IRREVERSIBLE NUCLEAR DISARMAMENT

University of York

Irreversibility and Nuclear Disarmament: Unmaking Nuclear Weapon Complexes

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Cover photo: Aerial photograph of the U.S. Department of Energy Pantex Plant, Texas, where nuclear warheads are assembled and disassembled site.

Introduction

The idea of 'irreversibility' has long been a feature of nuclear disarmament discourse. It formally entered into NPT diplomacy in the final document of the 2000 Review Conference that set out 13 "practical steps for the systematic and progressive efforts to implement article VI of the Treaty" on disarmament obligations. The fifth of these steps was "The principle of irreversibility to apply to nuclear disarmament, nuclear and other related arms control and reduction measures". More recently, the 2017 Treaty on the Prohibition of Nuclear Weapons (TPNW) requires nuclear-armed states that join the treaty to "verify the irreversible elimination of their nuclear-weapons programme, including the elimination or irreversible conversion of all nuclear weapons-related facilities".

The purpose of this report is to examine what 'irreversibility' might mean in practice in a world in which nuclear-armed states have started a process of nuclear disarmament. The starting assumptions are therefore that:

- The changes necessary to convince nuclear-armed states to relinquish their nuclear arsenals have happened.
- This has occurred in *something like* the current inter-state system.[1]
- It has been a voluntary rather than forced or coerced process for the nuclear-armed major powers, such as the US, Russia and China.[2]
- It has been entered into in good faith.[3]

This analysis is therefore necessarily speculative, but informed speculation serves an important purpose, because thinking through processes to maximise the irreversibility of nuclear disarmament will shape shared understandings of the very possibility of nuclear disarmament in the first place. In doing so, the analysis pushes back against an often-assumed irreversibility of *nuclearisation*, what Benoit Pelopidas calls 'nuclear eternity'.[4]

First, it is necessary to clarify how disarmament and irreversibility are understood. Disarmament is understood here as a dynamic condition that has to be sustained over time, like being healthy, rather than a fixed destination to be arrived at when the last

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[1] I.e., one in which the world system has not undergone a revolutionary change, or humanity hasn't already been crippled by a different existential threat. For a discussion of this assumption and the 'survivability bias' in nuclear studies, see Pelopidas B. (2021). The Birth of Nuclear Eternity. In Kemp S. and Anderson J. (Eds.) *Futures* (Oxford University Press: Oxford).

[2] States like these will *not* be subjected to the type of coercive disarmament experienced by Iraq in the 1990s and 2000s because the power relationships between them as well as their place in global structures of power are so different and look set to remain so.

[3] The challenge here is that nuclear-armed states have, so far, *not* pursued nuclear disarmament in 'good faith'. See Egeland K. (2021). Nuclear Weapons and Adversarial Politics: Bursting the Abolitionist "Consensus". *Journal for Peace and Nuclear Disarmament*, 4: 1, pp. 107-115.

[4] Pelopidas B. (2021). The Birth of Nuclear Eternity.

nuclear weapons are dismantled. Nuclear disarmament will be a process of moving towards an increasingly 'denuclearised' world in which the cost and difficulty of reversing a disarmament process increases and the legitimacy and perceived necessity of doing so decreases. The referent of disarmament and irreversibility is therefore the 'nuclear weapons complex', rather than just warheads or weapon-usable fissile material.

Irreversibility must therefore be understood as a spectrum on which a state could more or less easily reverse a disarmament process. Moreover, irreversibility is about capability and intent: the capability to reverse a set of decisions to relinquish nuclear weapons, and a political intention to do so. Much of the limited work on irreversibility in relation to nuclear disarmament has focussed on the nexus of capability and intent through the lens of verification. Here, a verification regime determines those materials and practices that must be terminated or modified to meet a disarmament commitment, thereby inhibiting a state's capability to reverse the process. A verification regime is understood to diminish intent by deterring behaviour that would transgress a disarmament commitment through risk of detection.

However, irreversibility in terms of capability and intent can be understood and realised through other processes that are often overlooked, and this report unpacks these in three parts. Part one focuses on capabilities and 'irreversibility as structural disarmament' through the discontinuation of a nuclear weapons complex as a 'socio-technical system'. Structural disarmament refers to a process whereby the capacity of a state to reverse a disarmament process has eroded to the extent that the time and cost of doing so becomes politically prohibitive. Part two looks in detail at the US experience after the Cold War to illustrate these processes. Part three centres on intent and examines 'irreversibility as social change'. This is about changes in the meaning of nuclear weapons within a socio-historical context in relation to security, power and the state and how this affects an intention to reverse a disarmament process, irrespective of the capability to do so.

Understanding nuclear disarmament as a condition that can be more or less reversible means that there is no process through which irreversibility can be guaranteed. Any state that is determined to re-develop nuclear weapons as a national priority irrespective of time and cost will probably be able to do so. When we talk about irreversibility in nuclear disarmament, we are therefore talking about *maximising the extent to which* a disarmament process is irreversible based on changes in capability and intent, all of which could, in theory, be reversed given sufficient time and political will. In this sense, 'irreversible' is an example of what Kant called a 'regulative ideal':

something that is not practically realisable, but sets a direction and standards for a practice that can be approached though not attained.[5]

Irreversibility through 'structural disarmament'

The concept of structural disarmament was initially developed in the 1980s to capture the effects of defence inflation caused by the complexities of new generations of weaponry that locked defence procurement into an inflationary spiral and generated pressures to cut costs by unilaterally reducing weapon system numbers.[6][7] Neil Cooper called it "disarmament by default, as opposed to disarmament by diplomacy".[8] Others have defined structural disarmament more broadly. In their study of defence industrial change in South Africa, Batchelor and Willett describe a period of structural disarmament from 1989 to 1994. They acknowledge the original definition of structural disarmament in terms of defence economics, but then expand the concept to include the ways in which a disarmament process can become structurally embedded through significant changes in defence budgets, weapons procurement, organisations, defence sector employment, and defence industrial diversification.[9] This report uses this much broader conception of structural disarmament to describe the structural embedding of nuclear disarmament and, with that embeddedness, the challenges of reversal.

Actor-networks and 'large technical systems'

Useful frameworks for thinking about structural disarmament have been developed in the Science and Technology Studies (STS) scholarship on 'Large Technical Systems' (LTS) and Actor-Network Theory (ANT). The starting point is: 1) to understand a nuclear weapons complex as a socio-technical system; and 2) to then understand the

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[5] See Elmet D. (1994). The Role of the Unrealisable: A Study in Regulative Ideals (Macmillan Press: Basingstoke). Thanks to Benoit Pelopidas for this insight.

[6] This term was coined by Thomas A. Callaghan Jr. See Callaghan T. (1987). Structural Disarmament: A Vengeful Phenomenon. *Journal of Defense & Diplomacy*, 5: 9, pp. 28-31; Callaghan T. (1984). The Structural Disarmament of NATO. *NATO Review*, June, pp. 21-6. For a contemporary example, see e.g. Ho Lee S. (2013). South Korea's F-X Project and Structural Disarmament. *The Diplomat*. July 19. https://thediplomat.com/2013/07/south-koreas-f-x-project-and-structural-disarmament/

[7] See Matthews R. & Al-Saadi R. (2021). Organisational Complexity of the Eurofighter Typhoon Collaborative Supply Chain. *Defence and Peace Economics*, 34: 2, pp. 228-243. This remains a source of concern in the EU. See Welle K. (2013). Preparing for Complexity: The European Parliament in 2025 - The Answers. The European Parliament, Brussels, pp. 66, 83. https://www.parlament.cat/document/intrade/320330.

[8] Cooper N. (2006). Putting disarmament back in the frame. *Review of International Studies* 32: 2, p. 357.

