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Verifying Nuclear Disarmament: A Role for AWE Aldermaston

Tom Milne and Henrietta Wilson

With an Introduction from Professor Jack Harris FRS, Sir Martin Rees FRS and Sir Joseph Rotblat FRS

A Report from the British Pugwash Group

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This Report was made possible by a grant from the Joseph Rowntree Charitable Trust. The British Pugwash Group is grateful to the Trust for its support.

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CONTENTS

Verifying Nuclear Disarmament: A Role for AWE Aldermaston

Introduction

Nearly a decade after the end of the Cold War – and with an almost universal Non-Proliferation Treaty – achieving nuclear disarmament still appears to be an elusive objective. Formal negotiations on further nuclear disarmament in the two relevant bodies, the bilateral US-Russia START talks and the Conference on Disarmament (CD) in Geneva, have been at a standstill for a considerable time. The implementation of START II and the beginning of START III are being held up by the determined refusal of the Duma to ratify START II, a position which has hardened since the decision to enlarge NATO. In Geneva, the nuclear weapon states obstinately refuse the demands of the majority of the CD's members to put nuclear disarmament on the CD's agenda.

The prolonged impasse bodes ill for world security. There can be no standstill in politics; absence of progress results in regress. Such a regress was the series of nuclear tests carried out in 1998 by India and Pakistan, two countries that have been at loggerheads from the moment they became independent, and have fought several wars, mainly over the disputed territory of Kashmir. Another military confrontation between them may lead to a nuclear exchange into which other nuclear weapon states may be drawn. Moreover, the decision by India and Pakistan to go nuclear has broken the taboo against proliferation, and more countries may decide to follow suit. The whole political situation has suddenly become highly dangerous.

The official nuclear weapon states will have to take steps to deal with the danger, not by imposing sanctions – these will hurt but not solve the problem – but by agreeing to begin earnest discussion on the elimination of nuclear weapons, the only sure way to prevent proliferation.

At the intellectual level much progress towards this objective has been made in recent years. Until a few years ago, the notion of a nuclear-weapon-free world was generally viewed as a fanciful dream of fringe groups. Now it is the subject of serious analysis. Several institutions in the USA (including the Stimson Center, the Carnegie Foundation, and the Committee on International Security and Arms Control of the National Academy of Sciences) have carried out comprehensive studies on the elimination, or prohibition, of nuclear weapons.

Above all, the Canberra Commission, a group of 17 independent, highly knowledgeable personalities from 12 countries, put forward in its report powerful arguments against the concept of nuclear deterrence and for the elimination of nuclear weapons.[1]

In the light of these arguments, the advocates of the retention of nuclear arsenals have begun to emphasize the difficulties, indeed the impossibility, of achieving a nuclear-weapon-free world. Even if all nuclear weapon states agreed to a convention to ban nuclear weapons, such a convention could not be made foolproof, they claim. Nuclear weapons cannot be disinvented; it is impossible to guarantee that some country, at some future date, would not build up, clandestinely, a nuclear arsenal with which to blackmail the rest of the world. One cannot guarantee even that the present nuclear weapon states will not hide away a few of their bombs for such or other reasons.

It is of course true that nuclear weapons cannot be disinvented, but this is no reason why they should not be banned in an international treaty. Chemical and biological weapons cannot be disinvented, indeed they can be re-introduced much more easily than nuclear weapons, yet conventions to ban them have been agreed by the great majority of nations, including all five official nuclear weapon states. Landmines cannot be disinvented and yet a convention to ban them has been agreed.

All the same, considering that nuclear weapons are in a class of their own in terms of the scale of wholesale destruction they can cause, the advocates of a nuclear-weapon-free world must pay special attention to the integrity of a convention banning nuclear weapons. Such a convention will have to be anchored on a safeguard system robust enough to prevent cheating of a significant degree. This qualification is made because no system can be absolutely inviolate. The need is to show that a world without nuclear weapons will be safer than the alternative. For this reason verification systems merit thorough and detailed investigation.

Pugwash has been involved in the verification issue for many years. In 1991 we published a monograph *Verification: Monitoring Disarmament*,[2] in which we analysed the verification problems in disarmament treaties dealing with different types of weapons. The special problems in the verification of treaties banning nuclear weapons were investigated in a book published in 1993: *A Nuclear-Weapon-Free World: Desirable? Feasible?*.[3] The results of further studies on this topic were presented in the book in 1998 *Nuclear Weapons: The Road to Zero.*[4] In these books we point out that in view of the enormous destructive potential of nuclear weapons, two verification systems will be necessary, technological and societal, the latter relying on a sort of "whistleblowing" by ordinary citizens, as well as scientists. Although a paper in the last book[5] argues that the fears of cheating are somewhat exaggerated, a sound and vigorous technological verification system will have to be established if the nuclear weapon states are ever to agree on the elimination of nuclear weapons.

[1] *Report of the Canberra Commission,* Canberra Commission on the Elimination of Nuclear Weapons, Department of Foreign Affairs, Commonwealth of Australia, 1996.

[2] *Verification: Monitoring Disarmament*, ed. Francesco Calogero, Marvin L. Goldberger and Sergei P. Kapitza, Boulder, Co.: Westview Press, 1991.

A detailed study of the technological verification system requires a big effort and expenditure on manpower and equipment, an effort well beyond the means of a non-governmental organization such as Pugwash. Indeed, nuclear arms control and disarmament, if taken seriously, will require a large programme of research and development. At present, the US government has a programme for "non-proliferation and arms control" (but not explicitly "disarmament") which is largely carried out at the very establishments, Los Alamos, Livermore, Sandia, where nuclear weapons were – and still are – developed. Many scientists are employed and huge budgets are provided for this work, much of which is unclassified and the findings published.

The United Kingdom is of course also interested in a verification system for a nuclear weapons convention, but the effort it has invested in this area has been disappointingly small, and AWE Aldermaston, the UK's "Los Alamos", has paid hardly any attention to it.

The British Pugwash Group added to the above-mentioned international Pugwash research by a study of the UK's nuclear weapons. Its report, first published in 1995, *Does Britain Need Nuclear Weapons?*[6] contains a recommendation calling on the British government to "offer the technical services of the AWE to support the verification of nuclear disarmament." The project described in this Report is a direct follow up of this recommendation.

[3] *A Nuclear-Weapon-Free World: Desirable? Feasible?,* ed. by Joseph Rotblat, Jack Steinberger and Bhalchandra Udgaonkar, Boulder, Co.: Westview Press, 1995.

[4] *Nuclear Weapons: The Road to Zero*, ed. Joseph Rotblat, Boulder, Co.: Westview Press, 1998.

[5] Tom Milne and Joseph Rotblat, "Breakout from a Nuclear Weapons Convention," in *Nuclear Weapons: The Road to Zero, ibid.* pp. 145-54.

[6] *Does Britain Need Nuclear Weapons?*, Christopher Hill, Sebastian Pease, Rudolf Peierls and Joseph Rotblat, London: British Pugwash Group, 1995; second edition, 1997.

It may seem paradoxical that an anti-nuclear organization like Pugwash should recommend – as it may appear – the continuation of AWE, instead of calling for its closure. Actually, even after an agreement to ban nuclear weapons has been achieved, establishments like AWE could not be closed overnight. The process of dismantlement of nuclear weapons and the setting up of a tough safeguards system will take a considerable time, and will require – to a large extent – the expertise now existing in the weapons establishments. It would be foolish not to make use of this expertise. The recommendation in this Report is that a programme of arms control and disarmament be introduced into AWE alongside its other work. Our hope is that the disarmament aspect will steadily increase until it becomes the only task of the establishment.

The scientific staffing at Aldermaston is smaller than at Los Alamos or Livermore and the resources that the British government could devote towards such a project are bound to be relatively small, but this is no reason why the effort should not be made. Indeed, original ideas often originate in small establishments. In any case, it is important that the UK plays a significant role in the process of global nuclear disarmament, and can maintain an effective dialogue with the USA, perhaps stirring it towards more emphasis on disarmament aspects. But one needs to put forward arguments that demonstrate to the UK government that Aldermaston can play a distinctive role. This is the purpose of the project which culminated in this Report.

While this study is primarily concerned with the role of AWE, eventually other European countries, France in particular, will have to be brought into the process of developing nuclear arms control and disarmament technologies. Indeed, one may envisage AWE as playing a pivotal role in a European programme of R&D in this field.

From what has been said, it should be clear that, while our ultimate objective is to establish a robust verification system for a treaty on nuclear disarmament, we do not explicitly discuss the substance of the verification system in this Report. As stated, the merits of verification have been extensively discussed by Pugwash, but other aspects are beyond our capacity. The sole objective of this Report is to present arguments that by establishing a programme for arms control and disarmament, Aldermaston could begin immediately to do much of value towards the stated objective of the government: the elimination of nuclear weapons in a multinational agreement through mutual balanced and verifiable disarmament measures.

The British Pugwash Group submission to the Strategic Defence Review recommended that Aldermaston begin work on verification, and a summary of this Report was also submitted to the Review. It is gratifying that the Strategic Defence Review specifically states that:

> Britain has only a very limited capability at present to verify the reduction and elimination of nuclear weapons. A programme is therefore being set in hand to develop expertise in this area, drawing in particular on the skills of specialists at the Atomic Weapons Establishment. A small team will be established to consider technologies, skills and techniques, and to identify what is already available to us in the United Kingdom. The government will consider how to take this programme forward in the light of the team's interim conclusions. The aim is to ensure that, when the time comes for the inclusion of British nuclear weapons in multilateral negotiations, we will have a significant national capability to contribute to the verification process.[7]

We hope that the arguments presented in the Report will be of value in this investigation.

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The project was proposed by Tom Milne and promoted by the Executive Committee of the British Pugwash Group, under the chairmanship of Dr Sebastian Pease FRS. The undersigned (together with Tom Milne) were appointed as the steering committee for the project.

Thanks to a grant from the Joseph Rowntree Charitable Trust, it was possible to procure the help of a full-time research assistant, Henrietta Wilson, for one year. While the undersigned kept a supervising eye on the project, and took part in some of the visits, the work was done entirely by Tom Milne and Henrietta Wilson; this Report presents their findings.

We wish to express our gratitude to the Joseph Rowntree Charitable Trust for the grant and supportive attitude. Our thanks are also due to Sir Ronald Mason FRS, to Professor Richard Garwin, and to Dr Theodore Taylor, who kindly agreed to act as consultants to the project.

[7] *Strategic Defence Review*, Cm 3999, London: HMSO, July 1998 – Supporting Essay Five: Deterrence, Arms Control, and Proliferation, para. 30.

Apart from the numerous individual interviews with the persons mentioned in the acknowledgements at the end of the Report, much has been derived from visits to the Ministry of Defence and to AWE Aldermaston. We wish, in particular, to thank Mr Robin Bradley, the chief executive of Hunting-BRAE, for hospitality during our visit to Aldermaston.

The first draft of the Report was circulated to a number of people many of whom made valuable comments which were incorporated into the final text. We wish to express our warm thanks to them.

Jack Harris
Martin Rees
Joseph Rotblat

THE CHANGING CIRCUMSTANCES OF THE ATOMIC WEAPONS ESTABLISHMENT

The Atomic Weapons Research Establishment (now called the Atomic Weapons Establishment or AWE) was formed in the early 1950s to design and manufacture nuclear warheads for the UK's armed forces. By the late 1950s the UK had established itself as a thermonuclear state. After testing the warheads for Polaris (the UK's submarine-based nuclear deterrent) and WE-177 (a gravity bomb), the Labour government decided in 1965 that no further warhead designs and no more nuclear tests were required. The UK alone of the five nuclear weapon states conducted no nuclear tests from 1966 through 1973. The nuclear weapons programme was scaled back and some civil work initiated at AWE. This work withered away after 1970,[8] when a programme began, code-named Chevaline, to design a new re-entry system for the Polaris missile. Since then AWE has concentrated on its core nuclear weapons work, and today AWE follows a narrow Mission Statement: "To provide, maintain and certify the UK's nuclear deterrent, and to decommission redundant weapons, all in a safe and cost-effective manner."[9] But now that the UK has signed and ratified the Comprehensive Test Ban Treaty, and is not developing any new nuclear warhead, AWE finds itself in a situation with similarities to the pre-Chevaline years.

Aldermaston in Berkshire is AWE's main site. It has a second site a few miles away at Burghfield. The infrastructure at Aldermaston and Burghfield is being rationalized, and former facilities at Cardiff and Foulness have been closed down, as part of post-Cold War consolidation and retrenchment. AWE's workforce, which numbered 6,400 in 1993, is expected to fall to 4,000 by the turn of the century. The annual running costs are currently around £300m. AWE is owned by the Ministry of Defence and managed by the industrial consortium Hunting Engineering, Brown & Root and AEA Technology (Hunting-BRAE), which has a seven-year contract running until March 2000.

AWE is currently manufacturing warheads for the Trident nuclear submarine, the replacement for Polaris. The government's Strategic Defence Review has concluded that the UK needs a stockpile of "less than 200 operationally available warheads" – a reduction of a third from the maximum number announced by the previous government.[10] It can be expected, therefore, that production of the

[8] Some diversification initiatives, which transferred staff out of AWE, flourished. A substantial number of Aldermaston employees moved to Culham laboratory, for example, to work on controlled nuclear fusion, see Annual Reports of the United Kingdom Atomic Energy Authority.
[9] Hunting-BRAE, Annual Report, 1996.
[10] *The Strategic Defence Review*, Cm 3999, London: HMSO, July 1998, para. 64.

Trident warhead, which has been underway for a number of years, will soon be completed.

Trident is now the UK's sole nuclear weapon system (the last of the WE-177 were withdrawn from service in 1998). For the first decade of the next century at least, AWE's main task will be "stewarding" the Trident warhead. Trident is expected to remain in service beyond 2020; were a decision taken to replace Trident, development work would have to start 10-15 years before the required in-service date.

The stewardship programme, which is now the main laboratory programme, will refurbish warheads at the same rate as they have been constructed over recent years, and carry out research to advance understanding of the physics of the Trident warhead. In common with US and French approaches to warhead stewardship, AWE aims to understand scientifically the ways in which a warhead ages. Stewardship must assure the safety and reliability of the warhead (without nuclear explosion testing), and, when a problem is found, support the repair or remanufacturing of warhead components as necessary, possibly using replacement materials that are different from the original. The planned UK stewardship programme is small compared with the US Stockpile Stewardship and Management Program, and may be smaller than the French programme. Thus maintaining technical exchanges with the USA, and developing collaboration with France, is an important part of policy. The UK will, for example, develop computer models independently from the USA and France, and upgrade the laser facilities at AWE, so that it can make a fair contribution to technical exchanges.[11]

Under the last government, warhead stewardship also included the requirement to maintain a capability to design a new warhead. The Strategic Defence Review states that "it would be premature to abandon a minimum capability to design and produce a successor to Trident," although it is "the Government's aim to take forward the process of nuclear disarmament to ensure that our security can in future be secured without nuclear weapons."[12] In practice, stockpile stewardship will, in any case, help to retain design skills. It is already ten years since design work on the Trident warhead was completed, and as part of the stewardship

[11] Cooperation with the USA is under the 1958 Agreement for Cooperation on the Uses of Atomic Energy for Mutual Defence Purposes. There is no comparable arrangement for nuclear cooperation with France, but MoD has been considering possibilities for Anglo-French cooperation on warhead stewardship for a number of years, *see* Progress of the Trident Programme, *Second Report of the Defence Committee 1993-94,* May 1994, p. xvii, para. 35.
[12] *Strategic Defence Review*, Supporting Essay Five: "Deterrence, Arms Control, and Proliferation," para. 14.

programme AWE is consigning past design experience and data from nuclear tests to the archives.

Apart from the stewardship programme, over the next few years AWE will decommission a few hundred warheads withdrawn from service (Chevaline and WE-177). Decommissioning entails dismantling the warhead, recycling the nuclear materials or storing the warhead pit intact, and scrapping the rest.

