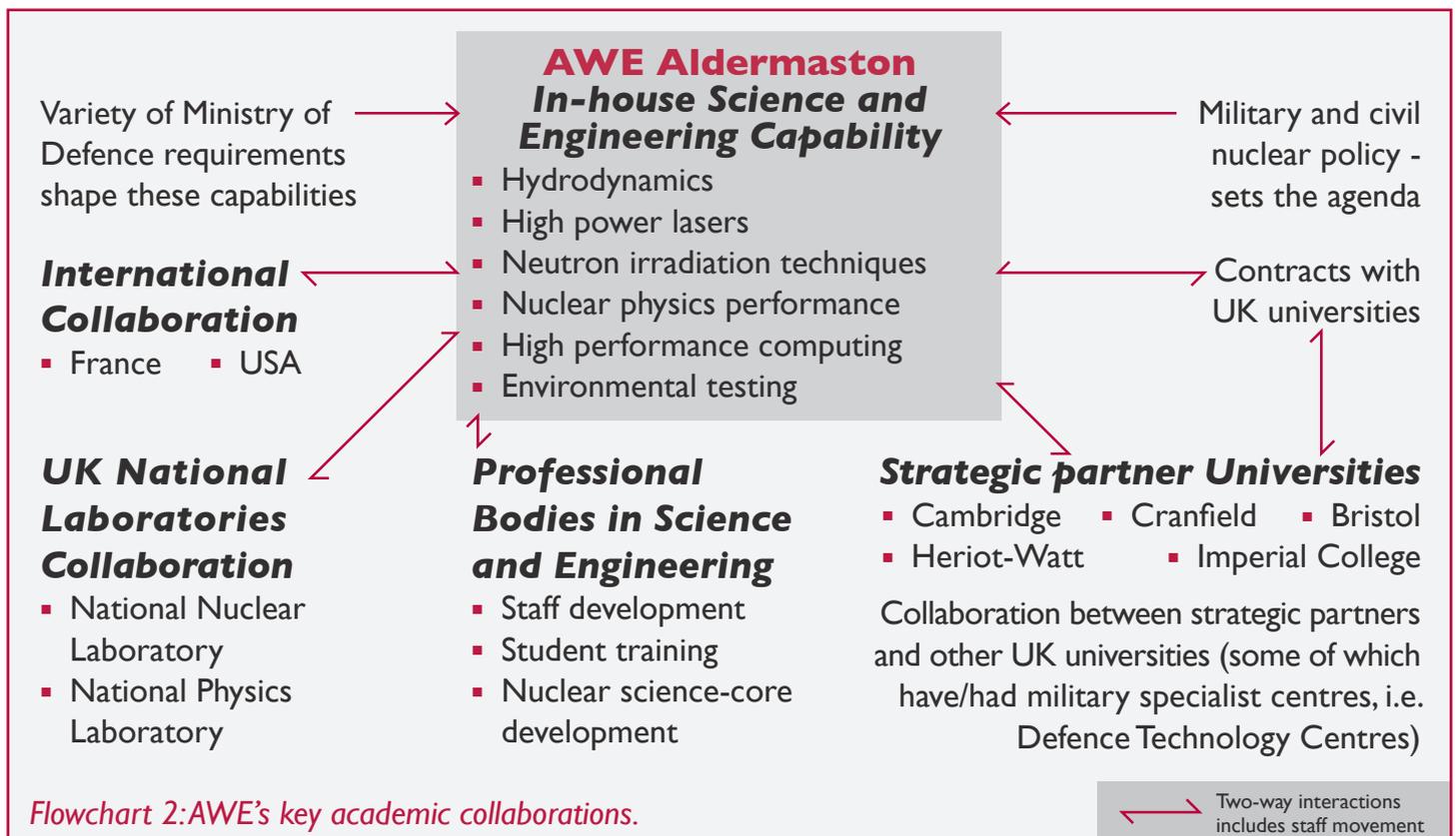
²⁶ 'Verification Regime'. Preparatory Commission for the Comprehensive Test Ban Treaty Organisation website. <http://www.ctbto.org/verification-regime/> (Accessed 13 May 2013).

²⁷ See Recommendation 5 in the Royal Society report 'Fuel cycle stewardship in a nuclear renaissance'. Royal Society, October 2011 Available at: <http://royalsociety.org/policy/projects/nuclear-non-proliferation/report/> (Accessed 13 May 2013)

3.3 AWE and UK universities

As well as retaining its own formidable in-house expertise in science, engineering, and technology, AWE also fosters strong links with academia and the broader scientific community through its Technical Outreach programme, which acts as an umbrella for its external research collaborations. AWE's Technical Outreach Programme is at the core of the Establishment's relationship with the UK's science, engineering and technology institutions, aiming to "build and share knowledge for mutual benefit"²⁸ by encouraging co-operation between AWE and universities, professional bodies, and government agencies. Such co-operation ranges from short-term individual research contracts to long term strategic alliances, and as well as funding for research work the programme covers support for academic posts, studentships and courses, and conferences and consultancy work.

In September 2012 the Ministry of Defence revealed the extent of AWE's collaboration with UK universities. In a written Parliamentary answer Gerald Howarth, former Parliamentary Under-Secretary of State at the Ministry of Defence, named 25 UK universities which received funding from AWE²⁹, although our investigations indicate that over 50 universities have received money from AWE since 2010. Research in universities is often undertaken through small, relatively short-term contracts with AWE, which are awarded on the basis of open competition, although there are also other deeper collaborative arrangements which are discussed below. A full list of universities which receive research funding from AWE is shown in Table 1³⁰, and details of AWE's key academic collaborations are summarised in Flowchart 2.



²⁸ 'Corporate Technical Outreach'. AWE plc website. http://www.awe.co.uk/set/corporate_technical_outreach.html (Accessed 15 May 2013).

²⁹ 'AWE: Research'. Parliamentary Written Answer from Peter Luff MP (substantive response from Gerald Howarth MP). Official Report (Hansard), 3 September 2012, c44W. <http://www.theyworkforyou.com/wrans/?id=2012-09-03d.113137.h&s> (Accessed 15 May 2013).

³⁰ Data provided 7 August 2012 from the Ministry of Defence as part of its response to a Freedom of Information Act request.

University	Calendar Year 2010	Calendar Year 2011	To the end of June 2012	Grand Total
Aston University			1,670.00	1,670.00
Birmingham City University (UCE)	53,495.00	35,040.00	5,140.00	93,675.00
Brunel University	12,134.00	2,240.00		14,374.00
Cardiff University	(21,000.00)	19,422.50	(12,300.00)	(13,877.50)
Coventry University	1,332.80	2,265.00	2,300.40	5,898.20
Cranfield University	1,289,567.17	1,482,707.94	565,390.27	3,337,665.38
Cranfield University (Bedford)	136,900.00	120,617.90	10,000.00	267,517.90
De Montfort University	2,470.00	1,588.00		4,058.00
Durham University	10,000.00		(7,300.00)	2,700.00
Heriot-Watt University	324,335.67	227,787.56	155,737.00	707,860.23
IC Consultants Ltd	56,540.00	22,837.84	3,750.00	83,127.84
Imperial College	2,965,888.38	3,061,680.40	1,710,566.35	7,738,135.13
Keele University	23,319.00	39,254.50	29,662.50	92,236.00
Kings College London	7,140.00	1,955.00	1,875.00	10,970.00
London Metropolitan University	800.00	2,540.00		3,340.00
Loughborough University	15,750.00	76,379.50	57,171.50	149,301.00
Loughborough University Enterprises Limited	3,712.86			3,712.86
Queen Mary's College		1,000.00		1,000.00
Queens University Belfast	171,708.60	5,000.00		176,708.60
South Bank University	4,095.00	8,138.00	(1,800.00)	10,433.00
Southampton Solent University	17,255.00	25,862.60	209.49	43,327.09
Thames Valley University (TVU)	910.00	(1,040.00)	(300.00)	(430.00)
The Open University	1,502.00	9,261.00	13,175.00	23,938.00
University College London	45,118.68	54,264.32	30,424.25	129,807.25
University Court of the University Of St Andrews	154,250.54	193,354.50	151,118.25	498,723.29
University of Bath	45,812.63	91,805.18	61,393.83	199,011.64
University of Birmingham	139,941.00	38,454.46	23,712.00	202,107.46
University of Brighton	1,913.00	3,033.00		4,946.00
University of Bristol	439,277.25	536,462.19	334,104.19	1,309,843.63
University of Cambridge	755,026.95	753,821.13	455,902.65	1,964,750.73
University of Edinburgh	74,183.32	150,368.92	129,367.33	353,919.57
University of Greenwich	1,346.90	934.38		2,281.28
University of Huddersfield Enterprises Ltd	2,764.00			2,764.00
University of Lancaster	4,995.00	4,995.00		9,990.00
University of Leeds	10,195.00	12,000.00	1,380.03	23,575.03
University of Leicester	161,326.00	69,972.00	37,827.79	269,125.79
University of Liverpool	236,346.00	36,293.00	69,992.00	342,631.00
University of Manchester	211,861.13	472,702.53	57,016.67	741,580.33
University of Newcastle		1,923.02	500.00	2,423.02
University of Nottingham	5,590.51	9,739.06		15,329.57
University of Oxford	230,234.20	248,437.10	53,619.83	532,291.13
University of Portsmouth Higher Education Corp.	10,556.00	13,955.25	5,208.50	29,719.75
University of Portsmouth Training Limited	3,960.00	1,230.00		5,190.00
University of Reading	54,586.00	10,626.40	6,477.60	71,690.00
University of Salford	42,245.65	33,796.52	16,898.26	92,940.43
University of Sheffield	23,600.00	6,200.00	(1,600.00)	28,200.00
University of Southampton	266,475.65	319,091.30	313,704.90	899,271.85
University of Strathclyde	189,950.48	69,570.00	25,297.87	284,818.35
University of Surrey	156,994.44	87,015.95	73,724.66	317,735.05
University of the West of England	(938.00)	(932.00)	1,874.00	4.00
University of Wales Swansea	7,900.00	800.00		8,700.00
University of Warwick	188,194.00	159,664.76	163,264.23	511,122.99
University of York		20,000.00	34,558.99	54,558.99
Westminster University	2,050.00	(375.00)		1,675.00

Table 1: UK Universities receiving funds from AWE for research.

Universities receiving funds from AWE, including the five Strategic Alliance universities and others for 2010-12. The spend at any such university is the sum of all individual contracts with that university. Data for this table was compiled from responses to a number of Freedom of Information Act requests to the Ministry of Defence.

Footnote to Table 1: Values in brackets are credits from the University. Information on departments or individual research teams within universities which received funds from AWE was not provided by the Ministry of Defence.

Several features of this data are worthy of note:

- This is the first time to our knowledge that this information has been collected and subjected to open scrutiny.
- Five universities with academic track records in disciplines of interest to AWE have agreed 'Strategic Alliances' with AWE (Bristol, Cambridge, Cranfield, Heriot-Watt and Imperial College) and receive long-term funding for wider research programmes. According to AWE's Technical Outreach senior manager, "the partnerships offer enhanced collaborations, secure financial leverage, and maximise contact with high calibre scientists and engineers. A Strategic Alliance with AWE enables both parties to collaborate – to their mutual benefit – in areas of science and engineering, including the use of the other party's facilities and the development of staff."³¹
- These five universities received significantly larger sums from AWE than others shown in Table 1. All five have been involved in a number of other military-university consortia since the early 2000s³². More information about the nature of these Strategic Alliance partnerships is given in Table 2.
- Individual sums paid to universities are variable and are concentrated in the five Strategic Alliance institutions, where funds are used for research, support of student training (including post-graduate studies) and staff support. These five institutions also sub-contract work to other universities using funds from AWE.
- Russell Group³³ universities and former polytechnics have all attracted funding from AWE.
- The funding that the five Strategic Alliance partners receive from AWE varies quite noticeably over the period 2008-2012. For example, the University of Cambridge received £450,278 in 2007-8 and £1.50 million in 2010-11. This may be a simple variation or may indicate changes in contractual arrangements between funder and university.
- Some of the research areas supported by AWE in universities also receive funding from other military sector sources such as DSTL, military companies and QinetiQ. In some cases detail is to be found on the staff research portfolios where these are published on the university website – as it is at, for example, Heriot-Watt³⁴ and Southampton³⁵.

³¹ Gary Burnell, AWE Technical Outreach senior manager, quoted in 'AWE's Outreach, Major Events, and Collaborative Activities'. Discovery, Atomic Weapons Establishment. Issue 18, March 2009.

³² C Langley: 'Soldiers in the laboratory: military involvement in science and technology – and some alternatives'. Folkestone, UK: Scientists for Global Responsibility, 2005 http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013) and M Beale, T Street and J Wittams, 'Study war no more' London, Campaign Against Arms Trade 2007. <http://www.studywarnomore.org.uk/documents/studywarnomore.pdf> (Accessed 13 May 2013).

³³ The Russell Group is a company limited by guarantee which represents 24 leading UK universities. <http://www.russellgroup.ac.uk/home/> (Accessed 13 May 2013).

³⁴ See search results from Heriot-Watt University website at: <http://www.hw.ac.uk/searchresults.htm?cx=016851904239341272249%3Ahgux3wwx244&cof=FORID%3A11&ie=UTF-8&q=AWE&sa.x=23&sa.y=27#gsc.tab=0&gsc.q=AWE&gsc.page=1> (Accessed 13 May 2013).

³⁵ See search results from Southampton University website at: <http://www.ecs.soton.ac.uk/people/search?role=acstaff&group=&nameq=&picsize=&submitted=1&Submit=%C2%A0go%C2%A0> (Accessed 13 May 2013).

- Many of the universities in Table I – such as the University of Southampton, Cranfield University and Imperial College³⁶ – have received funding from the Ministry of Defence and other military sector funders as well as from AWE, but many are new to such sources of funding, for instance Queens University Belfast and the Universities of Huddersfield and Portsmouth.

³⁶ Details of the military-university consortia and similar military funded programmes in UK universities can be found in the references in: C Langley, 'Soldiers in the laboratory: military involvement in science and technology – and some alternatives'. Folkestone, UK: Scientists for Global Responsibility, 2005 http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf (Accessed 13 May 2013).
C Langley, S Parkinson and P Webber, 'More soldiers in the laboratory: the militarisation of science and technology – an update'. Folkestone, UK: Scientists for Global Responsibility, 2007 http://www.sgr.org.uk/ArmsControl/More_Soldiers_in_Lab_Report.pdf (Accessed 13 May 2013).

University	Funds (£) Received From AWE	Areas Of Research Collaboration*	Consultancy	Studentships	Contracts	Courses	Publications	Conferences Supported	Staff Support
Bristol	For 2011-2012 £1.238m	High performance computing. Materials science.	x	√	?	x	√	√	?
Cambridge	For 2011-2012 £231,165 ≈	Design physics. Plasma physics. Hydrodynamics.	?	√	?	x	√	x	√
Cranfield	For 2008-2012 £4.85m	Design physics. Hydrodynamics. Systems engineering. Materials science. Manufacturing.	√	x	√	√	√	√	x
Heriot-Watt	For 2008-2012 £1.27m	Hydrodynamics. Engineering. Manufacturing.	?	√	x	x	√	x	√
Imperial College	For 2010-2012 £2.08m	Plasma physics. Hydrodynamics.	√	√	√	√	√	√	√

Table 2: UK universities with Strategic Alliances with AWE and the areas under which AWE funding was awarded for the periods indicated. Data compiled from responses to Freedom of Information Act requests to the universities made in March 2012.

* As listed in 'AWE Annual Review 2012: Building capability for the future' (page 33).

≈ The figure provided represents the amounts drawn from the funding awarded by AWE for 2011-12 as at March 2012, and not the size of the award itself, which may be larger at the end of 2012.

? Information not supplied.

x Indicates that this area was not supported by AWE funds in the period described.

Note that there are differences in the sums which are recorded as being received by the five Strategic Partner universities between Table 1 and Table 2. This may result from differences in how funding is recorded by universities and by AWE. We also found that there is a degree of sub-contracting undertaken by universities.

Footnotes to Table 2: Figures are rounded down. The periods quoted are those that were supplied by the institution. Although all five universities approached were asked to supply data for 2008-2012 three universities were unable, within the constraints of the cost limits for Freedom of Information requests, to supply data for this period.

Disciplines that AWE has funded at Strategic Alliance universities over the past two years include³⁷:

- Physics, which includes numerical modelling, uncertainty analysis, computational fluid dynamics, shock physics, plasma physics and solid mechanics.
- Materials science, ranging from chemical synthesis of polymers and adhesives through to properties of energetics (explosives), metallurgy, computational chemistry and nuclear materials.
- High performance computing focusing on the development of computer algorithms and future energy efficient computing platforms.
- Engineering and manufacturing, which includes developing sensor technologies, electronic components and integrated circuits both for experimental and project use.
- AWE also commissions academic involvement in the areas of nuclear detection techniques and nuclear forensics.

Much of this research take place through PhD studentships sponsored by AWE, but funding from AWE has also provided support for specialist centres which are discussed later. For instance Cranfield University's Centre for Defence Chemistry and the Institute of Shock Physics at Imperial College have received significant funds from AWE.

AWE currently spends around £8.5 million a year on its Technical Outreach programme (Table 3). The total amount that each individual partner university receives directly from AWE over the period 2008 to 2012 is small as a percentage of the overall research and teaching income received by the university. For instance, in the 2011/12 academic year the University of Cambridge received funding of £529,000 for a total of 19 research grants and contracts from AWE. This compares with a total income of £299 million from all research grants and contracts at the university for the same year³⁸. At Cranfield University the total funding from AWE for 2008-12 was £4.85 million, whilst the total income from the research councils and other research funding sources that the university received was £75.5 million for the 2012 financial year alone³⁹.