[9] They describe the original conception of structural disarmament as "as a form of disarmament which occurs in the absence of a political decision to disarm, resulting from the tendency for inflation in the defence sector to be higher than inflation in the rest of the economy and the tendencies of systems to become more expensive". Bachelor P. & Willet S. (1998) *Disarmament and Defence Industrial Adjustment in South Africa* (Oxford: Oxford University Press for SIPRI), p. 8.

structural embedding of nuclear disarmament as the 'unmaking' of this socio-technical system.[10]

The core argument is that we can only understand technologies like nuclear weapons in their social context. Technology and society 'constitute' each other, i.e., they shape and define each other. The development of technologies and what they are understood to mean are dependent on social context, and at the same time social context is shaped by technologies and what they are understood to mean. This includes 'social imaginaries' of technology and society such as the idea that irreversible nuclear disarmament is or isn't possible and necessary based on interpretations of the past, imaginings of the future, and understandings about nuclear weapons that have become embedded as 'social facts'.[11] The idea that technology is somehow autonomous and independent of the social world is therefore rejected.[12] Scholarship on 'large technical systems' investigates the emergence and consolidation of large infrastructure and production systems in their social contexts and draws on actor-network theory.[13] Actor-networks comprise a network of relationships or associations between a diverse set of actors. This encompasses people, institutions, organisations, regulations, material objects, knowledge, practices, ideas, and so on. Actor-networks have been studied in order to understand how a variety of social and technical elements are shaped and assimilated together into a network, or socio-technical system, rather than taking the existence of the system for granted or assuming the processes and histories that produced it are obvious.[14] The social and technical aspects of these systems are *always* "intertwined and constitute each other".[15]

Studies of LTS tend to start with 'system builders': those actors that unify and discipline diverse allies and orchestrate scientific, technological, political, economic and legislative processes to enable successful production of the system's technology.[16] Successful technological systems are not politically or technologically

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[10] See Mackenzie D. (1999). Theories of Technology and the Abolition of Nuclear Weapons. In Coutard O. (Ed.) *The Governance of Large Technical Systems* (Routledge: London), pp. 173-198 for an overview.
[11] See Pelopidas B. (2020). Power, Luck and Scholarly Responsibility at the End of the World(s). *International Theory* 12: 3, p. 466.
[12] Cressman D. (2009). A Brief Overview of Actor-Network Theory- Punctualization, Heterogeneous Engineering & Translation. Working paper. p. 9.
[13] Hughes T. (1983). *Networks of Power: Electrification n Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press).
[14] Law J. (1989). Technology and Heterogeneous Engineering: The Case of Portuguese Expansion. In Pinch T., Bijker W., and Hughes T. (Eds.). *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge: MIT Press), p. 113.
[15] Geels F. (2005). *Technological Transitions and System Innovations: A Co-Evolutionary and Socio-Technical Analysis* (Edward Elgar, Cheltenham, p. viii.
[16] Spinardi G. (1994). *From Polaris to Trident: The Development of US Fleet Ballistic Missile Technology* (Cambridge: Cambridge University Press).

inevitable, but contingent upon recruiting and sustaining a diverse set of allies in a large coalition whose interests have been successfully aligned with, or provide essential support for, the system's core technological output, for example safe, secure, deployed, and deliverable nuclear weapons.

Starting with system builders is helpful, because it enables us to see that being a nuclear-armed state means sustaining a national nuclear weapons complex over time because it won't endure by itself: decisions must be made, programmes must be funded, scientific and industrial sites must be modernised, organisations must work, manuals must be written, expertise must be sustained, new recruits must be trained, technologies must be developed, weapons must be refurbished, missiles and warheads must be tested, politicians must be enrolled, and so on. It takes organisational effort, knowledge, money, and political will to bring a nuclear weapons complex together and sustain it. If these dilute over time, then nuclear weapons complexes as socio-technical systems will start to come apart and become more and more difficult to put back together.

Steven Flank examined the assembling and then disassembling of the South African nuclear weapons actor-network. He shows that "a country's development of nuclear weapons *is* the evolution of a large technological system" that can be made and unmade.[17] From this perspective, structurally embedding a nuclear disarmament process and therefore maximising its irreversibility means disassembling or unmaking the actor-network or socio-technical system that produces nuclear weapons.[18]

Dismantling a socio-technical system

LTS studies have explored the phases LTS can go through, including stagnation and decline, but the *deliberate* dismantling of a LTS has not really been studied. As Koretsky and van Lente note in their study of 'Technology phase-out as unravelling of socio-technical configurations' in 2020: "Deliberate technology phase-out is being recognised as a viable policy option to weaken incumbent socio-technical configurations. At the same time, phase-out as a phenomenon has not been the focus of much attention in innovation studies and science and technology studies, where interest in emergence of technologies dominates."[19] Stegmaier et al. also note that "we

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p. 16; Hughes T. (1989). The Evolution of Large Technological Systems", in Pinch T., Bijker W., and Hughes T., (Eds). *The Social Construction of Technological Systems* (MIT Press: Cambridge, MA, 1989), p. 52.

[17] Flank S. (1993). Exploding the Black Box: The Historical Sociology of Nuclear Proliferation. *Security Studies* 3: 2, p. 259 (emphasis in original).

[18] Ritchie N. (2010). Relinquishing nuclear weapons: identities, networks and the British bomb. In*ternational Affairs* 86: 2, pp. 465-387; Flank (1993). Exploding the Black Box. p. 260.

[19] Koretsky Z. & van Lente H. (2020). Technology phase-out as unravelling of socio-technical configurations: Cloud seeding case. *Environmental Innovation and Societal Transitions* 37, p. 302. One of

know little about how socio-technical systems cease to exist and what it means to discontinue incumbent socio-technical systems actively"[20] and that "there is no literature to look in-depth at what happens in terms of active, purposeful destabilization".[21]

These scholars define the phase-out of a technology and the discontinuation of a socio-technical system in a variety of ways. Koretsky and van Lente define it as "a process of scaling down production, use and/or research and development of particular equipment, processes and associated practices to the point of their abandonment in wider society through a process of unravelling of the socio-technical configuration that makes up a technology".[22] Turnheim defines it as "deliberate (governance) interventions seeking the partial or total discontinuation of a socio-technical form that is deemed undesirable".[23] Stegmeier describes the discontinuation of a LTS as a broad process that affects "technology as well as the science, politics, economy, everyday practice, or law that supports it. It affects knowledge and ignorance, forgetting and preserving, strategies and routines, individual and collective action".[24]

Phase-out and discontinuation can also be more or less complete, deliberate or organic, as a result of technology substitution or obsolescence, or through policy termination through phase-out or outright ban, or a gradual decline ('decrementalism').[25] The scholarship on the destabilisation and discontinuation of socio-technical systems has mainly looked at energy-related LTS in relation to decarbonising economies and mitigating global heating.[26] Martin David, for example, uses the term 'exnovation' as the opposite of innovation to describe the process whereby "a given technology is currently no longer used because its physical

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the originators of LTS theory, Thomas Hughes, set out phases of (a) invention, (b) development, (c) innovation, (d) growth, competition and consolidation, and (e) momentum, but he does not discuss decline or termination. Hughes T. (1989). The Evolution of Large Technological Systems.

[20] Stegmaier P., Kuhlmann S. & Visser. V (2014). The discontinuation of socio-technical systems as a governance problem. In Borrás S. & Edler J. (Eds.) *The Governance of Socio-Technical Systems* (Elgar: Cheltenham), p. 111

[21] Ibid., p. 114.

[22] Koretsky & van Lente (2020). Technology phase-out, p. 302.

[23] Turnheim B. (2023). Destabilisation, Decline and Phase-out in Transitions Research. In Koretsky Z., Stegmaier P., Turnheim B. & van Lente H. (Eds.) *Technologies in Decline: Socio-Technical Approaches to Discontinuation and Destabilisation* (Routledge: London), p. 45.

[24] Ibid., p. 79.

[25] Ibid., pp. 86, 89; David M. (2017) Moving beyond the heuristic of creative destruction: Targeting exnovation with policy mixes for energy transitions. *Energy Research and Social Science* 33, p. 138.

