"Institutional initiatives and international academic efforts are gathering momentum in demonstrating the importance of verification to advance nuclear disarmament. Enhancing education in this realm will be crucial to ensure knowledge transfer among generations of nuclear professionals and the development of a new group of experts in the field."

VERTIC BRIEF • 33 • JUNE 2021

B R I E F

Encouraging Education in the Field of Nuclear Disarmament Verification

Elena Gai, VERTIC

VERTIC

"The year 2022 will mark the 20th anniversary of the United Nations study on disarmament and non-proliferation education."

Introduction

Institutional initiatives and international academic efforts are gathering momentum in demonstrating the importance of verification to advance nuclear disarmament. Enhancing education in this realm will be crucial to ensure knowledge transfer among generations of nuclear professionals and the development of a new group of experts in the field.

The report of the United Nations Secretary-General (UNSG) on disarmament and non-proliferation education, issued almost 20 years ago, highlighted 'the urgency for new thinking to pursue disarmament and non-proliferation goals'. That said, the study did not include a section devoted to the role of verification. Two decades on, a better understanding of verification approaches, techniques, and tools appears to be essential to participate in international nuclear disarmament consultations and negotiations to move towards the common objective of a world without nuclear weapons.[1] Indeed, *Securing Our Common Future: An Agenda for Disarmament*, published by the United Nations Office for Disarmament Affairs in 2018, underlines that 'all States must work together to achieve concrete and irreversible steps to prepare for a world free of nuclear weapons, including by making the nuclear test ban permanent, developing approaches for nuclear disarmament verification and ending the production of fissile material for use in weapons'. In this respect, the Office for Disarmament Affairs declared that it 'will support the development of nuclear disarmament verification standards, techniques and capacities, starting with expert-level discussions in 2018, as mandated by the General Assembly'.

This *VERTIC Brief* reviews recent United Nations (UN) Resolutions on the role of verification in fostering confidence in nuclear disarmament and the importance of capacity-building and education in the field to develop and maintain adequate techniques and tools. In addition, it reports on international efforts pursued so far and the current status of nuclear disarmament verification (NDV) education and research in universities and institutions. The *Brief* also identifies other initiatives that may contribute significantly in the future to efforts in this area. These include capacity-building activities in regions that have been less involved in the sector to date, and, in particular, the possibility of establishing an international NDV network of universities, governmental and non-governmental research and technical institutes, and other actors across all parts of the world. The creation of such a network could be very timely in terms of lending more support to the work of the Group of Governmental Experts (GGE) on the role of verification in advancing nuclear disarmament and the potential setting up of a Group of Scientific and Technical Experts (GSTE).

Twenty years after the UNSG's report: what role for verification?

The year 2022 will mark the 20th anniversary of the United Nations study on disarmament and non-proliferation education that the UN Secretary-General, with the assistance of the GGE, presented to the UN General Assembly. The report is a comprehensive review of disarmament and non-proliferation education and training. It describes ways to utilize evolving pedagogical methods, such as those deriving from the development of information and communication technologies, and to introduce disarmament and non-proliferation education into post-conflict situations, and includes a set of 34 practical recommendations to support disarmament and non-proliferation education and training.

The report, which echoes the importance of nuclear disarmament education, underlined initially in the First Special

Session of the General Assembly devoted to disarmament (SSOD-I) in 1978, also stated that 'the need for disarmament and non-proliferation education and training has never been greater' and 'changing concepts and perceptions of security and threat magnify the urgency for new thinking to pursue disarmament and non-proliferation goals'.

This new thinking certainly should address how to encourage education in verification as a core component of facilitating nuclear disarmament. States Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) affirmed in Action 2 of the 2010 Action Plan that verifiability, along with irreversibility and transparency, are central to them meeting their disarmament obligations as specified in Article VI of the NPT. Action 19 recalled the importance of supporting cooperation 'aimed at increasing confidence, improving transparency and developing efficient verification capabilities related to nuclear disarmament'.

More recently, in 2016, the UN General Assembly adopted a Resolution on NDV (A/RES/71/67), convinced that 'identifying and developing practical and effective measures of nuclear disarmament verification and monitoring will foster confidence and facilitate efforts to achieve and maintain a world without nuclear weapons'.

While expressing their views on the Resolution to the UNSG, Member States called for major support for the advancement of nuclear disarmament verification processes, approaches, and techniques. Among the Nuclear Weapon States (NWS),[2] the United States affirmed that 'effective verification is a key feature of all successful nuclear reduction agreements', whereas France stressed that 'an effective verification regime is essential to guarantee the credibility of disarmament instruments, including nuclear disarmament'. China pointed out that 'effective measures of nuclear disarmament verification are important means to guarantee the earnest implementation of nuclear disarmament, but also [serve as a] critical safeguard ultimately for the complete prohibition and thorough destruction of nuclear weapons'. Lastly, India, as a State with nuclear capabilities, acknowledged 'the utility of technical work on verification as proposed in Resolution 71/67, which can build upon past work done in the UNDC [United Nations Disarmament Commission] on the subject and keeping in mind the principles enshrined in SSOD-I'.

Among Non-Nuclear Weapon States (NNWS), Australia believed that 'identifying and developing workable and effective verification and monitoring measures will foster enhanced confidence, underpin disarmament efforts and contribute to the achievement and maintenance of a world free of nuclear weapons'. Canada reaffirmed that 'verification enhances credibility, builds transparency, and facilitates compliance'.

Building capacity

The 2016 NDV Resolution also notes that 'given the challenges associated with verifying nuclear disarmament, continuous capacity-building and technical development are critical to bridging any shortcomings and establishing effective multilateral nuclear disarmament verification'. In this context, the Government of Norway, while commenting on the Resolution, highlighted that there is a need for more experts that can combine expertise in the political domain of nuclear disarmament and non-proliferation with the technical skills required to ensure verifiable and irreversible nuclear disarmament. Promoting and nurturing a verification culture within Member States, along with building up networks, would be essential for training not just the experts that would operate within a multilateral verification regime, but also national stakeholders more broadly (such as civil servants, decision-makers, and members of the public), who

"More education and training opportunities are necessary to create an avenue for the entry of young people . . . into the disarmament field and to ensure that peace, security, and sustainable development are achieved by the international community."

