Stanton Nuclear Security Fellows Seminar

PANEL 4: Nuclear Arms Control Verification

1. Sébastien Philippe, BCSIA

Decentralized Approaches to Nuclear Disarmament Verification

- On what issue are you working and why is it important?

My project seeks to advance nuclear disarmament science and policy by developing new approaches to verification that seek to build in resilience through addressing issues of trust, secrecy, access, fairness, and participation.

Verification has played a central role in the negotiation and implementation of most nuclear non-proliferation and arms control treaties. It is expected to play an even greater role in future agreements seeking deep and multilateral reductions in the world's nuclear arsenals, in improving monitoring within existing treaty structures, and, eventually, in helping to monitor compliance in a world free of nuclear weapons.

Making progress on verification is seen as requiring both new technical analysis and capabilities, as well as new approaches, methods and institutional arrangements that go beyond the accounting and inspection mechanisms for fissile materials or nuclear weapon delivery systems used respectively in the nonproliferation and bilateral arms-control regimes. As the 2014 report of the US Defense Science Board's Task Force on Assessment of Nuclear Monitoring and Verification Technologies observed, "the technologies and processes designed for current treaty verification and inspections are inadequate to future monitoring realities" and there is a need for "a long period of building the political and technical groundwork for the next major steps."

- What is the big question that you are seeking to answer?

Nuclear arms control and non-proliferation verification has so far been organized either as state capabilities (known as national technical means) or through international organizations such as the International Atomic Energy Agency and the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, with leading nuclear weapon states playing a key role in both cases. Such arrangements may not be sufficient for any plausible future disarmament regime for three reasons.

First, in any future multilateral nuclear disarmament regime, all the participating nuclear weapon states as well as the non-weapon states, and the international community as a whole, may be expecting a direct role in determining treaty compliance. Future agreements therefore may need to include ways to build in broad support and participation in monitoring and verification activities. Second, the information necessary for international regimes to properly function has to be trusted and available to all participating actors – this is particularly problematic in regimes where trusted third parties are absent. Third,

monitoring systems relying on centralized structures can be critically impaired by the defection of even a single key state. The need to anticipate such a prospect is becoming more important in light of the United States and other countries beginning to disengage from what were seen until recently as core international agreements in areas such as trade, climate change, and nuclear non-proliferation and arms control.

To address these issues of participation, trust, and resilience, I propose to explore whether decentralized monitoring systems and processes can add to existing technologies controlled by a few states or a single international agency reliant on a few states for its technologies and other resources.

- How are you going to answer your question? What methods will you use and what evidence or cases will you explore?

To see if decentralized monitoring and verification is possible in principle, I will explore how new advances in hardware security and cryptography can enable trusted measurement systems and remote monitoring approaches applicable to nuclear weapon materials in secure locations with limited access. The goal will be to understand to what extent such tools make it possible to go beyond traditional systems of tamper-proof hardware, secure communication channels, and trusted centralized authority. I will investigate how block-chain technology and ledgers (the basis for digital crypto-currencies), can enable a robust chain of custody for such data from its creation until it is analyzed, and how such data could be publicly archived.

Along with this technical analysis, I will study the institutional requirements of a global decentralized monitoring system for nuclear disarmament verification. For this, I will engage with key intergovernmental processes in this area that will take place during the 2018-2019 period of the Fellowship. These processes include the International Partnership on Nuclear Disarmament Verification (IPNDV), launched in 2015 and sponsored by the United States Department of State, which involves 25 countries and focuses on "verification related to declarations and inventories; nuclear arms reductions; and technologies for verification." The second process involves states that have adopted the 2017 international treaty for the prohibition of nuclear weapons (TPNW), who will need to put in place a verification system to determine the "irreversible elimination of a State Party's nuclear-weapon programme," should a weapon-state join the treaty.