[26] For example, there have been detailed studies on the phase out of incandescent light bulbs in the EU, the ban of DDT pesticides through the Stockholm Convention, and the phase-out of nuclear power generation in Germany, and agreements by some states to phase out coal and nuclear power and decisions to phase out internal combustion engines in cars.

infrastructure has been deliberately removed".[27] He uses the example of the removal of technologies supporting fossil-based energy producing systems because "such technologies are societally framed as obsolete and undesirable".[28]

These scholars note that technology phase-out as a *deliberate* process is *increasing* in response to shared challenges facing modern industrialised societies, but that these processes need more research.[29] So the *problématique* of the deliberate unmaking of a nuclear weapons socio-technical system is not just novel in political terms, but also in terms of the scholarship that has developed the frameworks to help us understand such a process.

Governance of termination

This scholarship has also more recently developed the idea of the 'governance of termination' insofar as the termination, dismantling or discontinuation of complex socio-technological systems is a governance problem.[30] What scholars like Stegmaier et al. mean by this, is that new governance efforts are necessary to *unmake* the governance structures and processes underpinning the system to be discontinued and dismantled. This refers to "the governance and policies that accompany the ending and the aftercare of what cannot be fully dismantled (like nuclear waste)".[31] They contend that "The governance of the discontinuation of socio-technical systems appears on the political agenda whenever an actor or group of actors (a government, parliament, company or industry association, or group countries) make a sharp reversal of direction and actively disengage from on-going policy or governance commitment".[32] The focus of this work is on "ending phenomena: the processes and acts of destabilisation, deinstitutionalisation, deconstruction, dismantling, termination and related strategies and structures in socio-technological contexts".[33] Martin David looks at how this can be done by 'discontinuation entrepreneurs' promoting policy initiatives and change that can involve considerable effort "to invent and operate a governance of discontinuation".[34]

Parallels with the structural embedding of nuclear disarmament are clear, and from this perspective we can see that irreversibility is about two processes: "the

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[27] David M. (2017) Moving beyond the heuristic of creative destruction, p. 139.
[28] Ibid., p. 138
[29] Stegmeier P. (2023). Conceptual Aspects of Discontinuation Governance: An Exploration. In Koretsky Z., Stegmaier P., Turnheim B. & van Lente H. (Eds.) *Technologies in Decline: Socio-Technical Approaches to Discontinuation and Destabilisation* (Routledge: London), p. 103.
[30] Stegmaier P. et al (2014). The discontinuation of socio-technical systems as a governance problem, p. 115.
[31] Ibid., p. 115.
[32] Ibid., p. 112.
[33] Ibid., p. 116.
[34] Ibid., pp. 87, 88.

discontinuing of a governance (of a socio-technical system) *and* the governance of the discontinuing (of a socio-technical system)".[35] Doing so requires the mobilisation of existing governance instruments *and* the invention of new ones, insofar as "discontinuation is not mere retreat and downsizing, it is the construction of new forms of governance to support the discontinuation of existing orders".[36]

Turnheim examines three forms 'destabilisation governance': Reactive governance processes designed to mitigate the negative outcomes of destabilisation and decline (for example, financial assistance to affected constituencies); active governance processes that are more forward-looking interventions to trigger phase-out and respond to anticipated future transformations (for example, skills training to reskill an affected workforce); and emancipatory governance processes intended to transform social relations through the destabilisation and discontinuation of a socio-technical system (for example, by reducing inequality).[37]

In a similar way, Martin David argues that exnovation enables and drives innovation, and we can see this currently in terms of innovation in nuclear disarmament verification work in anticipation of the exnovation of nuclear weapons.[38] The anti-testing regime, for example, has required the invention of a network of technologies (for example for nuclear warhead stewardship programmes and the International Monitoring System), institutions (the Comprehensive Test Ban Treaty Organisation), norms, laws, and practices to normalise and operationalise the end of nuclear testing.[39]

An important part of the governance of termination will be processes of 'defence conversion': repurposing materials, sites, companies, bureaucracies, armed forces and expertise from nuclear weapons purposes to non-nuclear and non-military purposes. As noted above, conversion is anticipated in the TPNW's requirement that nuclear-armed states to verify "the elimination or irreversible conversion of all nuclear weapons-related facilities." There have been numerous studies of conversion in relation to both nuclear disarmament and the consolidation of sprawling Cold War nuclear weapons complexes often based on the economics of change and adjustment for the defence industry.[40] Many nuclear weapons sites, especially national

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[35] Ibid., p. 116 (emphasis added).
[36] Stegmeier P. (2023). Conceptual Aspects of Discontinuation Governance, p. 88
[37] Turnheim B. (2023). Destabilisation, Decline and Phase-out in Transitions Research, p. 45.
[38] David M. (2017) Moving beyond the heuristic of creative destruction, p. 140
[39] Rosert E., Becker-Jakob U., Giorgio F., & Schaper A. (2013). Arms Control Norms and Technology. In Muller H. & Wunderlich C. (Eds) *Norm Dynamics in Multilateral Arms Control* (Athens, GA: University of Georgia Press), pp. 122-7.
[40] In the UK, see Schofield S. (2007) Oceans of Work: Arms Conversion Revisited (BASIC: London); Scottish Trades Union Council and Scottish CND (2015). Trident and Jobs: The Case for a Scottish Defence Diversification Agency. https://stuc.org.uk/files/Congress%202015/DefenceDiversificationReport2014%20v2.pdf. See also

laboratories, will remain prized national assets for scientific research, including research related to nuclear disarmament processes.[41] Converting nuclear weapons sites and the like to non-nuclear weapon roles in ways that maximise the irreversibility of conversion processes will be crucial.

The notion of 'invention' is important here, and elsewhere I have defined 'inventing nuclear disarmament' as "the iterative and cumulative process of developing ideas and translating them into enduring practices, technologies, institutions, laws, and norms. This is an intrinsically pluralistic process encompassing overlapping transnational networks of state agencies, inter-governmental organisations, and civil society actors", and this gets close to the idea of the governance of termination.[42]

Hartley K. (1997). The Economics of Disarmament and Conversion. In Dundervil R., Gerity P., Hyder A. and Luessen L. (Eds.) *Defense Conversion Strategies* (Kluwer Academic Publishers: Amsterdam), pp. 83-98.

[41] For a discussion of US nuclear weapons laboratories, see Reppy J. (2010). U.S. Nuclear Laboratories in a Nuclear-Aero World. *Bulletin of the Atomic Scientists* 66: 4, pp. 42-57.

[42] Ritchie N. (2018). Inventing Nuclear Disarmament. *Critical Studies on Security* 7:1, pp. 73-77.

Cooperative Threat Reduction as discontinuation governance

The Cooperative Threat Reduction (CTR) programme established by the US Congress in 1991 through the leadership of Senators Richard Lugar and Sam Nunn is a good example of discontinuation governance. The purpose of the programme was to support the destruction of nuclear, chemical, and biological weapons and materials in the former Soviet Union, establish safe, secure and verifiable means of transport and storage for weapons and materials, and prevent the diversion of scientific expertise that could contribute to WMD programmes in other states. The programme was prompted by the disintegration of the Soviet Union, fears that the Soviet Union was a nuclear superpower "coming apart at the seams", and a strong sense that an emergency response from the US was needed to safeguard these weapons and materials.