Year	Payment (£)
2010	8,543,612
2011	8,543,741
2012 (to July 2012)	4,580,715

Table 3. Payments made by the Atomic Weapons Establishment under the Technical Outreach programme 2010 – 12⁴⁰.

³⁷ 'AWE: Research'. Parliamentary Written Answer from Peter Luff MP (substantive response from Gerald Howarth MP). Official Report (Hansard), 3 September 2012, c44W.
<http://www.theyworkforyou.com/wrans/?id=2012-09-03d.113137.h&s> (Accessed 15 May 2013).

³⁸ 'Financial Management Information for the year ended 31 July 2012'. University of Cambridge. <http://www.admin.cam.ac.uk/reporter/2012-13/special/06/06-FMI-2012-SectionL.pdf> (Accessed 13 May 2013).

³⁹ 'Financial Statements for the year ended 31st July, 2012'. Cranfield University. Page 20.
<http://www.cranfield.ac.uk/annualreport/accounts/annual%20accounts%20ye%2031%207%2012%20-%2012%20october%202012%20-%20web.pdf> (Accessed 13 May 2013).

⁴⁰ 'AWE'. Parliamentary written answer from Philip Dunne MP. Official Report (Hansard), 28 November 2012, c350W.
<http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm121128/text/121128w0001.htm#12112886001208> (Accessed 13 May 2013).

As well as directly funding research projects, AWE also offers support to universities in the form of staff posts such as William Penney Fellowships – professorships awarded to leading academics who specialise in disciplines of interest to AWE (see text box ‘AWE William Penney Fellowships’). Co-operation with leading academics in fields of interest to AWE helps the Establishment to stay abreast of developments at the cutting edge of science which, in years ahead, may have an important part to play in helping AWE fulfil its mission.

Text Box 1: AWE William Penney Fellowships

AWE William Penney Fellowships, named after Sir William Penney, the first Director of the Atomic Weapons Research Establishment and leader of the team that designed Britain's first atomic bomb, are professorships and funding awarded by AWE to leading academics at UK universities who specialise in academic disciplines of interest to AWE. The Fellowships help maintain AWE's profile among the scientific and academic community. AWE's publicity material says that "Our William Penney Fellows stimulate links with academia and an external perception of AWE as an internationally renowned research development organisation"⁴¹.

According to a written Parliamentary answer, the University of Bristol, Cranfield University, the University of Edinburgh, Heriot-Watt University and the University of Cambridge currently have academics who have been awarded a William Penney Fellowship (Table 4). In addition visiting William Penney Fellows are also hosted by the University of Cambridge. The Atomic Weapons Establishment budgeted £226,000 for the William Penney Fellowship for financial year 2011-2012, which is the last year for which figures are available⁴².

Postholder	University	Fellowship
Geoffrey Allen ⁴³	Interface Analysis Centre University of Bristol	Professor of Materials Science
Dimitris Drikakis ⁴⁴	School of Engineering, Cranfield University	Professor of Engineering Physics
Andrew Moore ⁴⁵	Heriot-Watt University	Professor of Mechanical Engineering
Malcolm McMahon ⁴⁶	School of Physics and Astronomy University of Edinburgh	Professor of High Pressure Physics
Eleuterio Toro OBE ⁴⁷	Visiting Professor at Cavendish Laboratory for Scientific Computing University of Cambridge	Professor of Numerical Analysis
Rade Vignjevic ⁴⁸	Crashworthiness Impact and Structural Mechanics Group, Department of Applied Mechanics, Cranfield University	Professor of Applied Mechanics

⁴¹ 'Delivering Excellence, Shaping The Future'. AWE Company Brochure 2011, page 31. Atomic Weapons Establishment. http://www.awe.co.uk/Contents/Publication/5e8eb68AWE_Annual_Review_2011.pdf (accessed 15 May 2013).

⁴² 'AWE'. Parliamentary written answer from Philip Dunne MP. Official Report (Hansard), 29 November 2012, c485W <http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm121129/text/121129w0001.htm#12112964002196> (Accessed 13 May 2013).

⁴³ Professor Geoffrey Allen personal profile, University of Bristol website. <http://www.bris.ac.uk/mcest-mission/contacts/phgca.html> (Accessed 13 May 2013).

⁴⁴ Professor Dimitris Drikakis personal profile, Cranfield University website. http://www.cranfield.ac.uk/soe/profiles/d_drikakis.html (Accessed 13 May 2013).

⁴⁵ Professor Andrew Moore personal profile, Heriot-Watt University website. <http://www.su2p.com/Portals/14/Profiles/Moore%20Andrew.pdf> (Accessed 13 May 2013).

⁴⁶ Professor Malcolm McMahon personal website. <http://mimcmahon.com> (Accessed 13 May 2013).

⁴⁷ Professor Eleuterio Toro personal profile, University of Cambridge website. http://www.lsc.phy.cam.ac.uk/people/tito_toro.shtml (Accessed 13 May 2013).

⁴⁸ Professor Rade Vignjevic personal profile, Cranfield University website. http://www.cranfield.ac.uk/soe/profiles/r_vignjevic.html (Accessed 13 May 2013).

AWE also provides full or partial funding for conferences and student training at the graduate and post-graduate level at some UK universities, including Strategic Alliance universities⁴⁹ (see text box ‘Conference sponsorship’).

Text Box 2: Conference sponsorship

Examples of recent conferences co-sponsored or organised by AWE at UK universities include:

- ‘Plutonium Futures – The Science 2012’: University of Cambridge, July 2012⁵⁰.
- ‘Institute of Physics Plasma Physics Group Annual Conference’: University of Oxford, April 2012⁵¹.
- ‘Condensed Matter and Materials Physics Conference’: Institute of Physics, Manchester, December 2011⁵².
- ‘Many-Core and Reconfigurable Supercomputing Conference’: University of Bristol, April 2011⁵³.
- ‘Group of Experts in Mitigation Systems Colloquium’: Imperial College, January 2011⁵⁴.
- The April 2011 conference on supercomputing at Bristol University was described by AWE as covering “an important area of research at AWE, in support of the calculations required in weapon physics, materials science, and engineering”⁵⁵, and all of these events relate to topics which are directly relevant to AWE’s work on nuclear weapons development and design.

⁴⁹ Data collected by Fol requests to alliance universities and also in a letter dated 10 July 2012 from Ms Catherine Waite, DE&S Secretariat, Ministry of Defence in response to a Fol request.

⁵⁰ ‘Conferences and events: Plutonium Futures – The Science 2012’ Royal Society of Chemistry website. <http://www.rsc.org/ConferencesAndEvents/conference/alldetails.cfm?evid=110615> (Accessed 15 May 2013).

⁵¹ ‘IOP Annual Plasma Physics Group Conference 2012’. Physics World website. <http://physicsworld.com/cws/event/16027> (Accessed 15 May 2013).

⁵² ‘Condensed Matter and Materials Physics CMMPI 1’ website. <http://www.cmmpl.org.uk/home> (Accessed 15 May 2013).

⁵³ ‘MRSC 2011’. OurGLocal Academic Resources website. <http://www.ourglocal.com/event/?eventid=6696%2C1> (accessed 15 May 2013).

⁵⁴ ‘Annual Review 2011: Shaping the Future’. Atomic Weapons Establishment. Page 19. http://www.awe.co.uk/Contents/Publication/5e8eb68AWE_Annual_Review_2011.pdf (accessed 15 May 2013).

⁵⁵ ‘AWE Annual Review 2012. Building capability for the future’. Atomic Weapons Establishment. Page 36. <http://www.awe.co.uk/Contents/Publication/AWEAnnualReport2012.pdf> (Accessed 13 May 2013).

3.4 Case study: AWE's work with Imperial College

AWE supports two research centres at Imperial College, London, which together provide a useful case study of an instance where significant funding has been provided to a leading university by AWE (see text box 'Co-operation between AWE and Imperial College'). The Institute of Shock Physics (ISP), hosted by Imperial College, is intended to increase UK capabilities in the field of high pressure processes by attracting and training new researchers and undertaking interdisciplinary research in this area. The ISP carries out research which could be seen as 'blue skies', and could have significant public good – for instance, in gaining better understanding of earthquakes and extreme weather events, or damage to human tissue caused by explosions and blasts. However, dual use issues might arise for some study areas within the core research programmes such as wave propagation and flow and optical examination of shock processes. A senior member of Imperial College staff has stated that one of the goals of the collaboration would be "for the Institute to attract physicists, in particular trained shock physicists, to AWE"⁵⁶. AWE itself, in its company brochure, describes the Institute's work "as being of great benefit to AWE"⁵⁷. Imperial College hosts a parallel centre, the Centre for Inertial Fusion Studies, also co-funded by AWE, which aims to help transfer AWE's experience of work in plasma physics and with high energy lasers into the civil sector to support research into inertial fusion energy.

Text Box 3: Co-operation between AWE and Imperial College

The Institute of Shock Physics

Imperial College announced in April 2008 the opening of the Institute of Shock Physics⁵⁸ – a £10 million research institute, funded in part by AWE, to investigate the fundamental science behind shock waves, high velocity collisions, heat and pressure extremes.

The funding, initially for five years, was intended to support research, studentships and teaching as well as creating new posts (including Director and Programme Director). Imperial College has provided core funding to help establish the Institute in 2008.

The Institute's founding Director was Professor Steven Rose, who joined Imperial College in 2006 following positions at AWE as Head of Plasma Physics, the Central Laser facility at Rutherford Appleton Laboratory and the University of Oxford, where he was a William Penney Visiting Professor⁵⁹.

The Institute conducts core research in the following areas:

- Fracture and fragmentation.
- Dynamic friction & mixing.
- Wave propagation & flow.

⁵⁶ Professor Chris Hankin, Deputy Principal of the Faculty of Engineering at Imperial College, quoted in 'AWE's Outreach, Major Events, and Collaborative Activities'. Page 40, 'Discovery', Issue 18, March 2009.

⁵⁷ 'Delivering Excellence, Shaping The Future' AWE Company Brochure 2011, page 31. Atomic Weapons Establishment.

⁵⁸ Institute of Shock Physics website. <http://www3.imperial.ac.uk/shockphysics/research> (Accessed 14 May 2013).

⁵⁹ Professor Steven J Rose personal profile, Imperial College website. <http://www3.imperial.ac.uk/people/s.rose> (Accessed 15 May 2013).

- Optical examination of shock processes.
- Isentropic compression.
- High pressure phase changes.
- Convergent & radiative shock waves.

Current partners in collaborative research at the Institute include:

- Surface and fracture group – University of Cambridge.
- Dynamic response group – Cranfield University.
- Extreme conditions group – University of Edinburgh.
- Blast mechanics and biophysics group – Imperial College.
- Impact studies group – University of Kent.
- Static high pressure group – University College London.
- High Energy Density Physics – Lawrence Livermore National Laboratory.
- Neutron Science centre – Los Alamos National Laboratory.
- High power laser group – University of Oxford.

The Institute also collaborates with other researchers at Imperial College on fundamental and more applied research.

The Centre for Inertial Fusion Studies

The Centre for Inertial Fusion Studies (CIFS) at Imperial College⁶⁰ is jointly funded by AWE and Imperial College and was established with the support of Professor Peter Roberts, Head of Plasma Physics at AWE. Since its inauguration in 2009 the Centre has been providing for close collaboration between academic staff at Imperial College working on inertial fusion energy and related subjects in laser-plasma interaction physics and their counterparts at AWE who carry out similar work in the new Orion laser facility at AWE. Recently, French scientists have also participated in events organised as part of the CIFS programme⁶¹. Engagement with the CIFS gives encouragement to AWE staff to publicise their work more widely and to take part in a wider range of international collaborations. It also brings AWE's expertise in laser-plasma physics, computational modelling and high energy density physics into the academic arena.

⁶⁰ 'The Centre for Inertial Fusion Studies' webpage. <http://www3.imperial.ac.uk/plasmaphysics/cifs> (Accessed 15 May 2013).

⁶¹ Minutes of the 72nd AWE Local Liaison Committee. 13 March 2013 at AWE Aldermaston. Paragraph 4b.

3.5 AWE's work with National Research Laboratories, Professional Institutes, and Industry Groups

As well as work with UK universities, AWE's corporate Technical Outreach programme extends to other research laboratories, such as the National Physical Laboratory and the Rutherford Appleton Laboratory in Oxfordshire. AWE has signed a memorandum of understanding with Rutherford Appleton Laboratory and the Lawrence Livermore National Laboratory in the USA to allow technical exchanges on laser fusion to take place between laser facilities hosted at the three laboratories: AWE's Orion laser, the Central Laser Facility at Rutherford Appleton, and the National Ignition Facility at Lawrence Livermore⁶².

AWE also collaborates with professional institutions representing scientists and engineers, such as the Institute of Physics and the Royal Society of Chemistry, and also with industrial organisations, primarily via the Institute of Collaborative Working (formerly Partnership Sourcing Ltd)⁶³. Active collaboration also takes place with a variety of government agencies, including the Defence Science and Technology Laboratory (DSTL) and the research councils.

In addition to collaborating with UK universities and professional institutions, AWE has in recent years engaged in scientific work alongside various non-government organisations and overseas research institutes, particularly in relation to its disarmament verification programme. British Pugwash has recently conducted a review of verification work which AWE has undertaken on behalf of the Ministry of Defence⁶⁴ and, as a partner in the UK-Norway Initiative on disarmament verification⁶⁵, AWE scientists have worked with colleagues from Norwegian research institutes and the Verification Research, Training and Information Centre (VERTIC). AWE also undertakes a range of outreach activities with schools and colleges to support education and training in science and promote career opportunities at AWE⁶⁶. These activities are, however, beyond the scope of this study.

⁶² 'AWE Annual Review 2012. Building capability for the future'. Atomic Weapons Establishment. Page 46. <http://www.awe.co.uk/Contents/Publication/AWEAnnualReport2012.pdf> (Accessed 13 May 2013).

⁶³ 'Corporate Technical Outreach' AWE website. http://www.awe.co.uk/set/Corporate_Technical_Outreach.html (accessed 13 May 2013). This company is a Department of Trade and Industry and Confederation of British Industry body established to promote the concept of partnerships in business, and has both corporate and university representatives on the Steering Group.

⁶⁴ Brian Anderson, Hugh Beach, John Finney, Nick Ritchie, Ruben Saakyan, and Christopher Watson: 'Verification of Nuclear Weapon Dismantlement: Peer Review of the UK MoD Programme'. British Pugwash, November 2012. <http://www.britishpugwash.org/documents/BPG%20Verification%20Report.pdf> (Accessed 2 July 2013).

⁶⁵ 'UK-Norway Initiative on Nuclear Warhead Disarmament Verification' <https://www.gov.uk/government/publications/uk-norway-initiative-on-nuclear-warhead-dismantlement-verification--2> (Accessed 2 July 2013).

⁶⁶ During 2011 AWE's Schools Liaison team undertook activities to support the teaching of science, engineering, and technology with 76 schools, ranging from infant schools to secondary schools and sixth form colleges. 'AWE Annual Review 2011', page 39. Atomic Weapons Establishment.

3.6 Finance

The money which funds AWE's Technical Outreach programme comes ultimately from the Ministry of Defence, meaning that it is public money provided in large part by taxpayers. The AWE management and operation contract between AWE Management Ltd and the Ministry of Defence requires AWE to support university research, training, consultancy and contracts, and payments are made from the MoD budget for this. In the main, AWE provides funding to UK universities on the basis of open competition, with the physical sciences, mathematics and computer sciences being the main university departments which attract AWE funds. The corporate partner companies which own AWE Management Ltd (Lockheed Martin, Jacobs Engineering, and Serco) do not appear to directly fund university-based research activities specifically through AWE, and their role in managing research at the site is not examined in this report.

Publication patterns of university research supported by AWE appear to be similar to those noted in previous studies of university involvement in military research⁶⁷. To date, research groups have tended to favour conference presentations over peer-reviewed papers to present the findings of research funded by AWE, although this can often be the case with engineering research, especially in rapidly-moving and industry-specific fields. Presentations at conferences can help increase the visibility and profile of a research unit and allow discussion to take place with other researchers and stakeholders. They can also play a role in the professional development process by providing opportunities for research students to improve their presentation skills and develop their arguments before submitting a paper to a journal. Nevertheless, it remains recognised good practice for research results to be published in due course in peer-reviewed journals.

⁶⁷ C Langley: 'Soldiers in the laboratory: military involvement in science and technology – and some alternatives'. Folkestone, UK: Scientists for Global Responsibility, 2005 http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).

C Langley, S Parkinson and P Webber: 'More soldiers in the laboratory: the militarisation of science and technology – an update'. Folkestone, UK: Scientists for Global Responsibility, 2007 http://www.sgr.org.uk/ArmsControl/More_Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).

C Langley: 'Universities, the military, and the means of destruction in the United Kingdom'. *The Economics of Peace and Security Journal*, Volume 3: 49-55, 2008 <http://www.epsjournal.org.uk> (Accessed 15 May 2013).

C Langley, S Parkinson and P Webber: 'Behind closed doors: Military influence, commercial pressures & the compromised university'. Folkestone, UK: Scientists for Global Responsibility, 2008. http://www.sgr.org.uk/ArmsControl/BehindClosedDoors_jun08.pdf (Accessed 15 May 2013).

M Beale, T Street and J Wittams, 'Study war no more' London, Campaign Against Arms Trade 2007. <http://www.studywarnomore.org.uk/documents/studywarnomore.pdf> (Accessed 13 May 2013).

3.7 AWE and the Research Councils

As well as co-operating with individual universities, AWE also works with the research councils – the main government agencies providing funding for university research. In 2012 AWE signed a memorandum of understanding with the Engineering and Physical Sciences Research Council (EPSRC) to explore areas of interest and realise mutual benefits in research, postgraduate training and knowledge exchange. AWE considers itself to be “one of EPSRC’s strategic partners” and the Establishment “advises EPSRC on the direction of UK university research, ensuring alignment with AWE’s Outreach programme and the joint commitment to UK academia”⁶⁸. AWE has seconded a member of staff to work at EPSRC⁶⁹, and is therefore able to have some influence in setting the direction of national policy in university research in engineering and the physical sciences.

