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THE DISARMAMENT LABORATORY

SUBSTANCE AND PERFORMANCE IN UK NUCLEAR DISARMAMENT VERIFICATION RESEARCH

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SUBSTANCE AND PERFORMANCE IN UK NUCLEAR DISARMAMENT VERIFICATION RESEARCH

Over the last twenty years, the UK has researched nuclear arms control and disarmament verification in increasing breadth and depth. This activity has become increasingly internationalised and has formed much of the UK's recent disarmament diplomacy. It stems in part from the degree of internal conflict in the UK about its nuclear weapon status, and the perceived need to take the lead in nuclear disarmament matters, set against decreasing room for manoeuvre in terms of substantive reductions to its declared nuclear arsenal; in the future it is likely to be increasingly central to the UK's disarmament diplomacy.

The degree to which UK verification research is genuinely intended to make a tangible disarmament contribution therefore merits scrutiny. This is particularly true for those states that are also working in the field or are interested in doing so. This paper lays out how Finland and other Nordic states could contribute by encouraging the UK to take more meaningful action, *inter alia* by linking UK verification research and its modernisation programme to potential arms control futures.

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LIST OF ABBREVIATIONS

ACVR	Arms Control Verification Research
AWE	Atomic Weapons Establishment
BTWC	Biological and Toxin Weapons Convention
CAEP	China Academy of Engineering Physics
CASD	Continuous At-Sea Deterrence
CTBT	Comprehensive Nuclear Test Ban Treaty
CWC	Chemical Weapons Convention
FOI	Totalförsvarets forskningsinstitut
GGE	Group of Government Experts
IAEA	International Atomic Energy Agency
IPNDV	International Partnership for Nuclear Disarmament Verification
JACIG	Joint Arms Control Implementation Group
MOD	(UK) Ministry of Defence
MP	Member of Parliament (UK)
NDA	Non-destructive assay
NNWS	Non Nuclear Weapon State
NPT	Nuclear Non Proliferation Treaty
NTV	Nuclear Treaty Verification
NWS	Nuclear Weapon State
OPCW	Organisation for the Prohibition of Chemical Weapons
QNVP	Quad Nuclear Verification Partnership
SSBN	Ship, submersible, ballistic, nuclear
UKNI	UK-Norway Initiative
UNIDIR	United Nations Institute of Disarmament Research
VERTIC	Verification Research Training and Information Centre

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INTRODUCTION

Over the last twenty years the UK has researched the verification of nuclear arms control and disarmament in steadily increasing breadth and depth. In the last ten years this activity has become more internationalised and has formed an important component of the UK's disarmament diplomacy. Its long-standing collaborations with the US and Norway, and more recently with Sweden, have been built on the foundations of a deep and capable national programme designed to "place the UK government in a position of strength in the event of its participation in the negotiation of future nuclear-related treaties".[1] More recently, the UK has taken a leading role in the International Partnership for Nuclear Disarmament Verification (IPNDV)[2] and the Group of Governmental Experts (GGE) on Nuclear Disarmament Verification.[3] The UK has also held at least one technical exchange with China on arms control verification issues.[4]

Its record is therefore one of expanding engagement and interest. But the UK is not party to any nuclear arms control agreements other than the Comprehensive Nuclear Test Ban Treaty (CTBT), nor has it given any indication that it might soon be so, and the substantive unilateral disarmament measures it has taken to date have been unverified. When then Foreign Secretary Margaret Beckett said at the Carnegie Nuclear Policy Conference in 2007 that she wanted "the UK to be at the forefront of both the thinking and the practical work… to be, as it were, a 'disarmament laboratory'", she laid out a vision where the UK would make real contributions to breaking down the technical obstacles to broader and deeper nuclear reductions.[5] But has this vision been realised? Can we now describe the UK as a disarmament laboratory or is it merely a laboratory for the diplomacy of disarmament?

This paper addresses these questions first by setting the UK's nuclear arms control and disarmament verification research in the context of its domestic nuclear discourse and politics, and its history of engagement in verification of biological, chemical and nuclear weapons. It then summarises technical work done to date before assessing the relevance of this activity to the substance and diplomacy of nuclear disarmament. It concludes with recommendations on how this research might be shaped in future, and how other nations, such as Finland and others in the Nordic group, which have demonstrated interest in the practical utility of verification research in advancing disarmament goals, might condition their engagement with it.

THE ORIGINS OF UK NUCLEAR DISARMAMENT VERIFICATION RESEARCH

Of all the states that possess nuclear weapons, the UK is perhaps the most conflicted about its status. All but one of its major political parties have at one time or another advocated substantial reductions to, or complete elimination of, the UK's nuclear arsenal.[6] Contemporary public polling data indicates "opinion has moved towards relinquishing nuclear weapons after Trident when given a simple yes/no choice… opinion is split more evenly three ways when a third option of a smaller, cheaper replacement is introduced"[7] and that "the British public is divided on the question of whether Trident should be renewed… [but] responses to public opinion polls are sensitive to the wording and framing of the question".[8] Several senior Cabinet Ministers, having defended UK nuclear policies while in office, expressed discomfort with contemporary UK

1 Plant, 2016.

2 "Working Groups For Nuclear Disarmament Monitoring Verification", International Partnership for Nuclear Disarmament Verification, https://www.ipndv.org/about/working-groups/ (accessed 29 March 2019).

3 "Group of Governmental Experts to consider the role of verification in advancing nuclear disarmament", United Nations Office at Geneva, https://www.unog.ch/80256EE600585943/(httpPages)/794372F61323EA8EC12580ED0053B8D5?OpenDocument (accessed 29 March 2019).

4 Berger, 2014, p. 8; Plant, 2016 op. cit.

5 Beckett, 2007.

6 Of the Conservative Party, the Labour Party, the Liberal Democrats and the Scottish National Party, only the former has never made such a case.