This resulted in a web of agreements, initiatives, practices relating to the Soviet nuclear weapons complex, including:

- The US Department of Energy's (DOE) Initiatives for Proliferation Prevention (IPP) programme to provide alternative employment for Russian nuclear scientists.
- A programme to facilitate the dismantlement and elimination of weapons of mass destruction and their launchers under the START I agreement.
- A chain of custody programme to ensure continued security and custody of nuclear weapons and materials, including transportation security, fissile material storage and weapons storage security.
- Establishing an International Science and Technology Center (ISTC) in Moscow and a Science and Technology Center of Ukraine (STCU) in Kiev to facilitate science projects with former weapons scientists, technicians and engineers.
- A Government-to-Government Agreement in 1998 to establish the Nuclear Cities Initiative (NCI) managed jointly by the US DOE and Russian Minatom to assist Russia with the downsizing of its nuclear weapons complex and to promote alternative, commercial enterprises in the closed nuclear cities.
- A programme in 2002 to shut down old plutonium production reactors and replace them with fossil fuel power stations.
- A DOE Material Protection, Control and Accounting (MPC&A) programme for Soviet-era nuclear materials.
- A Defense Enterprise Fund to support the demilitarisation of industries and conversion of military technologies and capabilities into civilian activities.

Related agreements included the Plutonium Management and Disposition Agreement signed in 2000 and the United States-Russia Highly Enriched Uranium Purchase Agreement in 1993 , also known as the 'Megatons to Megawatts Program' through which Russia down-blended highly-enriched uranium from retired nuclear weapons and supplied the low-enriched uranium to the US to convert into nuclear fuel and burn in its reactors. These initiatives were based on negotiation of agreements for provision of funds, contractor liabilities, rights and responsibilities assumed by each of the parties and specific project objectives with recipient countries and the passing of the 1993 Cooperative Threat Reduction Act by Congress to authorise these programmes. It involved a discursive reframing of Russian/Soviet nuclear weapons, risk, vulnerability and US national security around safety, cooperation, consolidation, reassurance and non-proliferation and the elevation of Cooperative Threat Reduction to the status of a 'core strategic concept' and a 'central organising principle' for dealing with nuclear dangers. Together, this constituted the invention of a system of direct discontinuation governance involving a range of active and reactive responses.

Processes of unmaking

A number of scholars have looked in more detail at the processes of destabilising and discontinuing socio-technical systems. Shove et al. develop a practice-based approach to understanding how socio-technological systems and 'complexes of practice' form and unravel, They argue that the process of phase-out/discontinuation is the process of disrupting, or unravelling, the linkages between these three sets of elements that comprise a socio-technical system: 1) materials (objects, infrastructures, tools, hardware, the body); 2) competencies (know-how, background knowledge and understanding, shared understandings); and 3) meanings (mental activities, emotion, beliefs, and motivational knowledge).[43] When links are disrupted, these elements can disappear, become dormant to potentially be reactivated in the future, or become parts of other practices. The re-emergence of a socio-technological system is therefore possible if materials, competencies and meanings still exist even if they have been disconnected. This is *enabled* by the precedent of these elements having been successfully connected before. It is only when the elements themselves start to disintegrate and be forgotten and unfamiliar that re-emergence, or reversibility, becomes much more difficult.[44]

In a similar vein, Zahar Koretsky explores decline as a series of 'misalignments' between materials, competencies and knowledge. He introduces a distinction between weak and strong decline. Weak decline is where a technology is not used or produced anymore but all the other strands of the socio-technical system remain in place and therefore the reversibility of the decline is more straightforward.[45] Strong decline refers to a more fundamental misalignment of the core relationships between materials, competencies and knowledge to the point where realignment is very hard: "associations are impossible because slippage, de-anchoring and/or un-learning are too profound (e.g., all materials are destroyed, carriers of competence or knowledge are gone, specific parts of technology are banned from use or manufacture… all that remains are dissociated materials, meanings, and competencies 'debris'".[46] Technologies can return from strong decline but the process will be very difficult.

The loss of tacit knowledge (discussed below) is an important part of the process of discontinuation. Koretsky looks at processes that can lead to a 'collective forgetting' or 'unlearning' in an organisation, such as the degradation of methodological instructions in scientific organisations, retirements and career changes, loss of data,

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[43] Shove E., Pantzar M. & Watson N. (2012) *The Dynamics of Social Practice: Everyday Life and How it Changes* (Sage: London), pp. 14, 23.
[44] Koretsky Z. & van Lente H. (2020). Technology phase-out as unravelling of socio-technical configurations, p. 312.
[45] Ibid., p. 30.
[46] Ibid., p. 32.

and loss of records when people die.[47] Sturm highlights precisely these processes in the nuclear power industries in Eastern Europe after the collapse of the Soviet Union.[48] Koretsky concludes that "decline is not a binary switch, but a spectrum between continual performance … or lack thereof".[49] This gives practice-based take on irreversibility as an *inability to perform core practices and thereby sustain competencies*.

This body of work on processes of unmaking shows that elements of a LTS are unlikely to completely disappear for a long time. Instead, "What is left is often a remnant of usage and knowledge, infrastructure, and function, for a transitional period… In short, it seems as if almost nothing disappears completely at first".[50] However, some studies have looked at examples where the termination of political support *did* lead "to the death of the socio-technical system as a whole", an example being the fate of Aramis automated train system in France.[51]

Finally, these studies highlight the rare but important effect of shock on policy termination, notably the abandonment of nuclear energy by some countries after the 1986 Chernobyl and 2011 Fukushima-Daiichi disasters.[52] A process of nuclear disarmament and denuclearisation following the shock of nuclear detonations or a wider nuclear war would be a different type of destabilisation process than one negotiated through an international diplomatic process or through unilateral steps and about which it is much more difficult to speculate.

In sum, the work in STS provides useful frameworks for thinking about irreversibility and nuclear disarmament and we can conceptualise structural nuclear disarmament as maximising irreversibility in terms of the destabilisation, discontinuation and 'strong decline' of a nuclear weapons socio-technical system. These studies also suggest that discontinuation will likely involve the restructuring, scaling down, and fracturing of parts of a larger set of LTS within which the target LTS is nested. For example, in the UK it will mean changes to the nuclear-powered submarine-building LTS, but not necessarily its termination. It will mean significant changes to UK fissile material stockpiles, processes, knowledge and practices, but not their end for non-nuclear weapons purposes. This forces us to think about where we draw the boundaries for a

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[47] Koretsky Z. (2023). Dynamics of technological decline as socio-material unravelling. In Koretsky Z., Stegmaier P., Turnheim B. & van Lente H. (Eds.) *Technologies in Decline: Socio-Technical Approaches to Discontinuation and Destabilisation* (Routledge: London), p. 28. He draws in particular on the work of Michener W., Brunt J., Helly J., Kirchner T., & Stafford S. (1997) Non geospatial metadata for the ecological sciences. *Ecological Applications.* 7: 1, pp. 330-342.
[48] Sturm R. (1993). Nuclear Power in Eastern Europe: Learning or Forgetting Curves? *Energy Economics* 15: 3, pp. 183-189.
[49] Koretsky Z. (2023). Dynamics of technological decline as socio-material unravelling, p. 30.
[50] Stegmeier P. (2023). Conceptual Aspects of Discontinuation Governance, p. 99
[51] Ibid., p. 101.
[52] Ibid., p. 90.

'nuclear weapons socio-technical system' whose range of activities, sites, materials, institutions, knowledges and so on should change enough to render reconstruction or re-stabilisation of the actor-network extremely difficult. Moreover, by introducing examples of the 'governance of termination', we can think about 'irreversibility as invention' as well as unmaking, and the different forms disarmament governance could take through a process of inventing nuclear disarmament.[53]

United States' 'structural disarmament' experience in the 1990s

The second part of this report uses the experience of the United States nuclear weapons complex in the 1990s to illustrate the ways in which a nuclear weapons socio-technical complex could *potentially* come apart. In the 1990s there was widespread concern in the US about the erosion of the nuclear weapons complex and nuclear weapons expertise following the end of the Cold War, the end of explosive nuclear weapons testing following a testing moratorium in 1992, and the deterioration of nuclear weapons production sites. The ability to sustain a Cold War legacy nuclear stockpile over the long term was in doubt. Under legal, budgetary and congressional pressure the nuclear weapons complex was forced to shift its focus from large scale nuclear weapons production to clean-up as safety, security and environmental problems caught up with the complex.[54] The problems affecting the complex severely limited ongoing nuclear weapon programme requirements that still required thousands of new warheads as the Cold War ended.[55] The closure of the Rocky Flats Plant, for example, left the White House little choice but to announce that no more W-88 warheads for the Trident D5 SLBM would be produced and that the US would cease production of fissile materials for nuclear weapons.[56] It was estimated at the time that it would take at least 12 years to relocate the capabilities performed at the Rocky Flats Plant.[57]

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[53] For example, nuclear disarmament will have some negative consequences requiring governance solutions. Irreversibility is likely to be enhanced if negative consequences are mitigated. Just as deindustrialisation has had negative effects on particular communities, so will denuclearisation will, for example in UK submarine building communities.