By rationalizing the Establishment's infrastructure, and implementing the stewardship and decommissioning programmes, Hunting-BRAE is fulfilling its remit as set out in the mission statement. But in the longer term the stewardship programme planned at AWE will probably not be sufficient to sustain the laboratory with the requisite skills and resources. Although the scientific problems in warhead stewardship are challenging, the science involved is less "interesting" than nuclear design work.[13] On top of this, nuclear weapons are widely seen to be of declining relevance to the UK's defence. As a result, there is no doubt that AWE has become a less attractive and less prestigious place to work. When it is also considered that AWE is isolated from the UK's academic community, and that salaries are uncompetitive with the private sector, markedly so in fields such as information technology, it follows that if AWE does not evolve, and find challenging new work, it will find it difficult to recruit and retain the scientists and engineers that it needs.

Since Aldermaston is very likely to stay in operation for as long as the UK has nuclear weapons, with responsibility for keeping the weapons in a safe condition, the maintenance of standards at the laboratory is a matter of general concern. When the Defence Committee of the House of Commons considered the issue in 1994, it concluded that diversification was the answer. The Committee wrote that:

> without some form of future diversification, and maintenance of a demanding research programme, it will become difficult to justify the scale of public funding for the AWE such as to maintain the capability to sustain the maximum standards of safety and efficiency . . .[14]

There are two ways in which the science programme at AWE could be diversified. One way would be for MoD to fund work unrelated to the maintenance of UK

[13] Nuclear testing also gave a structure to the laboratory's programme, requiring theory, design, organization, logistics, diagnostics, interpretation and so on. There is no equivalent focus in stewardship activities.
[14] Progress of the Trident Programme, *Second Report of the Defence Committee 1993-94*, London: HMSO, May 4, 1994, p. xxiv.

nuclear weapons – that is, to change or expand AWE's mission. The other would be for AWE to increase the work it does for non-MoD commercial customers.

In this Report we propose a major new laboratory programme – a change of mission – funded from the defence budget. *We recommend that AWE's mission be extended to include work towards a nuclear-weapon-free world, providing technical research on verification and other aspects of nuclear arms control, non-proliferation and disarmament.*

The Strategic Defence Review announced that an eighteen-month pilot study would be carried out at AWE on verifying the reduction and elimination of nuclear weapons.[15] As we will detail later in the Report, arms control, non-proliferation and disarmament provide a substantial body of work; they are a good "fit" with AWE's resources and expertise; and a strong contribution to arms control, non-proliferation and disarmament would support AWE's *raison d'être* in the post-Cold War world. All this has been shown to be the case at the US nuclear weapons laboratories, where arms control, non-proliferation and disarmament constitute a major research programme.

Broadening the science programme at AWE by incorporating work on arms control and disarmament would also help make AWE a more open environment. It would be a side-benefit of involvement in verification that AWE would be drawn into greater contact, and perhaps collaboration, with other institutions, both in the UK and abroad. This is important both for building confidence in disarmament and because it would allow independent peer review of scientific standards at the laboratory. In the USA many of the senior scientists at the weapons laboratories spend part of their time on unclassified research and participate in international conferences. The contributions of these scientists to open science can justify confidence that their handling of nuclear weapons is of a high standard. AWE employees, by contrast, are sequestered away from the mainstream scientific and technological communities.[16] Thus the same assessment cannot be made in the UK; outsiders (except for the few independent scientists on MoD committees) have little choice but to accept government assurances at face value. The desirability of wide peer review is greater now than ever before, because there are no nuclear test explosions to confirm the quality of AWE's science, and because it is likely to be harder to maintain scientific

[15] *Strategic Defence Review*, Supporting Essay Five: "Deterrence, Arms Control, and Proliferation," para. 30.

[16] MoD comments that it wants AWE to strengthen its links with the wider UK science base, and that while classification imposes a limit on what can be achieved, AWE is currently nowhere near that limit.

standards in a closed environment where work has more of a custodial than an innovative nature.

At first only limited numbers of staff would, realistically, be involved in verification work, so this could in itself be only a modest step towards fostering the more open and diverse "culture" that prevails at the nuclear weapons laboratories in the USA. We note, however, that there are other areas, quite apart from verification, where AWE staff could, with mutual benefit, share expertise with academia and with industrial researchers – for instance, hydrodynamic simulation, laser physics, materials science, ultra-fast phenomena, and electrochemistry.

The current management of AWE is positively disposed towards enhancing AWE's links with the external scientific and technical community.[17] Hunting-BRAE desires to keep the contract that it has with MoD to manage AWE when it comes up for renewal, and for this reason wishes to take steps to maintain intellectual vitality at the laboratory. It is attractive to a scientist to be part of a broad academic environment and to publish in the open literature. Some movement of staff back and forth between AWE and academia might even be possible.

To conclude this opening chapter, the opportunity exists to start work on nuclear arms control and disarmament at AWE; doing so would have the side benefit of making AWE more open. If the government is serious about working for nuclear disarmament, it will have to direct some of the UK's scientific resources to solving the many technical issues involved; indeed, by establishing an arms control and disarmament programme at Aldermaston, the government would go some way towards meeting the UK's obligation, under Article VI of the Non-Proliferation Treaty, to work for nuclear disarmament. And lastly, if in due course a decision is taken not to replace Trident, but rather to let the UK's nuclear expertise atrophy, then the UK will wish to promote arms control and disarmament all the more vigorously.

[17] AWE is initiating a programme of university sponsorships. In the USA there have been signs of a "backlash" against too great an involvement of universities in topics directly relevant to "stewardship" (see *Nature*, v. 391, January 22, 1998, pp. 311-312). There is no comparison between the situation in the USA and AWE's plans at this stage, and there would of course be no such concerns if the collaborative projects in the UK involved only verification issues, the subject of this Report.

POTENTIAL TECHNICAL CONTRIBUTIONS FROM THE UK TO NUCLEAR ARMS CONTROL, NON-PROLIFERATION AND DISARMAMENT

In this chapter we discuss aspects of nuclear arms control, non-proliferation and disarmament relevant to the UK's security and for which the UK has the expertise needed to make a contribution.

A high standard of technological verification will be a pre-requisite for nuclear disarmament and the UK has much to offer. To paint a picture of the sort of work that the UK might do, it is helpful to begin by briefly discussing verification technology and techniques in general, and reviewing some of the work on nuclear arms control, non-proliferation and disarmament that has been carried out to date, much of it at the US nuclear weapons laboratories.

VERIFYING NUCLEAR DISARMAMENT

Verification of arms control and disarmament is the system of measures whereby parties to an agreement can assure themselves sufficiently about the compliance of others. It has technical and political aspects, encompassing, for example, legal measures permitting inspections of a state's territory, equipment to detect violations, and systems of information collection. Technologies are used at every stage of a verification regime, to support the regime and indeed to define the scope of possibilities for detecting violations. They range from video cameras which can be used to monitor the flow of materials through a military facility, to computer software which makes possible the collection and processing of large amounts of information, to seismic monitoring for nuclear explosions.

While all aspects of treaty formation are ultimately a matter of politics, technologies can solve many of the basic problems of verification, starting with the question of whether it is possible to detect particular activities. Technical capabilities may also stimulate international arms control negotiations, by establishing that certain tasks can be done. By the same token, not doing verification R&D can constrain progress in arms control. This could be the case, for example, when it comes to verifying the destruction of nuclear warheads. There is widespread concern about verification of warhead dismantling, and there will be a lot of potential stalling points in future negotiations on this issue. Tried and trusted dismantling techniques will be needed, because technologies take years to develop whereas treaties can be negotiated in months.

In many ways, it is futile to talk of verification technology or techniques in isolation from their context; it is meaningless to consider the adequacy of particular verification techniques, for example, unless it is clear what they are meant to verify. On top of this, many of the verification technologies are well established, and whether they work or not depends on how they are allowed to work. So, in an on-site inspection there will be rules established through international political negotiations determining what equipment inspectors can use, and the existence of high technology solutions can become irrelevant. Thus, the level of verification in a regime is a political matter; the acceptable level of intrusion for verification measures will be decided by compromise and negotiation. Often, treaty verification employs low tech (or "dumbed down" high tech) equipment; countries may not wish to share their latest technologies, the technologies may be too intrusive, or they may be too expensive for use by an international organization. In the case of the Comprehensive Test Ban Treaty, for example, sophisticated hydroacoustic arrays were not included in the treaty verification arrangements for monitoring of underwater explosions because of their potential application to tracking submarines. In warhead authentication, "fuzzy" gamma ray imaging might be needed to protect sensitive design details.

In this regard, it is useful to distinguish verification or treaty support work from intelligence gathering. Intelligence gathering involves nations collecting the best possible information on potentially threatening activities around the world, without the consent of the parties being monitored. In contrast, verification measures are cooperative, done with an international agreement. Extremely sophisticated technology may be used in intelligence work, and cost may be no object. The UK will no doubt wish to continually improve its national detection and monitoring capabilities for intelligence work (sometimes called national technical means). Although in this Report we are mainly concerned with verification and treaty-based disarmament, verification is closely linked to, and supported by, intelligence gathering, and the two cannot be entirely separated.

When negotiating an international treaty, one goal is to secure as wide a commitment as possible to the treaty, making sure that the benefits to all nations outweigh the costs. A treaty's verification measures can be pivotal to achieving international support and ratification: an international arms control/disarmament regime that is well constructed, with good verification, can be a cost-effective means of ensuring national security. There are also economic benefits in joining some regimes, in clauses that promote trade, and political benefits, in that joining a regime can give countries prestige and a certain amount of moral high ground. The costs of being party to a regime can be financial – there are costs involved in implementing a treaty, for example in destroying prohibited weapons, and in setting up the verification measures; and they can be political – treaties require giving up some sovereignty, for example. And of course there are costs in terms of the security risks that could be posed by a treaty violation or by states or actors not party to the regime.

In the case of nuclear weapons, the security calculation will be of high importance throughout the reduction process and even more so as nuclear arsenals are reduced to low levels and eventually to zero. Verification cannot, of course, be foolproof, but before the nuclear weapon states will relinquish their weapons the verification system will have to reduce the uncertainties associated with nuclear disarmament to a level that makes disarming more attractive than continuing to rely on nuclear deterrence.

Verification measures for arms control and disarmament agreements build confidence in a regime in three ways. First, the need to circumvent a verification regime can make a clandestine treaty violation much harder, technologically and financially, and this deters potential violators. Second, a verification regime can provide assurance that a treaty violation will be detected in time to take preventive action. And third, transparency measures in a verification regime can help to build confidence between states, serving as acts of good intention by states parties to a treaty, and encouraging openness in areas previously kept secret. A "pattern of knowledge"[18] can be built up so that although cheating on agreements remains possible (not every kilogramme of plutonium can be accounted for) each side grows confident that no cheating is actually taking place. In this vein, the USA and Russia have an extensive programme of collaboration between their nuclear weapons laboratories, which is manifestly building confidence between the scientists of the two nations, and indirectly between their policy-making establishments (discussed in more detail on pp. 29-30).

Verifying nuclear disarmament presents extremely challenging technical problems. It may, however, be manageable in a way that chemical disarmament, for example, complicated by dual-use chemical precursors and a pervasive chemical industry, is not. For example, there are powerful techniques for detecting facilities producing plutonium or highly-enriched uranium; thus not only would a clandestine production programme be difficult to establish in a nuclear-weapon-free world with a strong verification regime, the cheating party would not be certain of avoiding detection. The nuclear weapon states have probably all studied the potential for detecting clandestine nuclear activities, based on extrapolations of their own industrial experience.

[18] See, Patricia Lewis, Laying the Foundations for Getting to Zero: Verifying the Transition to Low Levels of Nuclear Weapons, *Verification Matters*, July 1998.

The building blocks of comprehensive verification of nuclear disarmament will include baseline declarations of nuclear holdings; on-site inspections; monitoring systems, technical safeguards and means of physical containment; techniques for verifying the dismantlement of warheads and disposal of nuclear materials; and means to detect a clandestine nuclear weapons programme. All this will require a great deal of technical arms control, non-proliferation and disarmament research. To date, such work has mostly been carried out at the US nuclear weapons laboratories. The UK has made only a small, though significant, contribution, largely at AWE Aldermaston.

Historical Role of the US Nuclear Weapons Laboratories and AWE Aldermaston in Nuclear Arms Control, Non-Proliferation and Disarmament

The US nuclear laboratories have been involved in arms control treaty verification since the 1960s. In the early years the main part of their efforts was directed towards developing national technical means, because there was little cooperative verification in the treaties agreed at this time. As the nuclear treaties between the USA and the Soviet Union became more complex, nuclear weapon scientists provided an increasing amount of technical advice to US policy-making agencies. This advice ranged from estimating the effect of various arms control treaties on US nuclear capabilities, to assisting with the development of verification regimes. The nuclear laboratories have also played a major role in developing technology for verification.

The signing of the Partial Test Ban Treaty in 1963 saw the start at the US laboratories of a large programme of research and development of space-based monitoring equipment that has continued to the present day. US satellites detected the notorious "flash of light" over the South Atlantic in 1979, which is thought, but not proven, to have been a nuclear explosion. The failure of the existing sensors to resolve this case was a stimulus for further verification R&D, and today the USA deploys a wide range of sophisticated satellite-based sensors as part of a panoply of national technical means (based in space, in air, and on land and sea) for detecting and characterizing the proliferation and testing of weapons of mass destruction.

The tentative beginnings of cooperative nuclear arms control came in the 1960s when the USA, UK and Soviet Union worked together on banning nuclear testing, and with the achievement of the Non-Proliferation Treaty, which entered into force in 1970. It developed further in the 1970s (through negotiation of the

Threshold Test Ban Treaty (TTBT) and Peaceful Nuclear Explosions Treaty), followed by a pause after the Soviet Union's invasion of Afghanistan at the end of 1979 until Mikhail Gorbachev took power in the Soviet Union in 1985. The USA and Soviet Union were then able to agree to joint on-site monitoring of the TTBT, leading in 1988 to Joint Verification Experiments (JVEs), which allowed an on-site measurement of the yield of a nuclear explosion (that could then be compared with off-site measurements) and led to the ratification of the Treaty in 1990. The JVEs were more significant for the progress made in cooperative verification than the ratification of the TTBT, which in arms control terms is of only minor importance. The JVEs engaged members of the US and Soviet testing programmes in a close technical working relationship for over two years. Victor Mikhailov, who has until recently overseen the US-Russian collaborative arms control work as head of MINATOM,[19] attended the JVEs at the Nevada and Semipalatinsk test sites.

The late 1980s also saw the start of verified US-Russian nuclear weapon reductions. The 1987 Intermediate-range Nuclear Forces Treaty (eliminating land-based nuclear missiles with a range between 1,000 and 5,500 km) and the subsequent START agreements (limiting deployed strategic weapons and eliminating delivery systems) have detailed verification regimes based on declarations, on-site inspections and national technical means. The verification schemes were negotiated by teams including many scientists from the nuclear weapons laboratories.

The INF Treaty has been fully implemented, and the START reductions are continuing apace albeit with problems, unrelated to verification, over ratification of START II by Russia. Negotiation of a further START agreement is set to begin as soon as START II is ratified. START III has been conceived, among other things, to introduce much more transparency between the countries. The ramifications of increased transparency, particularly in warhead dismantlement, are the focus of major arms control programmes at the US laboratories.

The 1990s have seen a strong emphasis on non-proliferation at the US laboratories. The US/Soviet nuclear arms race, which during the Cold War dominated all other considerations, is in reverse, and partly as a consequence of the end of the Cold War a number of new threats have come to the fore. Notable among these are the dangers stemming from loss of control over nuclear materials in the former Soviet Union (FSU); from the clandestine proliferation of nuclear weapons, as illustrated by the revelations that South Africa secretly built and

[19] Ministry of Atomic Energy – the primary authority in Russia supporting the US-Russian lab-to-lab programme.

dismantled a small arsenal of nuclear weapons, and that Iraq, a signatory to the Non-Proliferation Treaty, managed to build up a large clandestine nuclear weapons programme; and from the acquisition of weapons of mass destruction by terrorist groups, a threat thrown into high relief by the nerve gas attack on the underground in Tokyo.

