EU NON-PROLIFERATION CONSORTIUM
The European network of independent non-proliferation think tanks

NON-PROLIFERATION PAPERS
No. 47 October 2015

ADVANCING DISARMAMENT VERIFICATION TOOLS: A TASK FOR EUROPE?*

MALTE GÖTTSCHE, MORITZ KÜTT, GÖTZ NEUNECK AND IRMGARD NIEMEYER

I. INTRODUCTION

In her statement in the general debate at the ninth Review Conference of the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT) in 2015, Federica Mogherini, the High Representative of the European Union for Foreign Affairs and Security Policy and Vice-President of the European Commission, reaffirmed the commitment of European Union (EU) member states to pursue nuclear disarmament in accordance with Article VI of the NPT and stressed the need for concrete progress in this field, especially through an overall reduction in the global stockpile of nuclear weapons.[1] In 2010, the eighth NPT Review Conference had reiterated the commitment to nuclear disarmament and the 'total elimination of nuclear weapons', applying 'the principles of irreversibility, verifiability and transparency in relation to the implementation of their treaty obligations'.[2] These important requirements will require well-elaborated, certified and robust technical procedures and technologies.

[1] See Mogherini, F., EU statement, General Debate, 2015 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), New York, 28 Apr. 2015, <http://www.un.org/en/conf/npt/2015/statements/pdf/EU_en.pdf>.

[2] 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, Final document, vol. 1, NPT/CONF.2010/50 (vol. I), New York, 18 June 2010, <http://www.un.org/en/conf/npt/2010/>.

*The authors would like to thank Giorgio Franceschini (PRIF, Frankfurt) for his encouragement to write this paper, all the other members of the German Disarmament Verification Network for the fruitful discussions and interesting presentations and Gerald Kirchner (ZNF, Hamburg) for his useful comments on the paper.

SUMMARY

A number of scientific-technical activities have been carried out to establish more robust and irreversible disarmament verification schemes. Regardless of the actual path towards deeper reductions in nuclear arsenals or their total elimination in the future, disarmament verification will require new verification procedures and techniques. This paper discusses the information that would be required as a basis for building confidence in disarmament, how it could be principally verified and the role the Europe could play.

Various ongoing activities are presented that could be brought together to produce a more intensified research and development environment in Europe. The paper argues that if 'effective multilateralism' is the main goal of the European Union's (EU) disarmament policy, EU efforts should be combined and strengthened to create a coordinated multilateral disarmament verification capacity in the EU and other European countries. The paper concludes with several recommendations that would have a significant impact on future developments. Among other things, the paper proposes a one-year review process that should include all relevant European actors.

ABOUT THE AUTHORS

Malte Göttsche recently completed his doctorate in physics at the Carl Friedrich von Weizsäcker Centre for Science and Peace Research (ZNF) at the University of Hamburg.

Moritz Kütt is a Research Assistant/Doctoral Student at the Technische Universität Darmstadt.

Götz Neuneck is Deputy Director of the Institute for Peace Research and Security Policy (IFSH) at the University of Hamburg and Professor of Physics at the Faculty of Mathematics, Informatics and Sciences.

Irmgard Niemeyer is the Head of the International Safeguards Working Group at the Institute of Nuclear Waste Management and Reactor Safety (IEK-6), Forschungszentrum Jülich GmbH.

Table 1. Major projects related to international collaboration on disarmament verification research

Project	Research areas	Results remarks
Trilateral Initiative (Russia, USA, IAEA)	Information barrier development, inventory monitoring systems	Cooperation between two NWS
UK—Norway Initiative	Managed access, information barrier development, confidence in verification processes	Cooperation between NWS and NNWS requires more research
Pilot Verification Project (NTI)	Proposals for: baseline declarations, global verification capacity, societal verification.	Multinational cooperation required
US–UK cooperation to address technical challenges in verification of nuclear disarmament	Managed access, measurement technologies, information barrier development, chain of custody	Cooperation between two NWS
International Partnership for Nuclear Disarmament Verification (USA)	Only recently announced, practical research areas and activities under discussion	

IAEA = International Atomic Energy Agency; NNWS = non-nuclear weapon state; NTI = Nuclear Threat Initiative; NWS = nuclear weapon state.

After the failure of the 2015 NPT Review Conference to reach agreement on a final document, new political initiatives, feasible concepts, courageous actions and technical work will be required to advance nuclear disarmament. Although the momentum for a quick path to a 'world without nuclear weapons', as proposed by US President Barack Obama in 2009, is fading, technical preparations for the verification of nuclear dismantlement and disarmament must continue. The non-approved draft final document of the 2015 NPT Review Conference stated in paragraph 152 that 'The Conference welcomes efforts towards the development of nuclear disarmament verification capabilities that will contribute to providing assurance of compliance with nuclear disarmament agreements for the achievement and maintenance of a nuclear-weapon-free world'.[3]

Although current political progress has been limited, technically oriented preparations can be undertaken now to enable irreversible disarmament when it becomes politically feasible. In particular, 'deep cuts' in nuclear arsenals through 'classical arms control measures' and the prospect of complete nuclear disarmament would require new technical verification measures.[4] Whereas deep cuts require verification of the dismantlement and storage of an agreed number of weapons ('verification of presence'), complete disarmament requires, at the final stage, verification of the fact that no nuclear weapons exist anywhere ('verification of absence'). There is a broad continuum of processes, techniques and technical methods between both objectives that needs to be elaborated and developed in detail in order to create confidence among all parties involved that the agreed goals of the disarmament regimes have been achieved.

Under the current conditions of an NPT-dominated world, such efforts would also be obligatory for all states parties on the basis of Article VI of the NPT: 'Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.'[5]

[3] 2015 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, Draft final document, NPT/CONF.2015/R.3, New York, 21 May 2015, <http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/npt/revcon2015/documents/DraftFinalDocument.pdf>, p. 17.

[4] For pragmatic recommendations, see Deep Cuts Commission, *Strengthening Stability in Turbulent Times*, Second report of the Deep Cuts Commission (Deep Cuts Commission: Hamburg, Apr. 2015), <www.deepcuts.org/publications/reports>.

[5] Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT), opened for signature 1 July 1968, entered into force 5 Mar. 1970, <http://disarmament.un.org/treaties/t/npt/text>. See also, e.g. 2015 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, 'The United Kingdom–Norway initiative: further research into the verification of nuclear warhead dismantlement', Working Paper submitted by the Norway and the United Kingdom, NPT/CONF.2015/WP.31, 22 Apr. 2015, <http://www.un.org/en/conf/npt/2015/pdf/NPT-CONF2015-WP.31_E.pdf>.

As the NPT demands 'international control', it would seem to be necessary for non-nuclear weapon states (NNWS) to play a more substantive and supportive role in all or at least most verification tasks. Concrete steps towards enabling verification of the disarmament process could be one part of demonstrating compliance with Article VI, bearing in mind the grand bargain of the NPT which requires a commitment to both disarmament and non-proliferation.

There are already a number of verification technologies linked to ensuring non-proliferation and safeguarding fissile materials. The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) promotes the development and constant maintenance of technologies to verify the non-existence of nuclear testing. The EU has a high degree of expertise and wide experience in the fields of nuclear safety and security, safeguards and non-proliferation in both nuclear weapon states (NWS) and NNWS.