7 Ritchie & Ingram, 2013.

8 "Replacing the UK's 'Trident' Nuclear Deterrent", House of Commons Library Briefing Paper Number 7353, 12 July 2016, pp. 94-101.

policy after leaving government.[9] Nevertheless, decision-makers have time and again felt it a step too far to relinquish nuclear weapons entirely.[10]

The UK's response to this complex political and moral tangle has been to become the most forward-leaning of nuclear states on disarmament issues. The UK's unilateral (albeit unverified) reductions in its warhead stockpile, number of deployed warheads, variety of weapons and delivery systems have taken it to a point where it has by some distance the fewest nuclear weapons of any of the Nuclear Weapon States (NWS) of the Nuclear Non-Proliferation Treaty (NPT). It has already been overtaken in variety of weapons by at least two of the other four possessors of nuclear weapons, India and Pakistan, and probably by all four, and it may well be overtaken in number of weapons during the 2020s by one or more of them.[11] It also asserts that it now keeps its nuclear forces on several days' notice to fire, that it does not routinely target its nuclear missiles at any state, and that it will not use, or threaten to use, its nuclear weapons against any Non Nuclear Weapon State (NNWS) party to the NPT that is not in material breach of its NPT obligations.[12]

To these substantial reductions, the UK added in the late 1990s its first tentative exploration of technical nuclear arms control and disarmament verification issues, further details on which are laid out in subsequent sections. We now know that this laid the foundations for technical exchanges with the US. It also paved the way for the UK to exploit technical research on arms control and disarmament verification for diplomatic ends in a way that no other state did until the initiation of the IPNDV by the US in March 2015.[13] Even now, no other state places its verification research efforts quite so centrally in its disarmament diplomacy.

It was in the mid-2000s that this programme began to find its feet, however. In 2005, at that year's NPT Review Conference, the UK offered to work with any NPT NNWS that was interested in collaborating on its verification work, and over the course of the next two years the UK-Norway Initiative was born. While further details of this collaboration are laid out below, it is worth briefly situating this seemingly outward-facing move in the UK's contemporary domestic politics.

In 1997, Tony Blair led the Labour Party into power for the first time in nearly two decades, with the biggest majority for any government since 1935.[14] He did this on the first ever Labour manifesto to unambiguously back retention of the UK's nuclear weapons without additionally specifying significant disarmament action. Instead, the manifesto committed an incoming government to "press for multilateral negotiations towards mutual, balanced and verifiable reductions in nuclear weapons" and that "[when] satisfied with verified progress towards our goal of the global elimination of nuclear weapons, [it would] ensure that British nuclear weapons are included in multilateral negotiations".[15] Given that the Labour Party had stood – and been roundly defeated – only three elections prior on a manifesto committing to entirely abandon the UK's nuclear weapons, this was a marked change of language.[16] One need only examine the official record of the British Parliament during the debate of the 1998 Strategic Defence Review – which affirmed the UK's intention to "retain [its] nuclear deterrent with fewer warheads to meet [the] twin challenges of minimum credible deterrence backed by a firm commitment to arms control"[17] – to see the extent of the disquiet within the party on this issue only a year after its landslide General Election victory.[18]

Nuclear weapons continued to be a source of neuralgia for Labour in government, with a key decision point arriving in March 2007. A parliamentary vote on the December 2006 Ministry of Defence White Paper on "The Future of the United Kingdom's Nuclear Deterrent", which recommended retention of the UK's

9 See for example: Portillo, M., "Does Britain need nuclear missiles? No. Scrap them", *Sunday Times*, 19 June 2005; Owen, D., *Nuclear Papers*, (Liverpool University Press, 2009); Williams, S., "A middle way on Trident", *The Guardian*, 20 June 2010, https://www.theguardian.com/commentisfree/2010/jun/20/trident-nuclear-weapons-deterrent-minimise (accessed 29 March 2019); Browne, D. and Kearns, I., "Trident is no longer key to Britain's security", *The Telegraph*, 5 February 2013, https://www.telegraph.co.uk/news/uknews/defence/9850192/Trident-is-no-longer-key-to-Britains-security.html, (accessed 29 March 2019).

10 Former UK Prime Minister Tony Blair wrote in his autobiography that "I could see clearly the force of the common sense and practical argument against Trident, yet in the final analysis I thought giving it up too big a downgrading of our status as a nation, and in an uncertain world, too big a risk for our defence"; Blair, 2011. "MPs debate the UK's nuclear deterrent", News from UK Parliament, 18 July 2016, https://www.parliament.uk/business/news/2016/july/mps-debate-the-uks-nuclear-deterrent-18-july-2016/ (accessed 29 March 2019).

11 For details on stockpiles and trajectories, see Kristensen, H.M. and Norris, R.S., *Nuclear Notebook: Nuclear Arsenals of the World*, Bulletin of Atomic Scientists, https://thebulletin.org/nuclear-risk/nuclear-weapons/nuclear-notebook/ (accessed 29 March 2019).

12 Ministry of Defence, 2015.

13 "International Partnership for Nuclear Disarmament Verification Kick Off Meeting", International Partnership for Nuclear Disarmament Verification, https://www.ipndv.org/events/international-partnership-nuclear-disarmament-verification-kick-off-meeting/ (accessed 29 March 2019).

14 "General Election 2005", House of Commons Library Research Paper 05/33, 10 March 2006.

15 Dale, 2000 (pp. 343–382).

16 Ibid., pp. 239–288.

17 Ministry of Defence, 1998.

18 See Hansard, "Strategic Defence Review", HC Deb, 8 July 1998, c1073; Hansard, "Strategic Defence Review", HC Deb, 19 October 1998, c968; Hansard, "Strategic Defence Review: Second Day", HC Deb, 20 October 1998, c1097.

nuclear weapons along with missile life extension and the start of concept work on replacement submarines, provided MPs with their first opportunity to vote on the UK's nuclear weapons status. Coming the year after the Labour Party had been returned to power with a significantly reduced (albeit still substantial) majority and a remarkably low share of the popular vote, and with its cohesion damaged by disagreements over the Iraq War,[19] this found the government far weaker than it was in 1998. Although the vote on the White Paper passed with a majority of 248, thanks to the support of the opposition Conservative Party, it also saw a substantial rebellion from Labour MPs, with over a quarter voting against their own government's policy.[20]