[54] Olshanksky S. & Williams R. (1990). Culture Shock at the Weapons Complex. *Bulletin of the Atomic Scientists,* 46: 8; Hecker S. (1992). Prepared Statement by Dr. Siegfried Hecker, Director, Los Alamos National Laboratory. Senate Committee on Armed Services hearing on "Department of Defense Authorization for Appropriations for Fiscal Year 1993 and the Future Years Defense Program". March 27.

[55] Albright H., Zamora T. and Lewis D. (1990). Turn off Rocky Flats. *Bulletin of the Atomic Scientists,* 46: 5; Herzfeld C. (1990). Statement of Dr. Charles Herzfeld, Chairman, Nuclear Weapons Council. House of Representatives Committee on Armed Services hearing on "National Defense Authorization Act for Fiscal Years 1991 - H.R. 4739, p. 53.

[56] Claytor R. (1992). Prepared Statement of Richard Claytor. House of Representatives Committee on Armed Services hearing on "National Defense Authorization Act for Fiscal Years 1993 - H.R. 5006", April 30, p. 19.

[57] Claytor R. (1992). Statement of Richard A. Claytor, Assistant Secretary of Energy for Defense Programs. Senate Committee on Governmental Affairs hearing on "Impacts of Nuclear Disarmament on the Department of Energy", February 25.

Critics argued that deterioration of the nuclear weapons complex constituted a form of "self-imposed structural disarmament".[58] President Bill Clinton was accused by a number of prominent Republicans in Congress of 'erosion by design' or 'benign neglect' – deliberately allowing the nuclear weapons production complex to deteriorate to reduce the role of nuclear weapons in US national security policy and planning leading eventually to unilateral disarmament.[59] Senator Strom Thurmond, Chair of the Senate Armed Services Committee from 1995 to 1999, stated in 1991 that "the United States is rapidly becoming a former nuclear power" because it could no longer produce nuclear weapons or nuclear weapons materials.[60] Thurmond and other members of the Senate Armed Services Committee urged the administration to "revive our nuclear weapons complex" or face an unsafe stockpile leading to unilateral disarmament.[61]

Political disinterest

The problems affecting the nuclear weapons complex were compounded by a growing political disinterest in nuclear weapons at senior political and military levels following the end of the Cold War because nuclear weapons now mattered far less to US national security than in the past and no major procurement decisions were required.[62] US nuclear weapons policy quickly became a second or third order priority in the US Department of Defense (DOD) and garnered much less senior-level attention.[63] There were fewer incentives to pursue a nuclear career in the armed services and no single dedicated nuclear career track. Nuclear missions became secondary missions for most personnel assigned them.[64] As Joseph and Lehman argued in 1998, "career military personnel today generally view the nuclear career fields as being out of the

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[58] Gaffney F. (1991). Self-Imposed Structural Disarmament: The Sorry State of the DOE Weapons Complex. House of Representatives Committee on Armed Services hearing on "National Defense Authorization Act for Fiscal Years 1992 and 1993 - H.R. 2100", April 18, p. 818.
[59] Spence F. (1994). The Clinton Administration and Nuclear Weapons Policy: Benign Neglect or Erosion by Design? *Congressional Record (House of Representatives)*, June 8. Kyl J. (1994). National Defense Authorization Act for Fiscal Year 1995. *Congressional Record (House of Representatives).* May 18, p. H3542.
[60] Thurmond S. (1991). Testimony of Hon. Strom Thurmond. Senate Committee on Governmental Affairs hearing on "DOE Nuclear Weapons Complex Reconfiguration Study". February 25, p. 3.
[61] See statements by Senators Thurmond and Kempthorne in (1994). Briefing on the Results of the Nuclear Posture Review. Senate Committee on Armed Services hearing on "Briefing on Results of the Nuclear Posture Review", September 22, pp. 3-5.
[62] Garrity P. (1991). The Depreciation of Nuclear Weapons in International Politics. *Journal of Strategic Studies,* 14: 4, p. 485.
[63] Gray C. (1999). *The Second Nuclear Age* (Lynne Rienner, London), pp. 41, 60.
[64] Smith J. M. (2005). The New Strategic Framework, the New Strategic Triad, and the Strategic Military Services. In Wirtz J. & Larsen J. (Eds.) *Nuclear Transformation: The New U.S. Nuclear Doctrine* (Palgrave Macmillan, New York), p. 141.

mainstream and having uncertain futures".[65] This led to a dwindling of nuclear policy and planning expertise in the services.[66]

The 1990s also saw an institutional de-emphasis of nuclear weapons. The Defense Nuclear Agency was reorganised and retitled the Defense Special Weapons Agency (DSWA) in 1996. It was then rolled into the new Defense Threat Reduction Agency (DTRA) in 1998 in which the nuclear weapons mission was only one of four core missions.[67] The position of Deputy Assistant Secretary of Defense for Nuclear Forces and Arms Control Policy with responsibility for nuclear weapons policy in the Office of the Secretary of Defense (OSD) changed to reflect the de-emphasis of nuclear weapons. By the time of the George W. Bush administration, the position was Deputy Assistant Secretary of Defense for Forces Policy with responsibility for conventional strategic forces, ballistic missile defence and the use of space systems for military purposes as well as nuclear weapons.[68] In addition, for much of Clinton's second term the position of Assistant to the Secretary of Defense for Nuclear, Chemical and Biological Defense Programs (ATSD(NBC)) was left vacant. The ATSD(NCB) was the principal staff assistant and advisor to the Secretary and Deputy Secretary of Defense for all matters concerning nuclear weapons policy and staff director of the Nuclear Weapons Council.[69] Elimination of this position left no single point of contact in DOD on nuclear weapons issues.[70]

By the end of the 1990s, critics argued that there was no focal point for US nuclear weapons policy, little senior-level involvement, no centre of expertise for nuclear policy issues, no planning to retain nuclear-related skills leading to critical expertise shortfalls, institutional fragmentation of nuclear weapons responsibilities, minimal activity at the Nuclear Weapons Council, and an erosion of the US nuclear deterrent posture. These concerns were set out in a number of official reports, including Defense Science Board's 1993 report of the Task Force on the Defense Nuclear

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[65] Joseph R. and Lehman R. (1998), *U.S. Nuclear Policy in the 21st Century: A Fresh Look at National Strategy and Requirements.* National Defense University and Lawrence Livermore National Laboratory, Washington, D.C. See also (1998). Report of the Defense Science Board Task Force on Nuclear Deterrence. Office of the Under Secretary of Defense for Acquisition and Technology, U.S. Department of Defense, Washington, D.C., p. 26.

[66] Millot M (1994). Facing the Emerging Reality of Regional Nuclear Adversaries. *The Washington Quarterly,* 17: 3, p. 66; Garrity (1991). The Depreciation of Nuclear Weapons, pp. 493-95; Hamre J. (1998). DOD News Briefing, Deputy Secretary of Defense John J. Hamre. U.S. Department of Defense, Washington, D.C. June 11

[67] Harahan J. & Bennett R. (2002). *Creating the Defense Threat Reduction Agency* (U.S. Department of Defense, Washington, D.C.), p. 10.