"Several pioneering initiatives have sought to guarantee effective control and monitoring of nuclear disarmament."

would understand better the challenges and appreciate the benefits of cultivating such a culture. The Government of Canada also recognized that much greater confidence in global disarmament regimes could be achieved by a professionally qualified cadre of specialists with wide geographical representation in NWS and NNWS. The Government of the United Kingdom, for its part, recommended considering how to encourage more States to undertake efforts to develop and strengthen nuclear disarmament verification measures.

In line with UN Security Council Resolutions (UNSCR) 2419 and 2250 on 'youth, peace, and security', more education and training opportunities are necessary to create an avenue for the entry of young people—'the ultimate force for change, at the local, national and international levels, to make the world safer and more secure for all'[3]—into the disarmament field and to ensure that peace, security, and sustainable development are achieved by the international community. As the UN Secretary-General reported in *Securing Our Common Future: An Agenda for Disarmament*: 'The active engagement of all States, especially developing countries, in policy discussions facilitates more effective and sustainable outcomes in all areas of peace and security. However, developing countries continue to be seriously underrepresented in disarmament meetings held within the framework of the United Nations, where they are less likely to attend, speak or hold formal roles'.

In this sense, the 2016 NDV Resolution again 'calls upon all States to work together to identify and develop practical and effective disarmament verification measures facilitating the objective of achieving and maintaining a world without nuclear weapons through, inter alia, advancing, understanding and addressing technical challenges of nuclear disarmament verification and monitoring, including tools, solutions and methods and capacity-building'.

The question, then, is: how does one ensure more inclusive and effective representation in a multilateral framework?

Former and current international governmental efforts towards nuclear disarmament verification

Several pioneering initiatives have sought to guarantee effective control and monitoring of nuclear disarmament. These date back as far as 1963 when the US Department of Defense and the US Arms Control and Disarmament Agency (ACDA) initiated 'Project Cloud Gap'[4] to 'test the technical feasibility of potential arms control and disarmament measures'. The project later culminated in 'Field Test FT-34', a collaborative exercise between the two actors to develop and test inspection procedures to monitor the demonstrated destruction of a nuclear weapon. The manoeuvre involved teams of different sizes operating at different levels of access that had the opportunity to monitor the destruction of nuclear weapons, assay the fissionable material derived from them, and test the credibility of the demonstration. Later, in 1989, a first tentative discussion on technical means to verify sea-based nuclear weapons resulted in the Black Sea Experiment, a series of seven trials conducted by the Academy of the Sciences of the Soviet Union and the US Natural Resources Defense Council that studied the utility of 'different radiation detectors for detecting the presence or absence of nuclear warheads on ships'.

At the beginning of the 1990s, the Trilateral Initiative, a collaborative endeavour of the International Atomic Energy Agency (IAEA), Russian Federation, and the US, served as an example of verification of 'weapon origin fissile material deemed excess to military needs' without revealing proliferation-sensitive information. It surveyed current measurement equipment (starting with approved IAEA equipment),

and gradually developed a measurement methodology agreed by the participants, including a statement of equipment requirements. Despite some outstanding issues that still need to be resolved, such as on authentication, the value of the initiative to future nuclear disarmament efforts was saliently summarized by Thomas E. Shea, the former Head of the IAEA Trilateral Initiative Office: 'ultimately, the steps taken by the Russian Federation and the United States may create a general arms control framework suitable for all States possessing nuclear weapons, providing a means for them to make available for international verification materials that result from progress toward nuclear disarmament'.[5]

The first collaboration on nuclear warhead dismantlement verification between a NNWS and a NWS occurred through the UK–Norway Initiative (UKNI). The UKNI began in 2007, with VERTIC as an observer, and it has implemented a series of practical projects. One focused on the development of an information barrier system designed to analyse gamma radiation from an object and to confirm, without revealing proliferation-sensitive information, whether the radiation was consistent with the presence of plutonium containing a high degree of Pu-239. Another comprised three exercises aimed at exploring the challenges associated with deploying inspectors to sensitive nuclear facilities. The UKNI later evolved into the Quad Nuclear Verification Partnership, involving Norway, Sweden, the UK, and the US. In late 2017, experts from these countries travelled to RAF Honington in Suffolk, England, to perform exercise 'Letterpress', which simulated the early stages of dismantling a mock-up nuclear weapon.

In 2000, the UK and the US commenced a collaboration to address a series of technical, operational, and security challenges to enable verification of sensitive processes at nuclear weapons facilities. The initiative focused on: the development of technologies and procedures to protect classified information while guaranteeing authentication of inspection equipment; managed access for inspectors at nuclear weapons sites; confirmation of declared nuclear weapons attributes; chain of custody; and monitored storage of materials and components for nuclear weapons. Such a collaboration, which is ongoing, identified gaps in current capabilities and recommended further research in the areas of data authentication, fissile material detection, and sensitive information protection.[6]

More recently, in 2014, the US Department of State launched, as part of a public–private partnership with the Nuclear Threat Initiative (NTI), the International Partnership for Nuclear Disarmament Verification (IPNDV). The initiative involves more than 25 countries that operate through three Working Groups[7] and aims to develop effective verification and monitoring solutions for nuclear disarmament technical challenges. Through the IPNDV outreach symposium 'Innovations in Nuclear Disarmament Verification: Advancing Technology and Approaches', which took place in March 2020, the IPNDV has also benefitted from studies undertaken by academics and researchers. VERTIC and partner institutes, for example, presented the poster *Fuel cycle modelling as a disarmament verification tool*, emphasising that understanding a state's fuel cycle is a prerequisite step in planning for disarmament verification.[8]

"The first collaboration on nuclear warhead dismantlement verification between a NNWS and a NWS occurred through the UK–Norway Initiative."