It is against the background of internal Labour Party politics that we should set the UK's early efforts on nuclear disarmament verification research. In 1998 the incoming government's Strategic Defence Review had committed it to reductions in warhead numbers, greater transparency on fissile material holdings and production, and development of "capabilities that could be used to verify reductions in nuclear weapons", while affirming an ongoing commitment to nuclear deterrence;[21] and over the period where the 2006 White Paper was being prepared, produced and voted on had likewise sought to internationalise its verification work, supported by prominent speeches from the Defence and Foreign Secretaries,[22] and followed up with demonstrable international action to convene the first meeting of the NPT Nuclear Weapon States on technical nuclear disarmament issues (which would become known as the P5 Process[23]). The Labour leadership was thus able to engage nuclear sceptics in its own party over this period with a balanced policy proposition, pointing to the government's actions on the "mutual, balanced and verifiable" programme of nuclear reductions for which it had promised to press when it first came to power.[24]

It would be wrong to accept this rather cynical reasoning as the whole truth, although it was undoubtedly a significant element of the rationale for the central role of verification research in UK disarmament diplomacy while Labour was in power in the 2000s. After all, it would be hard to sustain the claim that any of Tony Blair, Margaret Beckett or Des Browne – who, as Prime Minister, Foreign Secretary and Defence Secretary during this period respectively, were the key individuals with responsibility for the nuclear deterrence and disarmament portfolio – were dyed-in-the-wool nuclear deterrence hardliners. Rather, the evidence available at present points to a genuinely hard choice, somewhat reluctantly made, wishing it were possible for the UK to make a positive contribution to global and human security by doing otherwise, but assessing in the end that the risks of abandoning the UK's course on nuclear weapons would be too great when set against an uncertain benefit.

THE UK'S HERITAGE OF NON-PROLIFERATION AND DISARMAMENT VERIFICATION ACTIVITY

Even before it took its first steps into nuclear disarmament verification under Tony Blair's first Labour government, the UK had developed a substantial track record of leadership in other areas of disarmament verification. The first real exposure of the Atomic Weapons Establishment (AWE) to verification activities, for example, wasn't stimulated by nuclear issues at all but rather a practice challenge inspection under the Chemical Weapons Convention (CWC).[25]

There are several other examples of substantive UK leadership on verification of biological, chemical and nuclear non-proliferation and disarmament. On nuclear matters, the UK provided substantial technical input to negotiations on the CTBT, while its experts, laboratories and monitoring stations continue to play a leading role in almost all areas of monitoring and verification activity.[26] In the context of the Biological and Toxin Weapons Convention (BTWC), the UK was one of the prime movers behind the development of a verification protocol including managed access and challenge in-

19 See for example "Labour MPs revolt over Iraq", *The Guardian*, 26 February 2003, https://www.theguardian.com/politics/2003/feb/26/foreignpolicy.uk2 (accessed 29 March 2019).

20 See Hansard, "Trident", HC Deb, 14 March 2007, c298. The record includes an extended intervention from the current leader of the Labour Party, Jeremy Corbyn, describing the proposed decision to extend Trident as "costly and illegal".

21 *Strategic Defence Review* 1998, op. cit.

22 Beckett, op. cit.; Browne, 2008.

23 Berger, op. cit.

24 Dale, op. cit., pp. 343–382.

25 CD/1012 (also issued as CD/CW/WP.304), dated 11 July 1990, submitted to the Conference on Disarmament by the delegation of the United Kingdom of Great Britain and Northern Ireland, 'Verification of the Chemical Weapons Convention Practice Challenge Inspections of Government Facilities: Analysis of Results'; Walker, 2018.

26 See for example Johnson, 2009; "Interview: Jaap Ramaker, Chairman of the CTBT Negotiations in 1996", Comprehensive Test Ban Treaty Organisation Preparatory Commission, https://www.ctbto.org/the-treaty/developments-after-1996/interviewjaap-ramaker-chairman-of-the-ctbt-negotiations-in-1996/ (accessed 29 March 2019); "AWE experts support CTBTO in Vienna", AWE News Archive, 29 September 2017, https://www.awe.co.uk/2017/09/awe-experts-support-ctbto-in-vienna/ (accessed 29 March 2019).

spection,[27] the abandonment of negotiations on which caused no small irritation in London.[28] And returning to the CWC, the UK most recently led efforts to broaden the mandate of the Organisation for the Prohibition of Chemical Weapons (OPCW) to include attribution of responsibility for use.[29]

In embarking on its programme of nuclear warhead verification research, therefore, the UK was occupying familiar political territory even as it ventured into an uncharted technical landscape. The following sections lay out its exploration of that landscape over the past two decades. This treatment deals in turn with early UK national efforts and the beginnings of UK–US collaboration, the UK–Norway Initiative, and relatively recent developments such as collaboration between the UK and Sweden, and multilateralised efforts under the Quad Nuclear Verification Partnership (QNVP) and IPNDV.

It does not address discussions of verification under the P5 Process, as those are more fairly characterised as briefings and other information exchanges rather than collaboration or research. Nor does it address the UK's contribution to the GGE on Nuclear Disarmament Verification, as that group is more political than it is technical, and the UK's activity there should be seen in that light. Finally, although it is worth recalling that technical exchanges between the UK and China on nuclear disarmament verification research were being explored as of the 2014 NPT Preparatory Committee,[30] and we know that one such meeting happened that year,[31] there is no further discussion of them here. This is because there has been no public briefing on the subject by either the UK or China since then and, we must assume, no further such meetings have been held.

1998–2005: FIRST STEPS AND THE ORIGINS OF UK–US CO-OPERATION

The UK's first forays into nuclear disarmament verification followed the 1998 Strategic Defence Review commitment to investigate the potential for the UK to build practical capabilities to support future arms control and disarmament treaties. This involved an 18-month study, conducted by a multi-disciplinary team of scientists and engineers from AWE with the final report, "Confidence, Security & Verification: The challenge of global nuclear arms control" delivered in 2000. This investigation claimed to have "identified a technical route for the cost-effective development of UK technical verification capabilities", and "recommended to the MOD a programme of research into arms control verification as part of AWE's enduring Threat Reduction programme… and identified tasks for the first, or foundation, year of a three-year research programme".