I plan to engage with these diplomatic processes to understand in particular how states expect monitoring and verification to deal with a) the problems of defining scope and objectives; b) how to handle sensitive information and access to military facilities; c) how to trust monitoring instruments and data in the absence of a trusted third party or central authority; and d) what roles do they see for civil society groups, local communities and local governments, for-profit and transnational organizations, and individuals in contributing to the success of nuclear verification.

- What is your answer to the question you are asking? That is, what is your argument or conclusion even if it is still tentative at this point?

The conclusion I seek to test is that decentralized monitoring systems that build in trust and broaden participation in monitoring and verification activities beyond the usual set of states and organizations are possible and will be seen as strengthening the legitimacy and resilience of disarmament and nonproliferation monitoring.

- How does your work fit into the existing work on your subject?
    - What alternative arguments or explanations exist and why is your answer superior?

Existing work in this area mostly focuses on novel technologies for gathering data (such as real time satellite imagery, using cosmic ray muons to detect nuclear materials…) and the possible use of crowd-sourcing and data mining to gather verification relevant data. These approaches do not focus on the role of trust or participation or resilience.

    - How does your work add to or change our understanding of the issue you are studying?

To my knowledge, this is the first study of a bottom-up monitoring and verification architecture for nuclear governance that goes beyond conceptual papers on "societal verification" and "public technical means." It seeks to assess the scope for new verification technologies and approaches, as well as evaluate policy options with stakeholders.

Beyond nuclear disarmament and nonproliferation, I expect some of my findings to be applicable to other regulatory regimes, including international efforts to mitigate climate change, and strategies to manage global cyber activities.

    - What do you see as your most important contribution?

Providing a proof-of-concept for trusted measurement systems and how they could be merged with distributed information sharing mechanisms to provide information required by a regulatory or prohibition regime that seeks to incorporate trust and participation and resilience as key goals.

- What policy implications flow from your work? What concrete recommendations can you offer to policymakers?

This work intends to contribute to policy making on nuclear disarmament verification by adding to the models for possible technical and institutional approaches to achieving confidence in treaty compliance. One concrete recommendation would be for policy makers to promote research and development programs and collaborations on new approaches to the technical, legal, and policy aspects of verification.

- What do you think is the weakest or most vulnerable aspect of your study and what sort of feedback would be most useful to you?

At this point, I am trying to understand how to structure my interactions with diplomats and policymakers engaged either in the IPNDV or TPNW process. Feedback on the relative value of surveys, semi-structured interviews, confidential conversations, and other ways to explore the views of diplomats would be most welcome.

2. Mareena Robinson Snowden, CEIP

Verification Sufficiency in the 21st Century

Research Objective:

A central issue in nuclear nonproliferation and arms control negotiations is verification sufficiency – how much verification is enough? In answering this question, negotiators must identify goals and make trade-offs between them. They must, for example, seek to balance the desire for high confidence with a limit on the intrusiveness of verification measures.

My research aims to (i) identify what verification goals and trade-offs have been encountered in negotiating past arms control and nonproliferation agreements and understand how states have (or have not) defined these goals and assessed these trade-offs; and (ii) develop, on the basis of this historical research, a set of guiding questions for policy makers to assist them to systematically identify key issues in determining verification sufficiency.

The existing literature and its deficiencies:

In the absence of trust or a supranational enforcement body, the primary roles of verification in a nuclear security context is to assess compliance to the terms of a nuclear agreement, build confidence between the parties, and deter noncompliance through the threat of a response. Whether in regards to a U.S.-Russian nuclear arms control treaty or IAEA safeguards, verification regimes rely on a complex system of monitoring, data exchanges, and notifications to help senior leaders make compliance judgements. More broadly, verification is a pathway for treaty participants, and the international community, to gain insight into the nuclear activities of sovereign nations.

There are a number of reasons why assessing verification sufficiency is challenging. The first, and most fundamental, reason relates to the presence or absence of key definitions. The existing literature has stressed that the objective of verification is generally to detect militarily significant violations in a timely manner.[1] While this stated aim may seem straightforward, the specificity of definitions for terms like 'militarily significant' or 'timely' has historically depended on the context.