AWE is also involved in a number of individual partnerships and similar schemes which are co-funded by the EPSRC and the Science and Technology Facilities Council (STFC). (The STFC undertakes research at the Daresbury Laboratory⁷⁰ and at the Harwell Science and Innovation Centre in Oxfordshire). Research undertaken through each of these schemes is managed by a consortium co-ordinated by a specific university. Schemes vary considerably from university to university and can involve “direct cash contributions, in-kind contributions, joint supervision of students, access to facilities and hosting of meetings”⁷¹.

EPSRC funds dedicated research centres in particular disciplines (for instance, at York, Southampton, Cranfield and Loughborough universities, University College London, and Imperial College) to undertake a large programme of joint business-academic activities⁷². These centres are funded by the Research Council with varying sums of money, and funding from other sources is also drawn in. Some of these particular centres are ‘partnered’ with AWE and have other commercial and academic partners too (see text box ‘AWE and EPSRC Centres’). The precise role of AWE in such collaborations is decided between the university project partner and the grant holder and “the EPSRC plays no direct part in the detail of collaboration”⁷³.

⁶⁸ Minutes of the 71st AWE Local Liaison Committee Meeting, 5 December 2012.

⁶⁹ ‘Current strategic partnerships’. EPSRC website. <http://www.epsrc.ac.uk/about/partner/Pages/strategic.aspx> (Accessed 15 May 2013).

⁷⁰ The Daresbury Laboratory undertakes globally-recognised research in supercomputing, light acceleration and lasers together with electron spectroscopy, for which it is the UK national facility. The laboratory offers facilities to UK universities and is the location of a science park which makes use of the expertise on-site.

⁷¹ Information provided by EPSRC, 4 May 2012.

⁷² ‘Centres and Major Investments’. EPSRC website. <http://www.epsrc.ac.uk/research/centres/Pages/centres.aspx> (accessed 15 May 2013).

⁷³ Information provided by EPSRC, 4 May 2012.

Text Box 4: AWE and EPSRC Centres⁷⁴

- Industrial Doctorate Centre: Molecular modelling and materials science. University College London, 2009-2018. Value £6.6 million. Partners include AWE, Honeywell, AstraZeneca, the National Physical Laboratory and STFC Laboratories.
- Innovative Manufacturing in Additive Manufacturing. Loughborough University, 2011-2016. Value £5.9 million. Partners include AWE, Boeing Co., BAE Systems, the National Physical Laboratory and MTT Technologies Ltd.
- Innovative Manufacturing Research Centre. Cranfield University, 2007-2011. Value £9.7 million. Partners include AWE, Airbus UK, BAE Systems, Halliburton KBR, Lotus Engineering and the National Physical Laboratory.
- Innovative Manufacturing in Photonics. University of Southampton, 2010-2015. Value £5.1 million. Partners include AWE, BAE Systems, Selex-Galileo and SPI Lasers UK Ltd.
- Scottish Manufacturing Institute. Heriot-Watt University, 2008-2013. Value £7.1 million. Partners include Airbus Germany, BAE Systems Advanced Technology Centre, AWE, BAE Systems Avionics Management Ltd and Rolls-Royce plc.

EPSRC has also offered co-funding jointly with AWE for PhD studentships under the Collaborative Awards in Science and Engineering (CASE) scheme to support PhD research students working on topics which are of interest to AWE, where students spend some time working at AWE Aldermaston. Examples of research topics funded through this route include:

- The behaviour of solid materials at high stresses at the University of Oxford and AWE⁷⁵.
- Plasma physics at Imperial College⁷⁶.
- Performance modelling of high performance computer applications at the University of Warwick⁷⁷.
- Deformation mechanisms in metals at the University of Cambridge⁷⁸.

AWE is also jointly involved with the National Nuclear Laboratory (NNL)⁷⁹ in two EPSRC programmes which support nuclear engineering. One of these programmes is underway at the University of Manchester, and runs from 2009 to 2018 with support from the EPSRC of £3.59 million. The second took place at Imperial College from 2005 to 2010 with funding of £6.11 million. Research activities and training are central to these programmes and the stated aim of the programmes is to maintain nuclear science expertise in the UK. According to the National Nuclear Laboratory, neither of these two programmes are specifically partnerships between NNL and AWE. They are EPSRC

⁷⁴ Information from searches conducted in April 2012 on the EPSRC 'Grants on the web' website: <http://gow.epsrc.ac.uk/>

⁷⁵ 'Industrial CASE PhD Studentship at University of Oxford and AWE'. Connect website. https://connect.innovateuk.org/web/case/articles/-/blogs/industrial-case-phd-studentship-at-university-of-oxford-and-awe;jsessionid=7B01DC5A2CBACAABFCC66D2A5D28D97F.oav!ovMo?ns_33_redirect=%2Fweb%2Fcase%2Farticles (Accessed 15 May 2013).

⁷⁶ 'Research : Plasma Physics'. Imperial College website. <http://www3.imperial.ac.uk/plasmaphysics/opportunities/pgapplicants> (Accessed 15 May 2013).

⁷⁷ Professor Stephen Jarvis personal profile. University of Warwick website. http://www2.warwick.ac.uk/fac/sci/dcs/people/stephen_jarvis/ (Accessed 15 May 2013).

⁷⁸ 'Details of grant'. EPSRC website. <http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/I038691/1> (Accessed 15 May 2013).

⁷⁹ The National Nuclear Laboratory is a UK registered private limited company in which the Secretary of State for Energy and Climate Change holds the shares through a holding company, NNL Holdings Ltd. NNL represents the UK's nuclear research and development expertise which formerly existed at British Nuclear Fuels and Magnox Electric. National Nuclear Laboratory website, <http://www.nnl.co.uk/about-us.aspx> (Accessed 15 May 2013).

funded programmes on which both NNL and AWE – along with other companies – sit on the board.⁸⁰ AWE's involvement in the projects has been described as follows:“.....when AWE are a Project Partner on an EPSRC grant this is as a result of a relationship they (or any project partner) have with the grant holders, rather than EPSRC directly. The nature that this relationship takes can vary immensely from partner to partner and grant to grant and can include direct cash contributions, in kind contributions of things like staff time (possible joint supervision of students and RAs), access to facilities, hosting of meetings”⁸¹

⁸⁰ Information from the communication department of the National Nuclear laboratory, 26 March 2012.

⁸¹ E-mail of 4 May 2012 from the EPSRC Head Office.

3.8 What does AWE get for its money?

The links between AWE and the UK's mainstream science sector take place through a range of arrangements under the auspices of AWE's Technical Outreach programme. As discussed above, these span AWE-funded PhD studentships, fellowships, support for conferences and research centres, and contract research. The majority of these activities are funded directly by AWE, although sometimes funding can be channelled through an industrial or academic partnership.

The objectives of AWE's Technical Outreach programme are set out in the company's Technical Outreach Strategy (see text box 'The aims of AWE's Technical Outreach programme'), which spells out what AWE expects to obtain in return for its money. As well as receiving research services, AWE also receives academic credibility, an increased profile within the university sector, and a pool of expertise among graduates and researchers from which it is able to recruit staff skilled in disciplines which are key to AWE's role. In contrast to days past, when AWE operated as a much more secretive and closed establishment than it is now and was often viewed with some suspicion, both AWE and the government are keen that AWE should be seen as a reputable member of the UK's scientific community and, as a leading scientific establishment with unique capabilities and assets, play a role in setting national scientific priorities.

It is frequently said that AWE provides a platform for some of the best and brightest members of the UK's science community to undertake state-of-the-art research using unrivalled facilities and to collaborate with leading laboratories world-wide. This view was mentioned by several of those to whom we spoke when undertaking this study⁸². AWE's university links help to integrate the Establishment's work with more mainstream research, and a regular turnover of personnel and students moving between universities and AWE not only helps AWE to recruit staff with the specialist skills it needs, but also ensures that AWE keeps abreast of broader scientific developments which may be relevant to its mission.

Close liaison between AWE and the US nuclear weapons laboratories plays a key role in allowing the UK to pursue an effective nuclear weapons programme of its own and reducing the costs of the programme. In order to maintain credibility with the US laboratories, the UK must have something to 'trade' in return for the information it receives⁸³. Expertise derived from laser and hydrodynamic experiments conducted at Aldermaston has been important in this respect in years past, but as US capability in these fields gradually overtakes AWE's knowledge, co-operation on emerging areas such as nuclear threat reduction is likely to become increasingly important. AWE's collaboration with universities in this field may prove to play an increasingly important part in maintaining the US-UK nuclear relationship in the decades ahead.

The UK government and the commercial consortium which runs AWE see the role of the Establishment as being the UK's "centre of excellence" for military nuclear science including weapons research, design, stewardship and component fabrication. Their intention is to demonstrate to the world that the UK not only has the capability to remain a credible nuclear weapons power, but is investing money in the skills, knowledge, and equipment to retain this capability into the long-term future. However benignly it may be presented, the research conducted by UK universities on AWE's behalf ultimately contributes to this goal.

⁸² E-mails and telephone conversations with research informants: 27 March 2012, 9 July 2012 and 13 July 2012.

⁸³ Keith O'nions, Roy M. Anderson, and Robin Pitman: 'Reflections on the Strength of the 1958 Agreement'. In: 'U.S. – UK Nuclear Co-operation After Fifty Years' Edited by Jenifer Mackby and Paul Cornish. 2008, Center for Strategic and International Studies, Washington D.C, pp179-188.

Text Box 5: The aims of AWE's Technical Outreach programme⁸⁴

- To promote AWE's science, engineering and technological capabilities through collaboration to support the UK's deterrent posture.
- To benchmark with external bodies and experts to assure AWE's capabilities and pursue best practice.
- To enhance the professional aspirations of AWE staff to facilitate staff retention and foster a creative and innovative culture.
- To attract high calibre scientists and engineers to AWE, e.g. undergraduate students, PhD/ EngD students and Post Doctoral Research Fellows, and develop and sustain scarce skill recruitment streams.
- To facilitate leveraged R&D directly through seed-corn funding, and indirectly via AWE's R&D programmes.
- To improve value-for-money for AWE and its customers.
- To gain access to research facilities at other sites that would otherwise be unavailable or only available at substantially greater cost, thereby protecting AWE's dependencies in key areas.
- To maintain an awareness of relevant technical developments in the outside world.
- To promote AWE's key areas:
 - Design Physics
 - Hydrodynamics
 - Plasma Physics
 - Materials Science
 - High Performance Computing
 - Systems Engineering
 - Production
 - National Security
 - Treaty Verification

These requirements are about achieving and maintaining an overall technical capability that provides confidence AWE will achieve its Mission through excellence in SET.

⁸⁴ As presented in 'Technical Outreach at AWE.A Strategy Overview'. Atomic Weapons Establishment, December 2009. Page 4. <http://www.awe.co.uk/Contents/Publication/c74732bAWE%20Strategy%20Document%20-%20proof%202.pdf> (Accessed 13 May 2013).

3.9 Key issues arising from this section

- University funding from the Ministry of Defence through AWE is widespread and its extent is not made openly available in the public domain. More than fifty UK universities receive funding from AWE. That is roughly half the number of all UK universities – a very high proportion to be engaged in activities with research potentially linked to nuclear weapons. The Ministry of Defence did not provide detail (for instance, about publications or departments undertaking research) in response to our enquiries on universities that obtain funding from AWE. Limited information is publicly available on research funded by AWE in UK universities and the extent of information provided by AWE's Strategic Alliance partners varies between each of these universities.
- AWE provides support to UK universities through direct financial payments for research, financial support for academic posts and studentships, and support for conferences and training. Money from AWE is often supplemented by support from other partners with overlapping interests.
- As well as universities, AWE also has academic partnerships with other research laboratories, national and international, professional institutions, and works jointly with the Engineering and Physical Sciences Research Council and the Science and Technology Facilities Council.
- AWE's academic collaboration helps increase AWE's reputation, allows AWE to draw on expertise from universities to support its work, provides a pool of potential recruits for staff posts at AWE, and enables AWE to maintain a broader scientific and technological awareness. The aims of AWE's Technical Outreach programme clearly show that academic collaboration is directly intended to allow AWE to maintain its position as the UK's centre of expertise for military nuclear science.

4. AWE and the universities: Addressing dual use and ethical issues

4.1 Establishing an ethical reference point - our own ethical position

AWE's scientific work touches on sensitive areas of research which have important consequences for safety, security and the proliferation of nuclear weapons. Many of these areas of work are also controversial and raise complicated ethical issues.

This chapter of the report sets out in more detail the practical and ethical issues which challenge research in this field, and identifies what steps AWE and its university partners have taken to address them. The following chapter sets out a series of principles which Nuclear Information Service and Medact believe would help in making decisions on whether a university should undertake to work on a project where there may be difficult ethical and security implications.

Each person has their own individual ethical perspective, and it is not always easy to identify an ethical standpoint which everyone will agree on. For the purpose of this report, Nuclear Information Service and Medact have adopted an ethical position which is based around the international legal agreements which control the production and proliferation of weapons of mass destruction. The United Kingdom has binding legal obligations in international law which we consider should define the framework in which institutions and individuals undertake research into areas of science which could either directly or indirectly aid the development of indiscriminate weapons of mass destruction. These agreements are summarised in the accompanying text box 'Key international agreements relating to weapons of mass destruction'.

A key underlying issue relating to ethical matters is whether controversial decisions should be a matter for individuals, institutions, or society as a whole. Ultimately, we consider that research decisions must be the responsibility of the individual researcher, but a number of factors should shape how decisions are made. As a lowest common denominator, research should always comply with the law, signalling in crude terms that it falls within the bounds of what is generally acceptable to society. Likewise, it should also comply with policies of the host institution. However, ethical dilemmas faced by researchers are likely to be more complex and subtle than will allow them to be easily resolved by reference to the law or a set of policies. In such cases, consultation is important, and the more significant the potential implications of a research project, the broader and deeper consultation should be, taking in not just university ethical committees but professional institutes and other specialists, government departments, and in some cases seeking views from broader public opinion.

Text Box 6: Key international agreements relating to weapons of mass destruction

The ethical position that Nuclear Information Service and Medact adopt for the purposes of this study is based on the main international agreements relating to weapons of mass destruction. There are clear international norms against the use or possession of weapons of mass destruction because, if used, such weapons would have enormous humanitarian and environmental consequences. International treaties relating to weapons of mass destruction have an unassailable standing in international law and have all been accepted by UK governments.

An early international agreement aimed at banning the use of weapons of mass destruction was the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare – the Geneva Protocol of 1925, which came into force in response to the use of poison gas as a weapon of war during World War I, banning the use of chemical and biological weapons in war⁸⁵.

The Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction (Biological Weapons Convention) entered into force in 1975⁸⁶. Under Article I State Parties have agreed “never in any circumstance to develop, produce, stockpile or otherwise acquire or retain” biological weapons or agents.

The Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction (Chemical Weapons Convention) came into force in 1997. Article I of the convention prohibits a State Party from using chemical weapons, and state parties are never to “develop, produce, otherwise acquire, stockpile, or retain chemical weapons, or transfer, directly or indirectly, chemical weapons to anyone”⁸⁷.

A number of multilateral treaties have been established with the aim of preventing the proliferation and testing of nuclear weapons, while requiring progress in nuclear disarmament. These include the Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty)⁸⁸, which entered into force in 1970 and prohibits non-nuclear-weapon states from acquiring nuclear weapons and forbids nuclear-weapon states from providing them with assistance in acquiring nuclear weapons. Under Article VI of the Treaty nuclear weapon states have an obligation “to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament”. The obligations of the nuclear-weapon-states to take steps towards disarmament were reaffirmed in the Final Document and Action Plan agreed by all parties at the 2010 Review Conference of the Non-Proliferation Treaty⁸⁹.

⁸⁵ ‘The Geneva Protocol 1925’. United Nations Office for Disarmament Affairs website. <http://www.un.org/disarmament/WMD/Bio/1925GenevaProtocol.shtml> (Accessed 18 May 2013).

⁸⁶ ‘The Biological Weapons Convention’. United Nations Office for Disarmament Affairs website. <http://www.un.org/disarmament/WMD/Bio/> (Accessed 18 May 2013).

⁸⁷ ‘Overview of the Chemical Weapons Convention’. Organisation for the Prohibition of Chemical Weapons website. <http://www.opcw.org/chemical-weapons-convention/about-the-convention/> (Accessed 18 May 2013).

⁸⁸ ‘Treaty on the Non-Proliferation of Nuclear Weapons’. United Nations Office for Disarmament Affairs website. <http://www.un.org/disarmament/WMD/Nuclear/NPT.shtml> (Accessed 18 May 2013).

⁸⁹ ‘Final Document’. 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons. <http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/npt/revcon2010/FinalDocument.pdf> (Accessed 18 May 2013).

The Comprehensive Nuclear-Test-Ban Treaty⁹⁰ was signed in 1996 but has yet to come into force, although it has been ratified by and is thus binding on the United Kingdom. The Treaty bans all nuclear explosions on Earth whether for military or for peaceful purposes. The Preamble to the Treaty recognises the importance of “constraining the development and qualitative improvement of nuclear weapons and ending the development of advanced types of nuclear weapons”.

The 1996 Advisory Opinion of the International Court of Justice on the Legality of the Threat or Use of Nuclear Weapons⁹¹ concluded that “the threat or use of nuclear weapons would generally be contrary to the rules of international law applicable in armed conflict, and in particular the principles and rules of humanitarian law”.

Our view is that scientific research which clearly breaches the terms of these agreements should not be permitted to go ahead. In many cases, however, the issues will not be clear cut. In cases where there are potential dual use applications to the findings of research we consider that an important question for researchers to ask themselves is “will the research contribute to the aims of these international agreements, or could it undermine them?”