The report identified five themes to be addressed by this research programme: verification of weapon and component stockpile size and provenance, and signatures of the weapons complex as a whole; warhead authentication, which referred to the challenge of proving that an object was a specific warhead or component of one without revealing sensitive of proliferative information; verifiable dismantlement of warheads; disposition of components and materials; and system performance assessment of arms control and verification regimes in the round. The early years of research activity developed these themes by exploiting the dismantlement of retired Chevaline warheads[32] to allow collection through radiometric technologies of "real world… information at all stages in the dismantlement process… [creating] a unique UK database linked to the warhead authentication challenge". The UK also planned, at the time, to conduct similar campaigns in future on Trident warheads "on an opportunity basis". The issue of disposition was subsequently dropped from the research programme on the grounds that it was adequately covered by nuclear safeguards, leaving issues of warhead and component authentication, warhead dismantlement and monitoring of the weapon complex.[33]

Although at the time there was no hint in UK public diplomacy of this being anything other than a purely national effort, we now know that co-operation between the US and the UK on arms control verification began in 2000, immediately after the initial AWE fea-

27 Eighth Report of the House of Commons Select Committee on Foreign Affairs, Session 1999–2000: Weapons of Mass Destruction, paragraphs 96–104; "UK Still Favors Biological Weapons Verification", *Nuclear Threat Initiative Global Security Newswire*, 15 March 2006.

28 Private communications.

29 "CWC Conference of the States Parties Adopts Decision Addressing the Threat from Chemical Weapons Use", Organisation for the Prohibition of Chemical Weapons press release, 27 June 2018, https://opcw.org/media-centre/news/2018/06/cwc-conference-states-parties-adopts-decision-addressing-threat-chemical (accessed 29 March 2019).

30 Berger, op. cit.

31 Plant, op. cit.

32 Chevaline was a system of modified warheads and penetrations aids (such as decoys), developed from the mid-1970s and employed by the UK between the early 1980s and mid-1990s, designed to penetrate the increasingly capable Moscow anti-ballistic missile system.

33 Verification of nuclear disarmament: final report on studies into the verification of nuclear warheads and their components. Working Paper submitted by the United Kingdom of Great Britain and Northern Ireland to the 2005 NPT Review Conference, NPT/CONF.2005/WP.1.

sibility study was concluded.[34] This uncharacteristic quietness on the part of the UK, at a time when one might have imagined its interests would be best served by highlighting dimensions of this work that were not purely national, can be at least partly ascribed to delicacy towards the contemporary politics of the US. The ambivalence tending to opposition of the George W. Bush administration towards verification mechanisms that did not rely solely on national capabilities[35] meant that the programme could best proceed without public attention in the US – although that does not entirely explain why the collaboration was not avowed until the second term of Barack Obama's presidency.

Unlike the UK programme, which had at that point only very little experience of the issues associated with verification of nuclear weapons, the US had a very substantial heritage to draw upon. US work on nuclear warhead-related verification can be traced back to Project CLOUD GAP, which ran from 1963 to 1967 and culminated in Field Test 34: a study on the feasibility of determining through technical means whether fissile material nominally resulting from a dismantlement process could be said with any degree of certainty to have come from a nuclear weapon. The study concluded, in lessons that to this day frame the concerns of verification researchers, that some sort of weapon design disclosure would almost certainly be required for the monitoring party to have sufficient confidence that a process they were observing was indeed the dismantlement of a genuine warhead, and that potential evasion risks, including those associated with equipment tampering, were real and worthy of consideration.[36]

This programme then proceeded to support the negotiation of the series of Cold War treaties between the US and the Soviet Union, and latterly Russia, that restrained and reduced both parties' nuclear weapons capabilities. Research activity covered the same broad areas as those laid out above, albeit with detailed investigation of other areas – notably chain of custody issues for nuclear warheads and components, and the vulnerability to tampering of technical equipment – that the UK programme was yet to introduce.

The UK therefore had a lot to learn from the US. But US engagement with the UK was not entirely altruistic. As the 2015 *Joint US–UK Report on Technical Cooperation for Arms Control* outlined, collaboration between the two countries during this period involved two joint measurement campaigns "in conjunction with an ongoing warhead dismantlement programme" at the UK's nuclear weapons assembly/disassembly and storage facility in Burghfield.[37] Given the information laid out above, the warhead in question must be Chevaline. The US therefore had a strong incentive to participate in these early UK studies: a rare opportunity to deploy a range of detection technologies and prototype verification equipment against a warhead and warhead components not in the US arsenal, at a variety of stages of dismantlement. These campaigns were augmented by a managed access exercise at AWE Burghfield, which again represented a new opportunity for the US.

2005–2010: THE UK–NORWAY INITIATIVE TAKES CENTRE STAGE

As well as reporting on the previous five years of nuclear warhead verification work, the UK at the 2005 NPT Review Conference offered to work with any interested state in exploring further some of the open questions raised by UK (and, we now know, UK–US) work to date. Over the next two years the UK and Norway, which was supported by the Verification Research, Training and Information Centre (VERTIC), discussed and agreed the terms of a technical exchange involving staff from AWE in the UK and a range of research organisations in Norway.[38] It was agreed that this would focus on two strands of activity: managed access into nuclear weapon-related facilities; and research into information barriers for warhead verification. Research under the new UK–Norway Initiative (UKNI) began in 2007, with VERTIC transitioning to the role of independent observer and adviser as the collaboration work began in earnest.[39]

The first three years of the collaboration proceeded rather tentatively. Although the collaboration did

34 Joint U.S.–U.K. Report on Technical Cooperation for Arms Control, U.S. Department of Energy and UK Ministry of Defence, 2015.

35 Woolf, 2011.

36 It is worth noting that, despite the technical advances made since, many of the verification concepts, risks and conclusions outlined in the final report of Field Test 34 remain valid. See "Final Report – Volume I – Field Test FT-34: Demonstrated Destruction of Nuclear Weapons", United States Arms Control and Disarmament Agency, January 1969.

37 U.S. Department of Energy and UK Ministry of Defence, op. cit.

38 These organisations were the Institute for Energy Technology (IFE), the Norwegian Defence Research Establishment (FFI), NORSAR (the Norwegian National Data Centre for the CTBT) and the Norwegian Radiation Protection Authority (NRPA).