There is no way of knowing whether nuclear materials were illegally removed in the aftermath of the collapse of the Soviet Union. Although the USA quickly established joint programmes with the facilities in the FSU that they judged most vulnerable to nuclear theft, they may not have been in time. The international community will not be confident for many years to come that material was not stolen. Only if no material turns up over, say, the next ten years, will increasing confidence be justified.

In 1991 the US Congress passed legislation allocating funds to help the Soviet Union destroy its weapons of mass destruction and to develop non-proliferation safeguards. The Cooperative Threat Reduction Program, known also as the Nunn-Lugar programme (after Senators Sam Nunn and Richard Lugar who initiated the legislation), made progress with destruction of missiles and missile silos under START, but projects to increase security at facilities containing nuclear materials were slow to get underway. Against the background of the Nunn-Lugar government-to-government efforts, US and Russian nuclear weapons laboratories initiated scientific exchanges. In 1994 this provided a basis for what has now become a large "lab-to-lab" programme to "reduce the threat of nuclear proliferation and nuclear terrorism by rapidly improving the security of all weapons-usable nuclear material in forms other than nuclear weapons in Russia, the NIS [Newly-Independent States], and the Baltic States."[20] The US Department of Energy (DoE) national laboratories cooperate directly with nuclear institutes in the FSU, to install security fences, portal monitors, sensors, video cameras, material control equipment, computerized accounting systems, and so on – collectively known as material protection, control and accounting (MPC&A). To try to ensure that security standards are maintained when US support declines, efforts are being made to train local scientists and engineers to operate and maintain the MPC&A systems, and, where possible, local suppliers are used for maintenance support. By 1998 the DoE was working at around 60 sites in the FSU, with a programme budget of $137m, scheduled to increase to around $160m in 1999.

[20] *Partnership for Nuclear Security*, Department of Energy Nuclear Material Security Task Force, December 1997, p. xii.

The discovery of Iraq's nuclear programme also stimulated major new non-proliferation initiatives, both at the US nuclear weapons laboratories and at the international level. The international developments have included strengthening IAEA safeguards (in order to enhance the Agency's ability to detect clandestine nuclear activities) and extensive IAEA inspections in Iraq. These initiatives have made use of expertise and technology from national nuclear weapons laboratories. The further strengthening of the IAEA's non-proliferation role, and general technological approaches for detecting small scale clandestine nuclear programmes, are important areas of current research at the US nuclear weapons laboratories.

In terms of size, the UK's historical contribution to nuclear arms control and disarmament has been very small, even if, in many areas, second only to that of the USA. Despite the small investment in this area, however, scientists from AWE have made important contributions.

The only sustained involvement in arms control work at AWE has been research carried out on the use of forensic seismology for detecting nuclear test explosions. This is the field of nuclear arms control to which the UK has contributed the most. The current work on test detection is described later in this chapter and the UK's historical contributions are outlined in a case study on pp. 43-46.

Little is known about AWE's other work. Exercise "Overture" was a military intelligence exercise, which began in the 1960s and ran for many years, trying to divine what radiation detected outside a facility could reveal about the facility. It researched the possibility of identifying nuclear facilities, and their activities, through analysis of environmental samples. Experiments were done on Britain's nuclear facilities, with the aim of then using the techniques as an espionage tool for looking at the USSR's nuclear programme. The work was carried out by Aldermaston,[21] which continues defence intelligence work on monitoring nuclear proliferation, and has the best facilities in the UK for detecting minute quantities of radionuclides. In the early 1960s Aldermaston scientists prepared a number of papers dealing with aspects of verifying nuclear disarmament for the Eighteen Nation Disarmament Committee at the United Nations.[22] Another example, also dating back to the late 1960s, was a notable contribution from AWE to non-proliferation through a series of inspections at UK nuclear facilities (project "Libator"), led by Dr. Frank Morgan, which developed the definition of Information Circular 153 (INFCIRC 153), the standard safeguards agreement between the IAEA and non-nuclear-weapon states. More recently, Aldermaston hosted challenge inspections to test procedures written into the Chemical Weapons Convention.

[21] Details of Operation Overture are known through four declassified reports, released by the MoD in 1997 under the Code of Practice on Access to Government Information: Exercise Overture Interim Report number 1 (March 7, 1960), F.H. Cripps and F. Morgan; Exercise Overture Interim Report number 2 (June 30, 1960), F.H. Cripps and D. Farrington; Exercise Overture Interim Report number 3 (October 31, 1960), F.H. Cripps; Exercise Overture Interim Report number 4 (April 30, 1961), F.H. Cripps and J.J. McCormack.

[22] "Technical Possibility of International Control of Fissile Material Production," ENDC/60, August 31, 1962; "Preliminary Study of Problems Connected With the Elimination of Rockets as Nuclear Delivery Vehicles," ENDC/53, August 1, 1962; "Preliminary Study of Problems Connected With the Verification of the Destruction of Certain Nuclear Delivery Vehicles," ENDC/54, August 1, 1962.

Current and Prospective R&D on Nuclear Arms Control, Non-Proliferation and Disarmament

Arms control and non-proliferation is now a major programme at the US Department of Energy and Department of Defense – each spends perhaps $1bn a year in this field. Los Alamos National Laboratory has just created the position of Associate Laboratory Director for Threat Reduction, in parallel to the Associate Laboratory Director for Weapons Programs. More relevant to this project is that there are dedicated non-proliferation and arms control divisions at Los Alamos, Lawrence Livermore and Sandia national laboratories. At Los Alamos National Laboratory, for example, there is the Non-Proliferation and International Security Division, employing about 700 staff and with a budget for FY1998 of around $140m. The Proliferation Prevention and Arms Control Program at Lawrence Livermore, within the Non-Proliferation, Arms Control and International Security directorate, has an annual budget of $100m and employs 160 people.[23]

The main R&D programmes at the US laboratories cover nuclear transparency studies in preparation for START III; nuclear security in the FSU; non-proliferation; implementation of the CTBT; global fissile materials management, control and accounting; nuclear materials disposition; and openness between the nuclear weapon states, in particular cooperative programmes with Russia and China. These are the essential areas of research needed to support the next steps in nuclear disarmament. They also address longer-term issues relevant to moving to a nuclear-weapon-free world.

In contrast to the situation in the United States, current arms control and non-proliferation work at AWE is on a small scale. The total expenditure on work in

[23] The $100m includes $40m spent on contracts in the former Soviet Union, $10m for contracts with other DoE laboratories on fissile material disposition work, and a large budget for travel.

this area at Aldermaston is around £2.5m a year, the largest part of which is spent on the test monitoring programme. Aldermaston also contributes to defence intelligence work. MoD pays for radiochemical services from Aldermaston, which are used in support of IAEA safeguards.

All the issues researched at the US laboratories impinge on UK interests, and there is a potential for AWE Aldermaston to contribute to each area. Although an expanded arms control and disarmament research programme at Aldermaston must be independent of US work in this field, it will inevitably cover much of the same ground, with opportunities for collaboration, as discussed below.

1. *Nuclear Warhead Dismantlement Transparency.* At the summit between Presidents Clinton and Yeltsin at Helsinki in March 1997 it was agreed that START III

> will include, among other things, the following basic components: . . . Measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads and any other jointly agreed technical and organization measures, to promote the irreversibility of deep reductions including prevention of a rapid increase in the number of warheads.[24]

Thus START III will provide for the dismantlement of nuclear warheads, as well as the elimination of strategic delivery vehicles. This raises a new spectrum of technical problems, most importantly verifying warhead dismantlement without revealing classified design details. The verified disposition of weapon-usable materials, to help make the disarmament measures difficult to reverse, is also implied.

In the USA (and the UK) a warhead is considered to be fully dismantled when the high explosive is removed from the pit which is then stored or recycled. The term "transparency" is often used rather than "verification,"[25] because of the widespread concern that it would be impossible to "verify" that an object being dismantled is a warhead, without revealing more about design features than would be acceptable from a security standpoint, as well as more than would be legal under current national regulations (not that these are immutable). The expectation

[24] Joint Statement on Parameters of Future Reductions in Nuclear Forces, Helsinki, March 21, 1997.
[25] A DoE study on warhead dismantlement defines the difference between transparency and verification as follows: transparency provide confidence that a declared activity is taking place, whereas verification confirms that a declared activity is taking place, see *Transparency and Verification Options: An Intitial Analysis of Approaches for Monitoring Warhead Dismantlement,* Department of Energy, Office of Arms Control and Non-Proliferation, May 19, 1997.

is that mutual transparency, over time, will provide sufficient confidence for dismantlement agreements to work without rigorous verification as such. Additional reassurance may be gained from prior declarations of warhead and material stockpiles, verified by spot checks, and from establishing a "chain of custody" for warheads, from the deployment or storage site to the dismantlement facility.

The criteria on which potential dismantlement schemes will be evaluated will include the confidence the scheme gives that warheads are being dismantled as stated, the danger of inadvertent loss of classified information, and the international negotiability of the scheme, as well as the more mundane considerations such as the cost of inspections, impact on operations and so on.[26]

There is considerable scope for UK/US collaboration in developing verification techniques in this area. In particular there is a need for extensive "red teaming" of candidate technologies, in which one party plays inspector and the other the inspected party, to test whether verification techniques and measurements – radiation signature technologies for example – reveal classified information. The US/UK 1958 Agreement for Cooperation on the Uses of Atomic Energy for Mutual Defence Purposes allows for trial experiments between the USA and UK that are not possible between any other of the nuclear weapon states.

In collaborating with the USA on verifying warhead dismantlement, the UK would, in a sense, be "buying into" a disarmament process, as distinct from a refusal even to discuss dismantling its nuclear weapons. An active engagement by the UK in preparations for nuclear disarmament may not, however, be premature. Douglas Hurd, when Foreign Secretary, announced at the NPT Review and Extension Conference that the UK would join in multilateral disarmament when the US and Russian nuclear forces numbered hundreds rather than thousands, and this would still seem to be a realistic representation of the UK's position.[27] It is proposed that US and Russian stockpiles will be reduced to 2,000-2,500 under START III. Perhaps more importantly, economic conditions in Russia mean that its nuclear arsenal is shrinking faster than mandated by the START process; without an economic upturn, it has been estimated that the Russian arsenal might reduce to the same size as Britain's in ten to fifteen years.[28]

[26] *Ibid.*
[27] Speech by Foreign Secretary Douglas Hurd at the Non-Proliferation Treaty Review and Extension Conference, April 18, 1995.
[28] "Russia's Nuclear Collapse: The Case for a Mutual Stand-Down," Bruce Blair, paper presented at *Pugwash Meeting No. 241,* A Nuclear-Weapon-Free World: Steps Along the Way, London, November 6-8, 1998.

On the subject of beginning research into disarmament possibilities, the Strategic Defence Review states:

> . . . Britain has only a very limited capability at present to verify the reduction and elimination of nuclear weapons. A programme is therefore being set in hand to develop expertise in this area, drawing in particular on the skills of specialists at the Atomic Weapons Establishment. A small team will be established to consider technologies, skills and techniques, and to identify what is already available to us in the United Kingdom. The Government will consider how to take this programme forward in the light of the team's interim conclusions. The aim is to ensure that, when the time comes for the inclusion of British nuclear weapons in multilateral negotiations, we will have a significant national capability to contribute to the verification process.[29]

The study was due to start on September 1, 1998. The UK has the opportunity to try out some verification procedures in the course of dismantling Chevaline and WE-177.

2. *Nuclear Security in the former Soviet Union.* The UK should be making a substantial contribution to safeguarding nuclear materials in the states of the former Soviet Union. The threat of nuclear materials "leaking" out from the former Soviet Union should be taken very seriously, and given far higher a priority in Britain's security planning than at present.[30]

The US contributions to safeguards in the former Soviet Union have already been described. They are projected to continue on a large scale until around 2002. Extensive though these programmes are, they are nevertheless limited by the number of available personnel. Additional coordinated contributions from other countries are needed. Although there may in some cases be resistance on the Russian side to collaboration with the UK, a second-tier nuclear weapon state, as against the collaboration with the USA "side by side as equals," this can no doubt be overcome, particularly if the UK has money to bring to the process.

The contributions from the UK and other European countries have so far been paltry in view of the importance of the issues at stake. In 1993 MoD provided 250 "supercontainers" for transportation of Russian warheads (for which AWE

[29] *Strategic Defence Review,* Supporting Essay Five: Deterrence, Arms Control, and Proliferation, para 30.

[30] For an analysis of the situation in Russia, see Graham Allison, Owen Cote Jr., Richard Falkenrath and Steven Miller, *Avoiding Nuclear Anarchy: Containing the Threat of Loose Russian Nuclear Weapons and Fissile Material*, Cambridge, Mass: MIT Press, 1996.

carried out some design work and acted as the prime contractor); MoD also supplied 20 heavy duty trucks, but has done nothing since.

In the civil sector, the UK's efforts are concentrated on enhancing safeguards at the Mayak reprocessing plant in Russia and the ULBA uranium processing plant in Kazakhstan. Cooperation on nuclear materials management began in 1992, between the Department of Trade and Industry and British Nuclear Fuels (BNFL) and MINATOM and Gosatomnadzor (Russia's civil nuclear regulator).[31] There were a number of seminars on a wide range of safeguards issues, attended on the Russian side by officials from GAN, MINATOM and various MINATOM enterprises, and on the UK side by officials from DTI, BNFL and the UKAEA. Deeper cooperation then developed between BNFL and the Mayak Production Association. Modern control and accounting procedures and techniques used at the UK's Thermal Oxide Reprocessing Plant (THORP) are being introduced at the twenty-year-old Mayak RT-1 reprocessing plant, through direct collaboration between plant operators.

3. *Non-proliferation.* Technologies for detecting small scale nuclear activities – a nuclear programme developing one or a few weapons for example – are already needed, and will be seen as increasingly important as and when the nuclear weapon states reduce their arsenals to low levels. There will be a need for technologies that can be used in international monitoring by organizations such as the IAEA (e.g. the environmental sampling techniques introduced as part of the "93+2" reforms of IAEA safeguards[32]), and for technologies that provide the best possible information-gathering capability for intelligence (e.g. large programmes at the US laboratories for remote sensing of chemicals characteristic of weapons of mass destruction programmes).

The USA, UK and a number of other countries have for many years run technical support programmes to IAEA safeguards which could usefully be expanded. The IAEA does not have resources to develop verification technologies, so member

[31] "UK Cooperation with the Russian Federation and Kazakhstan in Nuclear Accountancy and Control," G. Andrew (DTI), A. Barlow (FCO), M. Beaman (DTI), B. Burrows (BNFL) and M. Ward (UKAEA), presented at European Safeguards Research and Development Association (ESARDA) symposium, 1995; "Preliminary Results of Cooperation between the "Mayak" Production Association and British Nuclear Fuels plc (BNFL) in Nuclear Materials Control and Accountacy," G.S. Starodubtsev *et al.* ("Mayak"), G. Andrew (DTI) and R. Howsley *et al.* (BNFL), 1997.

[32] Article 6. b. of the "model Additional Protocol" to NPT safeguards agreements, approved by the Board of the IAEA in 1997 for implementing the 93+2 recommendations states that the Agency may carry out: ". . . the collection of environmental samples; and other objective measures which have been demonstrated to be technically feasible . . ."

state support programmes are vital to its operation. The US programme is more than three times the size of any other, the UK's the next biggest. The UK's programme is managed by the UK Atomic Energy Authority (UKAEA) and funded by the Department of Trade and Industry (DTI) at roughly £1.5-1.7m a year.[33] About two-thirds of the budget goes in support of IAEA safeguards. The remaining third is spent on nuclear materials control work in support of the DTI, to assist the formation of policy on domestic and international safeguards. The primary recipients of safeguards money are BNFL and AEA Technology. The areas covered, over the last five years, include environmental monitoring, use of commercial satellite imagery in safeguards, safeguards on final disposal of spent fuel, verification at reprocessing plants, safeguards at enrichment facilities, remote monitoring technology, non-destructive assay techniques, and training of inspectors.[34] AWE does a small amount of work for the IAEA on high precision chemical analysis. The implementation of the 93+2 recommendations, which is only now beginning, should indicate several promising lines of verification R&D to which AWE could contribute.