⁹⁰ ‘The Treaty’. Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organisation. <http://ctbto.org/the-treaty/> (Accessed 18 May 2013).

⁹¹ ‘Legality of the Threat or Use of Nuclear Weapons’. International Court of Justice <http://www.icj-cij.org/docket/index.php?pl=3&p2=4&k=e1&p3=4&case=95> (Accessed 18 May 2013).

4.2 Research on controversial topics and dual use concerns

As stated earlier, as well as undertaking work to design and develop nuclear weapons, AWE also plays an important role in supporting the government's nuclear threat reduction and disarmament verification programmes – areas of work where there is likely to be a clearer consensus that research is in the general public interest than work which directly enables the manufacture of nuclear weapons. AWE Blacknest is recognised as a leading international research centre in seismology and regularly collaborates with university seismologists to address questions of interest to various clients on issues of public good. AWE also plays an important role in providing the government's nuclear forensics capability, and hosts the Conventional Forensics Analysis Capability laboratory, opened in May 2012 with funding from the Home Office and the Ministry of Defence⁹². Support and expertise from UK universities plays a crucial role in maintaining these national capabilities. Co-operation between AWE and universities can thus contribute to dealing with issues which are unrelated to the nuclear weapons stewardship programme.

On the other hand, much of the research funded by AWE at universities is centred in the fields of high energy physics, materials science, manufacturing, numerical modelling, and high performance computing. These areas might well prove to have dual use applications – by which we mean the capacity to be used for both benign, peaceful purposes or military purposes with destructive intent. Clear guidelines would therefore be valuable to help ensure that research taking place in universities which is sponsored by AWE leads to developments which are of positive benefit to humanity, rather than developments which may result in harm.

Encouragingly, several of our respondents⁹³ explained that in many cases funding from AWE supported 'open-ended' research and that AWE was not prescriptive about the direction of research in a given field. However, it is difficult to judge the nature of the research undertaken with AWE support in AWE's Strategic Alliance partner universities since the published details of research portfolios covered by the partnerships and information on publications resulting from AWE funding are patchy (see Table 2). The examples cited above suggest that research may often be linked to ends which are of practical value to AWE. We were unable to assess the potential for dual use applications^{94/95} resulting from work undertaken with support from AWE because of the limited detail available.

According to Ministers, "none of the Atomic Weapons Establishment commissioned research work undertaken by universities is security classified"⁹⁶. We found no evidence during this study to suggest that sensitive research requiring a security classification was conducted in any of the universities with which AWE has partnerships or contracts. Our interviewees advised that such work is rarely undertaken in the university environment because of the complexities in maintaining high levels of security and the requirement for premises, equipment, and record-keeping facilities which meet security standards. This does not, however, preclude the possibility that university academics who have been vetted to

⁹² 'May 2012 – AWE – New forensic laboratory hosted on site'. Atomic Weapons Establishment press release. http://www.awe.co.uk/shownews_3575a5a.html (Accessed 15 May 2013).

⁹³ Information provided from research informants, 9 July 2012 and 13 August 2012.

⁹⁴ Discussed at: National Institutes of Health, Office of Biotechnology Activities Dual use research at: <http://oba.od.nih.gov/biosecurity/biosecurity.html> (accessed 15 May 2013).

⁹⁵ C McLeish: 'Reflecting on the problem of dual use' in B Rappert and C McLeish (Eds) 'A web of prevention'. London, Earthscan, pp 189-207, 2007. McLeish's paper deals with biosciences issues.

⁹⁶ 'AWE'. Parliamentary written answer from Philip Dunne MP. Official Report (Hansard), 28 November 2012, c350W. <http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm121128/text/121128w0001.htm#12112886001208> (Accessed 15 May 2013).

the necessary level of security clearance may sometimes participate on classified research alongside AWE colleagues using facilities within the Atomic Weapons Establishment. Academic staff from Oxford university are known have taken part in exchange visits to US establishments over the last three years under the terms of the 1958 US-UK Mutual Defence Agreement on nuclear weapons co-operation⁹⁷.

The undertaking of classified research within the university research community is problematic and the National Academies of Science in the USA take the view that classified research in universities should not be undertaken without extensive independent expert advice, and some university schools in the USA – and indeed the UK – have categorically stated that they will accept no funding for classified research⁹⁸. Some observers, such as the British Pugwash Group, have suggested that the UK should consider following the example of the USA and establish something analogous to the JASON programme, in which academic staff are given sufficient level of security clearance to permit them to advise independently on classified research matters, so that academia can be enabled to contribute effectively to policy issues of national importance.

There is a complex web of support, research undertakings and staff movement (especially amongst younger members) between universities with an established relationship with AWE, such as the Strategic Alliance universities and other universities which have received long-term AWE support, and AWE itself. Several universities receiving AWE funding have other major research programmes with the military sector (both government and commercial) and staff may have heavily military-based research portfolios⁹⁹, which reduces their capacity to undertake work which is more clearly in the public good. For instance Cranfield University receives funding from AWE as a Strategic Alliance partner, and is also a long-term research collaborator in the Human Factor Integration Defence Technology Centre¹⁰⁰, funded by the military sector (government and commercial). Additionally Cranfield operates a ‘link office’ with BAE Systems which has as its principal objective “to establish and foster a broad area of contact between BAE Systems and Cranfield University to advance interaction between staff of both parties at all levels and, through these contacts, to actively develop a long term, strategic and mutually beneficial partnership founded upon the generation and transfer of world class knowledge and expertise”¹⁰¹.

It is clear from the present study and others undertaken in the arena¹⁰² that the complex funding and collaborative relationships between UK universities and funders such as AWE, as well as other

⁹⁷ ‘AWE’. Parliamentary written answer from Philip Dunne MP. Official Report (Hansard) 29 November 2012 c458W. <http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm121129/text/121129w0001.htm#12112964002196> (Accessed 15 May 2013).

⁹⁸ Information provided by e-mail from the Committee on International Security and Arms Control, National Academy of Sciences, July 2012.

⁹⁹ See C Langley: ‘Soldiers in the laboratory: military involvement in science and technology – and some alternatives’. Folkestone, UK: Scientists for Global Responsibility, 2005. http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).

¹⁰⁰ C Langley: ‘Soldiers in the laboratory: military involvement in science and technology – and some alternatives’. Folkestone, UK: Scientists for Global Responsibility, 2005. http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).

¹⁰¹ ‘BAE Systems – Cranfield link office’. Cranfield University website. <http://www.cranfield.ac.uk/baesystems/> (Accessed 15 May 2013).

¹⁰² C Langley: ‘Soldiers in the laboratory: military involvement in science and technology – and some alternatives’. Folkestone, UK: Scientists for Global Responsibility, 2005. http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).

C Langley, S Parkinson and P Webber: ‘More soldiers in the laboratory: the militarisation of science and technology – an update’. Folkestone, UK: Scientists for Global Responsibility, 2007. http://www.sgr.org.uk/ArmsControl/More_Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).

C Langley: ‘Universities, the military, and the means of destruction in the United Kingdom’. *The Economics of Peace and Security Journal*, Volume 3: 49-55, 2008. <http://www.epsjournal.org.uk> (Accessed 15 May 2013).

C Langley, S Parkinson and P Webber: ‘Behind closed doors: Military influence, commercial pressures and the compromised university’. Folkestone, UK: Scientists for Global Responsibility, 2008. http://www.sgr.org.uk/ArmsControl/BehindClosedDoors_jun08.pdf (Accessed 15 May 2013).

M Beale, T Street and J Wittams, ‘Study war no more’ London, Campaign Against Arms Trade 2007. <http://www.studywarnomore.org.uk/documents/studywarnomore.pdf> (Accessed 13 May 2013).

commercial players, make openness and public scrutiny difficult. This is especially so when highly specialised and high tech research is involved, where perhaps only a small group fully understand the details of the science and wider audiences are reliant on their judgement as to the value of a particular research programme. Possible impacts may be felt in research ethos, accountability, ethical concerns and the opportunity costs of high calibre researchers being unavailable or unwilling to undertake research which has a higher public interest but is perhaps less well rewarded. Transparency and accountability, even where security is concerned¹⁰³, are essential in a healthy and reliable science and technology sector.

These factors have the potential to compromise scientific standards and the research institutions themselves. The next section considers how relationships and ethical issues arising from research funded by AWE are managed by the various stakeholders.

¹⁰³ Royal Society Science Policy Centre report 02/12, Science as an open enterprise, London, The Royal Society 2012. <http://royalsociety.org/policy/projects/science-public-enterprise/report/> (Accessed 15 May 2013).

4.3 Contracts, research management, and ethics

Relationships between AWE and universities are in the main specified by formally agreed contracts between the two parties. The nature and areas covered by contracts between client and contractor are important to both the working ‘culture’ within the contractor and also how business is undertaken with the client. Good contractual relationships go hand-in-hand with codes of conduct and / or ethical guidelines to help ensure that best professional practice is followed¹⁰⁴.

The kinds of contracts undertaken between Strategic Alliance universities and AWE appear to be complex. For example, at Imperial College, the contract, a framework agreement with general terms, permits research staff at the College to draw up specific contracts for specific programmes of work with AWE. The contract is based on a Ministry of Defence template and adopts standard MoD terms and conditions, covering Intellectual Property Rights (IPR), business practice and confidentiality¹⁰⁵. We were informed that the situation at one AWE-funded Imperial College group, the Institute of Shock Physics, covers research areas which are decided by Imperial College with minimal input from AWE, allowing ‘blue skies’ research to take place through AWE funding.

AWE uses a variety of contract models with different contractors¹⁰⁶, which include:

- Product (supply or with installation);
- Professional services, including supply of personnel;
- Complex construction works and services;

In each case certain general conditions will be common to whichever form of contract is used. AWE has also published a Code of Conduct and Business Ethics to guide its dealings with external parties¹⁰⁷. The Establishment also has an Ethical Officer and a hotline which can be used by staff, and presumably also university researchers working with AWE, to seek advice¹⁰⁸.

AWE’s ethical code does not specifically address issues relating to research undertaken on behalf of AWE in universities or discuss how the ethical dimensions of research undertaken at AWE itself will be evaluated. Employees must “comply with all applicable laws, rules, and regulations” and must avoid involvement in “any unlawful practice”¹⁰⁹. Although employees “must act for the benefit of the Company and not be influenced by personal interests”¹¹⁰ issues of concern to an individual’s

¹⁰⁴ R Daly: ‘The Missenden Code of Practice for Ethics and Accountability’. Missenden Centre for the Development of Higher Education. Great Missenden, 2002. <http://www.missendencentre.co.uk/docs/MissCode.pdf> (Accessed 15 May 2013).

¹⁰⁵ Interview with research informant.

¹⁰⁶ ‘Becoming a Supplier’. Atomic Weapons Establishment website. http://www.awe.co.uk/business/Becoming_a_Supplier.html (Accessed 15 May 2013).

¹⁰⁷ ‘Code of Conduct and Business Ethics’. Atomic Weapons Establishment, 2011. http://www.awe.co.uk/Contents/Files/AWE_Code_Of_Conduct.pdf (Accessed 15 May 2013).

¹⁰⁸ ‘Code of Conduct and Business Ethics’. Atomic Weapons Establishment, 2011. Page 5. http://www.awe.co.uk/Contents/Files/AWE_Code_Of_Conduct.pdf (Accessed 15 May 2013).

¹⁰⁹ ‘Code of Conduct and Business Ethics’. Atomic Weapons Establishment, 2011. Page 3. http://www.awe.co.uk/Contents/Files/AWE_Code_Of_Conduct.pdf (Accessed 15 May 2013).

¹¹⁰ ‘Code of Conduct and Business Ethics’. Atomic Weapons Establishment, 2011. Page 3. http://www.awe.co.uk/Contents/Files/AWE_Code_Of_Conduct.pdf (Accessed 15 May 2013).

conscience are not mentioned. Managers at AWE are requested to ensure legal compliance with a person's job responsibilities and to maintain an open environment to examine ethical issues¹¹¹.

However, there appears to be no information in the code to specifically assist universities entering into partnership with AWE in dealing with questions of professional practice and standards, conscience, intellectual property rights, data collection, or publication practices. Although these matters are in part the domain of university ethics committees, provision of such information by AWE would improve transparency and provide clarity to the relationship for all interested parties. We discuss the various kinds of ethical codes which AWE and its partner universities might consider adopting to address such concerns in the next section.

We sought information from AWE directly about their policy on ethical questions and received the following reply:

“AWE seek business arrangements with suppliers, including our academic partners, that provide strategic support to our mission, are committed to delivering increased value on behalf of the taxpayer and demonstrably share our ethos and culture. We will only engage with suppliers and partners that are financially sound and demonstrably competent in the performance and management of their work and meet our assurance standards. We expect all business relations and personal behaviour of these suppliers and partners to be conducted in accordance with AWE business ethics policy”¹¹².

Discussion with representatives of institutions receiving research funding from AWE suggests that ethical and professional standards are expected to be covered by either ethical codes in force at the partner universities or through the personal ethical and professional standards and integrity of the individual researcher. However, none of the websites for AWE's Strategic Alliance partner universities specifically mentions collaboration with sensitive partners such as AWE for research purposes. The ways in which each of the five Alliance universities deal with ethics and the formation and scope of ethics committees varies widely between the five universities. In Bristol there are faculty-level ethics committees¹¹³ and individual ethics officers, whilst at Cambridge the university has Local Ethics Committees which are required to report annually to the University Ethics Committee, governed by the General Board and the University Council. This Committee has the authority to act within approved University policies including those governing research – but the university website¹¹⁴ does not go into detail about ways of ensuring transparency, intellectual rigour or how to settle conflicts of interest in publishing data from collaborations with partners such as AWE.

Heriot-Watt university provides information about its research ethics policy¹¹⁵ but does not address issues which are thrown up by security or commercial confidentiality and the need for transparency. Cranfield university's ethics policy embraces the Nolan Principles which include integrity, objectivity,

¹¹¹ 'Code of Conduct and Business Ethics'. Atomic Weapons Establishment, 2011. Page 5. http://www.awe.co.uk/Contents/Files/AWE_Code_Of_Conduct.pdf (Accessed 15 May 2013).

¹¹² E-mail from AWE dated 1 August 2012.

¹¹³ 'University of Bristol. Ethics of Research Policy and Procedure'. <http://www.bristol.ac.uk/red/research-governance/practice-training/researchethicspolicy.pdf> (Accessed 9 July 2013).

¹¹⁴ 'Ethics in Research'. University of Cambridge website. http://www.admin.cam.ac.uk/offices/research/documents/research/ethics_in_research.pdf (Accessed 15 May 2013).

¹¹⁵ 'Research Ethics Policy and Procedures'. Heriot-Watt University website. http://www.hw.ac.uk/policy/ethical_review_process.pdf (Accessed 15 May 2013).

accountability and openness but does not address issues which are raised by its widespread partnerships with the military sector including AWE¹¹⁶. At Imperial College the Head of Department is expected to judge whether the proposed area of research or collaboration raises any ethical questions and if so then the proposed project will be referred to the Research Ethics Committee – but it is not clear from material available on the Imperial College¹¹⁷ website how the Committee makes its decision and what guidance is provided in the case of collaboration in ‘sensitive’ areas.

The Ministry of Defence also has two research ethics committees, one of which is concerned with general issues whilst the other addresses personnel protection and effectiveness¹¹⁸, but their remit is largely limited to the use of human participation in research programmes. The code of practice for MoD scientists¹¹⁹ does not appear to address the concerns which we raise above, and does not appear to be used in practice to guide research relationships between AWE and universities.

Researchers at institutes collaborating with AWE with whom we spoke were aware of concerns relating to accepting funding from such a source and were quite receptive to the idea of ethical codes of conduct and guidelines to help in managing research with AWE. In the next part of the report we propose ethical guidelines to address potentially difficult issues in UK research in the science, engineering, and technology disciplines, and particularly in those areas which involve the security sector and AWE .

¹¹⁶ ‘Cranfield University Ethics Policy’. http://www.cranfield.ac.uk/about/policies/ethics_policy_2007.pdf (Accessed 15 May 2013).

¹¹⁷ ‘Imperial College Research Ethics Committee’. <http://www3.imperial.ac.uk/researchethicscommittee/icrecprocess> (Accessed 15 May 2013).

¹¹⁸ ‘Research Ethics Committees’ . DSTL website. <http://www.science.mod.uk/engagement/modrec/modrec.aspx> (Accessed 15 May 2013).

¹¹⁹ ‘Ethical Conduct and Scrutiny in MoD research Involving Human Participants’ (JSP 536). http://www.science.mod.uk/engagement/documents/modrec_jsp536.pdf (Accessed 15 May 2013).

4.4 Key issues arising from this section

- Many areas of AWE's scientific research work are conducted in sensitive and controversial areas, raising complex ethical and legal issues.
- Research conducted at universities with support from AWE may well have dual use applications – the capability to be used towards both benign, peaceful purposes or military purposes.
- The dual use nature of research work funded by AWE in universities means that valuable work on nuclear threat reduction and other areas of wide public benefit may be countered by the potential for research which may contribute to the development or proliferation of nuclear weapons.
- Relationships between AWE and universities take place on a formal contractual basis with limited recognition of the ethical issues relating to work funded by AWE.

5. Ethical guidelines and codes of conduct

5.1 The need for ethical guidelines and codes of conduct in scientific research¹²⁰

Over the last twenty years there has been a growing realisation of the power of science, engineering, and technology; the potential for its misuse and impact on security; and in light of growing commercial influence, the need to safeguard the robustness, openness and independence of research in these fields. The significantly increased pace and power of the research process calls for a clear grounding in ethics across all scientific disciplines.