By contrast, on effective control and monitoring of nuclear disarmament (or 'disarmament verification') there have been only few technological developments, and little has been published in recent decades. In 1967, the Untied States Department of Defense and the US Arms Control and Disarmament Agency (ACDA) conducted 'Field Test FT-34' on developing and testing inspection procedures to monitor the demonstrated dismantlement of nuclear warheads. The test also aimed to evaluate the effectiveness of various evasion techniques, such as diverting fissile material, and to assess the effectiveness of assay operations on fissile material.[6] In 1989, the Natural Resources Defense Council (a US-based non-governmental organization) and a Soviet team from the Russian Academy of Science organized the 'Black Sea Experiments' to determine whether a nuclear warhead was on board a Soviet nuclear-armed cruiser. This was the first time that scientists were allowed to conduct radiation measurements on an operational Soviet nuclear warhead, using a high-resolution germanium detector.[7] The lessons learned and results were published in 1990.[8]

Other activities have been carried out more recently (see table 1). The Trilateral Initiative—a cooperative project between Russia, the USA and the International Atomic Energy Agency (IAEA) in 1996–2002—aimed to establish a verification system under which Russia and the USA might submit excess fissile material to IAEA monitoring.[9] The US-based Nuclear Threat Initiative (NTI) established a verification pilot project in 2012 and published its results in 2014.[10] Interesting projects were also carried out in collaborations between the United Kingdom and Norway as well as between the USA and the UK, all of which raised the need for further research.[11]

More recently, some NWS, in particular the USA, have expressed an interest in and initiated further research on this issue. In 2014, the US State Department launched an 'International Partnership for Nuclear Disarmament Verification' by proposing 'to work with both nuclear weapon states and non-nuclear weapons states to better understand the technical problems of verifying nuclear disarmament, and to develop solutions'.[12] In March 2015 a meeting was held in Washington, DC, in which 26 countries and the EU participated.

In contrast, there have been very few coordinated efforts in Europe, with the exception of Norway and the UK, which have worked together on several exercises simulating the warhead dismantlement process.[13] However, the EU seems destined to play a coordinating role in the emerging sector of irreversible dismantlement verification, due to its non-proliferation and safeguards expertise. NWS and NNWS ought to work together because only a combination of both perspectives can open up avenues for irreversible multilateral nuclear disarmament. Some advances have been made. The European Safeguards Research and Development Association (ESARDA) has added special sessions on disarmament verification to its biannual

[6] See Cliff, D., Elbahtimy, H. and Persbo, A., 'Verifying warhead dismantlement: Past, present, future', VERTIC Research Report no. 9 (Sep. 2010), p. 22.

[7] For more detail see Cliff, Elbahtimy and Persbo (note 6), p. 36.

[8] Fetter, S. et al., 'The Black Sea experiment', *Science & Global Security*, vol. 1 (1990), pp. 323–33.

[9] Shea, T. E. and Rockwood, L., 'Nuclear disarmament: The legacy of the Trilateral Initiative', Deep Cuts Working Paper no. 4 (Mar. 2015), <http://www.deepcuts.org/images/PDF/DeepCuts_WP4_Shea_Rockwood_UK.pdf/>.

[10] Hartigan, K., Hinderstein, C. and Newman, A. (eds), *Innovating Verification: New Tools and New Actors to Reduce Nuclear Risks* (Nuclear Threat Initiative: Washington, DC, 2014), <www.nti.org/analysis/reports/innovating-verification-new-tools-new-actors-reduce-nuclear-risks/>.

[11] UK–Norway Initiative (note 5); US Department of Energy (DOE), National Nuclear Security Administration, NPAC and British Ministry of Defence, *Joint US–UK Report on Technical Cooperation for Arms Control* (US DOE: Washington, DC, 2015), <http://nnsa.energy.gov/sites/default/files/Joint_USUK_Report_FINAL.PDF>.

[12] Gottemoeller, R., US Under Secretary of State, Speech, Prague, 4 Dec. 2014.

[13] UK–Norway Initiative (note 5).

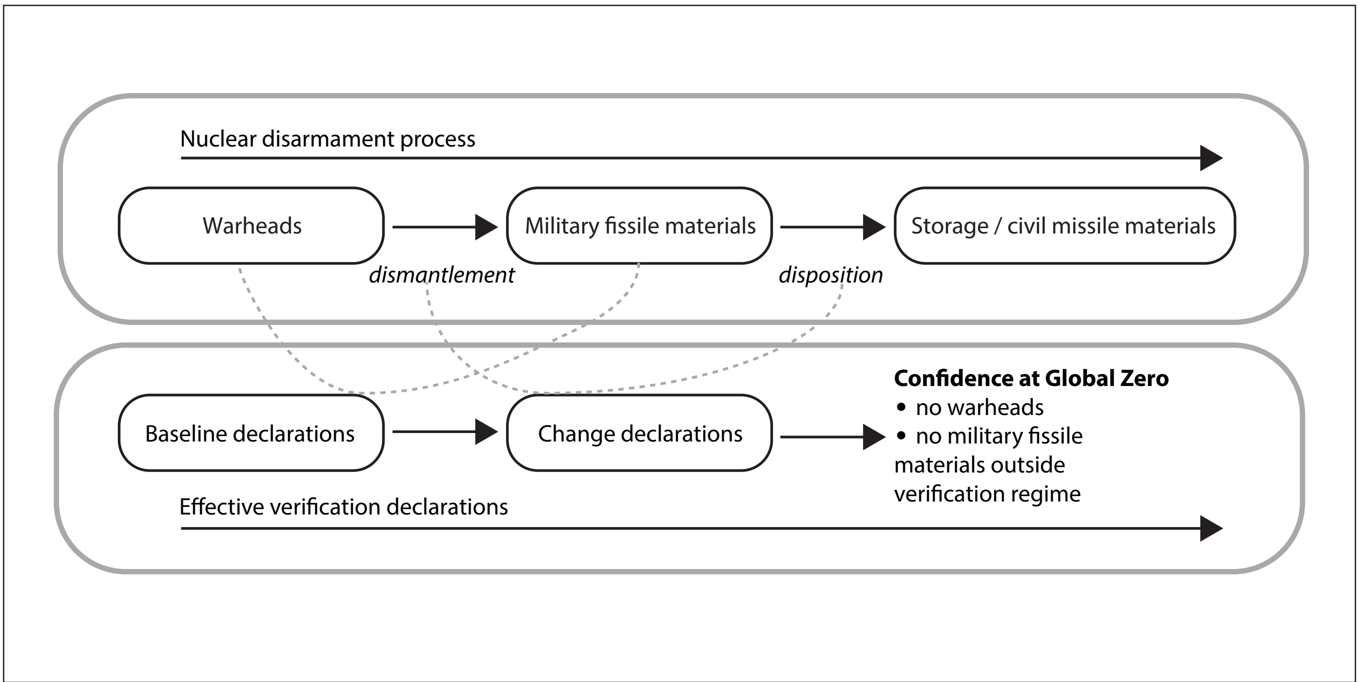

Figure 1. The technical disarmament process (above) and declarations (below) requiring effective verification to enable future confidence in a world without nuclear weapons (Global Zero). The dashed lines show which declarations are relevant for specific steps in the disarmament process. Please note that the timelines of both processes are different.

symposia, although ESARDA generally focuses on improving international safeguards. Arms control is also a topic in some of the eight ESARDA working groups.[14]

This paper provides information about the current state of research and development (R&D) and outlines new tasks for the European research community. Section II explains disarmament verification in more detail. Section III discusses possible areas for European-wide activity, emphasizing the benefits of increased engagement. Section IV draws conclusions and makes recommendations.

II. VERIFYING NUCLEAR DISARMAMENT AND DISMANTLEMENT

The disarmament process

It is not yet clear which future framework agreements may lead to further nuclear arms control and from there to complete disarmament (i.e. a world without nuclear weapons). It seems clear, however, that this vision can only be achieved through a multilateral process, which includes NWS as well as NNWS. In addition, robust and effective verification is a decisive precondition for maintaining disarmament progress on the way to a world free of nuclear weapons. Regardless of the specific provisions of future regimes, the disarmament and verification process can be discussed from a more technical perspective. One essential task is to identify which verification activities and combinations thereof are suited to providing confidence in irreversible nuclear disarmament. One way of approaching this is to envisage a world without nuclear weapons and deliberating on which verification activities should have been in place during the disarmament process to obtain confidence in the absence of nuclear warheads. From a logical point of view, confidence would be needed that (*a*) no nuclear warheads exist and (*b*) no fissile material can be used to build nuclear warheads anymore.