[68] Crouch J. (2001). Media Roundtable with ASD (ISP) Crouch. U.S. Department of Defense, Washington, D.C. August 28.

[69] Cohen W. (1997). *Nuclear Weapon Systems Sustainment Programs* (Office of the Secretary of Defense, Washington, D.C.).

[70] (1994). Department of Defense Directive 5134.8, June 8, 1994. U.S. Department of Defense, Washington, D.C; Harahan & Bennett, (2002), *Creating the Defense Threat Reduction Agency,* p. 14.

Agency, Defense Science Board's 1998 Task Force on Sustaining the Nuclear Deterrent led by, former Air Force Chief of Staff General Larry Welch, 1998 report by the National Defense University and Lawrence Livermore National Laboratory, U.S. Nuclear Policy in the 21st Century, and Defense Science Board 2006 report of the Task Force on Nuclear Capabilities.[71]

Knowledge and expertise

The loss of nuclear weapons expertise was a major concern. Congress responded by mandating a number of task forces throughout the 1990s. These included the 1996 Commission on Maintaining United States Nuclear Weapons Expertise to develop a plan for recruiting and retaining nuclear weapons expertise within the US Department of Energy (DOE) that published the Chiles Commission report in 1999[72]; a study of DOE's management of the nuclear weapons programme commissioned from the Institute for Defense Analysis in 1997, also known as the 120-day study[73], and a '30-day review' in 1999.[74] These reports criticised DOE, highlighting poor management, the importance of retaining nuclear weapons expertise, the significant difficulties the Los Alamos and Lawrence Livermore National Laboratories were experiencing in attracting and retaining staff for senior positions, the limited opportunities to exercise the full range of weapon design and production skills, and a piecemeal approach to sustaining critical nuclear skills.[75] These concerns have continued.[76]

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[71] (1993). Report of the Defense Science Board Task Force on the Defense Nuclear Agency. Office of the Under Secretary of Defense for Acquisition and Technology, U.S. Department of Defense, Washington, D.C., p. iii; (1998). Report of the Defense Science Board Task Force on Nuclear Deterrence, pp. 22-23; Joseph, & Lehman (1998), *U.S. Nuclear Policy in the 21st Century*, p. 1.2; (2006). Report of the Defense Science Board Task Force on Nuclear Capabilities. Office of the Under Secretary of Defense for Acquisition and Technology, U.S. Department of Defense, Washington, D.C., p. 33. See also Woolf A. (2001). U.S. Nuclear Weapons: Policy, Force Structure and Arms Control Issues. Congressional Research Service, Washington, D.C., p. 24; Joseph & Lehman R. (1998). U.S. Nuclear Policy in the 21st Century; Buchan G. (1994). U.S. Nuclear Strategy for the Post-Cold War Era (RAND: Santa Monica), p. ix; Cambone S. & Garrity P. (1994). The Future of U.S. Nuclear Policy. *Survival*, 36: 4, pp. 73-95, pp. 78-80. For full details, see Ritchie N. (2008). US nuclear weapons policy after the Cold War: Russians, 'rogues' and domestic division (Abingdon: Routledge).

[72] (1999). Nuclear Skills Retention Measures within the Department of Defense and Department of Energy (The Chiles Commission). U.S. Department of Energy, Washington, D.C.

[73] Richanbach P. Graham D., Bell J. & Silk J. (1997), *The Organization and Management of the Nuclear Weapons Program.* Institute for Defense Analysis, Alexandria.

[74] (1999). Stockpile Stewardship Program: 30-Day Review. U.S. Department of Energy, Washington, D.C., pp. 7-9.

[75] In 1996 the Senate Armed Services Committee Report on the National Defense Authorization Act for FY 1997 also expressed concern about the ability of the Department of Defense to maintain the necessary expertise to sustain the US nuclear arsenal without nuclear testing. Cohen W. (1997). Nuclear Weapon Systems Sustainment Programs, Office of the Secretary of Defense, Washington, D.C.

[76] See Scheber T. & Harvey J. (2015). Assessment of U.S. Readiness to Design, Develop and Produce Nuclear Warheads: Current Status and Some Remedial Steps (National Institute for Public Policy Press: Fairfax, VA), p. xiv; Kendall F., Haney C., Klotz F., McKeon B. & Elliiot M. (2015). Strategic Forces

Knowledge is particularly important when it comes to the irreversibility of nuclear disarmament, especially 'tacit knowledge'. This is the type of knowledge that is not explicated but acquired through experience and the practical craft of 'doing' rather than 'explicit knowledge' acquired through documents, technical manuals or instruction.[77] Spinardi and MacKenzie explored the role of tacit knowledge in nuclear weapons complexes. They argue that tacit knowledge is embodied in people and social relations, and people acquire it by working on the job with other experienced and skilled practitioners. In the US nuclear weapons complex, "It rests upon knowledge that has not been, and perhaps could not be, codified. It is built up gradually, over the years, in constant engagement with theory, the codes, the practicalities of production, and the results of testing".[78] They show that tacit knowledge is an essential part of sustaining something like a nuclear weapons complex. If it decays, which it surely would in a world without nuclear weapons, then it can become very difficult to reacquire and would have to be reinvented and relearned through experience.

Widespread concern about the atrophying of nuclear expertise, skills and tacit knowledge necessary for maintaining a nuclear weapons programme in an era without nuclear testing resulted in long-term investment in the nuclear weapons complex to develop sophisticated diagnostic facilities to enable nuclear scientists to ensure the safety and reliability of existing nuclear warheads and to potentially design new ones without nuclear testing.[79] This took the form of a science and technology-based Stockpile Stewardship Program (SSP) established in 1995 to ensure the safety and reliability of the US nuclear stockpile under a CTBT through a suite of expensive new facilities.[80]

Benjamin Sims and Christopher Henke from Los Alamos argue that the risks posed by atrophying knowledge in the nuclear weapons complex after the Cold War and after the end of nuclear testing were mitigated through a process they call 'sociotechnical

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Subcommittee, Senate Committee on Armed Forces, testimony on "U.S. Nuclear Weapons Policy, Programs, and Strategy". March 4, p. 7.

[77] For the best discussion, see Collins H. (2010). *Tacit and Explicit Knowledge* (University of Chicago Press: Chicago). He breaks down tacit knowledge in to relational, somatic and collective categories.

[78] Spinardi G. & MacKenzie D. (1995). Tacit Knowledge, Weapons Design, and the Uninvention of Nuclear Weapons. *American Journal of Sociology* 101: 1, p. 62.

[79] The weapons laboratories were keen to develop new nuclear weapons and promoted the 'mini-nuke' concept and nuclear directed energy weapons in the early 1990s in order to retain competence in and funding for nuclear weapons design and production. Dowler T. & Howard J. (1991). Countering the Well-Armed Tyrant: a Modest Proposal for Small Nuclear Weapons. *Strategic Review*, 19: 4, pp. 34-40; Arkin W. (1993). Nuclear Junkies: Those Lovable Little Bombs. *Bulletin of the Atomic Scientists,* 49: 6. See also (2006). Report of the Defense Science Board Task Force on Nuclear Capabilities. Office of the Under Secretary of Defense for Acquisition and Technology, U.S. Department of Defense, Washington, D.C.