Status of current NDV education and research

The governmental efforts outlined above have contributed to innovative research, inspiration, and practical insights into verification, as well as proposed solutions to technical and procedural problems. Nonetheless, experts in the field recognise that there are still outstanding issues, especially with regard to authentication

"Effort has been invested over the years in ensuring effective education and research and framing technical and political problems and advancing solutions."

processes, proliferation of sensitive information, and classification. To resolve them, effort has been invested over the years in ensuring effective education and research and framing technical and political problems and advancing solutions. As indicated, several of the activities above continue in this area. Meanwhile, academic and other research institutes are also contributing substantially to the drive.

In the US, Princeton University's Program on Science and Global Security (SGS) focuses on new approaches to nuclear arms control verification treaties, involving artificial intelligence, interactive mapping, and virtual reality, methods to reduce intrusiveness in the event of inspections in nuclear weapon states, new approaches to nuclear archaeology, and baselines for past fissile material production. Professor Alexander Glaser's team has conducted work that may be applicable to future denuclearisation of North Korea. Such research was recently expanded by introducing prototypes of information barriers and autonomous robots equipped with directional neutron and gamma detectors performing different actions at selected nuclear facilities. Most recently, Professor Glaser and Tamara Patton also examined the concept of 'deferred verification', used as a possible approach to a future Fissile Material Cut-Off Treaty (FMCT), and tried to identify solutions to a few unresolved verification challenges, such as the need for information barriers for warhead confirmation measurements.[9]

At the Massachusetts Institute of Technology (MIT), Professor Areg Danagoulian and his team are developing a new method of verifying the dismantlement of nuclear warheads, which uses neutron beams to authenticate a warhead's isotopic composition without revealing it. More precisely, a beam is dispatched horizontally through a warhead proxy. It then passes through a lithium filter, after having hit the target, which works to scramble the information embedded in the altered beam. In the final stage, the beam is sent to a glass detector, which captures the data recorded by the beam. The test can identify the specific isotope of the target element, which, in case of dismantlement, could allow inspectors to confirm the identity of a warhead.[10]

At the Center for International Security and Cooperation (CISAC), Stanford University, scholars have published work on a variety of issues connected to nuclear disarmament verification, ranging from examining the techniques applicable to the verification process of nuclear weapons reductions to options for verifying the denuclearisation of North Korea.

At the Center for Nuclear Security Science and Policy Initiatives, Texas A&M University—presented as 'the first US academic institution focused on technical graduate education, research, and service related to the safeguarding of nuclear materials and the reduction of nuclear threats'—researchers are spearheading efforts to develop techniques that potentially could reduce the need for an information barrier in the verification of nuclear warheads. Such procedures would use fluorescence imaging to determine fissile material attributes while verifying an un-canned nuclear warhead or warhead component without revealing proliferation-sensitive information.[11] Another area of work centres on technologies that employ pulsed high-energy photons to interrogate measurements objects, and examines the neutron signal from this interrogation to determine the characteristics of the object.[12] Such studies are preliminary; further investigation and assessment procedures will consolidate the results.

The James Martin Center for Nonproliferation Studies (CNS) is a leader in the analysis of open-source information, and its body of work is relevant to monitoring and disarmament issues. The contributions of CNS to the field include using

three-dimensional (3D) modelling to estimate the fuel capacity of North Korean and Iranian ballistic missiles and creating 3D models of Iran's uranium centrifuges and assessing their implication for the Joint Comprehensive Plan of Action (JCPOA). The Center has also leveraged innovative remote sensing and geospatial analysis techniques to monitor uranium mining and milling activities, as well as developments at nuclear sites in North Korea. In addition, it has created and maintained a database of that country's ballistic missile tests, and spearheaded pioneering efforts on societal verification, including data mining, gaming, crowdsourcing, and problem-solving.

In Europe, Germany and the UK are home to leading institutes on nuclear disarmament verification research. In Germany, the Nuclear Verification and Disarmament Group at the Aachen Institute for Advanced Study in Computational Engineering Science explores the conditions and avenues that enable reductions in nuclear weapons arsenals and weapons-usable fissile materials. This project seeks to develop new tools and methods to understand and reduce uncertainties pertaining to states' fissile material holdings. A decrease in uncertainty here would signify a substantial step forward in achieving a meaningful degree of predictability and irreversibility of future arms control initiatives. At the Carl Friedrich von Weizsäcker Centre for Science and Peace Research at the University of Hamburg (ZNF), scholars are focusing on disarmament verification of nuclear warheads. Specifically, they are conducting a feasibility study to demonstrate, through experiments performed and backed-up by simulations, that authentication of nuclear weapons is possible by measuring their components. As there are no warhead components available for measurement, highly-enriched uranium (HEU) and weapons-grade plutonium are used in gram quantities to create an information barrier that authenticates small masses. Such a scenario, which benefits from measurements performed at the Institute for Transuranium Elements of the Joint Research Centre, can be transferred, according to the authors, to the scenario of weapons authentication.

In the UK, the Centre for Science and Security Studies (CSSS) at King's College London, ran, from 2014–16, a project based on tailored lecturers and practical exercises with the Norwegian Institute of Energy Technology and the UK Atomic Weapons Establishment. Among other things, it entailed eight verification simulations in Norway involving British, German, Egyptian, South African, American and Russian participants. The goal of the project was to assess the influence of human factors on the verification of nuclear warhead dismantlement.[13]

Meanwhile, VERTIC has highlighted the importance of verification in advancing nuclear disarmament since its foundation in 1986. As noted, the Centre helped the UK and Norway to establish the joint research programme to look into the technical requirements of warhead dismantlement verification in the unique context of NWS and NNWS cooperation. For many years, it has been running initiatives focused on a variety of verification challenges, including developing multilateral options and arrangements for effective nuclear disarmament verification, covering nuclear material disposition, nuclear weapons facilities, and warheads and ongoing safeguards. The projects have also considered the involvement of multilateral organisations through an investigation of mandates, experience, and States' views. This work has been supported by the Government of Norway.