39 The United Kingdom–Norway Initiative: Research into the Verification of Nuclear Warhead Dismantlement. Working paper submitted by the Kingdom of Norway and the United Kingdom of Great Britain and Northern Ireland to the 2010 NPT Review Conference, NPT/CONF.2010/WP.41.

manage to conduct two managed access exercises and to develop a very simple information barrier (which could detect the presence of a radiation source under controlled conditions without revealing information about that source to the inspector), when set against the longer-standing and more firmly-rooted collaboration with the US these achievements do rather pale. In the same period, the UK and US jointly conducted chain of custody information exchanges, began collaboration on information barrier technology and methods for proving the integrity of verification equipment, exchanged information on monitored storage concepts, conducted a further measurement campaign against US classified and unclassified objects, and held managed access exercises at US and UK nuclear weapon assembly and disassembly facilities, alongside more regular research activity and information exchanges.[40]

But this should be expected – after all, UK–US collaboration under the 1958 Mutual Defence Agreement is permitted to include the exchange of sensitive nuclear materials, technology and information, and Articles I and II of the NPT do not place substantial restrictions on exchanges between two Nuclear Weapon States. It is easy to forget, now we are in a world over a decade on from the start of the UKNI and where the IPNDV involves many more states in discussions of nuclear disarmament verification, that these conversations were not easy at all to begin with. Both states attracted scrutiny over the potential for transfer under the UKNI, accidental or otherwise, of information that could be considered proliferative and thus violate Articles I and II of the NPT. Neither side had any understanding whatsoever of how the other might operate, and security and non-proliferation considerations pervaded everything that both sides did.[41] The fact that collaboration between nuclear weapon state and non-nuclear weapon state on these issues seems to so many to be unremarkable, perhaps to the point of being a *sine qua non* of effective disarmament verification, is a testament to the success of the UKNI rather than evidence of its decline. In any case, for the first few years of the UKNI at least, progress consisted more of enhancing mutual understanding than of making any serious technical progress; and its disarmament and diplomatic value resided principally in its nature rather than its content.

40 U.S. Department of Energy and UK Ministry of Defence, op. cit.

41 The United Kingdom–Norway Initiative: Further Research Into the Verification of Warhead Dismantlement. Working Paper submitted by the Kingdom of Norway and the United Kingdom of Great Britain and Northern Ireland to the 2015 NPT Review Conference, NPT/CONF.2015/WP.30.

2010–2015: BROADENING AND DEEPENING

As the UKNI progressed, habits of collaboration became more practiced, and VERTIC's role as an observer diminished. Following the 2010 NPT Review Conference, the collaboration broadened to encompass research into issues surrounding trust in verification processes, alongside its continuing work on managed access and information barriers. The exercises that had been conducted in Norway were followed up with a similar exercise in the UK in December 2010, involving a significant step up in realism.[42] Norwegian participants have noted that this was a real turning point for them in understanding that the detailed security and non-proliferation issues suggested to them as relevant complications to effective disarmament verification by their UK counterparts were in fact genuine.[43] Themes of trust and confidence in verification processes developed during this exercise were subsequently explored in more detail through a collaboration between the UKNI and King's College London that ran between 2013 and 2015. This research project used facilities associated with the JEEP II research reactor at Norway's Institute for Energy Technology in Kjeller to run controlled exercises designed to explore the role of human factors in verification processes.[44]

The final strand of activity during this period involved the further development of the UK–Norway Information Barrier. Information barriers are technical and procedural systems designed to strip out undesired information from a data stream – in this case, sensitive or proliferative information – transmitting only the data that is required for the task in question. Clearly this task is relevant to the possible involvement of NNWS in disarmament verification, as they should naturally have an interest in ensuring that objects that are dismantled as part of that process are indeed nuclear weapons, but must balance that interest against their NPT obligations not to receive nuclear weapons design information. The principal problem, however, is not one of detection and characterisation of nuclear material, but instead has to do with the degree to which it was possible to design and build verification equipment that could be trusted by both parties in a verification process.[45] This problem is fundamental to

42 Ibid.

43 Private communications.

44 'Trust and Confidence' Student Participation Exercises 2013–2015: Researching the Human Factors in Verification Processes, https://ukni.info/project/trust-and-confidence/ (accessed 29 March 2019).

45 UK–Norway Initiative, 2015.

the advancement of verification technology, and has limited its application in contemporary treaties: New START, for example, employs only relatively crude radiation detection equipment, and then only to confirm the absence of a radiation source in a particular area rather than to positively confirm its presence.[46]

Following a detailed report on the project in a side event at the 2015 NPT Review Conference, the UK–Norway Information Barrier project concluded the following year with the upload of project information – including complete design documentation, codes, studies on software authentication, performance data, analyses and so on – to a dedicated UKNI website.[47] The UKNI researchers made it clear that the final product of the project was not operational but instead served as a research tool and could serve as such for others. Some have subsequently conducted analyses reflecting on the UK–Norway Information Barrier experience and design, and it has been drawn upon at least in the context of the IPNDV to stimulate discussion of technical issues, but it has not formed a central plank of subsequent verification research.[48]

Although the research content of the UKNI between the 2010 and 2015 NPT Review Conferences was significantly more substantial than it had been in the early years of the collaboration, once again vastly more activity took place under the UK–US collaboration with vastly less fanfare. Perhaps most significant was the Warhead Monitored Dismantlement (WMD) Exercise of 2011, in which the UK and US conducted a "monitored dismantlement in an operational nuclear facility [AWE Burghfield] using a high-fidelity mock-up of a representative nuclear device with actual fissile material and simulated high explosives".[49] It would be no exaggeration to say that the experience of this exercise shaped UK thinking about warhead dismantlement verification and the programming of its research very substantially in subsequent years. Subsequent NDA campaigns focussed on understanding in greater detail the results of that exercise, while additional exchanges on authentication and chain of custody issues informed by that exercise resulted in a series of technical papers on procedures and technology options.[50]

As the 2015 NPT Review Conference loomed closer, the UK rapidly expanded its international engagement on verification issues, holding exchanges with the China Academy of Engineering Physics (CAEP, China's nuclear weapons laboratory) and Sweden's FOI, and participating in the first meeting of the US-led IPNDV. We know almost nothing about the former exchange, with the location – at CAEP's site in Mianyang – the only detail in the public domain. Slightly more has been disclosed about UK–Sweden interactions, with activity consisting of two strands: explosive detection and characterisation, and a dismantlement facility study.[51]

It would be understandable but wrong to describe these expanded interactions as attempts to secure last-minute diplomatic capital, because since the 2010 NPT Review Conference the UK had already taken further unilateral (albeit unverified) steps on nuclear disarmament by declaring a reduction in deployed warheads and missiles, as well as planning a reduction in total stockpile;[52] and publicity for exchanges with China and Sweden was respectively scant and absent. Instead, the diplomatic motive was likely longer term, laying the groundwork for a future where arms control verification would be increasingly central to the UK's disarmament offer.