Some elements of scientific ethics – those that deal with compliance with the law and professional standards relating to research work and publication – are well understood and widely accepted within the science community, and are already covered by a range of codes of conduct advocated by professional institutes and others. Other aspects, which can perhaps be described as ‘social responsibility’ – the potential impacts of a particular line of research on society and the environment – are less well embedded in an institutional context, and decisions tend to be left to individual scientists, perhaps in part because these issues relate to more complex situations and reflect personal values rather than universally accepted professional or legal standards.

Research ethics have received particular attention in the biosciences over recent years because of the risks and benefits arising from genetic manipulation and the power to change processes at the molecular level¹²¹. Ethical elements of biological research were an important factor in the debate during 2012 over whether the findings of controversial research on the H5N1 influenza virus should be published, and whether similar research should be conducted in future¹²². Since the events of 11 September 2001 and the anthrax attacks in the USA as well as bombings in Bali, Madrid, London, and Mumbai there have been a number of concerns expressed (including within the pages of scientific journals) about the security threats posed by biological research and the potential of such research for bioweapon development¹²³. Various commentators have raised questions about how threats might arise from biological research and how openly data from biosciences research should be communicated¹²⁴. Even within the science, engineering, and technology community some have suggested that certain research is simply too problematic to be undertaken. There have been calls for codes of conduct in order to guide and restrain research and thereby lessen the potential for the misuse of some research¹²⁵. As a result, research ethics in the life sciences has been subject to

¹²⁰ Our discussions in this section are limited to science, engineering, and technological activities in UK universities; other disciplines were not examined in this study but are recognised as being important for the broad development of ethical guidelines.

¹²¹ See for example: Nancy L Jones: ‘A code of ethics for the life sciences’, *Science and Engineering Ethics*, 13: 25-43, 2007. http://www.openu.ac.il/code_of_ethics/download/A_code_of_ethics_Jones_2007.pdf (Accessed 15 May 2013).

¹²² A S Fauci and F S Collins: ‘Benefits and risks of influenza research: Lessons learned’. *Science* 336; 1522-1523, 2012.

¹²³ B Rappert and C McLeish (Eds): ‘A web of prevention – Biological weapons, life sciences and the governance of research’. Earthscan 2007. A D James (Ed): ‘Science and technology policies for the anti-terrorism age’. NATO Science Series, Amsterdam, IOS Press 2006.

¹²⁴ A D James (Ed), *Science and technology policies for the anti-terrorism age* NATO Science Series, Amsterdam, IOS Press 2006.

¹²⁵ See discussions in B Rappert: ‘Biotechnology, security and the search for limits: An inquiry into research and methods’. London: Palgrave, 2007.

considerable public debate and scrutiny, but there remains a pressing need to extend the discussion to encompass the physical and engineering sciences as well as the biological sciences¹²⁶¹²⁷.

Our experiences with the physical sciences research community and during discussions as part of this study suggest that ethical considerations are not seen as an important part of research culture – even though the same concerns apply as with the biosciences¹²⁸. Dual use issues and the potential role that knowledge and technology could play in enabling the proliferation of weapons of mass destruction or the execution of a large scale terrorist incident are as relevant to work in the physical sciences as the biological sciences. One AWE scientist told us that the Establishment’s stance on issues related to research ethics was that: “MoD sets the guidelines on what experimental work AWE does, and AWE just does what MoD tells us to do as our customer. If you’re the kind of person who worries about that kind of thing you’re probably not the kind of person who will be working at AWE”¹²⁹. It is not uncommon for scientists and engineers – and indeed, professionals in all disciplines – to take this approach and leave decisions on what it is ethical to do to others (generally their superiors or the government), focusing themselves in a narrow sense on the ethics of how research is conducted and results presented.

Some say that the source of funds and the potential impact of the products of research are not ethical issues. However, many others in the science, engineering, and technology communities agree that there is a need for ‘social responsibility’ in science, and that codes of conduct have a part to play in research practice, especially within commercial areas, across all the scientific disciplines¹³⁰. Sir Joseph Rotblat, the nuclear physicist and Nobel peace prizewinner who worked on the Manhattan Project and established the Pugwash initiative to create dialogue on nuclear weapons and disarmament, worked for much of his life to point out that scientists have a responsibility to society and a responsibility to be accountable for their deeds. In his view, scientists should be aware of the consequences of their work and should not knowingly carry out research which would be used to the detriment of humanity. He specifically warned of the risks posed by work on nuclear weapons at research laboratories such as AWE Aldermaston; research which he saw as “the negation of scientific pursuit: the development of new, or improvement of old weapons of mass destruction”. Rotblat felt that it was important that scientists should pledge to use science and technology in socially responsible ways¹³¹.

Codes of conduct have a long history within professional disciplines. In the 19th century codes of conduct were fundamental to the professionalisation of law, medicine and engineering and helped provide a level of public confidence in the reliability of the practitioners. In medicine the ten ethical

¹²⁶ See discussions in P R Wolpe: ‘Reasons scientists avoid thinking about ethics’ Cell 125: 1023-1025 http://repository.upenn.edu/cgi/viewcontent.cgi?article=1015&context=neuroethics_pubs (Accessed 15 May 2013); N Doorn and Ivan de Poel: ‘Editor’s overview: Moral responsibility in technology and engineering’, Science and Engineering Ethics, 18: 1-11, 2012. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3275726/> (Accessed 15 May 2013).

¹²⁷ Marie-Andree Jacob: ‘Scientific Research Integrity – Background Paper’. Nuffield Council on Bioethics Forward Look, 7-8 May 2013. Personal Communication.

¹²⁸ Discussion with research informants, 9 July 2012 and 13 July 2012.

¹²⁹ Discussion with research informant, 12 November 2012.

¹³⁰ R Daly: ‘The Missenden Code of Practice for Ethics and Accountability’. Missenden Centre for the Development of Higher Education. Great Missenden, 2002. <http://www.missendencentre.co.uk/docs/MissCode.pdf> (Accessed 15 May 2013).

G R Evans and D E Packham: ‘Ethical issues at the university-industry interface: A way forward?’ Science and Engineering Ethics 9: 3-16, 2003. http://opus.bath.ac.uk/23275/1/82_Sci_Eng_Ethics_GRE2003.pdf (Accessed 15 May 2013).

¹³¹ Joseph Rotblat: ‘Science and Human Values’. Available online at: <http://www.britishpugwash.org/documents/ScienceandHumanValues.pdf> (Accessed 13 May 2013).

principles enshrined in the Nuremberg Code¹³² resulted from the disclosure of the experiments undertaken by doctors who were part of the Nazi regime. The Helsinki Declaration¹³³ later followed from these guidelines. Professional codes and training are important in helping address issues where doctors may face conflicting loyalties between patient care and other interests perceived to be in the interest of the state, rather than the individual, especially where there may be improper pressures from employing authorities to act contrary to professional principles¹³⁴.

Many of the leading bodies in science, engineering, and technology have discussed and formulated codes of conduct to guide and inform scientists who work in sensitive areas in the biosciences¹³⁵. But there is also a more general sense that ethical codes plus a fully implemented teaching of ethics at the undergraduate level are part and parcel of the development and the provision of the skills set of any responsible scientist¹³⁶, regardless of discipline.

The Royal Society and the Wellcome Trust held a meeting in October 2004 entitled 'Do no harm' which suggested that a science-community-based code of conduct or code of good practice should be put in place. This publication has led to a number of useful discussions about how leadership within the science, engineering, and technology communities could push forward standards of ethical behaviour¹³⁷. Today most UK universities have ethical codes which tend to provide simple guidelines for individuals, but such codes, which are often voluntary and not too onerous, may not address a wide range of potential concerns across the activities of the whole university.

A positive if small step forward in ensuring best practice was the founding in 2006 of the UK Research Integrity Office¹³⁸, which is modestly funded but promotes good practice in research¹³⁹. A further encouraging development is the recent publication by two bodies representing UK universities and funders, Universities UK and Research Councils UK, of a concordat which aims to support research integrity. The publication, 'The concordat to support research integrity' not only addresses research

¹³² <http://ori.dhhs.gov/education/products/RCRintro/c03/b1c3.html>

¹³³ World Medical Association: 'WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects'. <http://www.wma.net/en/30publications/10policies/b3/> (Accessed 15 May 2013).

¹³⁴ Medact: 'Preventing torture. The role of physicians and their professional organisations: principles and practice'. September 2013. <http://www.medact.org/content/health%20policy%20/MED104336%20Medact%20Preventing%20Torture%20WEBSITE%20VERSION.pdf> (Accessed 18 May 2013).

¹³⁵ Royal Society: 'The roles of codes of conduct in preventing the misuse of scientific research'. Royal Society Policy document 03/05, London, Royal Society, 2005 <http://royalsociety.org/policy/publications/2005/misuse-scientific-research/> (Accessed 15 May 2013).

P R Wolpe: 'Reasons scientists avoid thinking about ethics' Cell 125: 1023-1025 http://repository.upenn.edu/cgi/viewcontent.cgi?article=1015&context=neuroethics_pubs (Accessed 15 May 2013).

¹³⁶ A thorough examination and links on biological weapons and the history of codes of conduct can be found in Brian Rappert: 'Biological Weapons & Codes of Conduct'. <http://projects.exeter.ac.uk/codesofconduct/Chronology/index.htm> (Accessed 15 May 2013). See also 'On being a scientist: Responsible conduct in research' Second edition. National Academies 1995. http://astro.berkeley.edu/~kalas/labs/documents/On_being_a_scientist.pdf (Accessed 15 May 2013).

¹³⁷ 'Do no harm: reducing the potential for the misuse of life science research'. Royal Society and the Wellcome Trust, 2004. http://www.wellcome.ac.uk/stellent/groups/corporatesite/@policy_communications/documents/web_document/wtx023408.pdf (Accessed 15 May 2013). L Hibbert: 'On the straight and narrow'. Professional Engineering 32-33; 9 November 2005.

¹³⁸ The UK Research Integrity Office (UKRIO) is an independent charity providing expert advice and guidance about the conduct of research. UKRIO is able to provide guidance to: members of the public, individual researchers and research organisations including universities, NHS bodies, private sector organisations and charities. The aims of UKRIO are to:

- promote the good governance, management and conduct of academic, scientific and medical research;
- share good practice on how to address poor practice, misconduct and unethical behaviour;
- give confidential, independent and expert advice on specific research projects, cases, problems and issues.

¹³⁹ UK Research Integrity Office website. <http://www.ukrio.org> (Accessed 15 May 2013).

misconduct but also suggests that whistleblowers be offered protection¹⁴⁰. The concordat has apparently proved to be very popular with members of the UK research community¹⁴¹.

The International Nuclear Security Education Network (INSEN)¹⁴² was established by members of the research community and the International Atomic Energy Agency (IAEA) in 2010 to foster enhanced global nuclear security by the development and the sharing of best practice and co-operation in nuclear security education. INSEN thus occupies a pivotal place in educating future research scientists and so enhances ethical competence in nuclear science.

However, despite the increasing realisation, both within and outside science, that science is not actually 'value-free'¹⁴³ and that many areas of research throw up ethical dilemmas especially in a commercialised university environment, there is still limited ethical literacy on the part of many in science, engineering, and technology¹⁴⁴, with the physical sciences and engineering lagging behind the social sciences and biological sciences in this respect. Engineers and others in science, education, and technology are expected to follow professional standards and apply sound ethical principles in their work, but teaching has only recently begun to address this need¹⁴⁵. A report published by the Royal Academy of Engineering in 2005 showed that ethics teaching only took place in a minority of UK universities. Of the heads of university engineering departments canvassed, only 4 per cent claimed to deliver a substantial amount of ethics teaching, and about half provided some ethics content in their courses¹⁴⁶. Encouragingly, things have changed since this survey was conducted and most engineering departments now teach some research ethics and have introduced processes for declaring and ensuring good ethical conduct, although these are usually concerned with the way in which research projects are conducted rather than broader social responsibility issues.

At present the ethical codes to be found on the websites of many of the professional bodies representing engineering tend to concentrate upon legal and safety requirements (covering, for instance, environmental damage avoidance, client relations and safety¹⁴⁷). Much less attention is paid to questions of social responsibility, addressing matters such as 'dual use' research, the underpinning

¹⁴⁰ 'The concordat to support research integrity'. Universities UK, London 2012. <http://www.universitiesuk.ac.uk/highereducation/Documents/2012/TheConcordatToSupportResearchIntegrity.pdf> (Accessed 15 May 2013).

A useful discussion of the publication and the need for guidelines for best practice in research is to be found at: A Tavaré and F Godlee: 'Tackling research misconduct'. *BMJ* 345, e5402, 18 August 2012.

¹⁴¹ Information from research informant at Research Councils UK, 24 September 2012.

¹⁴² 'International Nuclear Security Education Network (INSEN)': IAEA webpage. <http://www-ns.iaea.org/security/workshops/insen-wshop.asp> (Accessed 15 May 2013).

¹⁴³ See discussions in H Collins and T Pinch: 'The Golem: What everyone should know about science'. Cambridge University Press, Cambridge, 1993; R Daly: 'The Missenden Code of Practice for Ethics and Accountability'. Missenden Centre for the Development of Higher Education. Great Missenden, 2002. <http://www.missendencentre.co.uk/docs/MissCode.pdf> (Accessed 15 May 2013).

¹⁴⁴ Discussed in L Hibbert: 'On the straight and narrow'. *Professional Engineering*, 9 November 2005, 32-33; and P R Wolpe: 'Reasons scientists avoid thinking about ethics' *Cell* 125: 1023-1025 http://repository.upenn.edu/cgi/viewcontent.cgi?article=1015&context=neuroethics_pubs (Accessed 15 May 2013).

Ruth Chadwick, 'Professional ethics and the 'good' of science', *Interdisciplinary Science Reviews* 30: 247-256, 2005.

¹⁴⁵ S J Bird: 'Editorial: Ethics as a core competency in science and engineering' *Science and Engineering Ethics* Volume 9; Issue 4, 2003. GR Evans and D E Packham: 'Overview: Ethical issues at the university-industry interface: A way forward?' *Science and Engineering Ethics* Volume 9; Issue 4, 2003.

¹⁴⁶ L Hibbert: 'On the straight and narrow'. *Professional Engineering*, 9 November 2005, 32-33.

¹⁴⁷ For example the Royal Academy of Engineering and the Engineering Council have a joint 'Statement of Ethical Principles' at: http://www.raeng.org.uk/news/publications/list/reports/Statement_of_Ethical_Principles.pdf (Accessed 15 May 2013).

The Institution of Engineering and Technology has published 'Rules of Conduct' at: <http://www.theiet.org/about/governance/rules-conduct/> (Accessed 15 May 2013).

The Institute of Electrical and Electronics Engineers has published the 'IEEE Code of Ethics' at: <http://www.ieee.org/about/corporate/governance/p7-8.html> (Accessed 15 May 2013).

issues of conscience, and openness in publishing research findings¹⁴⁸, although there are indications that there are many in the physical sciences keen to introduce such dimensions to their discipline¹⁴⁹. The Royal Academy of Engineering and the Engineering Professors' Council Teaching Engineering Group are aware that ethics are a pivotal part of engineering and should be taught as an integral part of the engineering curriculum. The Group suggests that practitioners should "understand the nature of professional responsibility and ... identify ethical elements in decisions"¹⁵⁰. The University of Leeds Inter-Disciplinary Ethics Applied Centre critiques the importance of ethics to engineers and draws together the initiatives being undertaken in the UK at present¹⁵¹.

¹⁴⁸ See: J Uff, 'Engineering ethics: Do engineers owe duties to the public?' Royal Academy of Engineering. https://www.raeng.org.uk/news/publications/list/lectures/Engineering_Ethics_Lecture.pdf (Accessed 15 May 2013).

¹⁴⁹ N Doorn and I van de Poel: 'Editor's overview: Moral responsibility in technology and engineering'. *Science and Engineering Ethics*, 18: 1-11; 2012. J Li and S Fu, 'A systematic approach to engineering ethics education'. *Science and Engineering Ethics*, 18: 339-349, 2012.

¹⁵⁰ Royal Academy of Engineering: 'An engineering ethics curriculum map'. http://www.raeng.org.uk/news/releases/pdf/ethics_curriculum_map.pdf (Accessed 15 May 2013).

¹⁵¹ 'Inter-Disciplinary Ethics Applied Centre'. University of Leeds website. http://www.leeds.ac.uk/arts/info/125160/inter-disciplinary_ethics_applied_centre/ (Accessed 15 May 2013).

5.2 Use of ethical guidelines and codes

To address the changing role of research in UK universities and the dilemmas discussed above we will apply some of the rationale for shaping ethical conduct that has been published recently in the scientific literature. When dealing with research funded by organisations such as AWE, we particularly need to recognise potential military and dual use applications, although more general concerns about commercialisation, short-term economic goals and the erosion of the traditional university ethos may also apply. The interested reader can follow the detailed arguments to be found in the footnote references below and in the supporting essay.

Scientists and others in the science, engineering, and technology sector have two fundamental kinds of responsibilities: one concerns the basic research approaches followed by professional scientists, particularly those aimed at ensuring robust, evidence-based findings and the need to match best practice in their discipline. The second responsibility focuses on social responsibility to the wider community and the environment. This latter responsibility involves the potential risks, costs and benefits posed to society and the biosphere. It may also include support of various kinds for scientific practitioners facing issues of conscience¹⁵².

Typically, the first kind of responsibility is well understood and covers, according to Carlson and Frankel¹⁵³, nine areas: data processing; conflicts of interest; experiments on human subjects; animal usage; research misconduct; publication practices and responsible authorship; training in research; peer review; and collaboration. As the authors point out, far less attention is traditionally paid to the second area – the social responsibility of scientists – where the issues are often far more complex and contested. Assessing the impacts of emerging technologies and the related need for better communication about science and technology are also part of the responsibility of scientists and engineers – issues which are seldom covered by the codes of conduct or guidelines concerning research or teaching which we examined. Encouraging public scrutiny and debate on the relationships between science, engineering, and technology and human rights and environmental damage is another part of the responsibility of scientists and engineers which also tends to be neglected in professional codes and guidelines.