In order to achieve (*a*) and (*b*), certain information must be available, such as the total number of existing nuclear warheads and the number being dismantled, furthermore the quantity of remaining fissile material would have to be known, and this would need to include knowledge about the quantities being disposed of and newly produced. This information would be required in order to make a record of all existing fissile

[14] For more information see the ESARDA website, <http://www.esarda.eu/>.

material and to be able to ensure that no fissile material remained outside the verification regime.[15] All the information provided would need to be strictly and effectively evaluated, as confidence in non-verified declarations would remain very limited. Information on existing warheads and materials can be verified for their correctness. Further measures would be necessary, however, to verify that the information declared was complete and that no hidden stocks of warheads and fissile materials existed.

So-called baseline declarations of total numbers of delivery vehicles, warheads and materials stocks would indicate current arsenals and capabilities.[16] Certain metadata would have to be part of such declarations in order to enable verification measures. This includes the location of items and materials or a subdivision of items and materials into certain categories, such as warhead types or the purpose of materials. Once baseline declarations have been issued, changes in arsenals and stocks would need to be declared. By comparing change declarations with the baseline, the total inventory would become known over time, assuming there were no undeclared stocks (see figure 1).

Change declarations would include information regarding the physical dismantlement of warheads or delivery vehicles, the disposition of materials and the production of new materials and warheads. The disassembly of a warhead must be handled in a protected environment or in special disassembly facilities with controlled access, due to the need for safety and security arrangements. The three-stages of the dismantlement process are (*a*) the warhead is placed in a disassembly facility and is identified; (*b*) warhead disassembly (of high-explosives, fissile material and non-nuclear components); and (*c*) component disposition and storage in the same or a different location.[17] Verification must provide confidence in this process. Technical visits to nuclear storage facilities by inspectors would be needed to verify the stored warheads and whether warheads have been transported to other locations. In addition, verification is required of the removal of warheads from delivery vehicles and other deployment-status changes.

Logically, confidence in the absence of nuclear warheads could be gained even though weapons-usable fissile materials remain, as long as their non-diversion has been verified. Irreversibility would be maximized, however, if these materials were disposed of. Materials could either be converted for civilian or commercial purposes (both uranium and plutonium can be used as reactor fuel) or transported to long-term storage. At this point, the particular disarmament verification issues linked to the protection of sensitive information will no longer exist and verification activities will be similar or identical to non-proliferation safeguards. In the very long term, declarations could possibly indicate that no directly weapon-usable fissile material exists.

Measures are needed to verify both the correctness and the completeness of the information declared by states. Analysis of the numbers provided by baseline and change declarations is suitable for verifying the correctness of declarations, but additional measures might be necessary to verify the absence of undeclared stocks of warheads and fissile materials—the completeness of declarations. Further declarations of data and information as well as a willingness to deal with requests for additional information will be instrumental to enabling at least a certain degree of confidence in completeness. This may include, among other things, details of past fissile material production to determine whether this data is consistent with the declared stocks and information on further facilities in cases of suspicious activity. Confidence in the absence of warheads can be increased by evaluating information on weapon delivery systems, military force structures and military doctrines for their consistency with declarations on disarmament.

Building confidence in the correctness of warhead and fissile material stock declarations and in the irreversible dismantlement and disposition processes will require time. During this long process, declarations would be checked periodically for consistency. It will be a much bigger challenge to successfully and consistently cheat over a long period, throughout years of verification activities, compared to just a single false declaration. Accordingly, confidence in the correctness and completeness of declarations will increase over time if no inconsistencies are discovered. Hiding stocks or material production facilities from declaration will be a more difficult undertaking over a period of decades, especially if the

[15] This paper only focuses on military fissile material stockpiles. Civilian stockpiles present additional challenges, although there is considerable experience of dealing with these within the IAEA and Euratom.

[16] Fuller, J. et al.,'Verifying baseline declarations of nuclear warheads and materials', eds Hartigan, Hinderstein and Newman (note 10).

[17] See Cliff, Elbahtimy and Persbo (note 6).

Table 2. Verification tools and techniques that require further research, development and testing

Verification type	Examples of verification tools and techniques
Warhead and military fissile materials authentication by attribute and template systems	• Gamma spectrometry • Passive neutron multiplicity counting • Active methods, such as neutron interrogation, neutron imaging and nuclear resonance fluorescence • Zero-knowledge protocol systems
Unique identification	• Ultrasonic intrinsic tag • RuBee tag
Continuity of knowledge	• Unique identification tools • Unattended monitoring, for example, using cameras and sensors • Seals • Managed access
Measures to verify the completeness of declarations	• Nuclear archaeology (past fissile materials production) • Challenge inspections at suspicious sites • Open source and intelligence data analyses • Satellite imagery

total amount of fissile material decreases. Verification of warhead and material stocks should therefore ideally commence as soon as possible. Such declarations and verification measures could occur before any disarmament activities take place.

Verification techniques and procedures

Although IAEA safeguards have many overlaps with disarmament verification requirements, such as the verification of nuclear material storage, verification of the basic disarmament process described above will require somewhat different techniques and procedures in order to meet the special challenges associated with disarmament verification. Accordingly, further technical research, development and testing will be needed to adapt existing technologies to such needs.

Three major, unprecedented challenges for disarmament verification have to be met. First, the most relevant information cannot be shared by the inspected state. Articles I and II of the NPT prohibit NWS from transferring proliferative knowledge such as warhead design properties to NNWS, and vice-versa. Other information might be retained for national security reasons, without specifying why. Thus, access to information by inspectors from NWS might be severely restricted. Inspectors' access to data will be strictly controlled. During on-site inspections, inspector movement inside sensitive facilities would be extremely limited—and many items could be masked. Moreover, the direct measurement of sensitive items would not be possible as the results would contain sensitive information. All this would create major challenges for the inspectors. It would be essential to work out procedures to address these challenges.

Second, safety and security requirements will need to be observed and could, under no circumstances, be compromised. In addition to access by personnel, tools must be certified for use near or on a nuclear explosive device, in particular with regard to explosive safety.[18] In some cases, special verification tools must be developed that could pass safety and security evaluations. The specifics of these evaluations are often sensitive, which requires careful cooperation between inspecting and inspected state or the IAEA.

Third, a particularly high level of confidence would be required in all verification activities. Verification failures concerning just a single warhead would not be acceptable. Some of the techniques applied in IAEA safeguards might not meet such high standards and, therefore, could not be used in disarmament verification. It follows that such procedures must be tested in advance and be developed further. A determined and comprehensive effort will be required on the development of new tools, techniques and procedures that can provide a sufficiently high level of confidence while at the same time complying with all restrictions.

Four generic types of methods are relevant to verifying warhead and fissile material stocks and processes: (*a*) authentication; (*b*) unique identification; (*c*) continuity of knowledge, to verify the correctness of

[18] Fuller et al. (note 16), p. 24.

declarations; and (*d*) nuclear archaeology, among other things, to verify their completeness.

Methods of *authentication* verify that an item truly is what it is declared to be. It is essential to ensure that declared warheads have not been replaced by mock-ups or fake warheads. Mock-ups could, for example, be used to divert declared items and materials in order to build up a hidden stock. Authentication poses immense challenges for sensitive items and materials where measurement data cannot be directly disclosed because it would contain sensitive information. This is the case not only for warheads, but also for the fissile materials that were produced for warheads or the result of warhead dismantlement. Typically, two authentication methods can be identified: the template approach and the attribute approach.

The template approach is based on the comparison of a reference item (the 'golden sample') with a test item (i.e. the warheads and materials to be authenticated). If test and reference items are equal and the golden sample is the declared warhead or fissile material it is supposed to be, then the test item is successfully authenticated. The main problems are the selection of the golden sample and of the initial test that it is indeed the presumed object. The attribute approach is based on measurements of several predefined parameters of a warhead, for example, the presence of specific materials, their composition and their mass. Ranges of possible values can be defined for each attribute based on the certified uncertainty of measurement and publicly known specifications of nuclear warheads. If all the attributes of an item are within this range, the item is successfully authenticated. The attribute types and quantitative ranges can be agreed among the inspected and inspecting states during verification procedure negotiations.