Export controls and work to counter nuclear smuggling/terrorism also fall under the non-proliferation rubric. Work on export controls identifies technologies that need controlling, reviews requests for export licenses, and supports international export control regimes. Combating nuclear smuggling involves work to intercept nuclear material at border crossings, airports and so on using portal radiation monitors, and to analyse and trace the origin of any material that is found. Intelligence information feeds into export licensing work and counter-nuclear smuggling operations. The USA and UK, which have arrangements for sharing intelligence, are well positioned to cooperate on such non-proliferation activities.

4. *Implementation of the Comprehensive Test Ban Treaty (CTBT).* When the CTBT enters into force it will have an extensive verification system, which is currently being set up. The main parts of the verification system will be the International Data Centre (IDC) in Vienna and the International Monitoring System (IMS). The IMS is a global data collection system, consisting of 321 seismic, acoustic, hydroacoustic and radionuclide monitoring stations. It will transmit data to the IDC which will make this data available to state parties.

The technical challenges involved in monitoring for nuclear explosions have not changed with the opening for signature of the CTBT. When the IMS is up and

[33] Personal Communication, Maurice Ward, Co-ordinator UK Safeguards R&D Programme to IAEA Safeguards, UKAEA, Risley.

[34] Annual reports on activities and progress of the UK Safeguards R&D Programme, from April 1, 1991 to March 31, 1992 through April 1, 1995 to March 31, 1996.

running, states parties will have access to more data than before, and there is provision for on-site inspection when a suspicious event is detected. But verification will rely on nations being able to analyse the data provided by the IDC and, if necessary, support, oppose or initiate calls for on-site inspections on sound scientific grounds.

There is a huge test monitoring programme at the US laboratories, developing a spectrum of technologies.[35] The USA is the only nation likely to carry out anything approaching a thorough examination of all significant disturbances detected by the IMS. The UK is not obliged to carry out independent verification of the Treaty but will surely wish to do so. To follow any other path would mean at best sliding into a position of reliance on the USA, and at worst relinquishing all responsibility for implementing the Treaty.[36]

A group of seismologists working at Blacknest, just outside Aldermaston, has provided the UK's expertise in nuclear test explosion monitoring since 1960. The director of the group believes that the UK needs a national programme employing 25 staff at a cost of a few million pounds a year. In this scheme, the UK would set up a National Data Centre to receive data from the IDC. UK teams would install IMS facilities on the territories of UK dependencies[37] and train CTBT Organization (CTBTO) inspectors in on-site inspection techniques. AWE would also be on stand-by to supply experienced staff and equipment for on-site

[35] www.ctbt.rnd.doe.gov/

[36] From one point of view, the need for an elaborate system to monitor compliance with the CTBT is questionable. It would be extremely difficult to conduct a clandestine nuclear test explosion anywhere in the world, and almost impossible in an open society. The nuclear weapon states, moreover, have little incentive to test secretly, because only marginal benefits would accrue to any one of them from one or a few further test explosions, given their already extensive testing experience. But, true or not, this misses an important point, which is that the USA, certainly, and other countries too, in all likelihood, would not have signed a CTBT, if there had not been arrangements for verification. Verification is central to the arguments in the US Senate over whether to ratify the Treaty; the potential for verification, and for on-site inspection if a suspicious event is detected, is the main argument made by proponents of the test ban. Without the Treaty, nuclear weapons development could, and probably would, resume. Lastly, but not unimportantly, even if the chances of clandestine testing are low, they are not zero, and a continuing vigilance is highly desirable.

[37] An existing seismic array at Eskdalemuir in Scotland needs upgrading. In addition, it is proposed that radionuclide detectors be installed at Halley Base (Antarctica), Diego Garcia, Tristan da Cunha and St Helena; hydrophone/seismograph facilities at Diego Garcia, Trista da Cunha and Ascension Island (the Ascension Island facility is the responsibility of the USA); and infrasound stations at Ascension Island, Bermuda, Diego Garcia and Tristan da Cunha. Blacknest personnel are trained to install seismic arrays, radionuclide detectors and infrasound stations. Installation of IMS facilities will be paid for by the CTBTO. A UK team might also tender for work installing other IMS stations.

inspections, augmenting the CTBTO's small cadre of permanent inspectors. The UK would continue research work on detecting and distinguishing low magnitude seismic disturbances, and carry out regional seismic calibrations, to understand normal seismic activity, travel times, and special geological features in regions where proliferation is of concern to the UK government. The historical seismic array data at Blacknest would be consigned to the archives. In time, the research group could develop expertise in interpreting acoustic and hydroacoustic data.

The main support to government would be analysis of ambiguous seismic disturbances. These analyses would generally be based on data received via the IDC from carefully targeted geographical areas. Given that there are tens of seismic disturbances every day of significant magnitudes, the central practical problem facing the Treaty is ensuring that there are not an excessive number of false alarms. The UK test monitoring programme would also evaluate any on-site inspection challenge made at the CTBTO, and might respond to a request from another country or from a non-governmental group for an opinion on a seismic disturbance. Lastly, it would be ready to respond to mischievous or misguided challenges made against the UK, its dependent territories, or members of the European Union, and to act as an arbiter in international disputes.

A national programme carrying out these functions would develop the UK's position as a world leader in test monitoring (see case study pp. 43-46 for the UK's historical contributions). The best possible advice on test monitoring would continue to be available to the UK government, valuable collaboration with the USA in this field would be maintained, and the UK would benefit from cost-effective national security.

Responsibility for setting up the UK's National Data Centre has been contracted to the British Geological Survey (BGS) in Edinburgh rather than, as might have been expected, to AWE Blacknest. The reason for this, according to MoD, is that involving BGS in test monitoring provides access to a pool of seismologists who, while not expert in forensic seismology, have the potential to improve the UK's ability to maintain a suitable skill base to draw on in the future.

If, as seems to be the case, the intention is that BGS eventually replaces the full function of Blacknest, then it is of the highest importance that the transfer of expertise from Blacknest is accomplished successfully. The two senior staff at Blacknest are due to retire within the next five years. They want to pass on their knowledge before retirement and oversee the establishment of a national monitoring programme for implementing the CTBT (which they would prefer to be sited at Blacknest). They must be given the time, resources and encouragement

to do this. The best available seismologists must be recruited immediately by BGS to begin work at Blacknest, while there is still time for transfer of expertise from the existing staff. In addition, a way should be found to involve younger scientists currently or recently employed at Blacknest, who are already expert in forensic seismology, in whatever new arrangements for verifying the CTBT eventually emerge in the UK.

Blacknest has represented both the UK and AWE in a positive light domestically and abroad. If test monitoring expertise is retained at Blacknest, then it would be an ideal focus – a centre of international renown – around which other arms control work could develop. The test monitoring Joint Working Group (JOWOG),[38] recently closed down, could be revived, as a first step in establishing wide-ranging US-UK collaboration on nuclear arms control and disarmament.[39]

5. *Fissile Material Control & Accounting; Negotiating a Fissile Material Cut-off Treaty.* The immediate requirement for the USA and the UK is to negotiate a fissile material cut-off treaty.[40] The UK's main concerns when negotiating a fissile cut-off will be building on UK experience and knowledge to apply managed access procedures to verification of the cut-off, including the need to prepare for intrusive inspections at AWE; and solving the problem of protecting sensitive information without creating a verification loophole should it become necessary, after the cut-off, to produce highly-enriched uranium for fuel for nuclear-powered submarines.

The USA is funding work researching global stockpiles of plutonium and highly-enriched uranium, including the fundamental problems facing attempts to establish comprehensive histories of nuclear programmes and comprehensive

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[38] JOWOGs are periodic technical discussions between representatives of US and UK nuclear weapons laboratories. They are set up (or curtailed) at regular 18-monthly meetings between US and UK officials, reviewing the overall functioning of the 1958 Agreement for Cooperation. The last such meeting was in June 1998.

[39] Exchanges between the US and the UK on test monitoring are currently continuing under the EIVR (Exchange of Information by Visits and Reports) arrangement. Whereas a JOWOG is a structure allowing the continuous exchange of information, EIVRs have to be authorized, on a case by case basis, by the MoD.

[40] The CD agreed on August 11, 1998 to start negotiations on a fissile material cut-off treaty. The Strategic Defence Review states that "the Government is prepared to enter into immediate negotiations for such a treaty in the Conference on Disarmament," *Strategic Defence Review*, Supporting Essay Five, *op.cit.*, para. 25.

inventories of nuclear materials.[41] The Strategic Defence Review promised increased transparency on UK military fissile material stockpiles, stating that:

> Eliminating nuclear weapons will require states which have had nuclear programmes outside international safeguards to account for fissile material produced. We will therefore begin a process of declassification and historical accounting with the aim of producing by Spring 2000 an initial report of defence fissile material production since the start of Britain's defence nuclear programme in the 1940s.[42]

There is obvious scope for collaboration among the nuclear weapon states on methodology, data collection, and so on.

6. *Fissile Materials Disposition.* The US Department of Energy is carrying out extensive studies of options for the disposition of plutonium from dismantled nuclear warheads. It is essential that the UK also develops a plutonium disposition strategy – the UK-owned stockpile of separated plutonium in the civil sector (currently 53 tonnes) is expected to exceed 100 tonnes by 2010 and represent two-thirds of the global total. A report from the Royal Society urges the government to initiate a comprehensive review of the options available.[43] AWE scientists could contribute to such a review.

Insofar as separated plutonium arising from UK reactors is concerned, BNFL apparently has no settled plans for its eventual disposal. There are a number of possible routes, and these are discussed in the Royal Society report, but the two main ones are: (a) mixing the plutonium with high-level radioactive waste and, with or without vitrification, depositing the mixture in a geological structure and (b) producing MOX fuel (by mixing plutonium and uranium oxide) for thermal reactors, and depositing the spent fuel at a geological site.

The UK's inventory of military plutonium (7.6 tonnes) is small in comparison to its civil plutonium stocks. Nevertheless AWE should establish how military plutonium that becomes surplus to requirements would be introduced into a national plutonium disposition programme, including the procedure for placing

[41] South Africa was required, by the relevant clause of its NPT safeguards agreement, to provide the IAEA with a detailed inventory of all its nuclear material. South Africa had been enriching uranium for 20 years, and accounting for all this material was complicated. Accounting for the highly-enriched uranium and plutonium produced in military programmes in the declared nuclear weapon states will be more difficult. In 1996 the USA revealed the total government-owned plutonium inventory, and a history of plutonium production, acquisition and removal.

[42] *Strategic Defence Review*, Supporting Essay Five, *op.cit.*, para. 28.

[43] *Management of Separated Plutonium*, The Royal Society, February 1998.

the material under international safeguards. The Strategic Defence Review declared that 4.4 tonnes of plutonium are no longer required for defence purposes.[44]

7. *Openness and International Collaboration.* Research on technical aspects of nuclear disarmament presents an opportunity to introduce openness at nuclear weapons establishments. Accordingly, verification work at AWE should be made as open as possible, subject not to disclosing information about how to make nuclear weapons. The opportunity should also be taken to promote collaboration on arms control and disarmament between AWE scientists and other scientific and technological workers in the UK and abroad, to perfect verification techniques and to build confidence in the disarmament process.

Since 1994, the US-Russian lab-to-lab programme has provided a framework for collaborative work between US and Russian nuclear weapons scientists. Areas covered under the programme include transparency measures for warhead and material storage, nuclear MPC&A, plutonium disposition, and joint scientific research unrelated to nuclear weapons.

In its short life to date, the lab-to-lab programme has engendered considerable confidence between the nuclear establishments of the two countries. Although classified topics are avoided, the scientists visit one another's laboratories, see for themselves the infrastructure and facilities available to their counterparts, and form working and personal relationships with their opposite numbers.

There is, for instance, a collaborative project on storage monitoring technology between Sandia National Laboratories and Arzamas-16. Both establishments house nuclear materials storage containers (for the time being not containing nuclear material) monitored by a range of sensors (temperature, motion, radiation, fibre optic seals, cameras etc.). The data from the sensors is transmitted directly onto the Internet. Over the next two years this experiment will be extended to include joint monitoring of storage magazines, and ultimately whole facilities, and to include use of actual nuclear materials. A further step will be to integrate storage monitoring with the physical protection and material accounting systems at the site. Live transmission of data from former "secret cities" such as Arzamas is remarkable of itself; site visits, over periods of years, to inspect instrumented containers of nuclear materials and the like, may be an important forerunner of future warhead dismantlement monitoring provisions.

[44] *Strategic Defence Review*, Supporting Essay Five, *op.cit.*, para. 26.

The technology being used in the exercise between Sandia and Arzamas is not specific to container monitoring. It might be applied to weapons, weapon storage vaults, weapons in the dismantlement stream, weapons being transported, production facilities, fissile material disposition, and so on. It has applications for cooperative verification between the nuclear weapon states, and for safeguards administered by international bodies such as the IAEA.

Storage monitoring is a growing programme at Sandia, though still fairly small, employing 15 people part-time. Because of the many sensitive issues involved, there is obvious scope for collaboration between the USA and the UK on trial procedures and techniques. Aldermaston has material storage facilities, and lengthy experience of material handling and operations. Currently Sandia conducts trials between its sites in New Mexico and California.

US/Russian technical collaboration has not been without problems. In particular, cooperation has so far foundered on most of the more sensitive questions of increasing transparency in connection with warheads and fissile materials. Progress in these technical discussions is, however, hampered by the soured political relationship between the two countries. Were the political context to improve, then although entrenched habits of secrecy would have still to be overcome these technical interactions might prove a useful stepping stone towards the openness needed for START III and all progress beyond.

There are tentative attempts underway in the USA to initiate collaboration with China in some technical areas of arms control. There have been some technical exchanges on seismology, and the USA staged a material control and accounting demonstration at a facility in China in 1998. The programme is still small by US standards, receiving about \$1.5m in 1998. Following their series of nuclear weapon tests in May 1998, India and Pakistan might also be interested in technical collaboration on arms control issues with other nuclear weapon states.

It would be straightforward, under existing arrangements for sharing information on nuclear weapons technology, for the UK to work together with the United States on technical aspects of nuclear arms control and disarmament. Indeed, the many opportunities for collaboration already pointed out suggest that if AWE Aldermaston were to take an active role in arms control and disarmament then there would be scope for one or more extensive Joint Working Groups in this field.

An arms control, non-proliferation and disarmament JOWOG would support a coordinated approach by the USA and UK to the development of international nuclear arms control and disarmament treaties. It would provide useful peer review to both sides, and an opportunity to test sensitive verification procedures. The scientists at the US nuclear weapons laboratories are keen to develop collaboration in these areas.

An arms control, non-proliferation and disarmament JOWOG might cover the following areas:

1. Warhead dismantlement: technology and techniques for verified dismantlement of nuclear warheads; chain of custody for warheads and materials removed from weapon systems; trial exchanges of warhead and nuclear materials inventory information.
2. MPC&A in the former Soviet Union: collaboration to maximize joint effectiveness.
3. Non-Proliferation: IAEA safeguards; export controls; counter-smuggling; defence intelligence; technical verification goals and standards.
4. CTBT Implementation: the International Monitoring System; forensic seismology.
5. Global nuclear materials management and accounting: development of fissile material cut-off regime; historical accounting of fissile material production.
6. Plutonium handling, storage, and disposition: techniques and standards for verified handling, storage and disposition of plutonium from the weapons programme.

At least as important as US/UK collaboration are similar opportunities for the UK to collaborate with Russia, France and China. The urgency for the UK to assist Russia in safeguarding its many nuclear facilities has already been argued. It is desirable that collaboration also begins on other aspects of arms control and disarmament. The Russian nuclear weapons laboratories are already working on arms control and non-proliferation, and beginning to set up discrete arms control centres, which will make it easier to establish British-Russian collaboration in this field.