For several years, VERTIC has modelled the entire nuclear fuel cycle to study proliferation, disarmament, and verification issues. The latest iteration of this work includes a focus on the use of open-source

"VERTIC has highlighted the importance of verification in advancing nuclear disarmament since its foundation in 1986."

"Currently, VERTIC, in partnership with the NPS Foundation, the ISTC, and the University of Witwatersrand, is implementing a multi-year project focused on building capacity for the multilateral verification of nuclear disarmament."

data to support the evaluation and verification of nuclear disarmament. This is being done in collaboration with the CNS and the Royal United Services Institute (RUSI).

In Sweden, the Armament and Disarmament programme of the Stockholm International Peace Research Institute (SIPRI) has a broad remit, including arms and military expenditure, arms control and non-proliferation, dual-use arms trade control, and emerging military and security technologies. It has also carried out work specifically on verification, starting in the 1970s with research on the concept of verification, its strategic value, and its relation with national security.[14] More recently, the Armament and Disarmament programme has published research on the technical and political challenges to furthering nuclear disarmament and elaborated on the requirements and possible monitoring solutions for the entry into force of the Treaty on the Prohibition of Nuclear Weapons (TPNW).[15]

Within the framework of the European Safeguards Research & Development Association (ESARDA), an Ad Hoc Working Group is specifically dedicated to verification technologies and methodologies (VTM), including inspection models such as managed access, challenge inspections, unannounced access, information gathering, environmental and infrasound monitoring, and assessing the effectiveness and efficiency of verification evaluation. A recent publication, *Verifying Treaty Compliance*, contains a compendium of views and analysis of verification techniques.[16]

In Russia, the PIR Center recently produced a special issue of *Security Index* entitled 'Verification of Nuclear Arms Control and Nuclear Disarmament: Experience, Prospects and New Ideas', containing excerpts from the international workshop on 'Arms Control and Disarmament Verification: Experience, Prospects, and New Ideas'. The gathering was organized by the PIR Center, the Diplomatic Academy of the Russian Ministry of Foreign Affairs, the Swedish Radiation Safety Authority, and the Trialogue Club International and held in November 2018. In the report, verification is presented as 'a key element of arms control and disarmament'. Nevertheless, it is underlined with regard to international verification that 'at this time, there is no ready-to-use mechanism of disarmament verification that could verify the disposal of all nuclear weapons components', and, in terms of the Quad Nuclear Verification Partnership and the IPNDV, that 'one of the main challenges facing such mechanisms is to achieve effective verification without requiring access to sensitive information'.[17] Even if there has been no support to date among these Russian experts on the NDV concept in academia and in UN international fora, a Russian organisation decided to investigate the topic and collect a variety of viewpoints on the challenges posed by nuclear disarmament verification. In fact, according to Russian representatives, 'any attempt to develop "generic" verification mechanisms and tools dissociated from actual nuclear arms control and disarmament regimes would be counterproductive and finally harmful to further progress in this area'.[18]

Lastly, the United Nations Institute for Disarmament Research (UNIDIR), which is 'an autonomous institution within the framework of the United Nations, established by the General Assembly for the purpose of undertaking independent research on disarmament and related problems'[19], has within its programme on Weapons of Mass Destruction and Other Strategic Weapons, a specific strand of work devoted to providing new approaches to transparency in and verification of nuclear security and disarmament. Its findings are applied to different contexts, one of which is the denuclearization of the Korean Peninsula.

Even if it is more difficult to find programmes specifically focused on nuclear disarmament verification, international collaborations or tailored research have been undertaken beyond Europe and the US by, inter alia, the China Arms Control and Disarmament Association (CACDA) and Tsinghua University in China, the Nonproliferation for Global Security (NPS) Foundation in Argentina, the International Science and Technology Center (ISTC) in Kazakhstan, and, on the continent of Africa, the University of Witwatersrand, Johannesburg, the American University of Cairo, and the Nonproliferation and Disarmament Program (NDP) of Ghana's African Centre for Science and International Security. These organisations commission research, identify regional perspectives, and engage in outreach with universities, while interacting with a variety of stakeholders, ranging from governments to regional organisations and academia.

Currently, VERTIC, in partnership with the NPS Foundation, the ISTC, and the University of Witwatersrand, is implementing a multi-year project focused on building capacity for the multilateral verification of nuclear disarmament. Supported by the Norwegian Ministry of Foreign Affairs, it seeks to harness, develop, and sustain capabilities in the countries and regions that contribute to NDV. The work will ultimately contribute to transferring and retaining knowledge and expertise among professionals and establishing a new generation of nuclear experts in the regions.

Towards an NDV network

The initiatives and research projects described above do not paint an exhaustive picture of the complex education and research taxonomy that are relevant to NDV awareness-raising and capacity-building. However, they do offer an indicative understanding of the work currently or recently undertaken by some institutes and universities and governments and international organisations.

VERTIC has been considering how to energize, facilitate, and sustain activities at the national and regional level and how this can complement existing and potential international fora. One idea is to have an NDV network of stakeholders active within countries and regions and to support newcomers to the area. This initiative could help those stakeholders to share and discuss their work with peers, and provide pathways for collaboration on research and education. Furthermore, it could support the community in general, since stakeholders can help one another, especially if one country is struggling to sustain engagement on the issue. Similarly, different institutes and initiatives will have different levels of capacity, so the ability to engage more will aid those smaller and more academically isolated bodies. Such a network could thus help to connect the institutes and stakeholders with whom VERTIC interacts across Asia, Africa, and Latin America, as well as those in Europe and the US that are concentrating on the issue.