Both approaches rely on numerous nuclear measurement techniques (see table 2). The main measurement methods are passive gamma (γ) spectrometry and neutron multiplicity measurements.[19] Both are non-destructive assay techniques that leave the samples intact. They can be used to estimate isotopic compositions, plutonium presence and the mass of the item. To determine uranium presence and mass, however, active interrogation methods must be used. These are based on neutron interrogation and measuring the resulting prompt/delayed neutrons and gammas, as well as a variety of imaging techniques based on γ-rays. They also include nuclear resonance fluorescence methods.[20] Some of these techniques are already used for IAEA safeguards, but none of them are reliable enough yet to be used for authentication. While the item configuration (e.g. its geometry) is usually known in IAEA safeguards, little or no useful information is available for disarmament verification purposes. The measurement techniques are, in particular, vulnerable to the presence of further materials that shield radiation emitted from the fissile material, such as explosives or the safety storage containers that hold warheads and fissile materials. Such materials might lead to incorrect results, such as wrong mass estimates. The high level of reliability required makes further development of measurement techniques necessary.[21] Such R&D should be directed at reducing the influence of shielding and other effects of an unknown configuration on the measurement results.

Different solutions have been proposed to protect sensitive information. So-called information barriers are technical devices that carry out detailed measurements but, instead of revealing detailed measurement data, only show the verification result. For instance, the device might give a green light if a warhead is identified; a red light if it is a different item; or a yellow light if the measurement is inconclusive. In addition to measurement reliability, information barriers present further challenges. The inspected state must be able to ensure that the inspecting state (or the IAEA) has not secretly built in a capacity to leak sensitive information. This could be achieved by sophisticated equipment certification prior to the measurements being taken. Both the inspecting state and the inspected state must have confidence in the authenticity of the equipment, for instance, that the information barrier was not tampered with by modifying the analysis algorithm in order to give false

[19] Gamma spectrometry records the energy spectrum of gamma rays emitted due to the radioactive decay of different sources and can be used to identify materials and material compositions. Neutron multiplicity measurements are based on correlations between the neutrons emitted by the radioactive decay and the reactions of materials, and can be used to analyse the mass of a neutron emitting material in a sample. Nuclear resonance fluorescence can be used to identify isotopes using fluorescence effects after a material has been irradiated with high-energy photons. See Göttsche, M. and Kirchner, G., 'Measurement techniques for warhead authentication with attributes: advantages and limitations', *Science & Global Security*, vol. 22, no. 2 (2014), pp. 83–110.

[20] Nuclear resonance fluorescence can be used to identify isotopes using fluorescence effects after a material has been irradiated with energy photons.

[21] Fuller et al. (note 16), p. 33.

results. Several multinational initiatives, such as the Trilateral and UK–Norway initiatives, have attempted to build such information barriers, but all of them either only covered a limited number of attributes or were not fully trusted, authenticated and certified by all parties.

Such equipment authentication and certification challenges could be reduced by implementing a 'zero-knowledge protocol', which does not require an information barrier. This approach avoids releasing sensitive information by specifically designed test procedures that apply non-electronic differential measurements and never measure sensitive information.[22] This technique, however, also requires further research, development and testing of equipment.

After authentication, the tested item or material container should be given a *unique identification*. This allows inspectors to recheck an item or the container again later without the need for new measurements. This is especially important as items may change locations. Without unique identification, inspectors would risk double counting items. If an item is missing, the inspectors will know exactly which item it is. Items can be uniquely identified by attaching a tag. This needs to be very robust to withstand tampering and ensure the safety of the tagged item, taking explosives safety into account.[23] Inspected states would have the capacity to invest vast amounts of resources in defeating tags, so the development of tamper-proof tags would be required, including the tools to identify tampering in a timely manner. Appropriate tags have not yet been successfully developed. Promising approaches and methods do exist (see table 2), but more testing and development are required.[24]

Unique identifiers would also help to preserve the *continuity of knowledge*, by which inspectors will be able to follow items through time and processes. Achieving continuity of knowledge is a significant challenge because access to facilities by inspectors and the breadth of allowable inspection measures will be severely restricted by the inspected party for reasons of non-proliferation and national security. Continuity of knowledge is of particular importance during warhead dismantlement. As inspectors may not be able to visually observe the physical dismantlement, procedures and tools based on observations and measurements before and after the activity, while using severely restricted information during the activity itself, must be in place to provide confidence in the dismantlement for the inspectors. The tools and techniques that contribute to the continuity of knowledge are also shown in table 2. Again, they will need to be certified and authenticated. Effective managed access procedures and protocols would restrict access in a reasonable way while at the same time supporting the continuity of knowledge by providing inspectors with sufficient access to the facility but preventing the disclosure of sensitive information. Past projects have shown that strict enforcement of access controls by the inspected party can negatively affect the confidence of inspectors in the process.[25] Further exercises should be conducted to identify procedures and protocols that balance safety, security and the protection of sensitive information, on the one hand, with enabling inspector confidence, on the other.

Verification of the completeness of a declaration requires additional tools and techniques. Like the safeguards under an IAEA Additional Protocol, challenge inspections could be conducted at suspicious sites, but access to facilities might remain severely limited if sensitive information were at stake, and as a result the confidence gained from such activities may remain low. Open source and intelligence information, including satellite imagery, can also be analysed in connection with suspicious sites and activities, but the level of confidence obtained from the use of these techniques may not be sufficient. Comparing past fissile material production to declared warhead and materials stocks can be a very powerful tool. Past production can be estimated by applying nuclear forensic methods or, more specifically, *nuclear archaeology* could be used. If the declared warhead and fissile material stocks are in agreement with the estimated material production, confidence in the absence of undeclared materials or warheads is increased. Nuclear archaeology techniques analyse microparticles and the activation products found at fissile material production facilities to estimate their production histories over long periods of time.[26] It is, however, necessary to carry out such

[22] Glaser, A., Barak, B. and Goldston, R. J., 'A zero-knowledge protocol for nuclear warhead verification', *Nature*, 26 June 2014, pp. 497–502.

[23] These are classic tasks for safeguards and have already been applied, but current technologies must be developed further.

[24] Fuller et al. (note 16), p. 36.

[25] UK–Norway Initiative (note 5), p. 8.

[26] Fetter, S., 'Nuclear archaeology: verifying declarations of fissile material production', *Science & Global Security* vol. 3, nos. 3–4 (1993).

measurements before plants are decommissioned and, like the other methods, more research in sampling technologies is needed to achieve a high degree of accuracy and validity of results. Overall, verification of the absence of hidden stocks may pose the largest verification challenge and will require substantive R&D.

Finally, measures on nuclear disarmament would be strongly supported by the successful negotiation of a treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices (a Fissile material cut-off treaty, FMCT). Such a treaty would entail further verification challenges, the most obvious of which are ensuring that there is no (*a*) re-commissioning of shut down enrichment and reprocessing facilities; (*b*) diversion of fissile materials produced at currently operational enrichment and reprocessing plants; (*c*) production at clandestine facilities; (*d*) production at suspect military nuclear facilities; and (*e*) diversion of HEU from naval fuel.[27] The R&D activities required for an FMCT, such as verifying inventories of weapon-usable materials, overlap significantly with warhead dismantlement R&D.

Lessons learned from the verification regimes of other non-proliferation and disarmament treaties

R&D on verification methods and techniques has always played an important role in negotiating and implementing verification regimes for non-proliferation and disarmament treaties. Such R&D activities and their interplay with treaty development and implementation are described below.