The principal French work on nuclear arms control and disarmament is on test monitoring. France plans to maintain expertise in each of the four aspects of test detection included in the CTBT. Currently around 30 people are employed at France's NDC, and this number is expected to increase.[45] There would be no

[45] Personal communication, Yves Caristan, Head of Department d'Analyse et Surveilance de L'Environment, Commissariat a l'Energie Atomique.

obstacle to the UK and France collaborating in this, or any other, field of nuclear arms control and disarmament.

Hunting-BRAE has made a small start in promoting international links. In September 1997 it organized an international workshop on shock-wave physics at Oxford University, attended by, among others from around the world, a sizeable delegation of nuclear scientists from Russia, who visited Aldermaston in the course of their stay. A similar conference is planned for the summer of 1999 on materials science.

ENGAGING AWE SCIENTISTS IN DISARMAMENT WORK: PRACTICAL ISSUES

Having discussed why the UK should expand work on nuclear arms control and disarmament, and the particular areas on which it might productively concentrate, the next step is to consider in more detail where the work should be carried out. In the last chapter it was shown that AWE has the expertise to contribute to many areas of nuclear disarmament, but it should perhaps not be taken for granted that Aldermaston is the best site in the UK at which to carry out this work.

In this chapter we consider whether Aldermaston is the most appropriate location at which to research nuclear arms control and disarmament. We look at some of the "conversion" issues that might affect AWE scientists transferring from weapons work to an arms control, non-proliferation and disarmament programme, discuss the question of accountability at Aldermaston, and assess the scale of arms control and disarmament work that could be undertaken. Lastly, we consider the scope for a verification organization, independent of AWE, carrying out entirely unclassified work.

As a starting point, though, it is important to note that many nuclear weapons scientists view nuclear arms control, non-proliferation and disarmament as a natural continuation from weapons development in terms of working for "national security." These scientists have been motivated in their work by feelings of national loyalty, believing that they were helping to keep their country safe by contributing to deterrence. They will have enthusiasm for developing verification because it is in the national interest. More than this, most scientists enjoy participating in a process that is aimed at peaceful co-existence rather than mutual destruction. This is noticeably true at the US nuclear weapons laboratories, where arms control jobs are much sought after.

WHY ALDERMASTON?

It is inevitable that a large component of any future nuclear arms control, non-proliferation and disarmament work undertaken in the UK will be carried out at AWE. For safety and security reasons, the physical dismantling of warheads has to be carried out by experienced weapons designers and engineers. Designing verification techniques for all the stages of a warhead dismantlement process – from the storage facility, through transportation, authentication and destruction – requires access to highly classified information. And most other areas of nuclear arms control and disarmament have some security classification. In addition, AWE houses expertise on all aspects of nuclear weapons, and provides access to warheads, weapon components, nuclear materials, and storage facilities, all of which will be needed when developing verification technologies and techniques.

AWE has another advantage over any other UK institution, based on its long-standing arrangements for collaboration with the US nuclear weapons laboratories. As already discussed, the opportunity for collaborating with the USA in arms control and disarmament is an important means for adding value to the UK's work in this field, to the benefit of UK security.

These points make, by themselves, a persuasive case for basing a UK verification research centre at Aldermaston. But it is fruitful to discuss further the direct relevance to disarmament work of skills and techniques developed in the weapons programme. In a general sense those involved in developing weapons know what to look for. They know the characteristic signatures of nuclear explosions and the characteristic effluents from nuclear manufacturing processes. They have a tacit knowledge, built up from experience of manufacturing and handling nuclear weapons, that would help them to anticipate the actions of a clandestine nuclear bomb-maker.[46] And the relevant scientific data is at their fingertips.

More specifically, a number of verification technologies and techniques are derived directly from the weapons programme.[47] For example, techniques employed in the weapons testing programme carry over into verification work: hydro-wave propagation measurement techniques, employed in weapons development, have been applied to verification of the TTBT;[48] analysis of weapons debris requires some of the same technologies that will be utilized for on-site inspections for nuclear explosions; and technologies developed for weapons diagnostics can be utilized in detection devices for verification purposes. In another area, all the physical security measures, material accounting techniques

[46] For example, in 1958 when the USA, Russia and the UK were negotiating a test ban, Edward Teller suggested that a nuclear test explosion could be concealed by exploding the device in a large underground cavity. Hans Bethe argued the same at the talks in Geneva in 1959. Sir Ieuan Maddock, a leading Aldermaston scientist, was given the task of verifying the theory experimentally, using chemical explosions in disused mines. See, "Science and Politics in Early Nuclear Test Ban Negotiations," Kai-Henrik Barth, *Physics Today*, March 1998; and Ieuan Maddock F.R.S, *Biographical Memoirs of Fellows of the Royal Society*, vol. 37, 1991, pp. 323-339.

[47] We are grateful to Professor Maurice Bryson of Los Alamos National Laboratory for providing some of these examples.

[48] The CORRTEX technique (Continuous Reflectometry for Radius versus Time Experiment) in which a satellite hole is bored on the test-site parallel to the bomb emplacement hole, a cable laid down the satellite hole, and the yield calculated from the rate at which the cable is crushed.

and monitoring technologies employed at UK nuclear sites are transferable. This is important because Soviet nuclear installations, for example, relied heavily on military guards and on surveillance by state security forces such as the KGB, rather than technical controls. Radiochemical and microanalytical capabilities can be applied to environmental monitoring and used to detect proliferation activities. (Aldermaston has the best environmental monitoring capability in the UK.) And a final example is the application of weapons design studies to proliferation threat assessment. Carson Mark's design studies (Carson Mark was head of theoretical physics at Los Alamos), for instance, showed that so-called "reactor grade" plutonium could be used to make a nuclear explosive, which was subsequently confirmed experimentally. AWE has also carried out mathematical modelling of weapon designs that might be used by potential proliferators.

Thus the belief that the "old poacher makes the best keeper" has substance with respect to AWE. It applies both to specific applications of specific skills – in warhead dismantling, for example – and to a general understanding of what to look for – when developing safeguards instrumentation, sensing devices, and the like.

The case for doing verification work at Aldermaston is compelling. But although the unique expertise and facilities at AWE would be necessary for most nuclear verification work, they would not always be sufficient – collaboration with other UK bodies would be essential. These would be likely to include BNFL (e.g. on materials safeguards and disposition issues), AEA Technology (e.g. on tamper-proof seals), the Defence Research Agency (e.g. on sensors), and CBD Porton Down (e.g. on on-site inspection techniques). The case for a national (or European) verification laboratory, independent of AWE, is discussed later in the chapter.

FROM WEAPONS DEVELOPMENT TO ARMS CONTROL AND DISARMAMENT

A starting point when looking at the practical issues affecting weapon scientists changing jobs to work on arms control and disarmament is that there are vibrant arms control programmes at each of the US nuclear weapons laboratories, employing many scientists and engineers who have transferred from the weapons programme.[49] Consider the example of the $100m a year Proliferation Prevention and Arms Control Program at Lawrence Livermore National Laboratory. The

[49] Typically, more than half of those employed in arms control and non-proliferation programmes have transferred from weapons work.

programme leader, William Dunlop, was formerly head of a thermonuclear weapons design team. He became involved in verification after serving on a US delegation at the Threshold Test Ban Treaty ratification negotiations. The deputy programme leader in charge of fissile materials programmes worked for 20 years as a leading weapons engineer; Dunlop's other deputy, in charge of foreign interactions, CTBT implementation and START III development, was also a weapons designer. The scientist in charge of work on warhead dismantlement transparency and radiation detection technologies was previously head of the radiation detection group for test experiments in Nevada.

One can also look to senior weapons scientists who have left the nuclear laboratories and been influential in forwarding verification concepts from the outside. Richard Garwin and Theodore Taylor, both once leading weapons designers at Los Alamos National Laboratory, are two well-known such individuals.[50]

Arms control and disarmament research will not always be of comparable interest, in scientific terms, with weapons design work, and therefore will not appeal to every scientist and engineer. But there are many compensating factors. Arms control and disarmament is a "live" programme, in distinction to the stewardship programme, which is no longer producing warheads for the stockpile. It is a highly important, developing field, and in the United States at least is seen as such.[51] And it could be attractive to AWE's scientists to work on projects with increased international dimensions, and to get to know and collaborate with their counterparts in Russia, China and France – almost all the principal points of contact that the USA has at the Russian laboratories are former weapons scientists.

Lastly, because the government would remain the main customer for the work, none of the problems that complicate conversion to work for commercial customers arise.

[50] *cf.* contributions to *Verification: Monitoring Disarmament*, ed. F. Calogero, M.L. Goldberger and S.P. Kapitza, Boulder, Co.: Westview Press, 1991.

[51] President Bush first declared a state of national emergency from proliferation of weapons of mass destruction in 1990 (Executive Order 12735, November 16, 1990). In 1994 President Clinton declared a national emergency to deal with threats posed by weapons of mass destruction and their means of delivery.

Making Arms Control and Disarmament Work at AWE Accountable

Given the considerable opposition to nuclear disarmament that is perceived to exist within the MoD and at AWE itself, it is important to find means to ensure public confidence in the arms control and disarmament work carried out at Aldermaston.

Accordingly, such work at AWE should be the subject of a published annual report submitted to parliament. (In the 1960s, when AWRE (as it was then called) was a part of UKAEA, the progress of seismological research at Blacknest was reported each year in the UKAEA's Annual Report.) The report should encourage those from the broader scientific and technical community interested in arms control and disarmament to communicate with AWE scientists about their research. The arms control work at AWE would also, presumably, be investigated annually by the Defence Committee of the House of Commons, as part of its overall scrutiny of the Establishment.

Should, in due course, the UK sign a nuclear disarmament treaty, then it might prove useful to emulate some of the provisions established for oversight of the UK's implementation of the CWC. A requirement of the 1993 Chemical Weapons Convention is that its parties must enact penal legislation to implement its terms within their jurisdictions. They must also appoint a National Authority to liaise with the international implementing body – the Organization for the Prohibition of Chemical Weapons. The UK government has established a bureau within its Department of Trade and Industry to function as the UK National Authority, and during the requisite legislative process introduced a mechanism that now provides some transparency and accountability in the National Authority work. This mechanism is based on two related measures: the National Authority is required by statute to make an annual report of its activities to the British parliament, and it has an Advisory Committee comprising officials from other departments and people from academia and industry that is charged with reviewing drafts of the statutory report before it is transmitted to parliament. The committee is briefed about all aspects of the Authority's work and about the country's chemical defence programmes. It has its own access to the minister responsible for the National Authority.

POTENTIAL SCALE OF ARMS CONTROL AND DISARMAMENT WORK AT AWE

It may be asked, in the light of the substantial US investment in arms control and non-proliferation technology over many years, how much arms control work could productively be undertaken at Aldermaston?

The starting point, in answering this question, should be that it would be irresponsible to leave any aspect of this work to the USA alone. Every country that participates in the preparations for warhead elimination will have to decide whether the associated verification meets its needs. If the UK is not up to speed on the technological verification possibilities, then when it comes to nuclear disarmament negotiations the UK's negotiators will be liable to make bad decisions. UK scientists will have to advise the UK government on the capabilities and limitations of all aspects of verification in the course of nuclear disarmament. On this basis there is scope for a substantial arms control and disarmament research programme at AWE.

The fact that the US programme is many times bigger than the UK's would ever become should not, in any case, dissuade the UK from becoming involved. Aside from the need for UK expertise, it is not only the amount of resources applied to a problem that is important. The quantity of chemical and biological disarmament research undertaken in the USA is several times greater than that carried out in the UK, yet, as shown in the case study on pp. 46-51, the UK has made leading contributions to this field. The same has been true for the application of forensic seismology to nuclear test explosion monitoring at Blacknest.

Also relevant is whether the field of verification technology has been thoroughly explored, or whether we remain close to the bottom of the learning curve, i.e. is progress in verification capabilities likely to be proportional to the resources invested in R&D over the coming years, or is research in this field in the USA already approaching the point of diminishing returns?

The general feeling at the US laboratories is that while there is not scope for a massive increase in expenditure on arms control, non-proliferation and disarmament, more money (that is, over and above the existing budgets) could be spent wisely. Take as an example nuclear test monitoring, which has been studied a long time and is a fairly mature field. The USA has already produced sensors for test detection to be installed on the next generation of satellites, due for operation around 2002/3. The phenomena that are characteristic of a nuclear detonation are quite well known, so there are limits on new R&D that could sensibly be funded. In seismic and acoustic detection of nuclear tests, the basic phenomena are similarly well understood but there is a need for much more detailed geological and meteorological information in order to apply advanced detection techniques. Continuing research is also needed on detecting and distinguishing between low magnitude seismic disturbances. In other areas, there is, for example, considerable scope for improvements in sensors for detecting nuclear facilities and signs of proliferation of weapons of mass destruction – including detecting traces of chemicals, or finding means to detect underground structures. And while many of the current programmes at the US laboratories are due to decline early in the next century, particularly the MPC&A work in the former Soviet Union, there is no reason to suppose that new programmes, on warhead dismantlement for instance, will not grow to replace them.

Returning, thus, to the issue of the scale of potential work at AWE: for illustrative purposes, a programme on the same relative scale as the arms control and disarmament programme at CBD Porton Down[52] – approximately five per cent of staff and budget, that is, employing 100 scientists and engineers and costing £10-20m a year – could be envisaged. The nuclear arms control and disarmament research programme must be bigger in absolute terms than the programme at Porton Down because there will be a greater technological component to nuclear disarmament than for chemical or biological disarmament. The main elements of the programme would be those already discussed, namely warhead dismantlement transparency, nuclear security in the former Soviet Union, non-proliferation and intelligence, test monitoring, global control & accounting of fissile material, materials disposition, and technical collaboration with the nuclear weapons laboratories in the other nuclear weapon states.

The numbers of scientists and technical staff needed for the UK test monitoring programme depend on what verification of the treaty the UK government wishes to carry out. As already noted, the head of the Blacknest group believes that 25 people would provide the level of verification that the UK would want – 10 staff to maintain and operate the arrays, 10 staff to operate the UK's National Data Centre and perform routine analysis of data, and a research group of five geophysicists. It will take several technical staff to produce the historical records of fissile material production promised in the Strategic Defence Review. There is sufficient work to deploy 15 staff on this project in conjunction with preparations for a fissile material cut-off treaty, which quite possibly will be the next major step in multilateral nuclear arms control and disarmament. Likewise, 15 staff could readily be employed on topics as wide-ranging, and as important to national

[52] The UK's chemical and biological warfare defence establishment, described in the case study on pp. 46-51.

security, as verifying nuclear reductions (if prototype equipment and facilities were to be constructed, then a greater number would be involved), securing nuclear materials in the former Soviet Union, dealing with surplus stockpiles of plutonium, and strengthening the non-proliferation regime.

Ten to twenty million pounds is a very small amount of money in the context of the UK's defence budget. As in other matters of national security, it would be prudent to err on the side of caution, by investing in a wide range of promising work, at least initially, rather than to risk overlooking an important line of technical development.

AN INDEPENDENT CENTRE OF EXPERTISE ON VERIFYING NUCLEAR DISARMAMENT

David Fischer writes that "Each nuclear weapon state will be concerned to ensure that no other nuclear weapon state, let alone any non-nuclear weapon state, gains information of military value about the design and construction of the nuclear weapon state's own nuclear weapons by observing their dismantling."[53] Indeed, the nuclear weapon states are bound, by the NPT, not to disclose information about nuclear weapons technology.

Although the non-nuclear weapon states are, therefore, unlikely to have a direct involvement in observing the dismantlement of warheads, they must play a major role in developing any future international system for verifying compliance with a nuclear weapons convention, so that they are confident that the system will work. A number of states not possessing chemical weapons played a leading role in devising the verification system for the Chemical Weapons Convention, and indeed several non-nuclear weapon states (Argentina, Australia, Belgium, Canada, Finland, Germany, Hungary, Indonesia, Japan, Netherlands, Sweden) already have programmes supporting IAEA safeguards.