2015–THE PRESENT DAY: THE QUAD, THE IPNDV AND CONTEMPORARY UK RESEARCH

The contemporary UK Arms Control and Verification Research (ACVR) programme sits in a broader Nuclear Treaty Verification (NTV) programme that also deals with support to the IAEA, other non-proliferation issues, and CTBT monitoring. Much of the work of the programme seems similar to earlier years, but at least as of 2016 it did include some assessment of the impact of various inspection regimes on security and proliferation risks at UK facilities. This offers a tantalising hint of a UK programme preparing more earnestly to "support government in implementing any future verification activities".[53]

46 Gottemoeller, 2010, pp. 8–12; Annex on Inspection Activities to the Protocol to the Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, signed in Prague, April 8, 2010, https://state.gov/t/avc/newstart/c44126.htm (accessed 29 March 2019).

47 United Kingdom–Norway Initiative, https://ukni.info (accessed 29 March 2019).

48 See for example Yan & Glaser, 2015, and Høibråten & Plant, 2016.

49 U.S. Department of Energy and UK Ministry of Defence, op. cit.

50 See for example: White et al., 2014; Tanner et al., 2014; Evans, 2015.

51 Plant, op. cit.

52 UK Ministry of Defence, 2010.

53 Plant, op. cit.

Following the failure of the 2015 NPT Review Conference to reach consensus, the UK exhibited further signs of this interest when later that year it hosted the first exploratory meeting of the group that would come to call itself the Quad Nuclear Verification Partnership.[54] Over the next two years the group would collaborate to develop "a repeatable, highly realistic arms control simulation, executed in representative facilities and using non-proliferative, but representative treaty items, within which monitoring technologies and approaches can be developed, exercised and evaluated".[55] This two-week event, called Exercise LETTERPRESS, was held in October 2017 at RAF Honington, a former nuclear weapons base in the UK, and took advantage of much of the still-existing nuclear warhead-related infrastructure to support immersive and realistic exercises.

This exercise marked the UK's most significant undertaking in terms of resource and effort since the WMD exercise of 2011. The exercise scenario differed markedly from the operating context of all other work conducted by the UK up to that point, focusing not on a monitored warhead dismantlement process that might realistically be expected to happen towards the later stages of multilateral nuclear disarmament, but instead addressing issues that might need to be tackled to advance the current era of strategic arms control by monitoring warhead withdrawal from deployment.[56] This deeper political significance was married to greater realism than previous UKNI exercises, using UK WE177 cases and containers, along with realistic handling procedures and historical facilities; and it marked both the first time that the US had engaged with NNWS in verification research activities, and the first ever multilateral initiative of its kind to involve NWS and NNWS.[57] Participant feedback appears to have been excellent, with one senior Swedish participant commenting that they "learned more in that two weeks than in any other two weeks of my life".[58]

The path of international collaboration never did run smooth though, and one can discern from the outside a few small signs of tensions within the collaboration. Although the UK and its partners have given occasional briefings on the outcome of the exercise, these have been very general and no detailed exercise report on LETTERPRESS has been made publicly available as they were for the UKNI. It seems unlikely, given the cost of the endeavour set against a relatively low UK programme budget, that the original vision of a repeatable exercise capable of providing "hands on practical experience of nuclear weapon-related verification to a range of arms control professionals"[59] will be realised, despite its obvious applicability to capacity-building, to the goals of the IPNDV and to the UK's professed desire to develop human capital on managed access issues. Tabletop exercises, perhaps supported by 3D visualisation tools under development at AWE, might be as far as the programme goes.[60]

Perhaps most tellingly, subtle changes in the wording of the group's terms of reference over time speak to different points of view within it. For example, whereas in the early years of the project the QNVP committed to "provide to the international community… A model verification protocol, to be developed during simulation design, which could contribute to future discussions on how treaty monitoring activities could be implemented in the real world",[61] in its statement to the 2018 NPT PrepCom the group indicated that it would provide "model verification strategies that could contribute to future discussions on how treaty monitoring activities could be implemented in the real world".[62] The development of a model protocol would be a substantial thing indeed, even if it were to be set against a fictional environment and must therefore itself contain elements of fiction, and – as a concrete disarmament deliverable – might be expected to be the element of the collaboration of most appeal to Norway and Sweden. Model strategies are perhaps more realistic, but they are less substantive, and one wonders whether this is wording with which the UK and US now feel more politically comfortable.

The final area where the UK has been particularly active in recent years has been the IPNDV. A fair proportion of the intellectual capital resulting from that initiative bears UK fingerprints – the 14-step analytical framework of dismantlement activities that it has

54 Statement delivered by Sweden on behalf of the QUAD, 2018 Preparatory Committee for the 2020 Review Conference of the Treaty on Non-Proliferation of Nuclear Weapons, Vienna, 26 April 2018.

55 UK statement to the Third IPNDV Plenary Meeting, Tokyo, June 2016. Released by the Ministry of Defence in response to Freedom of Information request FOI2017/13171.

56 Ibid.

57 "NNSA leads U.S. participation in international nuclear verification initiative", Department of Energy, 16 November 2017, https://www.energy.gov/nnsa/articles/nnsa-leads-us-participation-international-nuclear-verification-initiative (accessed 29 March 2019).