The nuclear safeguards system was laid down in the early IAEA safeguards agreements (INFCIRC/26, INFCIRC/66 and INFCIRC/153). It was strengthened based on the lessons learned from the discovery of clandestine nuclear weapon development in Iraq in the early 1990s, the experience gained in verifying South Africa's dismantlement of its nuclear weapon programme, and the verification challenges encountered in the Democratic People's Republic of Korea (DPRK). As a result, the IAEA approved the so-called 93+2 programme, which was in its first part an R&D programme that aimed to identify and adopt additional or new methods and techniques to better support the detection of undeclared activities. The scientific and engineering communities obviously played essential roles in this process. In the second part of the programme, some of the new methods and techniques were incorporated into the IAEA's toolbox as part of the Additional Protocol to current safeguards agreements.

Since 1977, the IAEA has based its technical and scientific programme for nuclear verification on voluntary contributions by member states. These contributions, referred to as the IAEA Member States Support Programmes (MSSPs), have consisted of financial support, R&D, training and consultancy to improve the implementation of safeguards. They, therefore, represent an important pillar in enhancing verification methods and techniques for safeguards purposes and, from a broader view, for non-proliferation regimes in general.

Recognizing the need to constantly scan the horizon, the IAEA has recently established a technology foresight process focused on instrumentation that could be applicable to safeguards fields and laboratory activities. Again, the involvement and engagement of the scientific and engineering communities have been essential in this regard.

R&D to establish verification methods and technologies for the Comprehensive Nuclear-Test-Ban Treaty (CTBT) also has a long tradition, and has had a significant impact on CTBT negotiation and adoption. The need to develop a scientific basis for monitoring nuclear testing in all environments was explicitly recognized following the first CTBT negotiations in 1958. This marked the start of programmes of basic and applied research that have continued to this day.[28] Within the framework of other arms control treaties, such as the 1993 Chemical Weapon Convention (CWC) and the 1990 Treaty of Conventional Armed Forces in Europe (CFE), sophisticated inspection procedures, such as 'on-site inspections', have been developed and used. Managed access to military facilities is always an enormous challenge for the inspectors and the inspected party alike. This includes the certification of

[27] See Schaper, A., 'Verifying the nonproduction and elimination of fissile material for weapons', ed. C. Hinderstein, *Cultivating Confidence: Verification, Monitoring and Enforcement for a World Free of Nuclear Weapons* (Nuclear Threat Initiative: Washington, DC, 2010), pp. 67–122; and Feiveson, H. et al., *Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation* (MIT Press: Cambridge, MA, 2014), p. 148.

[28] National Academy of Sciences, *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty* (National Academies Press: Atlanta, GA, 2002), <http://www.nap.edu/catalog/10471/technical-issues-related-to-the-comprehensive-nuclear-test-ban-treaty\>.

authorized technical equipment, agreed timelines and inspection rights.

During the cold war, however, scientific and technical disagreements over verification methods hindered the successful conclusion of a CTBT. It was in the early 1970s, when a long-term group of scientific experts (GSE) including representatives from up to 40 countries was established to study the technical aspects of monitoring for nuclear explosions, that the scientific and engineering communities started to contribute significantly to the design and implementation of monitoring systems, confidence building, and finally to the successful negotiation of a verification regime and its measures.[29] After the CTBT was opened for signature, the Preparatory Commission for the CTBTO was established in 1996. Since then, the Provisional Technical Secretariat (PTS) has been tasked with establishing a verification regime. The scientific and engineering communities have continued to contribute to the further development and implementation of the International Monitoring System (IMS), the International Data Centre, and procedures and techniques for on-site inspections. Numerous publications and reports, biannual 'science and technology conferences' with more than 1100 registered participants and 550 abstracts in 2015 alone, as well as Integrated Field Exercises aimed at simulating on-site inspections all demonstrate the major contribution of R&D to CTBT verification.

Given the useful role that scientific experts have played in various disarmament negotiations, Germany and the Netherlands held two Scientific Experts Meetings on Technical Issues Related to an FMCT in 2012.[30] About 100 participants attended from 47 states. The first meeting addressed the questions of how facilities for the production of fissile material for nuclear weapons could be decommissioned in a verifiable and transparent manner; how to deal with facilities in nuclear weapon states that were not originally designed with safeguards in mind; and how to handle the transformation of military facilities into civilian facilities. The second meeting focused on the role and limitations of 'nuclear archaeology' in the verification of a future FMCT, with special attention to the detection of secret and/or undeclared activities; and on an FMCT-specific system of managed access and other verification provisions to ensure the non-diversion of nuclear material for prohibited purposes. Further contributions by the scientific and engineering communities are needed in order to move the FMCT negotiations forward. Following four meetings of the Group of Governmental Experts in 2014 and 2015 to discuss recommendations for advancing FMCT negotiations, France announced its intention to issue an initial draft of an FMCT treaty.[31]

All these examples illustrate that coordinated technical discussions are an important element of treaty negotiation and treaty implementation. These important precedents show that technical R&D on disarmament verification capabilities, according to the technical requirements presented above, will be prerequisites for the negotiation of disarmament agreements, and that technical activities can enhance the implementation of disarmament activities.

III. EUROPEAN ACTIVITIES: ENGAGEMENT AND ITS FUTURE BENEFITS

This section argues why it should be in the interest of the European countries and the EU to play a coordinating role in the emerging sector of irreversible dismantlement verification. Existing European activities and approaches are discussed; and the case is put for multilateralism and participation by the NNWS. The standpoint of the EU on disarmament verification, as a supporter of effective multilateralism, is presented; and the benefits of European engagement articulated.

Current European activities and approaches

In her keynote speech at the 2007 Carnegie Conference, the British Foreign Secretary, Margaret Beckett, proposed that the UK should be at the forefront of the conceptual and practical work required to achieve a world without nuclear weapons.

[29] Dahlman, O., Mykkeltveit, S. and Hein, H., *Nuclear Test Ban: Converting Political Visions to Reality* (Springer: Dordrecht, 2009).

[30] Conference on Disarmament, Germany–Netherlands FMCT Scientific Experts Meeting: Technical Issues Related to a Fissile Material Cut-Off Treaty (FMCT), CD/1935, 2012, <http://daccess-dds-ny.un.org/doc/UNDOC/GEN/G12/613/90/PDF/G1261390.pdf?OpenElement?\>; and Conference on Disarmament, Scientific Experts Meeting on technical issues related to a treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices based on resolution 66/44 of the General Assembly of the United Nations, CD/1943, 2012, <http://daccess-dds-ny.un.org/doc/UNDOC/GEN/G12/626/21/PDF/G1262621.pdf?OpenElement\>.

[31] Conference on Disarmament, Draft Treaty Banning the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices, CD/2020, 2015, <http://daccess-dds-ny.un.org/doc/UNDOC/GEN/G15/076/39/PDF/G1507639.pdf?OpenElement\>.

She also suggested that the country should become a ‘disarmament laboratory’ and elaborated concrete steps towards multilateral disarmament. The UK–Norway initiative was established in 2007 to explore effective verification measures, which are an important precondition for fulfilling Article VI of the NPT. At the 2010 NPT Review Conference, the British Government distributed a document, *The Road to 2010*, which proposed the establishment of a ‘Nuclear Centre of Excellence’ with a planned budget of 20 million pounds (approximately 23.5 million euros in May 2010), but this initiative was later dropped after a change of government.

In April 2014, British Pugwash discussed a proposal to establish a national ‘British International Nuclear Disarmament Institute’ (BRINDI), which aimed ‘to facilitate the achievement of the complete, stable, sustainable and irreversible elimination of nuclear weapons by creating the enabling conditions towards universal nuclear disarmament’.[32] The independent trilateral Deep Cuts Commission issued a report in May 2015 in which its 21 commissioners from Germany, Russia and the USA recommended, among other things, ‘the creation of an international center for nuclear disarmament, research, development, testing and demonstration of fissile material’.[33] All these activities, concepts and proposals underline that the time is ripe to elaborate more detailed R&D programs in order to establish effective multilateral verification measures. First, however, it is useful to describe some concrete past activities involving mainly European actors.