[80] (1999). *Stockpile Stewardship Program: 30-Day Review.*

repair'. In the US case, this centred on the Stockpile Stewardship Program and the Reliable Replacement Warhead programme that came later.[81] For Sims and Henke, 'sociotechnical repair' is a way of sustaining a social order facing a systemic crisis and it encompasses "the techniques actors use to maintain the practices, institutions, and technologies that form a system such as the nuclear weapons complex".[82] They identify three forms of repair: 'discursive repair' to sustain the discourses that make sense of the social order and normalise and legitimise its continuation; 'material repair' to fix, rebuild, manufacture or replace the material components of the social order; and 'institutional repair' to revitalise the social structures and practices essential to the social order.[83] The purpose of repair is to stabilise a destabilised system/network. This can require 'maintenance' through changes that preserve the current system, these can be small-scale or they can be significant and costly. Or it can require 'transformation' through "radical change in existing structures and practices in order to maintain what actors see as core elements of a system".[84] Their study shows that "regimes of knowledge and credibility are not static, but are dynamically maintained through ongoing processes of repair and revision" in which weapons knowledge at risk of erosion "has been continually reinvented and repositioned within new contexts". What they are talking about here is a deliberate process to hold a destabilised actor-network together over time.[85]

Reinventing Fogbank

The US experience with the material called 'Fogbank' illustrates the challenges of structural disarmament, loss of tacit knowledge, and sustaining or reconstructing actor-networks. Modern thermonuclear weapons have two-stages: a primary fission stage that is detonated first in order to produce sufficient temperatures and pressures to ignite the secondary fusion stage and produce a thermonuclear reaction that produces orders of magnitude more energy than a fission explosion alone. The temperatures and pressures required to induce fusion are similar to those at the centre of the sun. Efficient transmission of the temperature and pressure produced by

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[81] Sims B., & Henke C. (2012). Repairing credibility: Repositioning nuclear weapons knowledge after the Cold War. *Social Studies of Science*, 42: 3, p. 325. The RRW concept emerged in the 1990s, gained political traction in Congress in the 2000s, and was funded from 2005-07. Funding was subsequently cut and the programme formally terminated by the Obama administration in 2009. RRWs were conceived as completely re-engineered and remanufactured warheads based on existing tested designs that would incorporate less exacting design requirements and enhanced safety features. They would also be easier to monitor and maintain than the existing arsenal of Cold War-era warheads that had tight performance margins designed to minimise weight and size and maximise yield giving very little room for error as weapons age. Medalia J. (1997). The Reliable Replacement Warhead Program: Background and Current Developments. CRS Report for Congress (Congressional Research Service, Washington, D.C.).
[82] Ibid., p. 326.
[83] Ibid., p. 326.
[84] Ibid., p. 327.
[85] Ibid., p. 343.

the primary fission detonation to the secondary fusion assembly within the warhead in a microsecond requires a special material. This is called the 'interstage' material, or radiation channel. For a number of US warheads, including the W76 thermonuclear warheads that are deployed on its Trident submarine-launched ballistic missiles, the interstage material was a substance called an aerogel. This particular aerogel was called Fogbank, and it channels energy from the primary to secondary when it becomes a superheated plasma following the detonation of the primary. Fogbank was manufactured from the mid-1970s to 1989 in Building 9404-11 at the massive Y-12 nuclear works in Oak Ridge, Tennessee.[86] Production ended around 1990.[87] Last reports that "By 1993 it was slated for decommissioning, leaving behind only a pilot plant which had been used to produce small batches of Fogbank for test purposes".[88] We don't know much more about Fogbank because, as Dennis Ruddy, the former general manager at Oak Ridge, once told reporters, "The material is classified. Its composition is classified. Its use in the weapon is classified, and the process itself is classified."[89]

Fast forward a decade from the closure of the Fogbank production facility to 2000, and the National Nuclear Security Administration (NNSA) has settled on a plan to extend the service life of the stockpile of W76 warheads. This major 'life extension program' (LEP) will keep the warheads in operational service until at least 2040. This was one of several long, complicated, expensive LEPs for different nuclear warheads in the US arsenal. The W76 LEP involved upgrades and replacements for a number of important warhead sub-systems, and in the late-1990s a requirement to re-manufacture Fogbank was identified as part of the process. The problem was that the original Fogbank manufacturing facility had been decommissioned and dismantled, record keeping from the original manufacturing process was not complete, and many of the scientists and technicians involved in the process had retired so that "As time passed, the precise techniques used to manufacture Fogbank were forgotten", as the Los Alamos National Laboratory put it.[90] The group attempting to reproduce the material "discovered that some of the historical design records were vague and that some of the new equipment was equivalent, but not identical, to the old equipment. Differences that seemed small during the design phase became more significant once

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[86] (1993). Y-12 Safety Analyses/Criticality/Chemical Safety Review. Defense Nuclear Facilities Safety Board. November 3-5.
[87] (2004). Oak Ridge Reservation Annual Site Environmental Report for 2003. US Department of Energy, p. 6-52. https://www.osti.gov/servlets/purl/1183768
[88] Last J. (2009). The Fog of War. *The Washington Examiner*, 18 May. https://www.washingtonexaminer.com/weekly-standard/the-fog-of-war.
[89] Ibid.
[90] Lillard J. (2009). Fogbank: Lost Knowledge Regained. *Nuclear Weapons Journal* 2, p. 20. https://www.lanl.gov/orgs/padwp/pdfs/nwj2_09.pdf; Godsberg A. (2009). Thought for the Day Courtesy of Fogbank. Strategic Security Blog. Federation of American Scientists. August 5. https://fas.org/blogs/security/2009/08/thought-for-the-day-courtesy-of-fogbank/;

the new facility began to produce material".[91] The US Government Accountability Office reported in 2006 that the NNSA "had lost knowledge of how to manufacture the material because it had kept few records of the process when the material was made in the 1980s and almost all staff with expertise on production had retired or left the agency".[92]

The US could have decided to gradually retire its W76 warheads and build a new warhead based on modern materials and simplified designs, but this would have been expensive and controversial. Instead, the US opted for a refurbishment programme to extend the life of the existing warheads – warheads whose design and materials had been subject to a full round of explosive nuclear tests in the New Mexico desert before the end of US nuclear testing in 1992. NNSA then considered developing an alternative to the original Fogbank that would have been cheaper and easier to produce, but this idea was abandoned because of uncertainty as to whether the sophisticated warhead diagnostic capabilities at the US nuclear weapons laboratories would be able to demonstrate conclusively that a new material would function in the exactly the same way as Fogbank. Fogbank had been tested in explosive nuclear warheads tests; a new material could not be.[93]

NNSA initially planned to "restart the existing Special Materials Facility in Building 9404-11".[94] However, this plan was abandoned because "The evolution of health and safety requirements and considerations makes reuse of the original facility not viable".[95] Instead, and after much delay, a new facility was built at Oak Ridge in 2006 called the 'Purification Facility' to produce new Fogbank material to match its original composition. Trying to make this material again proved to be very difficult because the new facility was not exactly the same as the original, such that "the resultant equipment and processing methods failed to produce equivalent Fogbank. The final product simply did not meet quality requirements".[96] One of the problems was that the production of Fogbank involved the use of the solvent acetonitrile, which is very toxic,

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[91] Lillard J. (2009). Fogbank, p. 20.
[92] (2009). Nuclear Weapons: NNSA and DOD Need to More Effectively Manage the Stockpile Life Extension Program. Report to the Subcommittee on Strategic Forces, Committee on Armed Services, House of Representatives (GAO-09-385). Government Accountability Office, Washington D.C. p. 15. Pincus W. (2009). Fine Print: Nuclear Program Issues Lead to Congressional Attention. *The Washington Post.* August 4.
http://www.washingtonpost.com/wp-dyn/content/article/2009/08/03/AR2009080302776.html?hpid=sec-nation
[93] (2009). Nuclear Weapons: NNSA and DOD Need to More Effectively Manage the Stockpile Life Extension Program. Report to the Subcommittee on Strategic Forces, Committee on Armed Services, House of Representatives (GAO-09-385). Government Accountability Office, Washington D.C. p. 18
[94] (1999). 98-D-124, Stockpile Management Restructuring Initiative, Y-12 Consolidation, Y-12 Plant Pak Ridge, Tennessee. FY 2000 Congressional Budget. National Nuclear Security Administration.
[95] (2004). Oak Ridge Reservation Annual Site Environmental Report for 2003, p. 6-52.
[96] Lillard J. (2009). Fogbank, p. 20.

volatile and flammable. It would not be used today, but "that's what we used 30, 40, 50 years ago, when we made this special material [Fogbank]" so that's what they had to use when they needed to remanufacture it, according to Tom D'Agostino, Administrator of the NNSA.[97] The problem became so important that NNSA "launched a major effort – 'Code Blue' – that made the manufacture of Fogbank a priority for the design laboratories and production facilities" across the nuclear weapons complex.[98] Eventually a direct equivalent of the original Fogbank was manufactured after multiple simultaneous changes to the production process and NNSA eventually produced its first batch in Spring 2008.[99] But even then, it was reported that "personnel still did not know the root cause of the manufacturing problems. In fact, they did not know which process changes were responsible for fixing the problem."[100] This led to knock-on delays with the W76 LEP production programme.[101]

The story of reinventing Fogbank is instructive. It only refers to one key material for one type of warhead, but it highlights the possibilities for uninventing nuclear weapons as facilities are mothballed, tacit knowledge dissipates, technologies become redundant, materials science and engineering moves on, and health and safety regulations evolve resulting in significant costs and delays in trying to re-invent the science and the art of producing safe and reliable nuclear warheads.