58 Private communication.

59 UK statement to the Third IPNDV Plenary Meeting, op. cit.

60 See for example Palmer & Stevanovic, 2017.

61 UK statement to the Third IPNDV Plenary Meeting, op. cit.

62 Statement delivered by Sweden on behalf of the QUAD, 2018 Preparatory Committee for the 2020 Review Conference of the Treaty on Non-Proliferation of Nuclear Weapons, Vienna, 26 April 2018.

developed was derived largely from a UK concept, for example[63] – although it is by no means alone in being active in that forum, and the US in particular has provided vastly more background research information to the initiative; and, as a co-chair of one of the three working groups for much of Phase 1 and a co-chair of one of the three working groups in Phase 2, the UK has played a leading role in shaping the direction of that collaboration. It is in this Phase that the IPNDV and, by extension, the UK, will be really tested though, as it is much more ambitious than Phase 1 – which only addressed the dismantlement in isolation of a single warhead without considering wider treaty factors – in that it considers verification of total stockpiles, verification of reductions, and attempts to advance some specific technologies to those ends.[64] This means that technical work can no longer remain apolitical as we approach the 2020 NPT Review Conference.

THE FUTURE OF NUCLEAR ARMS CONTROL AND DISARMAMENT VERIFICATION IN THE UK

The verification portfolio is likely to become more diplomatically important to the UK in the years to come. In large part this is because the UK feels it has little room to demonstrate its NPT Article VI credentials through further substantive reductions to its declared arsenal of warheads and deployed weapons. It took the WE177 free-fall nuclear weapon out of service in 1998, leaving the Trident II D5 missile on board Vanguard-class SSBNs as the UK's only delivery system, and Trident Holbrook as the only class of warheads in the arsenal; it has indicated that its overall stockpile of nuclear warheads is coming down from 225 to 180 by the mid-2020s; the declared number of operationally available warheads has been reduced to 120; and the UK has stated that its deterrent submarines now go on patrol with no more than 40 nuclear warheads mounted on a maximum of eight operational missiles (set against a theoretical maximum of 192 warheads per SSBN, mounted 12 per missile to each of 16 missiles).[65] At the same time, the UK has retained its long-standing commitment – now in its 50th year – to a posture of Continuous At-Sea Deterrence (CASD)[66] apparently based on a requirement to hold at risk a target defended by the most capable anti-ballistic missile system in the world: the so-called Moscow criterion.[67]

These reductions by the UK over many years therefore have the effect of pushing it closer and closer to the limits of the deterrent requirements it sets itself. Indeed, although it would be politically difficult to do so, the UK's commitment to a minimum deterrent does leave open the possibility that it will, at some point in the future, interpret this minimum to be somewhat greater than its current capabilities. Whether or not that is the case, while UK policy-makers decide to retain the Moscow criterion as the ultimate test of the technical credibility of the UK's nuclear deterrent, they will be reluctant to contemplate further reductions in quantity or quality of the nuclear weapons and delivery systems that comprise it. This also imposes limits on what concrete arms control agreements the UK, under its current planning assumptions, could sign up to while the Moscow anti-ballistic missile system capability remains unrestrained.

This means that there is no reason why the UK would choose to step back from its current, highly internationalised posture, whatever resource constraints there may be. It is likely that relations with Norway will continue to be maintained through the QNVP rather than independently through the UKNI; there is a fairly substantial probability that the same approach will be taken with UK-Sweden collaboration once agreed programmes of work are discharged. Engagement with IPNDV will likely continue while the US is engaged, which means that the UK will see the initiative through to the end, bitter or otherwise. And UK-US collaboration appears as deep and fundamental as ever.

We can still legitimately ask just how meaningful this all is. The UK has been intensely comfortable talking about disarmament verification, especially in the monitored warhead dismantlement context, which looks vanishingly unlikely in the near term. It has been less comfortable, as the LETTERPRESS experience hints, when this work starts to bring it closer to the appearance of a real-world commitment. It has also failed to allocate anything more than token resources to the research programme: with an estimated budget

63 "Deliverable 1: Framework Document with Definitions, Principles, and Good Practices", International Partnership for Nuclear Disarmament Verification, 2017, https://www.ipndv.org/reports-analysis/deliverable-one-principles-nuclear-disarmament-verification-key-steps-process-dismantling-nuclear-weapons-14-step-diagram/ (accessed 29 March 2019).

64 "Working Groups", International Partnership for Nuclear Disarmament Verification, https://www.ipndv.org/about/working-groups/ (accessed 29 March 2019).

65 National Security Strategy and Strategic Defence Review 2015, op. cit.

66 Under CASD, the UK always maintains at least one submarine equipped with nuclear armed Trident ballistic missiles on patrol. See "UK nuclear deterrence", Ministry of Defence, https://www.gov.uk/government/collections/uk-nuclear-deterrence-the-facts (accessed 29 March 2019).

67 See for example Owen, op cit.

of £2–3m/year, the ACVR programme allocation represents less than 0.01% of the government's funding of the nuclear weapons programme as a whole;[68] and, unlike the US, it has not funded any non-government technical arms control research at all since the programme began.[69] Finally, it does not appear to have incorporated the elements of the military responsible for existing UK arms control commitments – the Joint Arms Control Implementation Group, or JACIG – into the research programme.

An objective assessment of UK arms control verification research work must therefore return a mixed scorecard. The UK has not lived up to the high bar of Margaret Beckett's Carnegie Conference speech by becoming a "disarmament laboratory", or even to the bar set by the 1998 SDSR of ensuring "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". The UK is further on its way than it was in 1998, of course, and it deserves continued praise for its willingness to work on detailed practical issues with NNWS. But two decades of relatively scant investment, targeted more heavily for most of the programme's life at disarmament diplomacy than at serious technical progress, do not a practical capability make.

POSSIBLE ADDITIONAL STEPS FOR THE UK AND NORDIC PARTNERS

One might argue that this is perfectly sensible, given that the UK is unlikely to participate in nuclear arms control agreements in the near future. In the light of the deterrence requirements laid out above, there would need to have been significant reductions in Russian nuclear capabilities across the board, and probably also some restraint on Russian missile defences, before that could be contemplated. Policymakers might also point to China, and even other nuclear weapon possessors, as states which should also be engaged in any such agreement, given the relatively small size of the UK's nuclear arsenal. But that would be to overestimate the likelihood and desirability of the status quo. Who is to say that the next government of the UK might not want to make significant strides in verified reductions, or to verify retrospectively disarmament steps already taken, or that circumstances might evolve such that the present crisis in arms control is suddenly replaced by an atmosphere where breakthroughs seem possible? This position would also neglect the potential of the UK to do more to create the conditions under which it could conceivably participate in verified nuclear arms control, rather than waiting for the conditions to arise through the actions of others. And it also risks a circumstance where one or more collaborators – through the IPNDV, QNVP, GGE, or wherever else – gradually increase their own technical capabilities to a point where they independently make the judgement that the UK is more interested in performance than practice.