In order to promote the involvement of non-nuclear weapon states in research on verifying nuclear disarmament, there may be a case for increasing the quantity of R&D on verifying nuclear disarmament carried out in the UK at a site or sites other than AWE, and which could involve broadly-based international collaboration. (This would add to, not replace, any work carried out at Aldermaston.)

[53] "Verification: The Contribution Likely to be made by IAEA 93+2," David Fischer, presented at *Pugwash Meeting No. 241,* A Nuclear-Weapon-Free World: Steps Along The Way, London, November 6-8, 1998.

As already discussed, much of the UK's work in support of IAEA safeguards is conducted at BNFL and AEA Technology, both of which might take on more responsibility for verification research, contracting work to AWE as necessary. It is also possible that the British Geological Survey in Edinburgh will become, in a few years' time, the UK's centre for test monitoring – in place of AWE Blacknest.

An ambitious project, for which there are precedents in the UK, would be to establish a national centre of excellence on verification in support of nuclear disarmament. Such a verification centre could well be associated with Aldermaston, in order to make the best use of this concentration of nuclear weapons expertise (it could be housed in buildings on the Aldermaston site outside the wire), but it would be an independent body, carrying out entirely unclassified work and breaking away from the culture of secrecy that inevitably dominates a weapons establishment.

The laboratories associated with the UKAEA laboratory at Harwell provide examples of unclassified research programmes set up alongside related classified research work. The Harwell laboratory was established in 1946 to carry out research and development of nuclear science and technology. Some of the work carried out at Harwell was secret, but the laboratory became a major national centre of expertise in nuclear and related sciences. Against this background, it became appropriate to establish, adjacent to Harwell but "outside the wire," a number of associated research, development and operational organizations. These included the SERC Rutherford Appleton Laboratory, the MRC Radiobiological Laboratory, and the National Radiological Protection Board (NRPB) laboratories. The Rutherford Laboratory is based around specialized facilities for high energy physics and serves as a collaborative centre for British universities and overseas workers, with activities that have now extended to various industrial and medical spin-offs. The Radiobiological Laboratory is similarly a national centre with costly specialized facilities that are available for collaborative work between British and overseas scientists. The NRPB is predominantly a service organization but provides a national focus for developing procedures and regulations for radiation protection. This, of course, is part of an international collaborative process, and indeed NRPB provides accommodation for the secretariat of the International Commission on Radiation Protection. It is thus fair to say that all three of these satellite organizations have served to extend appropriate areas of Harwell expertise to the point of being major, internationally respected centres of excellence.[54] The NRPB is of particular interest because it

[54] We would like to thank Kit Hill for suggesting a national centre of excellence, independent from AWE Aldermaston, and providing the example of spin-offs from Harwell.

works in a politically controversial field – as would a research organization for verification.

Another possibility would be for the UK to take a lead in establishing a European Centre for Verification Research. A European Centre for Verification Research might serve, in various ways, to strengthen Europe's contribution to nuclear arms control and disarmament. The most obvious role for the centre would be to support and develop the IAEA's involvement in nuclear disarmament. Another option would be for a European verification establishment to emulate the Cooperative Monitoring Center (CMC), located at Sandia National Laboratories Albuquerque site. The CMC describes its purpose as "to assist political and technical experts from around the world acquire the technology-based tools they need to analyse, design, and implement non-proliferation, arms control, and other security measures," and to "promote the application of unclassified, exportable technologies for cooperative monitoring." A European verification centre might receive a part of its funding from the European Union.

THE UK'S PAST CONTRIBUTIONS TO INTERNATIONAL ARMS CONTROL AND DISARMAMENT

CASE STUDIES

An argument that we encountered on several occasions, in the course of researching this project, is that because the USA puts so many resources into international arms control and disarmament – far more than the UK ever could – there is little point in the UK becoming involved because it would not add anything to the US work.

Aside from not wishing to rely on the USA in matters of nuclear arms control and disarmament – indeed this would be quite unacceptable in so vital an area – the following case studies show that the UK can make a worthwhile contribution to multilateral arms control and disarmament initiatives.

Each of the case studies discusses an important area in which the UK has contributed to international disarmament of weapons of mass destruction, namely in the development and negotiation of the Comprehensive Test Ban Treaty, Chemical Weapons Convention and Biological Weapons Convention, and in the activities monitoring the destruction of Iraq's weapons of mass destruction. In each case, the UK has expended only very modest resources in making its contribution. We conclude the case studies by drawing together some of the main factors that enable the UK to work so effectively in these areas.

THE UK'S CONTRIBUTION TO MONITORING NUCLEAR TEST EXPLOSIONS

By the early 1960s AWE (then AWRE) was involved in monitoring nuclear test explosions in all environments. From 1958 the UK had been negotiating with the USA and Soviet Union for a comprehensive ban on nuclear testing. In 1963 the three governments signed and ratified the Partial Test Ban Treaty, which banned nuclear explosions in the atmosphere, in outer space and under water, and AWE then concentrated its efforts on detecting underground testing.

Seismological research began at AWE in 1958. The work was carried out at Aldermaston until 1960, when it moved to its present location at Blacknest, a mile down the road. Blacknest is administratively linked to Aldermaston, but is "outside the wire," engaged in open, unclassified work.

Over the years, an average of 15 staff have worked at Blacknest at any one time, constituting the UK's principal expertise in forensic seismology. Blacknest scientists have provided advice to government on ambiguous seismic events and foreign test explosions, and supported over many years the development of a comprehensive ban on nuclear testing. Blacknest has amassed a unique library of technical reports and seismic data from arrays around the world. Its staff have published widely in the open literature, and maintained close links with academic seismological research in the UK.

Blacknest has a firmly established international reputation. Blacknest scientists have achieved important advances in forensic seismology, developing leading expertise in seismological methods for estimating the yield of underground nuclear explosions, and distinguishing explosions from earthquakes. They have designed steerable seismometer arrays, and pioneered their application to seismic detection (technology and techniques later used by the USA); and they have proposed an explanation, now widely accepted, of the physical basis for the best criterion for discriminating between explosions and earthquakes.

This expertise has been usefully applied to politically sensitive issues, notably to demonstrate that the Soviet Union was not violating the Threshold Test Ban Treaty between 1974 and 1990, when the Treaty remained unratified. In this period, US seismological techniques estimated the yield of several of the Soviet test explosions at significantly above 150kt, whereas Blacknest was able to show that the seismological evidence was compatible with yields within the Treaty's 150kt threshold. The USA subsequently came to agree with the UK's estimates and analyses. The UK's moderating influence was important because it stopped the United States from adopting too strong a position, making the final ratification process less difficult than it might otherwise have been.[55] In addition, Blacknest has produced conclusive analyses of ambiguous seismic disturbances in the vicinity of the Soviet test sites at Semipalatinsk in 1976[56] and Novaya Zemlya in 1986.[57] Most recently, in August 1997, Blacknest scientists correctly identified a seismic disturbance in the Novaya Zemlya region as an earthquake, while suspicions were voiced in the USA for more than a month after the event that this might have been a nuclear explosion.

[55] Statement by Robert Blandford, Senior Scientist, Treaty Monitoring Directorate, Air Force Technical Applications Center (US National Data Centre), US Department of Defense.
[56] "The Seismic Disturbance of March 20, 1976, East Kazakhstan: earthquake or explosion?," *Geophys. R R astr Soc*, 1983, v. 74, pp. 621-631.
[57] "The Seismic Disturbance on 1 August 1986 near Novaya Zemlya: a source of concern?," P.D. Marshall, R.C. Stewart, & R.C. Lilwall, *Geophysical Journal*, 98, 1989, pp. 565-573.

The excellence and independence of Blacknest's work is acknowledged in the USA; indeed, Blacknest should be seen as an important component of the "Special Relationship." Exchanges have been formalized in a Test Monitoring Joint Working Group, in operation since the 1960s (but recently curtailed), and, according to the senior scientist at the US National Data Centre "The Blacknest group has been of immense assistance to the United States monitoring community over the course of approximately 40 years, and continues to be so to this day."[58] For the UK, collaboration with the USA provides the opportunity for technical exchanges with members of a richly-funded test detection programme, as well as access to classified data and analyses.

The Comprehensive Test Ban Treaty

The Blacknest group played an important role in the Comprehensive Test Ban Treaty (CTBT) negotiations. From 1977-1980, a second series of intensive tripartite negotiations took place in Geneva. The British delegation included two representatives from AWE, one of them Peter Marshall from Blacknest. Verification was a major issue and the three delegations devoted much work to the detailed arrangements for on-site inspections and the exchange of data from seismic stations. The negotiations did not resume after President Reagan's election in November 1980 but the work done, and the mutual understanding achieved between the verification experts, were to be of great value in the multilateral negotiation of the CTBT at the Conference on Disarmament from 1994 to 1996.

Peter Marshall, by now Blacknest's deputy director, was again a member of the British delegation. At an early stage in the negotiations he was appointed Friend of the Chair of the Verification Working Group on Non-Seismic Techniques, and then, when it was agreed that seismic detection technologies should not be considered separately from other verification systems, he was made chairman of the Group of Scientific Experts on Verification, occupying this position until the Treaty was opened for signature. Marshall was qualified to guide the negotiations by his expertise in technical verification of nuclear explosions. His negotiating experience from 1977-80 also helped to secure the collaboration of scientists on the Russian delegation with whom he had worked in this earlier period. Blacknest's international reputation lent Marshall further credibility helpful for brokering compromises among the nuclear weapon states, and between the nuclear weapon states and other concerned parties.

[58] Statement by Robert Blandford, Senior Scientist, Treaty Monitoring Directorate, Air Force Technical Applications Center (US National Data Centre), US Department of Defense, 1998.

In a seminal speech at the Conference on Disarmament,[59] Marshall proposed the four technologies (seismic, acoustic, hydroacoustic and radionuclide) that were eventually used in the International Monitoring System. He later helped to fix the location of the IMS monitoring stations, assuaged Russian concerns (regarding the monitoring of Novaya Zemlya compared with Lop Nor), French and Chinese concerns (regarding the potential of hydroacoustic technology to track submarines), and US concerns (regarding the redundancy of infrasound monitoring, in light of their satellite capabilities).[60] Working alongside Marshall, Peter Sankey from AWE made contributions to the Treaty provision for on-site inspections.

The UK's Contribution To Chemical And Biological Warfare Disarmament

The UK's influence on chemical and biological warfare (CBW) disarmament has been significant and cost-effective. It has been among the major players that have developed CBW disarmament measures, and has been influential in the development of the existing CBW anti-proliferation regime.

The 1972 Biological and Toxin Weapons Convention (BWC) and the 1993 Chemical Weapons Convention (CWC) are the two main pillars of the existing CBW non-proliferation regime. The BWC was the first multilateral treaty to ban an entire class of weapons of mass destruction, entering into force in 1975. Although it is limited by its lack of verification and enforcement measures, as will be discussed later, the negotiation of a protocol including such measures is underway. Like the BWC, the CWC is a multilateral treaty which bans an entire class of weapons of mass destruction. However, the CWC is the first such treaty to include verification and enforcement measures. It prohibits the development, production, stockpiling and use of chemical weapons, and requires their destruction; it also requires the destruction of chemical weapons production facilities. The Convention provides for monitoring of permitted facilities and short notice challenge inspection in cases of suspected non-compliance. It entered into force in April 1997.

[59] "Personal view" from Dr. Peter Marshall at the 25th meeting of Working Group 1 of the Ad Hoc Committee on a Nuclear Test Ban, June 8, 1994.

[60] For a discussion of negotiations on required coverage and details of the IMS, see A Comprehensive Test Ban Treaty: Signed But Not Sealed, Rebecca Johnson, *Acronym* No.10, May 1997.

In general it is very difficult to assess the contributions of different nations to the CWC and BWC since both are multilateral conventions, which could not have entered into force without genuine multilateral support from, and compromises being made by, all contributing nations. The list of people that have been involved in the negotiations is long and diverse, and many different approaches and interests have been taken into account in the formation of the treaties, so it is difficult to apportion credit to particular countries. Nevertheless it is widely recognized that the UK had a positive impact on the CWC and the BWC, and is doing so again in the negotiations to strengthen the BWC. Britain has resolved disputes in the international negotiations, and several aspects of the treaties that are widely recognized as being effective began as British suggestions.

To a certain extent the UK's influence on the anti-CBW regime has been wielded behind closed doors; in international negotiations consensus may be achieved through personal persuasion in informal interactions, and in some cases countries may exert their influence through third parties. It is impossible to assess such influence. Bearing this in mind, the following sections will detail and discuss only those aspects of the UK's influence on developing international constraints against CBW which it is possible to trace, through identifying elements of the existing regime that had their origin in British ideas.

The 1993 Chemical Weapons Convention

The UK was one of a small group of nations that had a role in shaping the CWC. In the treaty negotiations the UK did a lot of work developing the verification measures of the treaty, particularly procedures for challenge inspections, and it was a prominent negotiator. It has been proactive in involving its industry, which was important for developing pragmatic negotiating positions and for preparing industry for the Convention. It has implemented the treaty well, and has a role in training international inspectors.

Perhaps the most significant contribution the UK made to the CWC was in developing procedures for challenge inspections. The CWC has the most intrusive verification regime of any disarmament treaty to date and a fundamental part of this are the challenge inspection procedures which are contained in Article IX and Parts X and XI of the Verification Annex. These are short-notice inspections, invoked when one member state is concerned about the possible non-compliance of another. Challenge inspections were the cause of much contention during the CWC negotiations in the 1980s, with some states insisting on the importance of intrusive verification measures and others finding the idea of access to sensitive military and commercial sites unacceptable.

The UK devised several measures that made challenge inspections more effective and encouraged support for them in the international negotiations. Particularly important, the British invented the process of "managed access" whereby the host of an inspection can restrict access to areas of the site being inspected – in order to protect legitimate commercial or national confidential information – but in doing so must still provide sufficient access to demonstrate compliance with the Convention. Managed access techniques are a cornerstone of the CWC's mechanism for challenge inspection, itself a cornerstone of the CWC. Complementary to this, another important principle that began as a British suggestion is that the inspected party is under an obligation to demonstrate compliance in a challenge inspection.

The British researched these ideas through a series of practice challenge inspections in the UK at sensitive government sites, starting in 1988.[61] These practice challenge inspections were particularly influential; although other countries ran practice challenge inspections too, the British programme ran at a very contentious time when there was disagreement in the negotiations over the scope of the challenge inspection regime, notably from the USA and USSR. The UK is still developing its expertise in practice challenge inspections; in February 1998 it hosted a mock challenge inspection designed to provide a training opportunity for both the OPCW and UK authorities.

The UK also contributed to developing systems for handling the verification of non-production of chemical warfare agents by industry. During the negotiations it was clear that the verification measures of the CWC would necessarily impinge on civilian industry as well as military activities, since many of the precursors for chemical warfare agents have dual use, with commercial as well as military application. Verification of non-production of chemical warfare agents in industry is a vital part of the treaty, but for many years negotiations were impeded by an assumption that the verification regime should be based on the toxicity of chemicals – that is, the greater the toxicity of the chemicals being looked for, the more intrusive should be the verification measures. But this was inappropriate since such a system would not provide adequate verification of non-production of incapacitating chemicals or their precursors.

[61] Arms Control and Disarmament Research Unit, Foreign and Commonwealth Office, "Chemical Weapons Convention Negotiations 1972-92", FCO, UK, 1993, p. 18.

A British approach bypassed the question of toxicity, and instead thought about verification in terms of the risks of cheating in the prospective Convention. This led the UK negotiators to promote a three-tiered classification of chemicals, which in turn led to the three Schedules of Chemicals in the Chemical Weapons Convention on which the system of declarations and routine inspection is based.

The UK delegation tabled a total of 32 working papers between 1970 and 1992,[62] and was consistent in the issues it contributed to, taking a long-term interest in verification aspects, and the requirements of a central organization implementing the Convention, that is now the Organization for the Prohibition of Chemical Weapons, based in The Hague. And as well as being active in Geneva, the UK government was conscientious in developing its position, being one of the few countries which had early and ongoing consultations with its industry.[63] This was fruitful – the UK's was one of the three most informed chemical industry groups at the first consultation of industry by the international negotiations in a meeting at the Conference on Disarmament in Geneva in 1987.