A network of this kind may also support the work of the IPNDV, which, according to the US, not only can supplement the important work of other initiatives in the field, but also can engage other non-traditional stakeholders, such as NGOs and universities, in joint efforts to respond to the challenge of monitoring nuclear disarmament verification.

The more recent initiative on 'Creating an Environment for Nuclear Disarmament', similarly backed by the US, is potentially more inclusive: notably, China and Russia are participants. Moreover, one of its 'clusters' is devoted to the 'institutions and processes nuclear-weapon states and non-nuclear-weapon states can put in place to bolster non-proliferation efforts and build confidence in nuclear disarmament'.

"VERTIC has been considering how to energize, facilitate, and sustain activities at the national and regional level and how this can complement existing and potential international fora."

"Reenergizing the debate on the establishment of a nuclear disarmament network for stakeholders active within countries and regions specifically focused on nuclear disarmament verification seems particularly timely today."

However, it does not include multilateral verification systems and approaches as items of investigation to advance nuclear disarmament. What is more, there are uncertainties regarding the continuity of the initiative under the new Administration in the US.

At the national level, there have been attempts to create an NDV network in Germany; researchers from institutes such as Forschungszentrum Jülich, the Fraunhofer Institute for Technological Trend Analysis in Euskirchen, and the Carl Friedrich von Weizsäcker Centre at the University Hamburg meet on an independent basis biannually. In close cooperation with the Institute for Peace Research and Security at the University of Hamburg, the Carl Friedrich von Weizsäcker Centre is developing a project centred around nuclear weapons authentication using gamma and neutron measurements.

In 2019, the Government of Sweden recognized the importance of sound knowledge of nuclear weapons and effective disarmament methods in enhancing the country's role in global disarmament affairs. It also highlighted that a new centre with this focus based in Sweden would ensure comprehensive, versatile, and long-term expertise from which the government could benefit. Such a centre would serve in the first instance diplomats and politicians, but also students, members of civil society, and the media.[20] Even though it makes no specific reference to nuclear disarmament verification, it would be plausible to list this topic as one of those on which the centre will concentrate; nuclear disarmament verification is included in the 'Stepping Stones' approach and was recognized as an element to advance nuclear disarmament during the Stockholm Ministerial Meeting on Nuclear Disarmament and the Non-Proliferation Treaty in June 2019, in which Argentina, Canada, Finland, Ethiopia, Germany, Indonesia, Japan, Jordan, Kazakhstan, Netherlands, Norway, New Zealand, Republic of Korea, Spain, and Switzerland also participated.[21]

At the international level, it is worth recalling that a 2015 report issued by German, Russian and US experts who were part of the Independent Trilateral Deep Cuts Commission recommended 'the creation of an international center for nuclear disarmament, research, development, testing and demonstration of fissile material'. In the UK, British Pugwash discussed in 2014 the establishment of a British International Nuclear Disarmament Institute (BRINDI) as 'an independent institution that could advise governments, and bring together the technical, political, military, diplomatic and public outreach skills required eventually to reach global zero'. That would have been an outcome in line with a document distributed by the Government of the UK during the 2010 NPT Review Conference entitled 'The Road to 2010', proposing the establishment of a 'Nuclear Centre of Excellence' with an estimated budget of GBP 20 million. However, this initiative was abandoned after a change in government.[22]

Reenergizing the debate on the establishment of a nuclear disarmament network for stakeholders active within countries and regions specifically focused on nuclear disarmament verification seems particularly timely today. The GGE, established pursuant to A/Res/71/67 to consider the role of verification in advancing nuclear disarmament, defined disarmament in its 2019 report as 'an ongoing undertaking' for which 'there is a need for a continued international examination in all its aspects, including verification'. The Group concluded that 'all States could contribute to aspects of nuclear disarmament verification and no State is restricted from developing verification techniques and methodologies', and called for 'further work related to the role of verification'.

In A/Res/74/50, voted on a few months after the circulation of the GGE's report, the UN Secretary-General requested the establishment of a new group of up to 25 governmental experts. It will meet in Geneva for four sessions in 2021 and 2022 to consider further nuclear disarmament verification issues, including the concept of a GSTE, building on the suggestions in the GGE's report and the views of Member States.

The GSTE concept was introduced by Brazil during the third session of the GGE. According to its 'Proposal on the establishment of a multilateral Group of Scientific and Technical Experts on Nuclear Disarmament Verification (GSTE-NDV) within the Conference on Disarmament', the group should be open to 'experts from both nuclear-armed and non-nuclear-armed States and across regions'. Moreover, 'its establishment within the United Nations framework and, in particular, under the auspices of the Conference on Disarmament would be a robust confidence-building measure allowing for inclusive ownership and a coherent, comprehensive, and sustainable approach'. The GSTE would enable the work conducted to date to be examined and a consolidated approach going forward that aids all of the other initiatives, and it could provide a vessel for knowledge and approaches to be recorded at the UN level and preserved for use in the future. Such a group 'could be established to appraise scientific, technical and legal research into the processes of verifying nuclear arms reductions, as well as their elimination, and to provide a platform through which research could be disseminated and preserved within the disarmament machinery'. Its mandate could cover, inter alia, a review of past and current NDV initiatives, an exploration of scientific and technical solutions to verification challenges, and the identification of verification measures to be included in future international bilateral and multilateral agreements.

The GSTE could take inspiration from the 'Ad Hoc Group of Scientific Experts to Consider International Co-operative Measures to Detect and Identify Seismic Events', which gathered from 1976–96. Despite having a limited technical mandate,[23] the arrangement paved the way for the diplomatic and political discussions that eventually led to the negotiation of the Comprehensive Nuclear Test Ban Treaty (CTBT). This is a relevant example of science diplomacy that fostered a deeper understanding of verification challenges and its potential application in the nuclear disarmament verification field.[24]

During the discussions of 2018–19, not every GGE member supported the idea of a GSTE. Notably, the Russian Federation argued that 'any attempts to associate non-nuclear weapon States, NGOs and academic community to verification of practical steps in the area of nuclear arms control create strong risks of disclosing information on nuclear weapons technologies and composition'. According to Russia, sensitive details related to storage facilities, such as locations and security arrangements, might be disclosed and obligations under Articles I and II of the NPT would be undermined.[25]

While the GSTE concept will be assessed further by the GGE in 2021–22, the international academic and think tank community may reinforce the current diplomatic initiative and build momentum by establishing a nuclear disarmament verification network that could identify and address technical and political challenges and provide timely advice in response to governmental experts' requests.