The nature of international safeguards has resulted in definitions that are well established and precise, especially where detecting the diversion of special nuclear material (SNM) from declared activities is concerned. In particular, the objective of IAEA safeguards is the "timely detection of diversion of significant quantities of SNM from peaceful purposes … and the deterrence of such diversion by the risk

[1] See Meyer, S. (1984). Verification and Risk in Arms Control. International Security, 8(4), 111-126. doi:10.2307/2538565; Krass, A. S. (1985). Verification: How much is enough? London: Taylor & Francis; Nancy W. Gallagher (1997) The politics of verification: Why 'how much?' Is not enough, Contemporary Security Policy, 18:2, 138-170, DOI: 10.1080/13523269708404165

of early detection."[2] Terms that appear in this stated objective, like 'significant quantity' and 'timely detection', were defined quantitatively by technical experts. For example, for unirradiated plutonium, a significant quantity is 8kg and the timeliness detection goal is one month. These performance requirements serve as inputs in the construction of a verification system by, for example, determining the number of inspections done in a calendar year.

By contrast, in the nuclear arms control space, key definitions have not been nearly so clear, even though negotiators have been guided by concepts of military significance and timely detection – a point that has not been adequately understood in the existing literature.[3] Congressional testimony during the Intermediate Nuclear Force Treaty (INF) ratification hearings, for example, reveal a range of interpretations from policy makers and military leaders. In particular, definitions of militarily significant spanned specific numbers of treaty limited items, as was the case when as few as 50 missiles was offered as a threshold for violation, to more abstract subjective definitions that are based on how potential violations affect the military balance.[4]

One commonality between international safeguards and nuclear arms control verification with respect to definitions is their lack of specificity on what constitutes an intrusive verification design. Empirically, it is known that concerns about intrusion have consistently been sticking points in nuclear negotiations, but little has been presented in the academic literature or public commentary by decision makers that clarifies the specific considerations. One likely reason for the lack of clarity is the difficulty with which intrusiveness can be related back to quantifiable factors.

A key reason why definitions are hard to come by and trade-offs are hard to make is because, at the root, definitions deal with risk, specifically as it relates to the risk of undetected noncompliance or of sensitive information being revealed by intrusive verification arrangements. Risk is defined as the likelihood of an event multiplied by its consequence. Intuitively, one would expect assessments of the probability of violation to influence the construction of a verification regime, however, assessing this probability is extremely difficult. A review of the literature shows no discussion of how decision makers have traditionally approached assessing these probabilities in the context of the verification objectives they sought to achieve. My research aims to investigate the historical record to understand the process, or lack thereof, of determining violation probabilities and their intersection with verification performance requirements.

Research Design & Contributions:

Limiting this study to on-site inspections (OSI), as it is one of the most contentious tools and provides a more focused surrogate for verification, this research will be divided into two portions. The first will

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[2] INTERNATIONAL ATOMIC ENERGY AGENCY. (1972). The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153, IAEA, Vienna. 9.

[3] Passing reference to the ambiguity of definitions in Krass, Verification: How much is enough?, 201-206.
[4] U.S. Congress, Senate, Committee on Foreign Relations, The INF Treaty, Part I, 100th Cong., 2nd sess., 1988, 464-465 Also see pg 470-471 for bullet point list of factors.

evaluate how decision makers have traditionally defined the goals and trade-offs associated with OSI, in both the nuclear arms control and international safeguards contexts. Starting with the assumption that negotiations are a highly complex set of interactions at the international and domestic level[5], this analysis will draw on the experience of practitioners during negotiations like SALT and INF, as expressed in congressional testimony; government reports; and contemporary news and journal articles. A matrix of quantitative and qualitative considerations will be developed that include discussion on confidence. Through the use of interviews with experts in arms control and international safeguards, intrusiveness will be explored as a concept and distinct working definitions will be developed. Attention will be payed to how practitioners dealt with missing or ambiguous information around the probability of a violation, and how heuristics like availability and worst-case scenario planning at the higher decision making levels manifested in the performance requirements for the desired verification regime.