Implementation of the CWC

The UK is now implementing the CWC in accordance with the treaty provisions. At entry into force of the Convention, the UK was one of the few states parties to submit all the declarations required by the Convention within the prescribed time frames. It has also enacted well-considered domestic implementing legislation. Thus the UK has had some 15 inspections to date from the OPCW covering defence and industrial sites. In all of these the UK has shown good cooperation with the OPCW teams, ensuring smooth running of the inspections.

Before entry into force of the Convention, the work of the OPCW was done by a Preparatory Commission (PrepCom). The UK assisted the PrepCom in devising a system of proficiency tests to select Designated Laboratories, required by the CWC to handle any verification samples that come from OPCW inspections. Two UK laboratories were important in advising on the design of appropriate proficiency tests: CBD Porton Down and the Laboratory of the Government Chemist.

[62] *Ibid.*

[63] There were informal government-industry consultations through the 1980s – e.g. the government included industry in practice trial inspections – culminating in the establishment of the Government Industry Working Group in the late 1980s. This is an interdepartmental government group with industry representatives. It still meets two or three times a year.

The UK is continuing to support the OPCW, supplying expertise and ideas, and being prompt with its financial dues.[64] In addition, the UK also contributes to the OPCW's programme of training for inspectors and personnel of National Authorities. Most recently the UK hosted a training course at Cranfield University – in chemical and conventional munitions technologies – for international inspectors and munitions specialists from the OPCW. CBD Porton Down supplied lecturers and a day's training at their old chemical munitions storage facility.

In summary, we can see that the UK contributed to the international effort to design and implement an effective CW disarmament treaty, and that the UK's influence was significant in developing important components of the CWC.

The 1972 Biological Warfare Convention

The UK is one of three depositaries of the 1972 BWC, having been prominent in the negotiations for the treaty. As in the case of the CWC, several aspects of the treaty can be traced to British suggestions. Most obviously the separation of biological warfare and chemical warfare in the international arms control negotiations – a move which led to an early conclusion of the BWC – was first suggested by the British.

The Ad Hoc Group Negotiations to Strengthen the BWC

The BWC is limited by its lack of verification and enforcement measures, and attempts have been made to rectify this through the Convention's five-yearly Review Conferences and several ad hoc bodies. Currently, an additional protocol to consider appropriate measures, including possible verification measures, for strengthening the Convention is being negotiated by an Ad Hoc Group of states party to the BWC.

It is acknowledged that here, too, the UK is making a good contribution. The UK delegation has submitted a number of key working papers to the Ad Hoc Group – submitting papers is the mechanism by which delegations forward suggestions for

[64] Britain was one of the 9 (out of a total 107) states parties which "were full paid up for the 1998 budget year by the eighth session of the OPCW Executive Council from 27-30 January 1998," Mr Tony Lloyd (Minister of State in the Foreign and Commonwealth Office), *Hansard written answers*, March 16, 1998, column 471.

the final Protocol. In the Ad Hoc Group's 8th Session (September/October 1997) the UK supplied 3 out of 27 national Working Papers; in the 9th Session (January 1998) it supplied 6 out of 22. As in the CWC negotiations, the UK is favouring the development of a rigorous verification regime. The main UK contributions are in the declarations, visits and investigations sections: for example, it has tabled specific procedures for clarification visits, managed access, rules for use of particular on-site measures in investigations, and declaration triggers.

As with the CWC the UK is consulting with its industry to develop its position for the Ad Hoc Group negotiations and to prepare the industry for the future entry-into-force of the additional protocol of the BWC. The UK industry is well informed on the international negotiations, and UK industry representatives understand the key issues. The UK government has had ongoing consultations with industry since 1993, with regular informal liaison and formal interdepartmental meetings with individuals and company representatives.

The Ad Hoc Group meetings are run under Friend of Chair Sessions to consider different aspects of the protocol. Significantly, in the Ad Hoc Group the UK was appointed to the role of Friend of the Chair on Compliance Measures. The Compliance Measures sub-group is crucial, dealing with the verification aspects of the protocol including Declarations, Non-Challenge Visits and Non-compliance Concern Investigations. Friends of the Chair, as chairs of these subgroup meetings, occupy key positions, presiding over the negotiations where much of the detail of the draft protocol is developed. The UK was assigned the position of Friend of the Chair on Compliance Measures in part because of its reputation in this area, and the assignment was generally supported because the UK had been so active in this area, for example, because it was prominent in designing the confidence-building measures in the BWC Review Conferences in 1986 and 1991. A second reason that Britain was allotted this position was the quality of the individuals, including scientific experts, that it makes available to the international negotiating fora.

The UK's Contribution To Monitoring The Destruction Of Iraq's Weapons Of Mass Destruction

This case study reviews the UK's contribution to the international disarmament efforts in Iraq following the end of the 1990-1991 Gulf War. It was written before the use of military force in December 1998 following the failure of Iraq to cooperate with the United Nations Special Commission (UNSCOM) and the consequential suspension of the international disarmament efforts.

After describing the way the international activities have been organized, we discuss the UK's role, concentrating on two areas. First we describe the extent to which the UK has provided personnel and equipment, which gives a measure of the level of the UK's commitment to the initiatives. But perhaps more significant than this quantitative analysis is the quality of the UK's contributions, and so secondly we discuss the scientific and technical expertise associated with the UK's contribution, which has at its roots the national research laboratories.

The UN Security Council requirement for supervision of the destruction of Iraq's weapons of mass destruction, and for ongoing monitoring and verification to ensure that Iraq does not resume its weapons of mass destruction programmes, has been carried out by UNSCOM and the International Atomic Energy Agency (IAEA), as mandated by UN Security Council Resolutions 687 (April 1991), 707 (August 1991) and 715 (October 1991). The IAEA is mandated to verify Iraq's declarations and destruction of its nuclear weapons programme and stocks, and to monitor its long-term compliance with the UN Security Council Resolutions. Resolution 687 established UNSCOM to do the same for Iraq's chemical, biological and ballistic missile programmes, and UNSCOM is also mandated to assist the IAEA in its inspections of Iraq.

To fulfil their responsibilities, both UNSCOM and the IAEA appointed structures to store and analyse data, organize inspections, and so on. The UNSCOM headquarters in New York has been mostly staffed by individuals seconded from contributing nations on a semi-permanent basis, but includes UN professional staff. There have been approximately 65 individuals in the UNSCOM headquarters staff at any one time, about 45 of whom are on secondment. UNSCOM has also had a resident monitoring team in Baghdad comprising approximately 100 staff, similarly composed of seconded personnel from more than 15 nations (including between six to ten from the UK, depending on the tasks in hand). The IAEA set up an Iraq Action Team to deal with its duties under Security Resolution 687, which has comprised around 15 professional scientists,

some paid for by the United Nations and others provided cost-free by member states of the IAEA.

In addition to personnel for these long-term structures, experts have been seconded on an ad hoc basis from contributing countries, for example for visiting inspection teams. The salaries of seconded staff have all been paid for by the contributing countries. The contributing nations have also lent specialized inspection equipment (for example the USA has provided a U-2 reconnaissance plane which is flown and operated by US personnel under UNSCOM direction), and have bought equipment for UNSCOM (ranging from basic office equipment, such as personal computers, to sophisticated equipment for chemical analysis).

Thus the work of UNSCOM and the IAEA Iraq Action Team has been resourced through direct donations of staff and equipment from contributing states, although both bodies have also had a budget for operational costs which has been funded from the proceeds of limited Iraqi oil sales. (In theory, Iraq is liable for all the costs of the contributing nations.) Any discussion of the total costs of UNSCOM and the IAEA Iraq Action Team is necessarily vague, since much of the work is paid for in kind, and the costs vary constantly. Nevertheless it has been estimated that "A round figure of $100 million a year would seem reasonable for the total cost of UNSCOM."[65] The IAEA Action Team direct annual expenditure was budgeted as $3.5 million for FY1998-1999; the actual annual expenditure, including contributions in kind from member states, has been about twice this amount.

The work of UNSCOM and the IAEA Iraq Action Team was designed to be collective and multinational, and so it is not easy to distinguish particular national inputs. Nevertheless it is commonly held that the UK's contributions have been important. With regard to UNSCOM, Richard Butler, UNSCOM's Executive Chairman, speaking at a Press Conference in London on April 2, 1998, said "The United Kingdom is a very strong supporter of UNSCOM. I am not sure that we would be able to do our work in the way that we do today without that support so it is very important that I record the depth of our gratitude to the UK for its help."

Looking first at the scale of its contributions, the UK has had a budget of £1.3 million a year to supply personnel and equipment in response to requests from UNSCOM and the IAEA Action Team. It has been among the major contributors of equipment (others being the USA, France and Germany), and has also provided significant numbers of personnel to the headquarters and inspections staff.

[65] Graham Pearson, "An Optimum Organisation," *Briefing Paper No 5*, Department of Peace Studies, University of Bradford, Bradford, UK, January 1998, p. 6.

It is estimated that 300 UK nationals have been involved ad hoc in the UNSCOM inspections, with Britons accounting for 5 out of 50 Chief Inspectors for CW inspections, and 16 out of 51 Chief Inspectors for the BW inspections.[66]

In addition, the UK has had a long-term participation in UNSCOM's more permanent structures. Britain provides one of UNSCOM's 21 Commissioner posts whose role is to maintain an overview of the work of the Special Commission. The Commissioners have been appointed from 21 countries specified in a report of the Secretary General on the establishment of UNSCOM, which was later endorsed by the Security Council. As well as the Commissioners, the UK provides personnel to the UNSCOM headquarters in New York, and has supplied several people to key posts. These include the first Special Assistant to the Executive Chairman, an influential position which was subsequently replaced with a number of posts, one of which is again filled by a UK national. The UK has also had a major role setting up UNSCOM's Information Assessment Unit – an innovative approach to interfacing national intelligence with the international fieldwork of UNSCOM – supplying the head of the department. The UNSCOM senior legal adviser is also British.

Similarly, the UK has supplied one of the long-term cost-free experts to the IAEA Action Team (which will cost \$186,000 in FY1998-1999), and each year has supplied two people for two months to the Nuclear Monitoring Group, the IAEA's structure in Iraq, set up in August 1994 to monitor long-term compliance (which was expected to cost £20,000 in FY1998-1999). Most recently these have been from British Nuclear Fuels, but the expertise of AWE Aldermaston has been called upon throughout. Approximately 20 UK nationals have participated in IAEA inspections since 1991.

It is recognized that the UK's expertise has been important to the work of UNSCOM and the IAEA's Iraq Action Team. It is judged that the UK has been particularly important in the scientific and technical areas, where the UK members of the teams have demonstrated knowledge of what to look for and how to look

[66] Chief Inspectors are appointed by the Executive Chairman of UNSCOM; their selection takes into account their experience and availability. A breakdown of the approximate number of chief inspectors of CW inspections is: Germany 10; Netherlands 9; US 6; Russian Federation 6; Sweden 6; UK 5; Switzerland 2; France 2; Austria 2; Canada 2. (N.B. The high German and Dutch numbers reflect the inspections led by those nationals in the UNSCOM staff in New York.) For the BW inspections the numbers are: US 24; UK 16; Canada 3; Austria 2; France 2; Germany 2; Sweden 2. (The high number of US chief inspectors reflects the US nationals in the UNSCOM staff in New York. In recent years many successive inspections have been led by the same inspectors, who have brought to bear their prior experience as chief inspectors.) These statistics were provided by Graham Pearson.

for it. This has been particularly noticeable in the BW and nuclear inspections. Few countries other than the UK and USA have the necessary BW verification expertise, and it has been asserted that the UK was instrumental in uncovering the Iraqi BW programme. In fact, it has been claimed that some of the inspection teams that had European, but non-UK, chief inspectors concluded that there was no Iraqi BW programme. Similarly, not many countries have direct practical experience of the technologies associated with nuclear weapons production, and the IAEA has limited relevant expertise. Thus the IAEA Iraq Action Team has provided copies of Iraq's declarations to the five nuclear weapon states for evaluation, and when specific problems have arisen regarding the technicalities of nuclear weapons, it has consulted with, among others, UK experts.

In the scientific and technical aspects, the UK's contribution is dependent on its national laboratories, particularly CBD Porton Down and AWE Aldermaston, as well as other indigenous expertise. Porton Down has provided the UK with qualified scientific experts, well versed in aspects of CBW detection, destruction and defence, to supply to the UNSCOM inspections, and also provided the first UK Special Commissioner. And AWE scientists are the only people in the UK with the relevant expertise on nuclear weapons, with insights into nuclear weapons design and manufacture, valuable to designing and performing nuclear inspections in Iraq. In addition to the direct participation of UK scientists in the process as Inspectors, Chief Inspectors, or on secondment on a more permanent basis, the UK laboratory at Porton Down provided UNSCOM with high quality support with regard to Iraqi chemical and biological sample analyses.

FACTORS THAT HAVE ENABLED THE UK TO CONTRIBUTE TO INTERNATIONAL ARMS CONTROL AND DISARMAMENT

A number of factors have facilitated the UK's contribution to the CTBT, CWC, BWC and UNSCOM/IAEA activities in Iraq. The UK could draw on these same factors, or build on analogous resources, to contribute to multilateral nuclear disarmament, and so it is useful to highlight some of the key aspects. Although most of these are not unique to the UK, the combination of factors has enhanced its influence.

TECHNICAL KNOWLEDGE - ROLE OF NATIONAL LABORATORIES (WITH SPECIAL REFERENCE TO CBD PORTON DOWN)

A recurring theme throughout the cases studies is that the UK's strong understanding of the technical issues relating to international disarmament is important to its impact in this field, and that this understanding is in large part based on the expertise at its national laboratories. For the nuclear test ban, the relevant expertise is located at AWE Blacknest, discussed above. In CBW defence, this expertise is located in the chemical and biological research establishment at Porton Down. As a national laboratory researching weapons of mass destruction, the way Porton Down organizes its arms control and disarmament work might serve as a useful model for the changes at AWE Aldermaston that we are suggesting in this Report. For this reason it is helpful to look at the arms control and disarmament work of Porton Down in some detail.

The UK has had a site dedicated to chemical and biological research at Porton Down continuously since 1916 (thus Porton Down is the longest running chemical and biological research institute in the world), although the UK renounced its offensive CBW capability in 1957, since when the research programme has been defensive. Currently called Chemical and Biological Defence (CBD) Porton Down, it is a world leader in the science and technology of CBW defence.

Porton Down has specialized knowledge of CBW both from its past offensive programme and subsequent work evaluating the potential hazards, which includes researching the potential threat from new agents. Its work has always incorporated elements of CBW non-proliferation, for example in its detection R&D, and in 1995 a non-proliferation group was formally established. This comprises 23 man-years annually – staff are assigned by the hour to particular tasks – including 6 or 7 full time posts. The non-proliferation group budget for 1997 was approximately £1.8 million (Porton's total budget for this time was £47

million, and so the work of the non-proliferation group takes approximately 4% of the total). The group works on many facets of CBW non-proliferation; it forms, negotiates and puts into practice the UK's non-proliferation policies, and it works on export controls. Roughly 70% of the work of the non-proliferation group is on the CWC, 25% on the BWC, and 10% on export controls (some work on BWC/CWC is interchangeable and counted twice in this breakdown).

There are advantages in having all the CBW non-proliferation work in one department in this way, since there are synergies to exploit. The integration of related work in the non-proliferation group gives staff an overview of international arms control and disarmament, and there can be useful overlap of issues, for example between the work for the Biological Weapons Convention (BWC) and the Chemical Weapons Convention (CWC). Note that it is unusual for all aspects of CBW non-proliferation work to be managed together; in other countries they are usually worked on by separate sets of people.

The UK's access to expertise in CBW matters is unusual in that it has experience of an active weapons programme though it gave up its offensive capabilities in the late 1950s and early 1960s. After this, the work at Porton Down was entirely defensive, but included some research on new agents for threat assessment and in order to design the best detection and protective equipment.