In 2007 the UK government's then Chief Scientific Advisor, Sir David King, launched a 'Universal ethical code for scientists'¹⁵⁴ which was a voluntary code, intended to raise the profile of broad ethical concerns within the scientific community. It partly addresses the second set of responsibilities and goes some way to recognising that practitioners in science, engineering, and technology do have a responsibility to engage with and take account of public concerns. However, even the King 'Universal Code' has some blind spots: for instance it does not prohibit work on weapons of mass destruction (including nuclear weapons) and appears to be unclear about the distinction between ethical and legal

¹⁵² Such support has been instrumental not only in the non-governmental organisations such as Scientists for Global Responsibility and European Social Forum but the Center for Engineering, Ethics and Society in the USA – for more on the latter see: 'Centre for Ethics, Engineering, and Society (CEES)', National Academy of Engineering website.. <http://www.nae.edu/26187.aspx> (Accessed 15 May 2013).

¹⁵³ R Carlson and M S Frankel: 'Reshaping responsible conduct of research education'. Professional Ethics XXIV, No: 1, Winter 2011 at: <http://shr.aaas.org/newsletter/per/archives/newper64.shtml#Cover> (Accessed 15 May 2013). See also R Daly: 'The Missenden Code of Practice for Ethics and Accountability'. Missenden Centre for the Development of Higher Education. Great Missenden, 2002. <http://www.missendencentre.co.uk/docs/MissCode.pdf> (Accessed 15 May 2013).

¹⁵⁴ Department of Trade and Industry [now the Department of Business, Innovation, and Skills]: 'Rigour, respect and responsibility: a universal ethical code for scientists'. See archival material at: http://webarchive.nationalarchives.gov.uk/+http://www.dti.gov.uk/science/science-and-society/public_engagement/code/page28030.html (Accessed 15 May 2013).

obligations. As in ethical codes produced by some of the UK professional bodies, the King ethical code stresses that one should ‘ensure that your work is lawful and justified’ which does not address concerns about research which is within the law but unethical¹⁵⁵. A further problem which besets all ethical codes and guidelines is the question of maintaining the balance between responsibly enforcing ethical practices in science, engineering, and technology and being so rigid that a non-voluntary code inhibits research excessively¹⁵⁶.

The need for an increased ethical awareness within the science, engineering and technology community was recognised by UNESCO in 1998 with the setting up of the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST). This advisory body consists of scholars from science, engineering and technology as well as from legal, philosophical and political disciplines to formulate ethical principles that are intended to provide decision-makers with criteria that extend beyond purely economic considerations¹⁵⁷.

The teaching of a broadly-based ethical understanding (and the range of possible uses for research) for all those entering the scientific and engineering professions would go a long way to providing the tools needed to make fully informed and considered decisions. The IAEA’s INSEN programme mentioned above goes some way towards such a provision in the specific field of nuclear safety. The general need for enhanced ethical education was suggested in 2003 at a high profile UNESCO international conference¹⁵⁸, and by the launch in 2005 by UNESCO of a Global Ethics Observatory¹⁵⁹ (GEObs) which collected an online network of databases containing global ethics information from scientists with ethical expertise, as well as from ethical institutions, ethics teaching programmes, guidelines, codes and resources in ethical issues in science, engineering, and technology¹⁶⁰. There have also been a number of publications, including resources from the American Association for the Advancement of Science¹⁶¹ and the International Network of Engineers and Scientists for Global Responsibility (INES)¹⁶² which stress the importance of ethical education in the fullest sense. The European Science Foundation also produces briefing papers which highlight a range of issues in science, engineering, and technology which call for deeper examination¹⁶³. Similar resources are also available from Scientists for Global Responsibility in the UK¹⁶⁴.

¹⁵⁵ S Parkinson: ‘The universal ethical code for scientists – how good is it?’ In Scientists for Global Responsibility Newsletter Issue 35, Winter 2008.

¹⁵⁶ See discussion of dual use and the biosciences in C McLeish: ‘Reflecting on the problem of dual use’. In: ‘A web of prevention’, B Rappert and C McLeish (Eds), Earthscan, London, 2007, 189-207.

¹⁵⁷ ‘World Commission on the Ethics of Scientific Knowledge and Technology (COMEST)’. UNESCO website. <http://www.unesco.org/new/en/social-and-human-sciences/themes/global-environmental-change/comest/> (Accessed 15 May 2013).

¹⁵⁸ ‘Ethics Education Programme’. UNESCO website. <http://www.unesco.org/new/en/social-and-human-sciences/themes/bioethics/ethics-education-programme/> (Accessed 15 May 2013).

¹⁵⁹ J L Sta. Ana: ‘The ethical responsibility of monitoring science and technology – Is the focus of ethicists in developed nations too narrow?’ Professional Ethics Report XXII, Number 1, Winter 2009. <http://shr.aaas.org/newsletter/per/archives/per56.pdf> (Accessed 15 May 2013).

¹⁶⁰ J Li and S Fu: ‘A systematic approach to engineering ethics education’. *Science and Engineering Ethics* 18: 339-349, 2012.

¹⁶¹ ‘Integrity in scientific research: Resource guide’. American Association for the Advancement of Science website. <http://www.aaas.org/spp/video/resource.htm> (Accessed 15 May 2013).

¹⁶² ‘Ethical Principles’. INES website. <http://www.inesglobal.com/ethical-principles.phtml> (Accessed 15 May 2013).

¹⁶³ ‘Science policy briefings’. European Science Foundation website. <http://www.esf.org/publications/science-policy-briefings.html> (Accessed 15 May 2013).

¹⁶⁴ ‘Ethical careers project: Main outputs’. Scientists for Global Responsibility website. <http://www.sgr.org.uk/projects/ethical-careers-project-main-outputs> (Accessed 15 May 2013).

Clearly there are many fora in which ethical dimensions of science, engineering, and technology are currently being discussed and where professional bodies and non-governmental organisations are examining both newly emerging issues and those which are still unresolved. However, there needs to be the political will and vision on the part of governments, educators, and funders of scientific research to ensure that such guidelines are embedded in the funding and evaluation process.

It is also essential to provide space for those scientists who are facing difficult ethical choices to have their concerns taken seriously. Cambridge University¹⁶⁵ and the Institute of Physics¹⁶⁶ have good points in their web-based guidelines for sound research practice which embrace the need for the provision of such a space, as does the UK Research Integrity Office¹⁶⁷.

There are examples of good practice in addressing ethical issues in UK universities (see text box 'The ethical framework at the University of Leeds'). University and business ethical committees could be strengthened by inviting more practitioners and experts on ethics to sit on them, and giving such committees greater power to advise and influence on how scientists might avoid ethical dilemmas and on making decisions in difficult areas fully transparent. Sustained funding for the UK Research Integrity Office would help in developing a one-stop shop for ethical guidance, providing the kinds of support, including teaching materials, that we describe.

¹⁶⁵ 'Good Research Practice'. University of Cambridge website. http://www.admin.cam.ac.uk/offices/research/documents/research/Good_Research_Practice.pdf (Accessed 15 May 2013).

¹⁶⁶ 'Code of Professional Conduct'. Institute of Physics website. https://www.iop.org/about/royal_charter/file_38393.pdf (Accessed 15 May 2013).

¹⁶⁷ UK Research Integrity Office website. <http://www.ukrio.org/> (Accessed 15 May 2013).

Text Box 7: The ethical framework at the University of Leeds

The University of Leeds is an example of a university where the importance of ethical issues has been grasped at the most senior levels, and senior academics have shown leadership in attempting to develop an ethical framework which is embedded at all levels in the university.

The University Council has published its research ethics policy, which is reviewed annually¹⁶⁸, and has established a University Research Ethics Committee. Responsibility for review of research projects is delegated to Faculty Research Ethics Committees, with representation from senior research staff, student representatives and lay members.

The University's ethical policy sets out a number of areas where proposed research must be reviewed by the appropriate research ethics committee, but also states that research that may raise other significant ethical issues should also be referred for advice and / or review. If in any doubt, researchers must seek advice on the proposed project. The policy makes it clear that the purpose of ethical review is not to discourage controversial or high-risk research but to help recognise and prepare for any risks in the pursuit of knowledge.

To help support researchers, the University of Leeds Research and Innovation Service has published a webpage on good practice and ethics¹⁶⁹. The University's Staff and Departmental Development Unit offers a programme of research ethics courses designed for academic and research staff in any discipline¹⁷⁰ and online training materials in ethics are also available¹⁷¹.

The University of Leeds has established the Inter-Disciplinary Ethics Applied Centre to help students, professionals, and employees to identify, analyse and effectively respond to the ethical issues they encounter in their disciplines and their working lives. Drop-in centres are open to provide advice on projects and ethical issues¹⁷².

The grounding in ethics provided by the University is valued by students¹⁷³ and gives them an advantage when seeking employment.

Although not perfect, the approach taken at Leeds is a model which other universities could adapt to help address ethical dilemmas in their own institutions.

¹⁶⁸ 'University of Leeds Research Ethics Policy'. January 2013. http://researchsupportarchive.leeds.ac.uk/images/uploads/docs/Research_Ethics_Policy.pdf (Accessed 18 May 2013).

¹⁶⁹ 'Good practice & ethics'. University of Leeds Research and Innovation Service webpage. <http://ris.leeds.ac.uk/goodpractice> (Accessed 18 May 2013).

¹⁷⁰ 'Research ethics courses'. Staff and Departmental Development Unit, University of Leeds. <http://www.sddu.leeds.ac.uk/sddu-research-ethics-courses.html> (Accessed 18 May 2013).

¹⁷¹ 'Research ethics materials wimba 2.doc' University of Leeds website. <https://vlebb.leeds.ac.uk/bbcswebdav/orgs/INTF00001/Ethics%20reviewers%20materials/Research%20ethics%20materials%20wimba%202/index.htm> (Accessed 18 May 2013).

¹⁷² 'Inter-Disciplinary Ethics Applied Centre'. University of Leeds website. http://www.leeds.ac.uk/arts/info/125160/inter-disciplinary_ethics_applied_centre//# (Accessed 18 May 2013).

¹⁷³ 'Student voices' Inter-Disciplinary Ethics Applied Centre. University of Leeds website. http://www.leeds.ac.uk/arts/people/125160/inter-disciplinary_ethics_applied_centre/20/student_voices (Accessed 18 May 2013).

5.3 Dual use issues, AWE and UK universities

Research collaboration between AWE and the university sector may give rise to any of the ethical issues which are discussed above, but a fundamental aspect of AWE's work is particularly important in this respect. As has been discussed above, expertise in scientific disciplines of interest to AWE can be used not only in civilian applications, but also in applications which relate directly to the development and design of nuclear weapons. Research supported by AWE is often likely to have 'dual use' applications, and without appropriate countermeasures, there is a risk that knowledge derived from this research may be used to assist in the proliferation of nuclear weapons. The Royal Society recognised this in its 2011 report on 'Fuel cycle stewardship in a nuclear renaissance', stating: "To ensure nuclear skills continue to be used responsibly, education and awareness raising courses on nuclear non-proliferation and nuclear security should be included in relevant university and industrial training courses. As part of their induction, researchers at postgraduate level could be informed about the ethical and legal responsibilities relating to their work"¹⁷⁴.

Mark Frankel has recently discussed dual use research and its problems and regulation in the pages of the journal 'Science'¹⁷⁵. Although writing about the recent controversy over the H5N1 influenza virus and the intervention of government in the publication of research into the infectivity of the virus, Frankel's analysis is relevant to nuclear science and the dual use issues involving AWE and its collaborators. The H5N1 controversy is important for a number of reasons, most especially as it highlights the responsibilities of researchers and the potential for research (when in the public domain) to be used for the public good and/or for harmful purposes¹⁷⁶. Research in nuclear science poses similar issues to those raised by the H5N1 controversy since such research may generate information which is of value to nuclear threat reduction programmes, but may also be open to misuse by hostile or irresponsible parties, or could aid the development of nuclear weapons. It is our view that ethical guidelines, together with appropriate education programmes for researchers about the risks and benefits of developments in science, engineering, and technology, would go a long way to help in addressing dual use dilemmas. Again, the Royal Society takes a similar view, stating: "Codes of conduct can serve as a valuable education tool to address the risk that scientific research will be misused ... They can remind scientists of their legal and ethical responsibilities, and to consider both the benefits and potential consequences of dual use research. By involving extensive consultation amongst the target groups, the process of producing these codes is itself an important mechanism to raise awareness"¹⁷⁷.

¹⁷⁴ 'Fuel cycle stewardship in a nuclear renaissance'. Royal Society Policy Report, October 2011. Paragraph 3.3.2, page 19. Available online at <http://royalsociety.org/policy/projects/nuclear-non-proliferation/report/> (Accessed 15 May 2013).

¹⁷⁵ M S Frankel: 'Regulating the boundaries of dual-use research'. *Science* 336; 1523-1525, 2012; and also A S Fauci and F S Collins: 'Benefits and risks of influenza research: Lessons learned'. *Science* 336; 1522-1523, 2012. See also comments by Bruce Alderts in 'Science Magazine Podcast Transcript', 22 June 2012. Available online at http://www.sciencemag.org/content/suppl/2012/06/20/336.6088.1599-b.DC1/SciencePodcast_120622.pdf (accessed 2 July 2013).

¹⁷⁶ See Editorial: 'For better or worse', *Nature* 484, 415, 2012. doi:10.1038/484415a. B Maher: 'Bird-flu research: The biosecurity oversight'. *Nature* 485, 431-434 May 2012 doi:10.1038/485434a. Y Kawaoka: 'Flu transmission work is urgent'. *Nature* 482, 155 9 February 2012 doi:10.1038/nature10884. Cameron Neylon: 'Science publishing: Open access must enable open use'. *Nature* 492, 348-349, 19 December 2012 doi 10:1038/492348a.

¹⁷⁷ 'Fuel cycle stewardship in a nuclear renaissance'. Royal Society Policy Report, October 2011. Paragraph 3.3.2, page 19. Available online at <http://royalsociety.org/policy/projects/nuclear-non-proliferation/report/> (Accessed 15 May 2013).

5.4 Practical issues in developing ethical guidelines or codes of conduct

To be useful, ethical guidelines need to be robust yet be clearly seen as pragmatic and applicable by those members of the scientific community who will apply them. This report proposes a set of model ethical guidelines which could be adopted by university researchers who work on research with dual use potential in nuclear weapons science or in collaboration with AWE (see text box ‘Model ethical guidelines covering research with dual use potential in nuclear weapons science’). They have been developed with the following points in mind.

- Ethical guidelines need to be relatively brief and accepted by both AWE and those co-operating in research with the Establishment. Those co-operating include individual researchers, universities, research councils, the Ministry of Defence and other stakeholders involved in research and development with the Establishment.
- Ethical guidelines are most likely to be adopted if they add to existing guidelines at AWE and universities, research councils, and the UK Research Integrity Office.
- Consultation on the introduction of ethical guidelines is vital, and discussion on guidelines at professional meetings and forums is invaluable in developing them further, collecting a wide range of views on ethical issues from researchers and practitioners, and addressing how they might work in practice. Consultation with AWE and those co-operating in research with AWE and the broader security sector will, of course, be particularly important in relation to guidelines which aim to promote critical thought about research funded by the Establishment.
- Consultation with professional bodies such as the Institute of Physics, Royal Academy of Engineering, and the Royal Society will also be important in developing relevant guidelines and promoting their adoption among scientists. Consultation with organisations such as Scientists for Global Responsibility, the European Science Foundation and the International Network of Engineers and Scientists for Global Responsibility will allow experience of members’ ethical dilemmas to be drawn on.
- There are limitations to the effectiveness of ethical guidelines and codes of practice which should be recognised. Guidelines are not a substitute for sound and far reaching decisions on science policy, a commitment to openness and transparency in research programmes, and open and frank debate on contentious issues on the university campus.
- Ethical guidelines must be seen to be robust and universally applicable, and result in better professional and ethical standards. Toothless guidelines may serve as little more than a public relations exercise covering up poor ethical commitment, and do not address the problems they are intended to address. Ethical guidelines must apply to institutions and their practices and not just to the individual researcher.
- Ultimate responsibility for the direction of a research project lies with the researcher themselves. At the same time, researchers may often need help and support from their host institutions and others in thinking through ethical dilemmas and defining their responsibilities. Academic institutions involved in sensitive areas of research should provide teaching and training on research ethics,

social responsibility, and dual use dilemmas as part of the curriculum for courses in the subject areas in question, and should ensure that researchers working on collaborative projects have an adequate understanding of the ethical issues involved.

- Guidelines cannot cover detailed consideration of every individual case. Situations where people have completely different ideas about whether a course of action is acceptable or not should not be avoided but confronted and discussed openly and widely. Institutions should provide a supportive structure that encourages wide discussion and constructive debate in such cases.

Text Box 8: Model ethical guidelines covering research with dual use potential in nuclear weapons science

The purpose of the model guidelines

Ethical guidelines need to be based on clearly articulated ethical principles. In the case of research work which may have the potential to assist in the development of nuclear weapons, we propose that these principles should be the international legal principles which outlaw the development and use of weapons of mass destruction (see earlier text box ‘Key international agreements relating to weapons of mass destruction’).