Targeted toward nuclear arms control and nonproliferation policy practitioners with substantive interest in verification adequacy, the second portion of this research will offer a set of guiding questions that allows for the systematic and comprehensive consideration of key sufficiency factors. Insights from this line of inquiry will be applied to at least two contemporary case studies that capture possible future negotiations. Possible case studies include the OSI needs for the verifiable roll back of North Korea's nuclear program or further reduction of deployed strategic nuclear weapons from New START levels to 1000 total warheads.

Where Feedback would be Useful:

At this early stage in the research, I have been able to find clear evidence to support the lack of definition of key terms in the arms control space. It is less clear that I will be able to access information that helps give insight into the process, or lack thereof, decision makers used for estimating the probability of violation. Suggestions on possible sources or experts to interview on this topic would be helpful. Additionally, suggestions on possible backward and forward looking case studies in international safeguards, where OSI was a substantial focus, would be helpful.

[5] Gallagher, The politics of verification: Why 'how much?' Is not enough, 148-154.

3. Cameron Tracy, BCSIA

Comparative Analysis of US Chemical Weapon and Weapons Plutonium Stockpile Reductions

1. Background

In recent decades the United States and the Russian Federation have made great progress in bilateral nuclear arms control, removing thousands of weapons and delivery vehicles from deployment. While this cooperation has surely reduced the risk of nuclear conflict, its effect on global nuclear armament remains modest. Arms limitations and weapon dismantlement do nothing to diminish the size of a state's stockpile of weapons-grade plutonium, the synthesis of which is typically the limiting factor in weapon production. The excessive size of these stockpiles aggravates global nuclear risk, potentially facilitating rapid nuclear rearmament or proliferation by means of theft.

Cognizant of these risks, in 2000 the United States and Russia signed the Plutonium Management and Disposition Agreement (PMDA), obliging each to eliminate 34 tonnes of weapons plutonium via conversion to nuclear reactor fuel. However, initial enthusiasm for this first-of-its-kind stockpile reduction scheme proved short-lived. The United States, faced with rapidly rising cost projections and decadal delays in the construction of conversion facilities, declared in 2016 its intent to instead bury the plutonium in a geologic repository. This contravened the terms of the PMDA and prompted Russia to withdraw, citing the potential for excavation of the plutonium and reincorporation into the US nuclear arsenal. Thus, an agreement once referred to by Congress as "one of the most important nonproliferation initiatives undertaken by the United States and Russia" unraveled.[6]

In parallel, a collection of non-nuclear-armed states, dissatisfied with the pace of disarmament, formulated and negotiated what would become the 2017 Treaty on the Prohibition of Nuclear Weapons (TPNW). Modelled on the success of the 1993 Chemical Weapons Convention (CWC), this treaty includes a blanket prohibition on the weapons plutonium stockpiling that the PMDA was meant to incrementally address. Yet, considering the failure of the United States and Russia to achieve even modest stockpile reductions, prospects for the deep cuts sought by TPNW signatories appear bleak. Even if nuclear-armed states were amenable to calls for accelerated disarmament, they would likely find it difficult to do so in a manner that preserved the strategic balance.

2. Approach and methods

In light of these developments, there is a clear need to better understand the obstacles to weapons plutonium elimination and, more broadly, the challenges of weapon stockpile reduction. Comparative study of prior, more successful endeavors offers one means of doing so. While history is replete with examples of stockpile reduction, from the slaughter of Carthage's war elephants under a 201 BC peace treaty with Rome to the destruction of military vehicles under the 1990 Treaty on

[6] House Rept. 107-258 - *Making appropriations for energy and water development for the fiscal year ending September 30, 2002, and for other purposes*, October 30, 2001, p. 131.