The UK–Norway Initiative

Although not ‘intra-EU’, the initiative between the UK and Norway is probably the most prominent example of good cooperation in Europe. Since 2009, the two states have cooperated in a broad project. Several organizations have been involved, such as the Norwegian Foreign Ministry and the British Ministry of Defence, the British Atomic Weapons Establishment, several Norwegian research institutions and, at the beginning of the project, the Verification Research, Training and Information Centre (VERTIC). The initiative’s central aim has been the simulation of nuclear disarmament verification exercises between a nuclear weapon state and a non-nuclear weapon state. The exercises have been carried out in the form of role plays. One of the goals was to learn about the possible effects of restricted access on inspector–host interaction. A second, more technical strand involved the development, fabrication and testing of an information barrier, which was used during the exercises. The two states have made presentations on outcomes on numerous occasions, including at the most recent meetings of the NPT Review Cycle. The project is currently ongoing. Working with the King’s College, London, the project has been extended as a social science study. The verification exercise has been carried out repeatedly in order to gain empirical data on the development of trust and confidence between inspector and host personnel.

ESARDA activities

The European Safeguards Research and Development Association (ESARDA) is an association of European organizations actively involved in R&D on nuclear safeguards. The control of civil nuclear material is mandatory on the territory of EU member states, in line with the 1958 Treaty establishing the European Atomic Energy Community (Euratom Treaty) and the NPT. ESARDA was formed in 1969 to facilitate collaboration on R&D in the field of safeguards and the application of such knowledge to the safeguarding of source and special fissile materials. ESARDA has 32 member organizations and 5 associated partners from Norway, Switzerland and the USA. These include regulatory authorities, operators of nuclear facilities, research centres and universities. The principal areas of activity are the coordination of research, frequent exchanges of information and joint execution of R&D programmes. ESARDA also strives to play an educational role that reaches the general public. To this end, there are (*a*) annual meetings and symposia, which provide opportunities for collaboration and exchanges of scientific information; (*b*) dedicated working group activities, currently by nine working groups; (*c*) a one-week ESARDA Course, which complements nuclear engineering studies by including nuclear safeguards in the academic curriculum; (*d*) the peer-reviewed journal, *ESARDA Bulletin*; and (*e*) the ESARDA website.

ESARDA is currently more active than ever, due to the lively cooperation among its members and its strong linkages to other safeguards-related organizations, such as the US-based Institute of Nuclear Materials Management (INMM), as well as the proactive

[32] For more detail see ‘Realising the Disarmament Institute (BRINDI)’, British Pugwash, 19 Feb. 2015, <http://britishpugwash.org/realising-the-disarmament-institute-brindi/>.

[33] Deep Cuts Commission (note 4).

tackling of new and emerging issues through its diverse working groups. As a result, ESARDA has put more emphasis on specific topics including arms control and disarmament verification, in addition to the traditional safeguards-related topics of ESARDA. A sub-group on arms control verification has been established by the novel approaches/novel technologies working group, and the verification technologies and methodologies working group regularly considers arms control and disarmament verification approaches at its meetings. During the 35th ESARDA Symposium in 2013, the first special panel discussion was held on this very topic. The panellists concluded that ESARDA would be an excellent forum for further deliberations on dismantlement verification, as its members have the required expertise and ESARDA offers a heterogeneous platform for both nuclear weapon and non-nuclear weapon states.[34]

Nuclear Disarmament Verification Network in Germany

For several years, individual researchers in Germany have met to discuss the issue of nuclear disarmament verification on an independent basis. To clarify their goal, they founded the Nuclear Disarmament Verification Network. Its biannual meetings discuss the progress of research in Germany. The group organized a special session and a panel at the ESARDA Symposium in 2013 to discuss the needs of nuclear disarmament verification. Several institutions are working on disarmament verification in Germany. There are research groups at Forschungszentrum Jülich, the Fraunhofer Institute for Technological Trend Analysis in Euskirchen and the Carl Friedrich von Weizsäcker Centre at the University Hamburg. In close cooperation with the Institute for Peace Research and Security at the University of Hamburg, the Centre is conducting a project on disarmament verification, focused on nuclear weapons authentication using gamma and neutron measurements. Various scientific publications have resulted from a first PhD project that was completed in 2015.[35]

Discussion on the humanitarian consequences of nuclear weapons

EU member states, in particular Austria and Ireland, play a visible role in the global initiative on the humanitarian consequences of nuclear weapons. A discourse about the humanitarian dimension of nuclear weapons and the risks associated with their use has been held for several years as part of international negotiations. The humanitarian consequences or impact of the use of these weapons was addressed by several states and debated in three international conferences in Norway (2013), Mexico (2014) and Austria (2014). While there is no direct relation to technical disarmament verification, it is important to note that calls were made during these conferences for a treaty banning nuclear weapons. Initiated by non-governmental organizations (NGOs), the call was later supported by many countries. The so-called Austrian Pledge for a global legal instrument on the prohibition and elimination of nuclear weapons—later known as the 'Humanitarian Pledge' during the ninth NPT Review Conference—has been supported by 112 states to date. The pledge focuses very much on the use and risk of nuclear weapons, but it does not articulate the huge technical, legal and safety challenges linked to dismantling and destroying existing nuclear weapons. Although the need for verification is not mentioned in the Humanitarian Pledge, it is obvious that more rapid and drastic disarmament would create the need for effective verification measures and instruments, including multilateral verification of nuclear warhead dismantlement.

The case for multilateralism and NNWS participation

If disarmament is to be verified by a multilateral regime and include NNWS, all the inspectors involved will need to have confidence in the functionality of the equipment, as detailed above. If not, the verification measures will not give inspecting states the required confidence in the compliance of inspected states. There is a parallel need for the inspected state to have confidence that all the equipment and procedures will not disclose sensitive information.

Perhaps the only option to achieve this confidence is to directly involve all relevant parties, both NWS and NNWS, in the R&D of all verification

[34] Göttsche, M. and Neuneck, G., 'Panel discussion: disarmament verification, a dialogue on technical and transparency issues', *Esarda Bulletin*, no. 50 (Dec. 2013).

[35] See Göttsche, M. and Kirchner, G., 'Improving neutron multiplicity counting for the spatial dependence of multiplication: results for spherical plutonium samples', *Nuclear Instruments and Methods in Physics Research A* 798, 99–106 (2015); Göttsche, M., 'Reducing neutron multiplicity counting bias for plutonium warhead authentication', PhD dissertation, University of Hamburg, 2015, <http://ediss.sub.uni-hamburg.de/volltexte/2015/7356>; Göttsche and Kirchner (note 19).

measures and related equipment. This would include, among other things, a careful dialogue among the participants about their different expectations and requirements. Attention must be paid to the potential vulnerabilities and limitations of equipment, to enable a comprehensive assessment of its reliability and thus the confidence that can be gained. Assessments could be based on joint testing exercises with the benefit of the ability to discuss all vulnerabilities and limitations and arrive at a mutual understanding.

The need for capacity building and the multilateral engagement of a comprehensive variety of actors was recognized in the Final Document of the 2010 NPT Review Conference: 'All States agree on the importance of supporting cooperation among Governments, the United Nations, other international and regional organizations and civil society aimed at increasing confidence, improving transparency and developing efficient verification capabilities related to nuclear disarmament'.[36]

The European Union: a strong supporter of 'effective multilateralism'?