1. All ethical guidelines, including this set, should be used as an integral part of the process of applying professional judgement and practice, providing a state-of-the-art skills set aimed at assisting practitioners of science, engineering and technology to make principled decisions in the public interest.
2. The model ethical guidelines we are proposing encompass issues which we do not believe are at present covered by the many different codes of practice drawn up by universities, commercial organisations or the UK research councils. The guidelines provide a broad ethical framework covering security issues, dual use research and technology in the nuclear arena, and a range of concerns stemming from the recognition that science and technology are not value-free and that an individual has the right to follow their conscience. The guidelines are intended to start a conversation on ethical issues relating to AWE-university partnerships.
3. The complex nature of AWE-university collaboration (including contracts with individual university researchers as well as institutional partnerships) involves both commercial sensitivities and a range of security issues and thus calls for a more comprehensive set of ethical guidelines than those currently in place at universities, professional bodies and AWE. It should also be recognised that different areas of research will throw up a variety of different complex issues which may not be regularly encountered in other ‘non-security’ ethical contexts.
4. The model ethical guidelines presented in this study should be used alongside existing guidelines at AWE and universities. They could also be applied where AWE funds or co-funds scientific education and training in schools and in managing AWE’s interactions with professional bodies such as the Institute of Physics.
5. Ethical committees at AWE, universities, and peer review panels at research councils play an important role in the implementation of the guidelines. Committees which use these guidelines should include not only representatives from the participating institutions among their members, but also non-partisan representatives appointed to help safeguard the public interest and those who have independent expert knowledge of security and ethical areas. Such committees need to meet regularly and be prepared to offer informed guidance often within tight deadlines. It may be necessary to strengthen existing ethical committees and processes in order to meet the demands of the guidelines we are proposing, and broaden their remit to look beyond issues relating solely to compliance with the law.
6. Collaborative ventures or projects with universities which involve AWE, the Ministry of Defence or others in the security arena should be examined by an ethics committee to assess the public value of the intended programme.

Model ethical guidelines

1. All university staff and students participating in AWE-university partnerships must take personal responsibility for understanding the range of potential impacts that may arise from the intended research on the environment, human rights and wellbeing globally, and on the potential proliferation or development of nuclear weapons. In some cases this responsibility might involve seeking expertise from outside the research community.

2. Collaboration should support the aims of the key international treaties relating to the control of weapons of mass destruction. Work with potential dual use outcomes that could undermine the objects of these treaties should not take place in universities. Specific mechanisms should be put in place to assess whether 'blue skies' research funded by AWE will pass this test and ensure that such research will be targeted at disinterested end-points and the broader public interest. Space should be created to allow consideration and discussion of such issues before decisions to undertake research with AWE are taken.

3. There should be full transparency concerning collaboration between AWE and university researchers, wherever possible, and the output from such funding, including patents, publications and presentations should be easily accessible in the public domain. This process should include disclosure of the collaboration with names of researchers, quantities and sources of funding. Details of research studies should be published in public spaces such as websites and press briefings prepared by participating universities, AWE, the Ministry of Defence and / or the UK research councils.

Comment: Clarity and ease of public access should be made central to the processes of funding research. Interested individuals should be able to identify who funds university research, the nature of the funding (whether it is from commercial or disinterested sources), and any linked sources of funding. This clarity is especially important where public funds are involved, in order to stress transparency and public accountability and to allow the public to see how their money is being used.

4. Clear instructions should be widely circulated on how and under what circumstances concerns about unethical or irresponsible behaviours can be reported to those in an appropriate position to take action.

Comment: Such 'whistle-blowing' arrangements are well covered at the Institute of Physics website, (although without touching on security research¹⁷⁸), and in the joint concordat from Universities UK and Research Councils UK¹⁷⁹. Instructions should be given to those involved in joint research programmes together with guidance on well-defined ways in which intellectual property rights and openness should be protected across teaching, research and training¹⁸⁰.

5. Security-classified research should only be undertaken by AWE in-house staff and not by university researchers, or in university facilities, in order to facilitate an open university environment for publishing and discussing research¹⁸¹.

¹⁷⁸ 'Code of Professional Conduct'. Institute of Physics website. https://www.iop.org/about/royal_charter/file_38393.pdf (Accessed 15 May 2013).

¹⁷⁹ 'The concordat to support research integrity'. Universities UK, London 2012. <http://www.universitiesuk.ac.uk/highereducation/Documents/2012/TheConcordatToSupportResearchIntegrity.pdf> (Accessed 15 May 2013).

¹⁸⁰ For an overview of the ethical issues associated with whistle-blowing see 'Whistleblowing: Ethical and Legal Issues in Expressing Dissent'. James C. Petersen and Dan Farrell. Kendall / Hunt Publishing Company, Iowa. 1986. Available online at http://ethics.iit.edu/publication/WhistleBlowing_PetersonI.pdf (Accessed 24 August 2013).

¹⁸¹ We are aware that it is often difficult to clearly define the differences between research that is of a classified nature from that which is not. Making

Comment: Some US universities, such as the Massachusetts Institute of Technology¹⁸², have taken the view that classified research should not take place on the campus of the institution itself. Lessons on how to deal with research in controversial areas whether or not there are potential ‘dual use’ implications can be learnt from the debate on publication of research findings concerning the avian flu virus and its manipulation¹⁸³. These lessons are likely to include having a fully-informed discussion involving those with significant knowledge of the research area at an early stage of the publication process, taking steps to ensure that as far as possible no harm is caused by publication of potentially dual use research findings, and ensuring that all involved in dual use research are fully aware of the ethical issues involved¹⁸⁴.

6. There should be a paramount right for university staff and students to have freedom of investigation, publication after peer review and the dissemination of data arising from research undertaken through an AWE contract or funding.

7. Publication of the findings of research funded by AWE should follow guidance from the Committee on Publication Ethics (COPE)¹⁸⁵, and clearly show the source of funding and acknowledge any conflicts or potential conflicts of interest in publications that arise from the collaboration.

8. University ethics committees, AWE’s Corporate Ethics Manager (and, at the programme level, possibly also the UK Research Integrity Office) should be approached to provide pro-active advice and guidance and give a robust ethical evaluation of proposed research projects and advise whether they are in the public interest. The emphasis should be on publicly available knowledge creation rather than short-term economic collaboration where researchers in universities function as close-to-patentable R&D departments for their commercial clients¹⁸⁶.

9. Conflicts of interest, bias and censorship should be dealt with by ethics committees whose primary objectives are to allow the pursuit of disinterested research (which has potential broad value to the public and the knowledge base) of the highest quality and maintain standards of academic freedom and transparency.

10. Ethics committees responsible for implementing these model guidelines should contain not only representatives from the participating institutions but also non-partisan representatives appointed to help safeguard the public interest as well as those who have independent and expert knowledge of security and ethical areas.

such a distinction would call upon the expertise not only of experienced researchers but also those with security knowledge and clearance.

¹⁸² ‘MIT panel urges off-panel sites for classified research’. MIT news release, 12 June 2002. <http://web.mit.edu/newsoffice/2002/classified-0612.html> (Accessed 17 May 2013).

¹⁸³ ‘Declan Butler: Caution urged for mutant flu work’ Nature 481 417-8, 26 January 2012. <http://www.nature.com/news/caution-urged-for-mutant-flu-work-1.9882> (Accessed 17 May 2013).

¹⁸⁴ R R Faden and R A Karron, ‘The obligation to prevent the next dual use controversy’, Science, 335:802-804, 17 February 2012. <https://www.sciencemag.org/content/335/6070/802.full> (Accessed 17 May 2013). Cameron Neylon: ‘Science publishing: Open access must enable open use’. Nature 492, 348-349, 19 December 2012 doi 10: 1038/492348a.

¹⁸⁵ ‘Guidelines’. Committee on Publication Ethics website. <http://publicationethics.org/resources/guidelines> (Accessed May 2013).

¹⁸⁶ D F Thompson: ‘Restoring responsibility: Ethics in government, business and healthcare’. Cambridge, Cambridge University Press, 2005.

6. Conclusions

This report examines in detail the key areas in which collaboration is undertaken between the Atomic Weapons Establishment and UK universities. The process of collaboration which we outline focuses on funding provided by AWE and various co-funding programmes which involve AWE and the research councils or other partners. Data was obtained using the Freedom of Information Act 2000 and from other sources to identify means of collaboration between AWE and UK universities, and provide a more detailed analysis of AWE links with its five 'Strategic Alliance' universities – Bristol, Cambridge, Cranfield, Heriot-Watt and Imperial College. Fifty universities receive funds from AWE – a significant proportion (almost half) of all UK universities. Funds from AWE support not only research but also training, teaching, conferences, consultancies and support for fellowships and studentships.

Commercial factors favour the partnering of UK universities with AWE and other businesses with military interests, and such businesses benefit in a number of ways from the expertise which resides in the university sector through collaboration on research and also in teaching and training. We have provided case studies of situations in which AWE has provided significant funding to create a concentration of expertise to address areas of interest to the Establishment.

In addition to mapping areas which are of potential concern in the collaboration between AWE and universities we have also discussed how ethical guidelines or codes – which have increasingly become part of the research and teaching of science, engineering, medicine and technology – have particular importance for research in which security or military work is involved, and present a set of model guidelines which could be used to manage research work funded by AWE in UK universities, and help in addressing the associated ethical issues.

The study drew out three general issues of potential concern in relation to collaboration between AWE and universities:

1. The need for increased transparency: Data was gathered for this study through Freedom of Information requests put to the Ministry of Defence and AWE's Strategic Alliance Universities, plus interviews, web-based data collection and desk research concerning research, teaching and training at UK universities. We found that responses to requests for information were often patchy and that only a limited amount of information is available from published sources. This suggests that there is a need for greater transparency from both AWE and universities about their collaborative work – particularly so given that such work is funded from the public purse. The current process does not present easily accessible ways for the public to see how or where public money is being spent or judge the value for money from such funding.

Although Ministers have stated that no security-classified work is undertaken at universities on behalf of AWE, a clearer statement of the objectives, nature, and purpose of research conducted by universities for AWE would be useful.

2. The impact upon the research environment: During this study we found that academics were sometimes reluctant to discuss work funded by AWE which was underway within their departments. In addition, there is a risk that such work might reduce the amount of civilian research and innovation (including 'blue skies' research) which takes place in departments in receipt of funding from AWE or the military sector.

3. A weak framework for considering ethical implications: Significant amounts of public funding, obtained through taxation, are being spent on controversial areas of research, often without clear ethical guidelines being in place and with a low level of public accountability. The increasingly commercialised nature of universities also raises a number of important questions about intellectual integrity and objectivity¹⁸⁷. This report presents the case for introducing ethical guidelines to help in managing research with dual use nuclear implications and suggests ways in which they can be implemented.

¹⁸⁷ R Daly: 'The Missenden Code of Practice for Ethics and Accountability'. Missenden Centre for the Development of Higher Education. Great Missenden, 2002. <http://www.missendencentre.co.uk/docs/MissCode.pdf> (Accessed 15 May 2013).
'Keeping science open: the effects of intellectual policy property on the conduct of science'. Royal Society policy document 02/03/2003. April 2003. <http://royalsociety.org/policy/publications/2003/keeping-science-open/> (Accessed 15 May 2013).
These sources discuss what some of these concerns are and their are valuable sources of further information on the changes which UK universities have undergone and the challenges which they face.

7. Recommendations

1. AWE should adopt a set of ethical guidelines (based on the model guidelines which we propose) to manage relationships under its Technical Outreach programme and require universities and institutes with which it collaborates to adopt code of conducts similar to the model guidelines.
2. Universities should voluntarily adopt ethical guidelines similar to the model guidelines which we propose to cover research and development in the physical sciences (and other areas) where there are potential 'dual use' applications, and increase the quality of training in ethical awareness for students and researchers.
3. As a major research institute in its own right, AWE should review its own Code of Ethics to address the issues raised in this report and adopt guidelines for its scientific staff along the lines of the model guidelines we propose.
4. Ethical committees in universities and AWE itself should be more pro-active in advising all who receive funds from AWE that they have personal responsibility for the research which they undertake and the outcomes of their investigations. These committees should have representatives with expertise in security and ethical issues together with independent advisers representative of the public interest.
5. AWE should publish an annual report outlining the programmes it has funded in universities, the level of funding provided, papers and publications arising from these research programmes, and key findings. The report should include a clear statement of the objectives, nature, and purpose of research programmes conducted at universities for AWE.
6. An independent audit of the impact of AWE funding or co-funding on research output and training in universities should be periodically undertaken (say every five years) in order to assess the results, effectiveness, and value for money resulting from such funding.

Supporting Essay:

University research in the modern world: The influences of commercialisation and the military

I. Scientific research in modern universities

Today's world is highly complex, interconnected and dynamic. Rapid changes, especially in science, engineering and technology are impacting on all our lives. It is not only the speed of change but also the potential power of new technologies (for example, nanotechnology, synthetic biology, robotics, and technologies with security applications such as surveillance and recognition technology, personal profiling and data-mining) and their future impacts on our lives which, for many, sound warning bells¹⁸⁸.

The increasing involvement of global financial institutions in setting the direction and driving the development of science, engineering, and technology, often with the active encouragement of governments in a limited number of wealthier countries, tends to undermine citizen involvement in public decision-making (see, for example, David Beetham on the context of the influence of multinational corporations in the UK today¹⁸⁹). These issues need to be kept in mind when the impact of science, engineering, and technology on society is discussed¹⁹⁰.

We currently face major global issues such as climate change, the proliferation and control of weapons of mass destruction, including nuclear weapons, energy, food, and water security, geopolitical instability and growing corporate power. These issues are increasingly becoming felt in the lives of every citizen on the planet, especially the poor. Human innovation, through advances in science, engineering, and technology, will have a key role to play in tackling these challenges. Independence, openness, robustness, and a firm ethical-grounding are important qualities underpinning scientific research undertaken with the aim of benefiting humanity as a whole, rather than the enrichment of a minority¹⁹¹.

There has been a growing recognition over the past twenty years of the need for strong ethical guidelines in directing both business and science, engineering, and technology. The Committee on Standards in Public Life – an independent advisory non-departmental public body – was set up in 1994 to ensure integrity, transparency and accountability in government and related areas, and the Committee's work has also had an impact on the working environment within the science,

¹⁸⁸ For a non-partisan discussion on synthetic biology see the Synbiosafe website: <http://www.synbiosafe.eu> (Accessed 18 May 2013) and Anon, 'Publishing risky research', *Nature* 485; 5; 3 May 2012. doi 10.1038/485005a <http://www.nature.com/nature/journal/v485/n7396/full/485005a.html> (Accessed 18 May 2013).

On security technology see William J. Perry: 'Technology and National Security: Risks and Responsibilities'. Address at Stanford University, 7-8 April 2003. <http://stanford.edu/dept/france-stanford/Conferences/Risk/Perry.pdf> (Accessed 18 May 2013).

¹⁸⁹ David Beetham: 'Unelected Oligarchy: Corporate and Financial Dominance in Britain's Democracy'. *Democratic Audit*, 2012. <http://filestore.democraticaudit.com/file/de232c951e8286baa79af208ac250112-1311676243/oligarchy.pdf> (Accessed 18 May 2013).

¹⁹⁰ J Poyago-Theotoky, J Beath and D S Siegel: 'Universities and fundamental research: Reflections on the growth of university-industry partnerships'. *Oxford Review of Economic Policy* 18; 10-21, 2002. M Leach, I Scoones and B Wynne (Eds): 'Science and citizens'. Zed Books, London, 2005.

¹⁹¹ R Daly: 'The Missenden Code of Practice for Ethics and Accountability'. Missenden Centre for the Development of Higher Education. Great Missenden, 2002. <http://www.missendencentre.co.uk/docs/MissCode.pdf> (Accessed 15 May 2013). 'Keeping science open: the effects of intellectual property on the conduct of science'. Royal Society policy document 02/03/2003. April 2003. <http://royalsociety.org/policy/publications/2003/keeping-science-open/> (Accessed 15 May 2013).

engineering, and technology sector¹⁹². Political decisions informed by a reliable science, engineering, and technology framework are an important element in any democracy.

Universities have not been immune to international corporate trends, and have undergone major and continuing changes in the last twenty years, not least in developing close links with business. As we will read later, commercial support for university research imports a variety of dilemmas for scientists and researchers and these problems increase when business is represented by the military sector.

Over the past twenty years the role of universities and their identity has changed markedly, and the UK's Conservative-Liberal Democrat coalition government, elected in 2010, has increased both the pace and extent of change¹⁹³. Governments since the 1970s have progressively commercialised universities, by decreasing funding for 'blue-skies' research and producing a wide range of legislation and initiatives aimed at fostering alliances and partnerships with business¹⁹⁴.

During this period the funding of research, teaching and training in UK universities has become far more focused on commercial end-points. Economic expectations are increasingly a major part of the rationale for research funding from the UK research councils, the principal public funders of university research (in great part because of the Worry Report of 2006¹⁹⁵), and the Wellcome Trust (the UK's largest provider of non governmental funding for scientific research and the world's second largest private funder in the field of medical research). An escalation in commercial involvement by the military sector with research in UK universities has also been documented over the last twenty years¹⁹⁶. These trends and their impact on openness, independence and the long-term value of research, especially 'blue-skies' research aimed at areas which have not yet demonstrated commercial potential and on teaching for the public interest, have been described in detail elsewhere¹⁹⁷.

¹⁹² See discussions in: C Langley and S Parkinson: 'Science and the corporate agenda'. Folkestone, UK, 2009: Scientists for Global Responsibility http://www.sgr.org.uk/SciencePolicy/SGR_corp_science_full.pdf (Accessed 15 May 2013).
S Krinsky: 'Science in the private interest'. Rowman and Littlefield, 2003;
Anon, 'Unfortunate oversight'. Nature 488, 5 2 August 2012. doi: 10.1038/488005a <http://www.nature.com/nature/journal/v488/n7409/full/488005a.html> (Accessed 17 May 2013).
'Keeping science open: the effects of intellectual property on the conduct of science'. Royal Society policy document 02/03/2003. April 2003. <http://royalsociety.org/policy/publications/2003/keeping-science-open/> (Accessed 15 May 2013).

¹⁹³ S Collini: 'What are universities for?' Penguin Books, London, 2012.