Similar networks already exist in different fields and they present governance elements on which an NDV network could draw. For instance, the Communications Experts Network, one of the European Food Safety Authority's (EFSA) scientific arrangements focused on communicating the risks associated with the food chain across the EU,

"In A/Res/74/50, voted on a few months after the circulation of the GGE's report, the UN Secretary-General requested the establishment of a new group of up to 25 governmental experts. It will meet in Geneva for four sessions in 2021 and 2022 to consider further nuclear disarmament verification issues."

"A network can also serve as a platform to overcome diplomatic impasses."

plays an important role during food-related emergencies and coordinates the sharing of information among Member States, with the ultimate goal of providing consistent advice to consumers and affected people. It meets two to three times a year at workshops or symposia on relevant aspects of risk communication and social science. Other means of collaboration include: online exchanges (for example, using communication platforms such as Yammer) to share ideas, updates, and promotions; bilateral or multilateral teleconferences on sensitive issues during food outbreaks and incidents; and bilateral or multilateral meetings to share experiences and competency-based expertise.

In the economic and industrial sector, the World Economic Forum's Expert Network includes specialists from academia, business, government, international organizations, civil society, the arts, and the media, providing leadership, guidance, and innovative thinking on, inter alia, industrial innovation, digital capabilities, and new technologies. Members are selected upon individual expression of interest by the World Economic Forum and are entitled to continue to be part of the network if they remain constantly engaged through analysis, commentary, and dialogue. They share their research on the World Economic Forum's Strategic Intelligence Platform and are encouraged to build collaborations with other members of the network. They are also invited to take part in webinars and podcasts; there is even the possibility of participating in some events and projects of the World Economic Forum as well.

The InterAcademy Partnership (IAP) is a global network of academies engaged in science, medicine, and engineering that offers support to its members to enhance academic research and collaborations, as well as to issue consensus statements on global health-related matters, such as achieving a sustainable energy future, improving African agriculture, reviewing the process of the UN's Intergovernmental Panel on Climate Change, and advancing the Sustainable Development Goals. The network ultimately provides in-depth analysis to international organisations and governments.

A network can also serve as a platform to overcome diplomatic impasses. The EU–Russia Expert Network on Foreign Policy (EUREN) brings together regularly EU and Russian academics and think tank experts in international relations, economics, and defence and security matters to discuss points of disagreement. The goal is to increase mutual understanding between the EU and Russia and eventually to influence the decision-making audience.

In the non-proliferation sector, the EU Non-proliferation and Disarmament Consortium (EUNPDC) is an European network of more than 60 independent non-proliferation think tanks. It supports the implementation of the 'EU Strategy against the Proliferation of Weapons of Mass Destruction', which is managed by the Foundation for Strategic Research (FRS), the Peace Research Institute Frankfurt (PRIF), the International Institute for Strategic Studies (IISS), SIPRI, the International Affairs Institute (IAI), and the Vienna Center for Disarmament and Non-Proliferation (VCDNP). Members of the network are invited to the Annual Conference, held in Brussels, at which they can highlight the EU's role in policies on CBRN (chemical, biological, radiological, and nuclear) risks, prevention, and mitigation, the accumulation and trafficking of small arms and light weapons, and, more generally, measures to counter the proliferation of weapons of mass destruction. The Consortium also provides expertise through publications, reports, and e-learning courses.

The EUNPDC is certainly a positive example, but its scope is much broader than verification and membership is limited to EU institutions. As underlined

earlier, developing countries continue to be under-represented at disarmament and non-proliferation meetings held within the UN framework, at a historic moment in which the active engagement of all States is fundamental to advancing multilateral negotiations and nuclear disarmament goals. In VERTIC's aforementioned project on building capacity for the multilateral verification of nuclear disarmament (in partnership with the NPS Foundation, the ISTC, and the University of Witwatersrand), it is envisaged that expert hubs in each region can link with one another. An NDV network may support further interrelations with other institutions and initiatives in other parts of the world than those mentioned in this paper, creating a truly global arrangement.

To ensure a balanced and comprehensive approach, a future NDV network of national and regional initiatives could be managed by an executive board of institutions with balanced and appropriate regional representation. It could offer timely analysis to governments and international organisations, as well as issue consensus statements on UN Resolutions related to nuclear disarmament verification, as in the case of the IAP on global health issues. It could help to enhance scientific dialogue and overcome impasses among those countries that represent divergent views in the UN, following the example of the EUREN. An annual conference of members would be the opportunity to assess the status of research on nuclear disarmament verification, address gaps, and implement new innovative strategies.

The NDV network would not just be a fundamental channel for the diffusion of information, knowledge, expertise, and innovation among experts, but also it would nurture the next generation of nuclear experts and provide enthusiasm and knowledge retention within each country. Such a network could be used to connect young scholars and professionals through internships, fellowships, scholarships, and other training opportunities, and possibly to generate its own training and education programmes. Training emerging experts in disarmament and verification issues at both the diplomatic and technical level is crucial to developing and maintaining national capacity, and eventually creating national expert pools. This aspect could be particularly valuable to countries that encounter more difficulties in identifying experts for UN-level consultations and negotiations. In addition, the network could offer modules and tailored lessons to newly appointed diplomats still developing adequate NDV expertise in Geneva, New York, and Vienna.