The 28 member states of the EU hold fairly diverse positions on their approach to nuclear matters. The majority of member states are also members of the North Atlantic Treaty Organization (NATO), and NATO declares itself to be a nuclear alliance for as long as nuclear weapons exist. The countries represent a wide spectrum of nuclear policies, which stem from their different political, geostrategic and cultural origins. France and the UK, two of five recognized NWS, possess small nuclear stockpiles and a mostly sea-based nuclear arsenal. In addition, five NATO members—Belgium, Germany, Italy, the Netherlands and Turkey—host approximately 200 US sub-strategic nuclear weapons in several locations. Non-NATO EU member states such as Finland and Sweden are more committed to a strict disarmament policy. Only Austria, Cyprus, Ireland and Malta have signed the Humanitarian Pledge, but 20 EU member states—including the Baltic states, the Benelux countries, many states of Central and Eastern Europe, as well as Greece, Italy, Germany and Spain—have associated themselves with the 'Statement on the Humanitarian Consequences of Nuclear Weapons' presented by Australia to the NPT Review Conference in 2015. This stated that these countries would 'welcome initiatives to develop a better understanding of the complexities of international nuclear disarmament verification'.[37]

The EU is a strong supporter of the NPT as 'the cornerstone of the global non-proliferation regime' and 'as a key priority, and as a multilateral instrument for reinforcing international peace, security and stability'.[38] The EU has played an important role in the 'EU 3 plus 3 talks' with Iran and helped to agree the key parameters of the Joint Comprehensive Action Plan in 2014.[39]

At the ninth NPT Review Conference, the EU committed 'to continue to promote a comprehensive, balanced and substantive full implementation of the 2010 NPT Action Plan, which includes the total elimination of nuclear arsenals (Action 3) and 'rapidly moving towards overall reductions' (Action 5). Action 19 from 2010 in particular states that: 'All States agree on the importance of supporting cooperation among Governments, the United Nations, other international and regional organizations and civil society aimed at increasing confidence, improving transparency and developing efficient verification capabilities related to nuclear disarmament'.[40]

The EU participated in the ninth Review Conference of the NPT in 2015 and published several useful working papers: on the EU's support for the CTBT (Working Paper no. 50); 'safeguards implementation in the EU' (no. 55) and 'nuclear safety' (no. 56). These reflect the areas of activity of the EU. Despite these efforts, however, the EU had a fairly low profile in terms of activities and action at the conference, even though the EU hosts much experience and research activity and many institutions with related expertise in the field of nuclear verification. From a technical point of view, there are also activities and experience in the field of the security and physical protection of nuclear materials and facilities (Action 40). Under Action 42, the final document called on states 'to improve their national capabilities to detect, deter and disrupt illicit trafficking in nuclear materials'. Special detection equipment for portal monitoring would be required

[36] NPT/CONF.2010/50 (note 2), p. 24.

[37] Bird, G., Permanent Representative of Australia to the United Nations, 'Statement on the humanitarian consequences of nuclear weapons', 30 Apr. 2015, <http://www.un.org/en/conf/npt/2015/statements/pdf/HCG_en.pdf>.

[38] See Mogherini (note 1).

[39] EU/E3+3 and Iran, 'Joint Comprehensive Plan of Action', Vienna, 14 July 2015, <http://www.eeas.europa.eu/statements-eeas/docs/iran_agreement/iran_joint-comprehensive-plan-of-action_en.pdf >.

[40] NPT/CONF.2010/50 (note 2), pp. 20, 21, 24.

to achieve this. In addition to being used for security, this could also contribute to fissile material control. In Main Committee I (on disarmament), the EU Special Envoy for Non-proliferation and Disarmament, Jacek Bylica, stated that: 'The EU welcomes and encourages the holding of further P5 Conferences on the follow-up to the 2010 NPT Review Conference, including confidence-building, transparency, verification activities and discussions on reporting'.[41]

All these examples illustrate European interest in disarmament verification in principle. European engagement could take different forms. In addition to independent research activities, it could involve cooperation among various research institutions in European countries. Funding could be provided by research councils and other foundations. The activities of ESARDA could be expanded. On a different scale, activities could be initiated at the governmental level and follow the example of the UK–Norway Initiative. European cooperation could then involve cooperation among two or more states. Alternatively, the EU could involve the Joint Research Centre (JRC) and EURATOM to further engage with the issue. The JRC supports the European Commission's work on nuclear safeguards and security, led by the Commission's Directorates-General for Energy and Home Affairs, respectively, by developing efficient and effective systems for safeguards and the proliferation resistance of current and future nuclear fuel cycle systems, and for the security of nuclear and radioactive materials. It tackles R&D challenges in the areas of nuclear materials measurement, containment and surveillance, and process monitoring. In any event, activities carried out in Europe should be coordinated to ensure effectiveness. Accordingly, it is recommended below that the EU should start an initiative to review, coordinate and elaborate on current European verification activities with a view to setting up a European Centre for Nuclear Verification Research.

The benefits of European engagement

As noted above, several initiatives related to nuclear disarmament verification are currently under way. Besides the UK–Norway Initiative, there is the 'International Partnership for Nuclear Disarmament Verification' initiated by the USA, which brings together NWS and NNWS under a cooperative framework but only includes US allies and partners.[42] While there is a need for continuing progress on an international scale, there are also concrete benefits from cooperation that engages a multitude of European states. The EU community would benefit from an accelerated development of innovative verification technologies to become a more prominent player in the multilateral dismantlement discussions.

Dismantlement expertise of European nuclear weapon states

Significant expertise linked to the dismantlement activities of European NWS already exists. These will be helpful for the verification of nuclear warhead dismantlement but also for nuclear disarmament in a broader context: since the end of the cold war, France and the UK have carried out irreversible disarmament measures. France has dismantled its nuclear test site in Mururoa and its silo-based nuclear deterrent, and converted its fissile material production facility. Both NWS reduced their nuclear-related submarine and air components. Due to their civilian and military nuclear establishment, both countries have access to much knowledge, sophisticated equipment and proven procedures that will be instrumental to future dismantlement facilities. This expertise would for example be highly relevant for a dedicated dismantlement facility, as proposed by the British Pugwash Group in November 2012.[43] To this can be added the expertise of countries such as Sweden, which progressed quite far in developing elements of nuclear weapon facilities but abandoned the option in the 1950s and 1960s. It dismantled or converted facilities, but retained some specialist expertise on radiation protection and verification, which later flowed into international organizations such as the CTBTO.

[41] Bylica, J., Principal Adviser and Special Envoy for Non-proliferation and Disarmament, European External Action Service, 2015 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, 'EU Statement: United Nations Treaty on the Non-Proliferation of Nuclear Weapons', Main Committee I, 1 May 2015, <http://eu-un.europa.eu/articles/fr/article_16410_fr.htm>.

[42] US Department of State, 'An International Partnership for Nuclear Disarmament Verification', Fact sheet, 4 Dec. 2014, <http://www.state.gov/t/avc/rls/234680.htm>.

[43] Anderson, B. et al., *Verification of Nuclear Weapon Disarmament: Peer Review of the UK MOD Programme* (British Pugwash Group: London, Nov. 2012).

NWS–NNWS cooperation

For multilateral disarmament to be possible, it is obvious that a future verification regime and R&D cooperation would necessarily require cooperation between NWS and NNWS. Cooperation in a European context could bring various stakeholders together to review, coordinate and enable multilateral dismantlement R&D within Europe. The UK–Norway Initiative is a successful example. Their first managed access exercises, in which the UK played the role of the NNWS and Norway the NWS, were carried out in 2008 and 2009. A warhead was simulated by using a Co-60 source. In a later exercise, carried out in 2010, the roles were reversed.[44] A general benefit of reversing the roles and developing equipment for verifying Co-60 is the reduced risk of unwillingly sharing sensitive information, such as warhead design information. Successful cooperation between a NWS and NNWS would require sufficient time for a build-up of trust and common ground. European countries in general have similar cultures and attitudes. It is more difficult to envisage a corresponding cooperation between more adversarial states with different cultural backgrounds. While such cooperation would also be helpful, the challenges of engaging more European NWS and NNWS in a similar cooperation would be less severe and would be a good continuation in the right direction.