¹⁹⁴ C Langley and S Parkinson: 'Science and the corporate agenda'. Folkestone, UK, 2009: Scientists for Global Responsibility http://www.sgr.org.uk/SciencePolicy/SGR_corp_science_full.pdf (Accessed 15 May 2013).

¹⁹⁵ Research Council Economic Impact Group: 'Increasing the economic impact of Research Councils'. 14 July 2006. <http://www.dti.gov.uk/files/file32802.pdf> (Accessed 18 May 2013).

¹⁹⁶ C Langley: 'Soldiers in the laboratory: military involvement in science and technology – and some alternatives'. Folkestone, UK: Scientists for Global Responsibility, 2005 http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).
C Langley, S Parkinson and P Webber: 'More soldiers in the laboratory: the militarisation of science and technology – an update'. Folkestone, UK: Scientists for Global Responsibility, 2007 http://www.sgr.org.uk/ArmsControl/More_Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).
C Langley: 'Universities, the military, and the means of destruction in the United Kingdom'. The Economics of Peace and Security Journal, Volume 3: 49-55, 2008 <http://www.epsjournal.org.uk> (Accessed 15 May 2013).
C Langley, S Parkinson and P Webber: 'Behind closed doors: Military influence, commercial pressures & the compromised university'. Folkestone, UK: Scientists for Global Responsibility, 2008. http://www.sgr.org.uk/ArmsControl/BehindClosedDoors_jun08.pdf (Accessed 15 May 2013).
M. Beale, T Street and J Wittams, 'Study war no more' London, Campaign Against Arms Trade 2007. <http://www.studywarnomore.org.uk/documents/studywarnomore.pdf> (Accessed 13 May 2013).

¹⁹⁷ J Poyago-Theotoky, J Beath and D S Siegel: 'Universities and fundamental research: Reflections on the growth of university-industry partnerships'. Oxford Review of Economic Policy 18; 10-21, 2002.
M Leach, I Scoones and B Wynne (Eds): 'Science and citizens'. Zed Books, London, 2005.
S Collini: 'What are universities for?' Penguin Books, London, 2012.

2. The influence of business on science, engineering and technology and universities

The nature of science, engineering, and technology, their governance and influence, and their perception by the public are complex and outside the remit of this study¹⁹⁸. This section will outline some of the more important issues relevant to relations between institutions such as AWE and UK universities, and the interested reader is invited to visit the references cited to learn more.

It has become increasingly clear over the past twenty years that the nature of science, its reliability and robustness and the ways in which research is undertaken and published are significantly influenced by the source and nature of funding¹⁹⁹. Additionally, the world of scientific innovation and research is intimately linked to the global market-based economic system, where business seeks to maximise profits, especially those of a short-term nature²⁰⁰. The majority of research and development (R&D) in the UK and other industrialised countries takes place within industry and is mainly of an applied nature, with relatively little basic research conducted within the industrial sector. In 2009 (the latest date for which figures are available from the British government's 2010 R&D Scoreboard), the one thousand UK companies that invested most in research and development did so to the tune of £25.3 billion²⁰¹. In 2011 (the latest date for which figures were available at the time of writing), the UK's total expenditure on R&D was £27.4 billion²⁰². Research and development is thus very much influenced by the needs of business. Industry funding of university research has risen markedly in many Organisation for Economic Co-operation and Development (OECD) and other wealthy countries over the past two decades²⁰³. This trend accompanies the increasing commodification of knowledge and the reduction of funding for research that is of a 'blue skies', open-ended, nature²⁰⁴.

The influence of commercial funding on research and the involvement of business in many areas within the university sector – particularly in relation to the biosciences, where there is a significant body of evidence²⁰⁵ – raise a number of concerns, which include:

¹⁹⁸ Discussions of the role of science, engineering, and technology in society can be found in L C Soley: 'The corporate takeover of academia'. South End Press, Boston MA, 1995. J Calvert: 'What's special about basic research'. *Science, Technology and Human Values* 31; 199-220, 2006. M Wright, B Clarysse, P Mustar and A Lockett: 'Academic entrepreneurship in Europe'. Edward Elgar, Cheltenham, 2007.

¹⁹⁹ J Lexchin: 'Those who have the gold make the evidence: How the pharmaceutical industry biases the outcomes of clinical trials of medications' *Science and Engineering Ethics* 18: 247-261, 2012.
J E Bekelman, Y Li and C P Gross: 'Scope and impact of financial conflicts of interest in biomedical research: a systematic review'. *Journal of the American Medical Association* 289: 454-465, 2003.
H Hottenrott and S Thorwarth: 'Industry funding of university research and scientific productivity'. *Kyklos* 64; No:4, 534-555 2011.
C Langley and S Parkinson: 'Science and the corporate agenda'. *Scientists for Global Responsibility*, Folkestone, 2009. http://www.sgr.org.uk/SciencePolicy/SGR_corp_science_full.pdf (Accessed 18 May 2013).
S Krinsky: 'Science in the private interest'. Rowman and Littlefield, 2003;
Anon, 'Unfortunate oversight'. *Nature* 488, 5 2 August 2012. doi: 10.1038/488005a <http://www.nature.com/nature/journal/v488/n7409/full/488005a.html> (Accessed 17 May 2013).
J Lenzer: 'Truly independent research?' *BMJ* 337; 602-606; 2008, a1332.

²⁰⁰ J Washburn: 'University Inc.' Basic Books, New York, 2005.
H Hottenrott and S Thorwarth: 'Industry funding of university research and scientific productivity'. *Kyklos* 64; No:4, 534-555 2011
C Langley and S Parkinson: 'Science and the corporate agenda'. *Scientists for Global Responsibility*, Folkestone, 2009. http://www.sgr.org.uk/SciencePolicy/SGR_corp_science_full.pdf (Accessed 15 May 2013).

²⁰¹ R&D 'Scoreboard'. Department for Business, Innovation, and Skills (archived). http://webarchive.nationalarchives.gov.uk/20101208170217/http://www.innovation.gov.uk/rd_scoreboard/ (Accessed 18 May 2013).

²⁰² 'UK Gross Domestic Expenditure on Research and Development, 2011'. Office for National Statistics website. <http://www.ons.gov.uk/ons/rel/rdit1/gross-domestic-expenditure-on-research-and-development/2011/stb-gerd-2011.html> (Accessed 18 May 2013).

²⁰³ H Hottenrott and S Thorwarth: 'Industry funding of university research and scientific productivity'. *Kyklos* 64; No:4, 534-555 2011.

²⁰⁴ M Jacob: 'Rethinking science and commodifying knowledge'. *Policy Futures in Education* 1; 125-142, 2003.

²⁰⁵ See footnote 184 for references and in-depth discussions of this area in the biosciences in particular.

- Funder bias which skews the research agenda and the academic publication process.
- Potential conflicts of interest and a lack of openness about these.
- Less disinterested research being supported in universities and an increase in R&D, with close-to-patentable work becoming the norm.
- Loss of openness and accountability in the science, engineering, and technology sector as commercial confidentiality and intellectual property rights develop increased significance.
- An increase in the short-term focus of research conducted in UK universities, with erosion of the traditional broad freedom of enquiry.
- Career paths leading with increased frequency into commercial employment.
- Technology lock-in, which is a form of dependency where an approach to research or design is shaped by previous investment or methods and the field becomes 'stuck' with an approach which may be inefficient, conservative or limited.
- The potential for marginalising and silencing of dissenting or critical voices outside the mainstream in both research and teaching.

The voice of the military sector (government and commercial) is frequently heard in setting research and teaching priorities in the UK, USA and in other countries of the European Union, often above those with a different view. As well as helping to frame the security agenda at the national level, this voice colours research, training and teaching programmes across departments in many UK universities²⁰⁶.

²⁰⁶ C Langley: 'Soldiers in the laboratory: military involvement in science and technology – and some alternatives'. Folkestone, UK: Scientists for Global Responsibility, 2005. http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).
 C Langley, S Parkinson and P Webber: 'More soldiers in the laboratory: the militarisation of science and technology – an update'. Folkestone, UK: Scientists for Global Responsibility, 2007 http://www.sgr.org.uk/ArmsControl/More_Soldiers_in_Lab_Report.pdf (Accessed 15 May 2013).
 C Langley: 'Universities, the military, and the means of destruction in the United Kingdom'. *The Economics of Peace and Security Journal*, Volume 3: 49-55, 2008 <http://www.epsjournal.org.uk> (Accessed 15 May 2013).
 C Langley, S Parkinson and P Webber: 'Behind closed doors: Military influence, commercial pressures and the compromised university'. Folkestone, UK: Scientists for Global Responsibility, 2008. http://www.sgr.org.uk/ArmsControl/BehindClosedDoors_jun08.pdf (Accessed 15 May 2013).
 M Beale, T Street and J Wittams, 'Study war no more' London, Campaign Against Arms Trade 2007. <http://www.studywarnomore.org.uk/documents/studywarnomore.pdf> (Accessed 13 May 2013).
 J J Ramsden: 'The sustainability of "postmodern" university research', pp 74-87, in P J Kervalishvili and SA Michailidis (Eds): 'Philosophy and Synergy of Information: Sustainability and Security'. Amsterdam, The IOS Press, 2012.

3. University funding from the military sector

Universities in the UK undertake research and teaching with funding from a variety of sources. Monies are, in principle, available to support clearly defined projects as well as more open-ended and adventurous ('blue-skies') programmes. The UK government provides funds for research in science, engineering and technology through the 'dual support' system – where the research councils support both the research infrastructure and individual research programmes. Funds for research and teaching can also be provided by the non-profit sector (such as the Wellcome Trust and Leverhulme Trust), through the European Union (through the Framework programmes), universities themselves (endowments and through benefactors) and directly from business or as a joint venture between business and other sources including the research councils²⁰⁷ or the charitable sector²⁰⁸. As a consequence of these diverse routes, funding streams for research are sometimes complex and opaque.

From the mid-1980s onwards the UK government supported or launched several highly visible initiatives to transfer technologies generated through military research to a wide range of civilian applications, whilst stepping up the processes to privatise government research laboratories. This process was claimed to facilitate technology transfer across civilian and military areas, and thereby make economic sense; however, the reality was disappointing. Other forms of UK government-business consortia aimed at technology transfer from the military sector were to be found in the early 2000s but these have either disappeared or been assimilated in other kinds of partnerships²⁰⁹.

At present UK universities receive funding through many different routes from the military sector, including money from the Defence Science and Technology Laboratory²¹⁰, the Centre for Defence Enterprise (part of the Ministry of Defence's science and technology research portfolio²¹¹) and through the Joint Applied Research Programme for Defence operated by DSTL and the research councils²¹². The Ministry of Defence also co-funds, with business collaboration, entities such as the four Defence Technology Centres (DTCs), which undertake research in support of the MoD's equipment programme²¹³.

Industrial military contractors also fund research groups in UK universities through direct mechanisms such as Rolls-Royce University Technology Centres²¹⁴. At the time of writing there are twenty-eight Rolls-Royce UTCs globally, and of these, twenty are located in UK universities. They pursue research in the physical sciences including computation, material science and aerodynamics and are to be found at

²⁰⁷ S Christopherson, M Kitson and J Michie: 'Innovation, networks and knowledge exchange'. Cambridge Journal of Regions, Economy and Society 1; 165-173, 2008.

²⁰⁸ S Christopherson, M Kitson and J Michie: 'Innovation, networks and knowledge exchange'. Cambridge Journal of Regions, Economy and Society 1; 165-173, 2008.

²⁰⁹ C Langley, 'Soldiers in the laboratory: military involvement in science and technology – and some alternatives'. Folkestone, UK: Scientists for Global Responsibility, 2005 http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf (Accessed 15 May 2015).

²¹⁰ 'Who we work with'. Defence Science and Technology Laboratory website. <https://www.dstl.gov.uk/whoweworkwith> (Accessed 18 May 2013).

²¹¹ 'Centre for Defence Enterprise'. Defence Science and Technology website. <http://www.science.mod.uk/engagement/enterprise.aspx> (Accessed 18 May 2013).

²¹² Mike Steeden, Keynote speech to Defence Research 2010 Conference, Birmingham, 24 March 2010. http://www.defenceresearch.co.uk/pdf/dr10_mikesteeden_text.pdf (Accessed 18 May 2013).

²¹³ At the time of writing the four DTCs are in Systems Engineering for Autonomous Systems, Electro-Magnetic Remote Sensing, Human Factors Integration, and Data and Information Fusion. 'Defence Technology Centres'. Defence Science and Technology website. <http://www.science.mod.uk/engagement/dtcs.aspx> (Accessed 18 May 2013).

²¹⁴ 'Research and University Technology Centres'. Rolls-Royce website. http://www.rolls-royce.com/about/technology/uni_research_centres/ (Accessed 18 May 2013).

leading universities including Oxford, Cambridge, Bristol, Imperial College and Sheffield. BAE Systems, another major military contractor, also collaborates on research with UK universities such as Cranfield (where there is an on-campus BAE Systems link office²¹⁵) and Nottingham²¹⁶, funds tailor-made degree courses (at Loughborough and Cranfield) and has been involved with the DTCs. QinetiQ, which was, together with DSTL, part of the UK government DERA laboratories and was subsequently privatised, similarly actively seeks collaboration with UK universities – examples currently include Exeter, Cardiff and Birmingham. Like Rolls Royce and BAE, QinetiQ looks to expertise in the university sector to assist in developing research and development within its own business²¹⁷.

²¹⁵ BAE Systems / Cranfield Link Office. Cranfield University website. <http://www.cranfield.ac.uk/baesystems/> (Accessed 18 May 2013).

²¹⁶ 'BAE Systems'. University of Nottingham website. <http://www.nottingham.ac.uk/servicesforbusiness/services/rd-service/case-studies/bae-systems.aspx> (Accessed 18 May 2013).

²¹⁷ For an example of QinetiQ collaboration see 'Qinetiq leads consortium to work closely with Dstl on restricted cloud architecture to improve cyber situational awareness'. Qinetiq website. <http://www.qinetiq.com/news/PressReleases/Pages/qinetiq-leads-consortium-to-work-closely-with-dstl-on-restricted-cloud-architecture-to-improve-cyber-situational-awareness.aspx> (Accessed 18 May 2013).

4. The consequences of university commercialisation

The nature of commercial funding with its emphasis on ‘economic return’ imports a variety of ethical and practical concerns, including lack of transparency, complex issues of intellectual property rights (IPR), and the potential for compromised objectivity and bias. These issues are further complicated when commercial funding supports research in the often controversial security sector. Evidence suggests that all of these factors can, in principle, shape and compromise research integrity and practice, as well as the scope for public interest research²¹⁸. Power and strategy-making lies more often in the hands of those outside teaching and research groups within a university and all these tendencies colour and impact upon the nature of the academic ethos²¹⁹.

Funding for various activities, including research and teaching, is an increasingly commercial process where end-points are expected to deliver economic benefits (an approach embraced by most funders especially the research councils), and the Haldane Principle²²⁰ has been largely abandoned. Despite this, a variety of funding mechanisms are in place in the UK to facilitate and support research and teaching at universities, including support for specific projects, larger programmes, staff positions and contracts. Research funds in the sciences (and also other areas such as the humanities) are awarded on the basis of peer review of an application in open competition. It is encouraging to note that the Engineering and Physical Sciences Research Council’s various advisory panels and Board as well as its College of Peer Review (which undertake the essential process of review of the applications for research funding to the Council) are not heavily weighted with industry scientists – although many members do work with industrial partners or themselves have spin-out companies.

At present universities are seen by government as primary centres of innovation and economic development. The power and disparate, often unacknowledged, range of influences on the direction taken by scientific research and the various forms of university collaboration, with potential for compromise of academic and professional standards, play an important role in shaping the part played by science and technology in society.

Is there a need for a more ethically-grounded approach to scientific research to help in balancing the forces that set the directions taken in research and avoiding conflicts of interest? Might professional guidelines and Codes of Conduct help here? Hopefully these questions are addressed in the main part of our report, using AWE as a case study of an organisation with controversial security and commercial interests which works closely with a number of British universities.

²¹⁸ See references at footnote 192.

²¹⁹ For a full discussion of these points see: R Daly: ‘The Missenden Code of Practice for Ethics and Accountability’. Missenden Centre for the Development of Higher Education. Great Missenden, 2002. <http://www.missendencentre.co.uk/docs/MissCode.pdf> (Accessed 15 May 2013).

²²⁰ The Haldane Principle derives from a 1918 report by politician Richard Burdon Haldane which concluded that scientists rather than politicians should determine how research funds are allocated. The Haldane Principle was instrumental in setting up the UK research councils and guiding government policy on research. It was seriously challenged by the 2006 Cooksey Report which supported far more government control over health research. Sir David Cooksey: ‘A review of UK health research funding’. HM Treasury, 2006 <http://www.researchresearch.com/news/cfm?pagename=newsStory> (Accessed 18 May 2013) and P Moriarty and T Kealey: ‘Public science – public good? A dialogue, Nanotechnology Perceptions 6’; 75-84, 2010.

Key issues arising from this essay

- Commercial involvement with the universities in the UK has expanded significantly over the past twenty five years, and has the potential for changing the academic ethos to one based on a short-term economic agenda.
- The mechanisms of funding from the UK research councils direct research in ways which import commercial and conservative approaches to research questions.
- The growth of a pervasive and influential military sector influence within UK universities – in teaching, training and research – calls for a thorough examination to assess the full costs of such an involvement.

ATOMS FOR PEACE?

THE ATOMIC WEAPONS ESTABLISHMENT AND UK UNIVERSITIES

Nuclear Information Service is a not-for-profit, non-government information service which works to promote public awareness and foster debate on the risks and costs of the UK's military nuclear programme.

Medact is a global health charity tackling issues at the centre of international policy debates. Led by its health professional membership it undertakes education, research and advocacy on the health implications of conflict, development and environmental change.

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