Conventional Armed Forces in Europe, these predecessors lack the technical complexity associated with weapons plutonium elimination.

In contrast, the destruction of US chemical weapon inventories under the CWC largely parallels the weapons plutonium elimination endeavor. Both targeted Cold War legacy stockpiles. Both were mandated by international agreements, and entailed technically complex processes recommended by the US National Academy of Sciences. Both were plagued by frequent delays and near-identical cost growth, from initial predictions of a few billion dollars to eventual projections on the order of $30 billion. Finally, both efforts saw midcourse transitions in the technical means of material elimination, complicating implementation. Still, the success of chemical disarmament, with more than 90% of the US stockpile destroyed, suggests key differences in the two programs that prompted their divergent outcomes.

The goal of this project is the identification of dissimilarities in chemical weapon and weapons plutonium stockpile reduction efforts that might elucidate the causes of their success and failure, respectively. Why did financial obstacles topple the plutonium elimination effort, while similar challenges were overcome in the case of chemical disarmament? Drawing on lessons learned from the latter case, how might nuclear-armed states better manage their nuclear stockpiles, either to achieve their own arms control goals or to mollify the NWBT signatories?

Stockpile reduction is a multifaceted act, influenced by a wide spectrum of conditions ranging from the physical characteristics of stockpile materials to the intricacies of the international legal frameworks mandating their elimination. To address these various factors, both reduction efforts will be examined through three analytical lenses: the technical bases of stockpile reduction, the organizational management of the reduction process, and the political/strategic contexts in which reductions took place. First, the consequences of differences in the means by which chemical munitions and weapons plutonium can be destroyed, disposed of, or otherwise eliminated will be assessed. Second, organization theory will be applied in analysis of the role institutional characteristics of the Department of Defense (DOD) and the Department of Energy (DOE), the entities managing reductions, played in the outcomes of these two programs. Finally, concepts from science and technology studies (STS) will be used to investigate the influence of the social arrangements surrounding these weapon components, as tools of domestic politics and of warfighting, on the will and ability of their possessors to dispense with them.

3. Tentative results and policy implications

3.1 Technical basis

On the technical aspect of stockpile reduction, I will focus on the development of a framework for determination of irreversibility, and will subsequently relate this quantity to both the efficacy of an elimination method and the international confidence it engenders as a tool of disarmament. The core of this argument will be a delineation of elimination methods into means of destruction, wherein a weapon or weapon material is decisively and intrinsically changed into something less weaponizable, and disposal, wherein the weapon or material is unchanged, but extrinsic barriers to its recovery and use are erected. While the former approach is typically difficult to revert, the efficacy of the latter involves a

tension between the cost of recovery and the use-value of a weapon. The pivot from fuel conversion of weapons plutonium to its burial represented a switch from destruction to disposal, which aggravated Russian concerns regarding elimination permanence. The post-CWC elimination of chemical weapons took place exclusively by means of destruction, a fact that, it will be argued, contributed to the success of this endeavor relative to plutonium elimination. This analysis will conclude with the recommendation that irreversibility, rather than cost alone, should factor into decisions by the DOE about the means of plutonium elimination.

3.2 Organizational biases

Drawing from work on the path-dependent nature of organizational decision-making, this section will argue that the DOE's extensive prior experience with the burial of civilian nuclear wastes drove them to adopt burial as a means of weapons plutonium elimination, despite its glaring deficiencies.[7] In contrast, the lack of prior experience in the DOD with chemical munition elimination, as well as its distinct congressional funding situation and managerial structure, precluded similar deleterious effects of institutional path-dependence on the chemical disarmament mission. This assessment will lead to the recommendation that a new organization with a narrow purview of weapons plutonium management, rather than the DOE, should manage the implementation of US PMDA obligations.