The UK could address these weaknesses in its arms control and disarmament research programme relatively easily. Taking political aspects to begin with, it could lay out its strategy for arms control verification research more clearly, indicating the rough policy futures that its programmes are designed to address and the connections between them. This would not reveal the UK's negotiating hand, as neither the futures nor the linkages would have to be drawn in tremendous detail. Areas of sensitivity could still be kept private. But it would require the UK to show a level of consideration and openness to scrutiny that could be cast positively in the light of increasing demands for transparency in its nuclear decision-making. It could also clarify the political conditions that might make it more or less likely to submit its nuclear forces to multilateral arms control. For example, a world without treaties to restrain adversary anti-ballistic missile systems and non-strategic nuclear systems capable of threatening the UK is unlikely in this author's view to be one in which the UK would look positively at engaging in arms control; but whatever the *de minimis* requirements are, it would cost the UK little to sketch them out and to update them where necessary, potentially as part of future strategic defence reviews.

Turning to the conduct of the programme, the UK could also easily collate and make publicly available the non-sensitive contents of its verification research

68 This estimate is based on limited available information on the ACVR programme budget. In 2008, the then Secretary of State for Defence, John Hutton, indicated that the projected total spend on the ACVR programme since its inception was "forecast to exceed £3 million by the end of FY08–09" (Hansard, HC Deb, 6 October 2008, c247w), and in 2013 the then Parliamentary Under-Secretary of State for Defence indicated that "[in] financial year 2010–11 the funding [for the ACVR programme] was £2.227 million and in financial year 2011–12 it was £2.125 million" (Hansard, HC Deb, 21 January 2013, c69w). The UK's nuclear programme is budgeted to cost over £40bn over the next decade (*The 2018 Defence Equipment Plan*, Ministry of Defence, 5 November 2018, version 3 published 18 March 2019; https://www.gov.uk/government/publications/the-defence-equipment-plan-2018 (accessed 29 March 2019).

69 Academic work has been done outside AWE, but this has always been delivered as a subcontract to AWE and in partnership with its staff. The US in contrast has funded two five-year tranches of academic work, first under the Consortium for Verification Technology (https://cvt.engin.umich.edu/) and subsequently under the Consortium for Monitoring, Technology and Verification (https://mtv.engin.umich.edu/), with each yearly allocation of around $5m to these consortia outstripping UK investment in arms control verification research.

programmes in a single place, much as it did for the UK–Norway Initiative.[70] This would be a simple step that would serve to maximise the usefulness and accessibility of work already done, and would also help to retain institutional knowledge. The UK should also consider following in the footsteps of the US by stimulating academic research into technical arms control issues outside government institutions. Again, this could be relatively simply done by incorporating a new research area under one or more of the UK's Research Councils (the bodies that oversee government funding for research and innovation in the UK) and committing to sustain and renew it on an enduring basis, such that an organic cadre of independent researchers and innovators has time to grow and flourish, strengthening the base of arms control professionals in the UK by making it a significantly more viable career path than it is at present. This would have the useful by-product of improving the UK's ability to respond to future crises of arms control and strategic stability.

Finally, the UK should foreground the potential for participation in future arms control in its nuclear warhead and complex modernisation plans. This would mean taking potential arms control verification requirements into account as core considerations when designing new facilities and planning the future warhead complex,[71] bringing replacement warheads into service, and planning future operations. These clearly could not be treaty-specific, but they could take into account likely commonalities of future regimes of different types: a New START-like treaty would evidently involve inspection activities at the UK's submarine base in Faslane, for example; and implementation of any treaty involving verified stockpile numbers would require additional inspector activity at AWE's Aldermaston and Burghfield sites. In the technical domain, treaties involving confirmation of stockpile numbers might involve more intrusive warhead verification than would confirmation that this number was below a certain ceiling, and so on.

Of the Nordic group, Sweden and Norway have worked with the UK and with the US on arms control verification research, as this paper has laid out, and Finland has sponsored work by the United Nations Institute of Disarmament Research (UNIDIR) on arms control measures for nuclear weapons in Europe.[72] All three are active in the IPNDV; all three clearly recognise the salience of nuclear weapons to their security environment; all three want their efforts to be meaningful contributions to reducing that salience; and all three would wish to avoid being used as diplomatic cover by NWS that do not genuinely share their objectives. Hence, the above policy prescriptions also represent potential criteria that these countries could use to decide the parameters of their engagement in collaborative verification activity, bilaterally, in small groups, or through the IPNDV, with the UK; they might also choose to act separately or together, perhaps through the European Union where relevant, to improve and sustain fundamental research capabilities on the key verification challenges laid out elsewhere in this paper.

These proposed measures should not be seen as meaningless and expensive virtue-signalling by the UK, or indeed by the members of the Nordic group with which it works, but instead as prudent and proportionate risk reduction steps. They would allow the UK to maintain whatever nuclear posture it chooses under conditions of verified arms control that might plausibly arise in the future, would maximise the contribution by the UK and its partners to creating the conditions for verifiable multilateral disarmament, and bring greater European agency to discussions about arms control in Europe. Without this planning – and noting that the service life of any replacement Trident warhead might extend into the last quarter of this century, so the timescales we must consider are long indeed – it is possible that future arms control implementation would impose security or proliferation risks, or even have the potential to compromise the credibility of the UK's deterrent posture. And if the UK does not take seriously the potential for verified arms control on this timescale then why on earth should any other country believe that it is seriously working towards that end, or that its work on the verification portfolio is anything other than a diplomatic showpiece? The measures above would go some way towards recapturing the ideals that drove the early stages of the UK's work on nuclear arms control and disarmament verification, and they represent a more pragmatic, properly-resourced and credible contribution to balanced nuclear policy.

70 Varriale, 2018.

71 The UK has at present committed to consider during the design and building of its new warhead assembly/disassembly facility, MENSA, how it "might help to facilitate the future verification of weapons dismantlement", a significantly narrower and weaker commitment than envisaged here. See Hansard, HL Deb, 14 January 2009, c1220.

72 Podvig & Serrat, 2017.

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