Unique EURATOM experience

The EURATOM safeguards system, established by the EURATOM Treaty in 1957, is a set of controls and verification activities that cover all civil nuclear installations throughout the EU. Nuclear facilities in the military domain or related to national security are excluded from the EURATOM Treaty. However, in contrast to the IAEA, EURATOM has similar rights of access to all civilian nuclear facilities in both the NNWS and the NWS of the EU. In addition, EURATOM has experience of the conversion of facilities producing material for both nuclear weapons and civil purposes to exclusively civilian production facilities.

EURATOM runs a research programme on nuclear research and training under the European Framework Research Programmes. One of the objectives of the current EURATOM research and training programme (2014–18) is to 'improve nuclear security including: nuclear safeguards, non-proliferation, combating illicit trafficking and nuclear forensics'.

Existing technical expertise in Europe

To enable NNWS participation in disarmament verification, technical capacities must be built independently to create nuclear verification expertise that does not depend on the input of NWS alone. States with civil nuclear energy programmes usually have expertise in nuclear physics, nuclear engineering and radiation detection. This knowledge is highly relevant and required for the development of disarmament verification tools. It is not, however, sufficient on its own, but must be complemented by an understanding of specific disarmament verification challenges such as dealing with managed access and sensitive information. States that do not have this general level of nuclear expertise but do have an interest in participating in verification activities should also eventually be enabled to reach a level of expertise and capacity that allows for their meaningful participation. To make the required progress on the technical R&D agenda, cooperation should certainly include scientists and engineers who already have advanced knowledge.

The EU has significant expertise in the nuclear field: 17 states have had, currently have or plan to have civilian nuclear energy programmes. Research reactors either have been or are currently operated in four more states. This leaves only seven states with no expertise. At the EU level, in addition to the EURATOM safeguards inspectorate, the JRC has a wealth of expertise. The Institute for Transuranium Elements employs 370 academic, technical and support staff, and has developed an extensive range of advanced facilities over more than 50 years.[45] Its Nuclear Safeguards and Forensics, and Nuclear Security Units are of particular relevance.

IV. CONCLUSIONS AND RECOMMENDATIONS ON EUROPEAN COOPERATION

Section III lists current European research activities in the fields of nuclear security, nuclear safeguards and non-proliferation. It is clear that, among them, R&D initiatives and expertise exist that are also

[44] The UK–Norway Initiative, 'Further research into managed access of inspectors during warhead dismantlement verification', 53rd INMM Annual Meeting, Orlando, 2012.

[45] On the work of the JRC, see <https://ec.europa.eu/jrc/en/about/itu>.

related to potential nuclear disarmament verification technologies. Some of these initiatives, such as the related activities of the JRC, are funded by the European Commission. Others, such as ESARDA, are based on European and national support; while still others are funded as part of national research grants for nuclear safeguards and non-proliferation R&D activities.

Section III also discusses activities that focus exclusively on disarmament verification technologies, carried out by, among others, Germany, Norway and the UK, partly or jointly in cooperation with non-European partners. Although these activities have been small in number and at times budget, some have had a significant impact. However, thus far there has been no overall EU strategy on R&D in support of multilateral nuclear disarmament verification.

There are multiple arguments in favour of increased and coordinated European engagement and that demonstrate why Europe seems to be destined to play a leading role in future multilateral disarmament verification, with regard to both research and policy.

1. The EU has stated its interest in verified nuclear disarmament on numerous occasions. Such statements could be meaningfully underscored by supporting related R&D activities. If the EU had a coordinated, comprehensive R&D initiative aimed at investigating and advancing disarmament verification methodologies and technologies, it would further leverage international recognition of the EU's commitment to nuclear disarmament.

2. Successful nuclear disarmament must take a multilateral approach that also includes NNWS. European states represent this required diversity. In particular, a NWS–NNWS cooperation is feasible because there is sufficient trust to enable such cooperation, especially among the EU member states.

3. The EU has significant and unique experience that is instrumental to effectively advancing the disarmament verification agenda. Specifically, this includes the dismantlement expertise of France and the UK and the expertise of EURATOM in the verification of former military facilities and materials, as well as the significant R&D efforts by the JRC in regard to nuclear safety, security and non-proliferation. Significant technical expertise also exists among the non-nuclear weapon EU member states, linked to their nuclear energy programmes.

A number of recommendations are set out below on how to increase the expertise and visibility of the EU in its support of future global nuclear disarmament, the Global-Zero process, future FMCT negotiations and other future arms control and disarmament agreements. The recommendations contain actions that mainly focus on R&D methodologies and technologies. While these touch on policy questions and could lay the basis for different decision-making pathways in disarmament policy, the technical issues are emphasized.

1. Some aspects of the current research programme of the JRC focused on nuclear safety, security and non-proliferation might also be applicable to disarmament verification. It should be evaluated, to what extent past and current activities have been relevant for disarmament verification

2. In the past, EURATOM has taken over responsibilities for safeguarding former military fissile materials in the EU member states. These activities can provide unique experience of relevance to nuclear disarmament verification. As there has never been a detailed study or process to evaluate these experiences, this should be initiated, and the lessons learnt, if appropriate, fed into disarmament verification research activities.

3. Although global disarmament policy may generally be stalled until the next NPT Review Conference in 2020, further understanding of and technical solutions to the complex challenges implied in the verification of future disarmament agreements cannot be delayed. The EU should therefore provide appropriate support for the development and application of new technologies or concepts, in addition or as a significant contribution to the International Partnership for Nuclear Disarmament Verification. In this context, the European Commission should extend the scope of appropriate funding mechanisms to disarmament verification methodologies and technologies.

4. The US-led nuclear security summit process aims to reduce the amount of existing fissile material and secure it. Disarmament and its verification can also help to reduce the amount of and secure weapon-

usable nuclear material. The EU Chemical, Biological, Radiological and Nuclear Risk Mitigation Centres of Excellence Initiative could be considered a platform for intensified R&D in support of multilateral nuclear disarmament verification.

5. We propose the commencement of a one-year review process in Europe that includes all relevant national and European institutions, research groups, authorities (Euratom, IAEA) and associations (ESARDA, European Physical Society) in order to create a coordinated multilateral disarmament capacity in Europe. The results of this one-year review should be presented and discussed at an international workshop. The results could also lead to a European contribution to the NPT Action plan (Action 19), agreed at the 2010 NPT Review Conference.

6. Although the expertise gathered from the various institutions and R&D coordination through the review process would result in important progress, the establishment of an EU Centre for Disarmament Verification would maximize the effectiveness of R&D and the communication of results.

EU NON-PROLIFERATION CONSORTIUM

The European network of independent non-proliferation think tanks

A EUROPEAN NETWORK

In July 2010 the Council of the European Union decided to create a network bringing together foreign policy institutions and research centres from across the EU to encourage political and security-related dialogue and the long-term discussion of measures to combat the proliferation of weapons of mass destruction (WMD) and their delivery systems.

STRUCTURE

The EU Non-Proliferation Consortium is managed jointly by four institutes entrusted with the project, in close cooperation with the representative of the High Representative of the Union for Foreign Affairs and Security Policy. The four institutes are the Fondation pour la recherche stratégique (FRS) in Paris, the Peace Research Institute in Frankfurt (PRIF), the International Institute for Strategic Studies (IISS) in London, and Stockholm International Peace Research Institute (SIPRI). The Consortium began its work in January 2011 and forms the core of a wider network of European non-proliferation think tanks and research centres which will be closely associated with the activities of the Consortium.

MISSION

The main aim of the network of independent non-proliferation think tanks is to encourage discussion of measures to combat the proliferation of weapons of mass destruction and their delivery systems within civil society, particularly among experts, researchers and academics. The scope of activities shall also cover issues related to conventional weapons. The fruits of the network discussions can be submitted in the form of reports and recommendations to the responsible officials within the European Union.

It is expected that this network will support EU action to counter proliferation. To that end, the network can also establish cooperation with specialized institutions and research centres in third countries, in particular in those with which the EU is conducting specific non-proliferation dialogues.

http://www.nonproliferation.eu

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PEACE RESEARCH INSTITUTE IN FRANKFURT

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