3.3. Political context

In this section, I will draw primarily from STS work on the inter-sustaining relationship between technical systems and their corresponding social, political, and strategic arrangements.[8] In particular, this analysis will focus on the development and deployment of both chemical and nuclear weapons as tools of deterrence. Following their widespread use in the First World War, chemical weapons were stockpiled by all major belligerents of the Second World War so as to enable them to respond in kind against a chemical attack. However, their use was minimal, evincing a breakdown of their strategic context as deterrents. As this contextual dissolution progressed, a concomitant increase in the perceived desirability of chemical disarmament emerged among the public, policymakers, and war planners. This situation contrasts starkly with the role that nuclear weapons, and thus the weapons plutonium stockpile, play as a central pillar of US defense posture, primarily as a function of their deterrent effects. In terms of policy, this section will yield an assessment of the particular political and strategic conditions that might be necessary for substantial reduction of weapons plutonium stockpiles, a topic of clear interest to observers of the TPNW.

4. Relation to prior work

In drawing from a diverse collection of theoretical frameworks, much of this work will entail an extension of previous literature to an uncommonly analyzed facet of arms control and disarmament, rather than a reassessment or a refutation. Because prior scholarly work on the concept of irreversibility in nuclear arms control is scant, this section of the project will build primarily on recent work by the

[7] On path-dependence see James G. March, Herbert A. Simon, *Organizations*, 2nd ed (Cambridge: Blackwell, 1993)
[8] See Langdon Winner, "Do Artifacts Have Politics?" *Daedalus* vol. 109, 1980

Verification Research, Training, and Information Centre, which constitutes one of the only comprehensive analyses of this topic.[9] That said, on the specific subject of the feasibility of recovery of buried plutonium, I will argue that the small body of work addressing this concept to date underestimates the risk of recovery.[10] While these analyses consider only high-profile, easily-observed open pit and tunnel mining, low-profile leaching methods are, in fact, more typical means of actinide resource extraction. In applying organization theory to the reduction of nuclear weapon stockpiles, I will build on the work of Allison and Eden, who previously applied it to nuclear war planning.[11] Finally, my interrogation of the political context of stockpile reduction will extend work from the fields of STS and critical security studies, namely the thinking of Jones on ideological hindrances to global nuclear disarmament, recontextualizing this prior scholarship in terms of the more narrow plutonium elimination endeavor.[12]

Perhaps the weakest aspect of this work stems from my unfamiliarity with the organization theory, STS, and critical security studies literatures, relative to the technical literature. Thus, feedback regarding any potential misinterpretation or misapplication of these frameworks, or aspects which I am overlooking, would be particularly welcome. Additionally, I do not currently plan to incorporate issues of horizontal proliferation into my analysis of the role of reversibility in stockpile reductions, instead focusing solely on the potential for recovery by the possessor state. Advice regarding the appropriateness of this narrow focus would be appreciated.

[9] David Cliff, Hassan Elbahtimy, Andreas Persbo, *Irreversibility in Nuclear Disarmament: Practical Steps Against Nuclear Rearmament*, VERTIC

[10] Gordan Linsley, Abdul Farrah, "The interface between nuclear safeguards and radioactive waste disposal: Emerging issues," *IAEA Bulletin* vol. 2, 1994; Edwin S. Lyman, Harold A. Feiveson, "The proliferation risks of plutonium mines," *Sci. Global Sec.* vol. 7, 1998; Per F. Peterson, "Issues for detecting undeclared post-closure excavation at geologic repositories," *Sci. Global. Sec.* vol. 8, 1999; Risa Mongiello, Robert Finch, George Baldwin, *Safeguards Approaches for Geological Repositories: Status and Gap Analysis*, NNSA, 2013

[11] Graham Allison, Philip Zelikow, *Essence of Decision: Explaining the Cuban Missile Crisis*, 2nd ed, (New York: Addison-Wesley, 1999); Lynn Eden, *Whole World on Fire: Organizations, Knowledge, & Nuclear Weapons Devastation* (Ithaca: Cornell University Press, 2004)

[12] Richard Wyn Jones, *Security, Strategy, and Critical Theory* (Boulder: Lynne Rienner, 1999)