Weapons of mass destruction (WMD) are complex technologies and scientific understanding is important to the development of international regimes for their elimination, as well as to technical measures for treaty implementation, such as verification. Although relevant technical details can be and are understood by countries without any history of offensive measures, the historical background in Britain gives it a head start in technical infrastructure and knowledge. CBD Porton Down's access to classified details of a historical weapons programme has meant that during international negotiations, UK negotiators were able to draw on a full range of technical expertise whenever it was needed.

Porton Down's arms control and disarmament work has been useful to the laboratory itself in maintaining its visibility in government. To an extent, CBD Porton, which is part of the MoD agency DERA, has a proactive role in its arms control work, anticipating what is needed – for example, what technical issues should be addressed in the international negotiations – and recommending to MoD how this should shape its research programmes. The UK government has had an interagency Working Group on CWC Policy since the 1980s comprising representatives from MoD, FCO and CBD Porton Down, and a BWC Subgroup comprising representatives from MoD, FCO, DTI and CBD Porton Down. The commitment of individual directors of Porton Down can also be seen in the level of Porton's contributions to the international arms control negotiations.[67]

The UK government has made good use of technical advice from its national laboratories, supplementing the UK delegations to international negotiations with technical experts from Blacknest and Porton Down. We have discussed the role of Blacknest scientists in the achievement of the CTBT. Like their Blacknest counterparts, Porton Down scientists prepare internal documents for the government, which feed into the policy-making process, and contribute major parts of documents that the UK submits to international negotiations. The UK delegation to the CWC negotiations had several ad hoc experts supplied from Porton Down, who attended negotiations for a few weeks at a time to deal with specific technical questions, and had a permanent technical expert from Porton Down in the CWC negotiations from 1986 to 1993, who now continues this work from the British Embassy in The Hague (where the OPCW is located). Similarly, Porton Down supplies technical experts to the UK delegations at the Ad Hoc Group negotiations to strengthen the BWC.

The work of technical experts on negotiations goes beyond being strictly technical as they develop a long-term expertise in particular negotiations, and then contribute to the emerging regime at different levels. As well as providing scientific advice, technical experts are helpful in introducing a pragmatism to negotiations, encouraging progress towards solutions, and isolating key bits of the negotiations on which to focus.

In addition to the technical expertise specific to particular weapons of mass destruction in each of the national laboratories, the UK has accumulated a broader expertise in verification. It has participated in the negotiation and implementation of a succession of arms control and disarmament measures, and has constructively transferred the skills and people working on certain areas of arms control and disarmament to others. For example, Britain drew on the procedures for handling incoming inspection teams it had researched in developing its position for the Conventional Forces in Europe treaty for developing its position for the CWC negotiations, where the expertise was developed further. And similarly the expertise developed in the CWC is now being used in the Ad Hoc Group negotiations to strengthen the BWC.

[67] In particular, former directors Rex Watson and Graham Pearson were supportive of arms control and disarmament.

Political Commitment

Although political support for arms control and disarmament measures has varied over the years, the UK has viewed certain arms control and disarmament measures as important components of its national security, and has put resources into developing and implementing these. This is particularly notable in the case of CBW disarmament, where successive UK governments have been committed to arms control and disarmament for some 30 years. International arms control and disarmament measures can gain political support through being cost effective means of enhancing national security. For example the UK's rationale for taking a significant role in UNSCOM and the IAEA Iraq Action Team was to minimize the proliferation dangers in an unstable region through measures that are peaceful and much cheaper than would be the UK's involvement in renewed military action against Iraq.

Its long-term involvement with various arms control and disarmament measures has enabled the UK to develop an expertise in the ways in which the international process works, the logistics of negotiating an effective treaty, and the essential components of arms control and disarmament. Thus, in negotiating arms control and disarmament regimes it can be an advantage to have an understanding of how similar problems have been solved in the past. The accumulation of expertise also provides some insurance against the re-discussion of problems or ineffective solutions. Negotiating international arms control agreements usually takes a long time and is not necessarily a linear process in which problems are solved in a successive fashion. At times in the negotiations a problem that has been solved once can be revisited. Having some continuity in attention means that time can be saved on the discussion of these.

A continuity of attention to arms control, non-proliferation and disarmament is also important in building credibility within international negotiations, which gives the UK's suggestions added weight. Blacknest, for example, established over many years a reputation for independent reliable advice which gave its scientists extra credibility as technical experts on the UK delegation to the CTBT negotiations. Further, the UK's record in arms control and disarmament has gained its representatives a reputation as effective negotiators, which can have a knock-on effect on their ability to influence further developments. Thus, the UK is an important contributor to the Ad Hoc Group negotiations to strengthen the BWC in part because of its past achievements in BW disarmament.

THE UK'S NEGOTIATING ROLE

Within international negotiations, the UK has a tradition of finding good solutions to arms control and disarmament issues that are well researched and presented. This can partly be explained by the fact that the UK has to prioritize its work, since it allocates only a small amount of money to arms control, and therefore tends to identify the key components of an issue, and concentrate on these.

The UK's pragmatism can be seen in its approach to testing and developing techniques for challenge inspections in the CWC – rather than simply discussing the issues, the UK systematically tested them in a series of practice challenge inspections that started in the late 1980s. The UK's thinking about intrusive verification was stimulated by a draft convention tabled by the USA in 1984, which included provisions for "anytime anywhere" verification: the UK was particularly concerned about whether it could allow access to Russian inspectors at UK military sites. Thus a Ministry of Defence group began testing the implications of the US draft, organizing a series of practice challenge inspections of sensitive military sites. These were practical exercises invoking "role playing" techniques; one team would play the part of receiving an inspection, a second team would be the inspectors. Participants felt that such exercises were valuable, giving greater insights into various techniques and procedures than discussions on the same subject, and they were used to investigate and devise various measures for protecting the confidentiality of a site during a challenge inspection including "Managed Access" techniques.

The UK's practice challenge inspections were designed and carried out with three objectives: to investigate whether the prospective convention was reconcilable with confidentiality requirements; to examine ways of demonstrating compliance with the prospective convention while protecting legitimate security interests unrelated to chemical weapons; and to draw any lessons for how challenge inspections might be conducted. The results of the series of challenge inspections were circulated in the negotiations, and their practical basis inspired confidence in the UK's conclusions. And they were also used to build confidence in industry that their commercial secrets would not be revealed.

Another advantage is that English is the language of international negotiations, and is important in the informal discussions as well as in devising the wording of treaties, which benefits UK officials working to achieve consensus in negotiations.

THE UK'S INTERNATIONAL POLITICAL CONTEXT

Although it seems that the UK has usually managed to make decisions based on the national interest, the international context in which it operates has also been important to the UK's ability to influence disarmament. In particular, the UK's relationship with the USA has influenced its negotiating position. The UK frequently identifies its security needs with its "Special Relationship" with the USA; even when the UK is committed to disarmament it can be restricted in its position by the USA. (The relationship with the USA can also work in the other direction, as for example in 1993 when the USA forced the UK to renew its support for the CTBT.) But although in some instances the UK has been made to accept compromise, within international negotiations the UK has often maintained an independent voice from the USA. This is particularly evident in the work of Blacknest, which, as discussed, has often produced results at odds with those of the USA.

Other relations are also important to the UK's international standing. The UK's influence is very wide through being a permanent member of the UN Security Council and a member of NATO and the European Union. In addition the UK has traditionally had a big influence in the Western Europe and Others Group (WEOG), one of the various groupings of states within the international negotiating fora. WEOG has always been a particularly important caucus – a pre-agreed WEOG position may give a strong impetus to negotiations.

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In conclusion, it is clear that, when the political will exists, the UK is in a position to play a strong role in developing international regimes for the elimination of weapons of mass destruction. As noted, the government's stated objective is the elimination of nuclear weapons through mutual balanced and verifiable disarmament measures. One way of working towards this objective would be to start research at AWE Aldermaston into scientific and technological aspects of nuclear arms control and disarmament.

CONCLUSIONS

1. A concerted effort is needed, from a range of countries, to study the possibilities for verifying nuclear disarmament. Britain must be involved because before deciding to take part in international disarmament the British government and general public will require credible advice from their own scientists and engineers on the requisite verification measures. There are also acute problems of non-proliferation which the UK should do more to address, above all, the possibility that fissile material could be diverted from stockpiles in the states of the former Soviet Union.

2. Increasing the UK's contribution to nuclear disarmament efforts would be a cost-effective way of enhancing national and international security. It would go some way towards meeting the UK's obligation under Article VI of the NPT to work in good faith for nuclear disarmament. And should, when the time comes, the UK decide not to replace its strategic nuclear deterrent, Trident, then it will want to promote arms control and disarmament all the more vigorously.

3. The UK has expertise and facilities, mainly located at AWE Aldermaston, that could be applied to work on verification and other aspects of nuclear arms control, non-proliferation and disarmament.

4. Although several other UK bodies have relevant expertise, and would play a part in the UK's work in this field (indeed, the case for a national or European centre of verification expertise, independent from AWE, should be studied), the focus of the UK programme should be at AWE. AWE scientists have the skills and security clearances necessary to deal with sensitive issues; they have the knowledge of the details and the characteristic signatures of nuclear processes; and AWE provides access to the weapon components and facilities that will be needed when developing verification technologies and techniques.

5. There are precedents, in the USA, for nuclear weapons laboratories working on nuclear arms control and disarmament. Arms control and disarmament is a major programme at each of the three main weapons laboratories – Los Alamos, Livermore and Sandia. Arms control jobs are sought after at the US laboratories: more than half of those working on arms control have transferred from the weapons programme.

6. Because of the arrangement between the UK and USA for exchange of classified nuclear information, there is scope for extensive collaboration on nuclear arms control and disarmament, such as is not possible between other nuclear weapon states. UK-US collaboration would provide useful peer review to both sides; an opportunity to test sensitive verification procedures; and it would support, if the countries so desire, a coordinated Anglo-American approach to the development of nuclear arms control and disarmament treaties.

7. In addition to collaboration with the USA, it is desirable that AWE collaborates on nuclear arms control and disarmament work with France, Russia and China, in order to increase openness and thereby build confidence between the countries, as, for example, has been the result of the quite extensive interactions between US and Russian nuclear weapon scientists.

8. Although collaborating with the USA in particular would add value to the UK's work in this area, it would not stop the UK from making an independent and distinctive contribution. The UK has been among the states most influential in negotiating the comprehensive ban on nuclear testing and the chemical and biological weapons conventions, and has provided important expertise and resources to the UNSCOM/IAEA activities in Iraq.

9. The Chemical and Biological Defence establishment at Porton Down provides a precedent for arms control and disarmament work at one of the UK's national defence laboratories. For many years it has carried out research and development for chemical and biological arms control and disarmament alongside its main protective and defensive measures.

10. Accordingly, we recommend that the UK government establishes a nuclear arms control and disarmament research programme based at Aldermaston, and makes working towards a nuclear-weapon-free world a formal part of AWE's mission.

The work should focus on the seven main areas described in the Report:

i/ verifying the dismantlement of nuclear warheads;

ii/ safeguarding nuclear materials in the states of the former Soviet Union;

iii/ promoting non-proliferation, in particular by supporting the IAEA;

iv/ implementing the Comprehensive Test Ban Treaty;

v/ negotiating a fissile material cut-off treaty and increasing transparency surrounding military stockpiles of fissile material;

vi/ disposing of surplus fissile material;

vii/ increasing openness at AWE Aldermaston; promoting collaboration on nuclear arms control and disarmament technologies between Aldermaston, overseas nuclear weapons laboratories, and other bodies working on related science and technology.

Acknowledgements

We consulted widely in the course of our research and gained much valuable information without which we could not have produced this Report. The opinions expressed in the Report are, however, our own, and not necessarily shared by any of the interviewees. We would like warmly to thank the following people for assisting us in our research and, in many cases, for commenting on drafts of the Report:

At **AWE Aldermaston**: Robin Bradley, Alan Douglas, David Glue, Ken Johnston, Andrew Machin, Peter Marshall, Peter Roberts, and Peter Sankey. At **CBD Porton Down**: Gradon Carter, David Kelly, and Tony Phillips. At the **Ministry of Defence**: David Dearden, Hugh Gray-Wallis, L G Macdonald, Paul Roper, Paul Schulte, Sandy Stagg, Stephen Willmer, and Ian Woodman. At the **Foreign and Commonwealth Office**: Andrew Barlow, Graham Cooper, John Walker, Amanda Wedge, and Richard Whiteley. At the **Department of Trade and Industry**: Gary Foden. At **Los Alamos National Laboratory**: Maurice Bryson, for hosting a visit, and Tony Burris, Randy Erickson, Cliff Giles, Steve Maaranen, Jas Mercer-Smith, Jay Norman, David Simons, Bill Stanbro, Jim Tape, and Rick Wallace. **At Sandia National Laboratories** Albuquerque site: Richard Preston, for hosting a visit, and Dave Barber, Dennis Croessman, Mark Soo Hoo, and Al Zelicoff. **At Lawrence Livermore National Laboratory**: William Dunlop, for hosting a visit, and Bill Domke, Lee MacLean, Paul Herman, Jim Morgan, Nancy Suski, and Jerry Sweeney. At **the US Department of Energy**: Leslie Casey, Jon Wolfstahl, and Bob Waldron. At the **US Department of State**: Sallie Mullen and Mark Swiecicki. At the **Organization for the Prohibition of Chemical Weapons:** John Gee, Ron Manley, Ron Nelson, Johan Santesson, and Ralf Trapp.

Sir Michael Atiyah, Sir Hugh Beach, Frans Berkhout, Frank Blackaby, Ewan Buchanan, David Caplin, Malcolm Dando, Gary Dillon, Norman Dombey, David Edgerton, John Edmonds, Rob Evans, Trevor Findlay, David Fischer, Owen Greene, Paul Guinnessy, Phillip Gummett, Ross Hesketh, Christopher Hill, Robert Hinde, Rebecca Johnson, Ian Kenyon, Patricia Lewis, Pauline Marstrand, Suzanna von Moyland, Graham Pearson, Sebastian Pease, Julian Perry Robinson, Anthony de Reuck, John Simpson, Nicholas Sims, Terence Taylor, William Walker, and Simon Whitby.

ABBREVIATIONS AND ACRONYMS

AEA Technology	Atomic Energy Authority Technology
AWE	Atomic Weapons Establishment
AWRE	Atomic Weapons Research Establishment
BGS	British Geological Survey
BNFL	British Nuclear Fuels plc
BWC	Biological and Toxin Weapons Convention
CBD Porton Down	Chemical and Biological Defence Porton Down
CBW	chemical and biological warfare
CD	Conference on Disarmament
CTBT(O)	Comprehensive Test Ban Treaty (Organization)
CWC	Chemical Weapons Convention
DERA	Defence Evaluation and Research Agency
DoE	(US) Department of Energy
DTI	(UK) Department of Trade and Industry
FCO	(UK) Foreign and Commonwealth Office
FSU	Former Soviet Union
GAN	Gosatomnadzor (Russia's civilian nuclear regulator)
Hunting-BRAE	Hunting Engineering, Brown & Root and AEA Technology
IAEA	International Atomic Energy Agency
IDC	International Data Centre
IMS	International Monitoring System
INF	Intermediate-Range Nuclear Forces
JOWOG	Joint Working Group
JVE	Joint Verification Experiment
MINATOM	(Russian) Ministry of Atomic Energy
MoD	(UK) Ministry of Defence
MOX	mixed oxide (fuel)
MPC&A	material protection, control and accounting
NATO	North Atlantic Treaty Organization
NDC	National Data Centre
NIS	Newly-Independent States
NPT	(Nuclear) Non-Proliferation Treaty
NRPB	National Radiological Protection Board
OPCW	Organisation for the Prohibition of Chemical Weapons
PrepCom	Preparatory Commission
START	Strategic Arms Reduction Talks/Treaty
THORP	Thermal Oxide Reprocessing Plant
TTBT	Threshold Test Ban Treaty
UKAEA	UK Atomic Energy Authority
UNSCOM	United Nations Special Commission
WMD	weapons of mass destruction