Conclusion

Over the past few years, a new level of attention has been devoted to nuclear disarmament verification through UN resolutions, international initiatives such as the IPNDV, Quad, UK–US activities, and national academic and research institute efforts worldwide. Phase III of the IPNDV will continue to focus on crucial verification issues such as irreversibility and transparency through scenario-based discussions, practical exercises, and technology demonstrations, encouraging enhanced collaboration with non-traditional stakeholders such as universities and NGOs. The lessons learnt from the LETTERPRESS exercise led Quad to retain two streams of work, one focused on verification strategies and the other on verification technologies, with the aim of delivering substantive results for the NPT 2025 review cycle. Valuable joint work between the US and the UK is ongoing in the areas of data authentication, fissile material detection, and sensitive information protection. In the academic world, MIT continues its work on new, monochromatic methodologies for cargo

"The NDV network would not just be a fundamental channel for the diffusion of information, knowledge, expertise, and innovation among experts, but also it would nurture the next generation of nuclear experts."

"Kofi Annan once affirmed that 'education is, quite simply, peace-building by another name'. Similarly, capacity-building and education are complementary endeavours."

screening[26] as well as technologies for treaty verification via resonant phenomena and physical cryptography, whereas Texas A&M University has active projects on fluorescence imaging for nuclear arms control verification and investigating correlated neutrons from pulsed interrogation for treaty verification applications. Lastly, VERTIC is developing and implementing innovative technical methodologies for the assessment of nuclear weapons programmes and is spearheading efforts to build NDV capacity around the world.

The next sessions of the new GGE to consider the role of verification to advance nuclear disarmament, in 2021 and 2022, including the concept of a GSTE, constitute a unique opportunity to maintain a spotlight on the importance of verification, preserve the gains made in knowledge and understanding so far, and to think creatively about how to develop the next generation of 'nuclear leaders'. The development of an NDV network of universities, governmental and non-governmental research institutes, and other initiatives may be one possible answer to the urgent need for 'new thinking to pursue disarmament and non-proliferation', recalled in the UNSG's report on disarmament and non-proliferation education highlighted at the beginning of this *Brief*.

Former UN Secretary-General Kofi Annan once affirmed that 'education is, quite simply, peace-building by another name'. Similarly, capacity-building and education are complementary endeavours. It is increasingly clear that continuous capacity-building will be essential for guaranteeing multilateral nuclear disarmament verification approaches in which all countries have confidence. Such efforts will also contribute to pinpointing and refining nuclear disarmament verification solutions and ultimately facilitating the path towards a world without nuclear weapons, a common goal of the international community.

Endnotes

1 See Article VI of the Treaty on the Non-Proliferation of nuclear weapons (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'. States Parties reached consensus on nuclear disarmament again in 1995, when they identified three measures to fulfil the disarmament provisions of Article VI. In 2000, furthermore, they agreed on 13 'practical steps for the systematic and progressive efforts' to implement Article VI, and in 2010, they adopted an 'Action Plan' that included 22 provisions to advance nuclear disarmament.

2 Article IX of the NPT: 'For the purpose of this Treaty, a nuclear-weapon State is one which has manufactured and exploded a nuclear weapon or other nuclear explosive device prior to 1 January 1967'.

3 United Nations Secretary-General, *Securing Our Common Future: An Agenda for Disarmament*, 2018, Office for Disarmament Affairs, New York.

4 For more information, see US Arms Control and Disarmament Agency, *Field Test FT-34: Demonstrated Destruction of Nuclear Weapons. Final Report – Volume* 1, January 1969 (https://fas.org/nuke/guide/usa/cloudgap/ft-34.pdf).

5 Thomas E. Shea, 'Report on the Trilateral Initiative: IAEA Verification of Weapon-Origin Material in the Russian Federation & the United States', *IAEA Bulletin*, 43/4/2001 (https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull43-4/43403054953.pdf).

For a comprehensive review of the Trilateral Initiative and other NDV initiatives mentioned in this section please see: Means to Reinforce Research on Nuclear Disarmament Verification: Report on a series of regional conversations, Verification Matters, n.13, November 2017.

6 US Department of Energy and the UK Ministry of Defence, *Joint US–UK Report on Technical Cooperation for Arms Control*, 2015 (https://media.nti.org/pdfs/Joint_US_UK_report_on_technical_cooperation_for_arms_control.PDF).

7 Three technical working groups were established for Phase I ('Monitoring and Verification Objectives', 'On-site Inspections', and 'Technical Challenges and Solutions') and Phase II ('Verification of Nuclear Weapon Declarations', 'Verification of Reductions', and 'Technologies for Verification'). These working groups took on specific projects, tasks, and collaborative activities focused on nuclear weapon dismantlement. Building on the work of the first two phases, two Task Groups ('Inspectors' and 'Hosts') and a 'Technology Track' were introduced in Phase III.

8 VERTIC, CNS, and RUSI authors, *Fuel cycle modelling as a disarmament verification tool* (https://www.ipndv.org/wp-content/uploads/2020/04/Damale.pdf).

9 Tamara Patton and Alexander Glaser, 'Deferred verification: the role of new verification technologies and approaches', *The Nonproliferation Review*, Volume 26, Issue 3–4, 2019, pp. 219–230.

10 Brooks Hays, 'MIT scientists build bomb test to ensure nuclear disarmament compliance', *Science News*, 30 September 2019 (https://www.upi.com/Science_News/2019/09/30/MIT-scientists-build-bomb-test-to-ensure-nuclear-disarmament-compliance/7061569842091/). For more details, see Jake J. Hecla and Areg Danagoulian, 'Nuclear disarmament verification through resonant phenomena', *Nature Communications*, Issue 9, Article Number 1259, 2018 (https://doi.org/10.1038/s41467-018-03680-4).

11 J.S. Feener, *Fluorescence Imaging for Nuclear Arms Control Verification*, Ph.D. Dissertation, Nuclear Engineering, Texas A&M University, College Station, TX, 2014 (https://nsspi.tamu.edu/fluorescence-imaging-for-nuclear-arms-control-verification-33402).

12 Scott Stewart, *Investigating Correlated Neutrons from Pulsed Photonuclear Interrogation for Treaty Verification Applications*, Master of Science Thesis, Texas A&M University, 2013 (https://oaktrust.library.tamu.edu/handle/1969.1/151033).

13 For more information, see the webpage of Dr Hassan Elbahtimy, a Senior Lecturer at King's College London (https://www.kcl.ac.uk/people/hassan-elbahtimy).

14 Andrzej Karkoszka, *Strategic Disarmament Verification and National Security*, Taylor & Francis, 1977 (https://www.sipri.org/about/bios/andrzej-karkoszka).

15 Tytti Erästö, Ugnė Komžaitė, and Dr Petr Topychkanov, *Operationalizing Nuclear Disarmament Verification*, SIPRI Insights on Peace and Security, Number 2019/3, April 2019 (https://www.sipri.org/publications/2019/sipri-insights-peace-and-security/operationalizing-nuclear-disarmament-verification).

16 Rudolf Avenhaus, Nicholas Kyriakopoulos, Michel Richard, and Gotthard Stein, *Verifying Treaty Compliance: Limiting Weapons of Mass Destruction and Monitoring Kyoto Protocol Provisions*, Springer, 2020 (https://link.springer.com/book/10.1007/3-540-33854-3).

17 PIR Center, *Verification of Nuclear Arms Control and Nuclear Disarmament: Experience, Prospects and New Ideas*, Security Index Occasional Papers, Number 4, April 2020 (http://www.pircenter.org/en/security-index/200-4260238).

18 'Group of Governmental Experts to consider the role of verification in advancing nuclear disarmament', submitted by Mr. Vladimir Leontiev (Russian Federation), GE-NDV/2018/13 (https://undocs.org/pdf?symbol=en/GE-NDV/2018/13).

19 The Statute of UNIDIR was approved at the 39th session of the UN General Assembly, 102nd Plenary Meeting, 17 December 1984, and came into effect on 1 January 1985. See https://unidir.org/statute.

20 Ministry for Foreign Affairs of Sweden, 'The Government's continued work for nuclear disarmament', 12 July 2019 (https://www.government.se/articles/2019/07/the-governments-continued-work-for-nuclear-disarmament/).

21 Ministry for Foreign Affairs of Sweden, **'**The Stockholm Ministerial Meeting on Nuclear Disarmament and the Non-Proliferation Treaty', 11 June 2019 (https://www.government.se/statements/2019/06/the-stockholm-ministerial-meeting-on-nuclear-disarmament-and-the-non-proliferation-treaty/).

22 Malte Göttsche, Moritz Kütt, and Götz Neuneck, *Advancing Disarmament Verification Tools: A Task for Europe?*, EU Non-proliferation Papers, Number 47, October 2015 (https://www.sipri.org/publications/2015/eu-non-proliferation-papers/advancing-disarmament-verification-tools-task-europe).

23 The Ad Hoc Group's mandate was to 'consider and report on international co-operative measures to detect and identify seismic events, so as to facilitate the monitoring of a comprehensive test ban'.

24 For more information on the role and impact of the Ad Hoc Group, see: *Means to Reinforce Research in Nuclear Disarmament Verification: Report on a Series of Regional Conversations*, Verification Matters, Issue 13, November 2017 (http://www.vertic.org/media/assets/Publications/VM13.pdf); and Ola Dahlman, Frode Ringdal, Jenifer Mackby, and Svein Mykkeltveit, 'The Inside Story of the Group of Scientific Experts and its Key Role in Developing the CTBT Verification Regime', *The Nonproliferation Review,* June 2020 (https://www.tandfonline.com/doi/full/10.1080/10736700.2020.1764717).

25 'Group of Governmental Experts to consider the role of verification in advancing nuclear disarmament', submitted by Mr. Vladimir Leontiev (Russian Federation), GE-NDV/2018/13 (https://undocs.org/pdf?symbol=en/GE-NDV/2018/13).

26 MIT Laboratory for Nuclear Security and Policy, *Multiple Monoenergetic Gamma Radiography (MMGR)* (http://lnsp.mit.edu/monochromatic-cargo-interrogation/).

Editors
Larry Macfaul

Design and layout
Rick Jones

ISSN
1740-8083

About this paper

This paper has been produced by VERTIC under the project 'Building Capacity on Multilateral Verification of Nuclear Disarmament' funded by the Norwegian Government.

Such a project supports the development and strengthening of practical and effective nuclear disarmament verification (NDV) measures for the achievement and maintenance of a world without nuclear weapons.

This paper focuses on the role of education in NDV to support knowledge transfer among generations and create a new generation of experts in the field. Investing in such an effort would respond to a new attention devoted to the role of verification in advancing nuclear disarmament at international level (i.e. the UNSG *Securing Our Common Future: an Agenda for Disarmament*, the Group of Governmental Experts (GGE) on the role of verification to advance nuclear disarmament and several UN General Assembly resolutions). The paper also considers the possibility of establishing an NDV network to support national and regional activities as well as work conducted in international fora.

The author is very thankful to Mr. Attila Burjan (IAEA), Dr. Francesca Giovannini (Harvard University) and Dr. Joseph Pilat (Los Alamos National Laboratory) who provided helpful comments to an earlier version of this Brief.

VERTIC
The Green House, 244–254
Cambridge Heath Road,
London E2 9DA,
United Kingdom

Tel +44 (0)20 3559 6146
E-mail vertic@vertic.org
Website www.vertic.org

Building trust through verification

VERTIC is an independent, not-for-profit, non-governmental organisation. Our mission is to support the development, implementation and effectiveness of international agreements and related regional and national initiatives, with particular attention to issues of monitoring, review, legislation and verification. We conduct research, analysis and provide expert advice and information to governments and other stakeholders. We also provide support for capacity building, training, legislative assistance and cooperation.