Conclusions from the US experience

The US experience in the 1990s outlined above shows that the continuation of a LTS and actor-network is not inevitable but takes a lot of work, especially when incentives to sustain it start to change and diminish. In a context in which a nuclear disarmament process has been agreed, the types of processes outlined here would very likely escalate and make re-establishing a safe, secure and reliable minimal nuclear weapons arsenal and the complex to support it very difficult. Claims that a nuclear weapons complex could be sustained in a state of readiness to rapidly reproduce and redeploy nuclear weapons in a disarmed world should therefore be treated with caution. Not only will the actor-network and its components degrade significantly over time, but the political will to retain people, facilities, materials, and expertise to be rapidly mobilised to redevelop nuclear weapons will very likely diminish.

An ebbing away of the expertise and tacit knowledge necessary for sustaining a nuclear weapons complex would be an important part of the process of maximising

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[97] D'Agostino T. (2007). Speech at the Woodrow Wilson International Centre. 15 June.
[98] (2009). Nuclear Weapons. Government Accountability Office, p. 19.
[99] Munger F. (2009). Y-12 says it produced 'fogbank' for warheads a year ago. *Know News.* June 3. http://archive.knoxnews.com/news/local/y-12-says-it-produced-fogbank-for-warheads-a-year-ago-ep-409974367-359376961.html
[100] Lillard J. (2009). Fogbank, p. 20.
[101] (2009). Nuclear Weapons. Government Accountability Office, p. 15.

the irreversibility of nuclear disarmament. As Spinardi and MacKenzie put it: "Suppose… that specific, local, tacit knowledge was vital to their [nuclear weapons] design and production. Then there would be a sense in which relevant knowledge could be unlearned and in which these weapons could be uninvented. If there were a sufficiently long hiatus in their design and production (say a couple of generations), then that tacit knowledge might indeed vanish".[102] MacKenzie also uses the example of uninventing the car to make the case: "We cannot reverse the invention of the motor car, perhaps, but imagine a world in which there were no car factories, no gasoline, no roads, where no one alive had ever driven, and where there was satisfaction with whatever alternative form of transportation existed. The libraries might still contain pictures of automobiles and texts on motor mechanics, but there would be a sense in which that was a world in which the motor car had been uninvented".[103]

This is not to suggest that if nuclear weapons are eliminated, the erosion of the nuclear weapons complex and its base of tacit knowledge will assuredly prevent their reconstitution. Knowledge of the practical possibility of nuclear weapons and explicit knowledge of their design and production would remain alongside tacit knowledge within a residual community of practitioners for a period of time. A relatively simple nuclear bomb programme for delivery by bomber aircraft would require less tacit knowledge than small but much more powerful warheads for delivery by ballistic missile, and relevant tacit knowledge from the operation of a civil nuclear power programme might still be available.[104] Reconstituting the 'paradigmatic strategic weapon' comprising a miniaturised two-stage thermonuclear warhead designed to maximise explosive yield/weight and yield/diameter ratios using a minimum of specialised materials such tritium and delivered by intercontinental ballistic missile is a more unforgiving task – one that assumes long-range land- or sea-based ballistic missiles are still available with which reconstituted warheads can be safely integrated.[105] Nevertheless, it shows that 'uninvention' understood in this way is possible, perhaps even likely, and that we should be sceptical about deterministic claims that the uninvention of nuclear weapons is impossible.[106]

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[102] Ibid., p. 47.
[103] MacKenzie D. (1993) Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance. Cambridge, MA: MIT Press, p. 426.
[104] Spinardi & MacKenzie (1995). Tacit Knowledge, Weapons Design, and the Uninvention of Nuclear Weapons, pp. 82-83.
[105] MacKenzie D. (1999). Theories of Technology and the Abolition of Nuclear Weapons. In MacKenzie D. & Wajcman J. (Eds.) *The Social Shaping of Technology* (Open University Press, Maidenhead. 2nd ed.), p. 436.
[106] Bourne (2016) Invention and uninvention in nuclear weapons politics, p. 20. For a critique of the argument of disarmament impossibility, see Pelopidas B., Cornelia S., and Verschuren J. (2023) Writing IR after COVID-19: Reassessing Political Possibilities, Good Faith, and Policy-Relevant Scholarship on Climate Change Mitigation and Nuclear Disarmament. Global Studies Quarterly, 3: 1, pp. 4-6.

Irreversibility as social change

The final part of the report looks at the *intention* to reverse a disarmament process, specifically the system of meaning through which nuclear weapons are understood to make sense. 'Irreversibility as social change' is about how changes in the meaning of nuclear weapons within a society in relation to ideas about security, power and the state affect an intention to reverse a disarmament process, irrespective of the capability to do so (though the capability might well have eroded too). The outcome that maximises irreversibility is one where the social acceptability of reversing a nuclear disarmament process and redeveloping nuclear weapons becomes marginalised and delegitimised and/or the social relevance of reversing is perplexing and makes little sense.

Our starting point is that the meanings of nuclear weapons are socially constructed, i.e. there are no objective meanings innate to nuclear weapons as material things outside of their social-historical context.[107] Roscow, for example, writing in 1989, argued that nuclear weapons are "cultural artefacts which derive meaning from the complex interaction of economic, cultural, and political forces" and that "nuclear weapons are not 'things', mere objects separable from the social, economic, and cultural systems which produce them".[108] In fact, meanings *constitute* nuclear weapons, i.e. make them what they are understood to be. Just as Science and Technology Studies shows us that technologies cannot be understood outside of their social context, social constructivism from Sociology and International Relations shows us that what a society understands something to be cannot be understood outside of social context either.

History shows us that the meanings associated with weapons and violent practices can change. The advent of new technologies, an accumulation of minor changes in shared understandings within a society, a new generation of policy-makers that hold different understandings about security and the state, and dramatic events such as the end of the Cold War or the climate crisis, can all challenge a dominant system of meaning within society.[109] This can open up political space for competing understandings. A normalised 'common sense' about how society interprets particular events, issues and actors and splinter and become unclear and contested.[110] Changed

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[107] Finnemore M. (1996). *National Interests in International Society* (Ithaca, NY: Cornell University Press), p. 6; Wendt A. (1999). *Social Theory of International Politics* (Cambridge: Cambridge University Press); Adler A. (1993). Seizing the middle ground: constructivism in world politics. *European Journal of International Relations* 3: 3, pp. 319-363.
[108] Roscow S. (1989). Nuclear Deterrence, State Legitimation, & Liberal Democracy. *Polity* 21: 3, p. 568.
[109] Wendt A. (1992). Anarchy is What States Make of It: The Social Construction of Power Politics. *International Organization,* 46: 2, 417, pp. 420-22.
[110] Adler E. & Haas P. (1992). Epistemic Communities, World Order, and the Creation of a Reflective Research Program. *International Organization* 46: 1, pp. 373-79; Jervis (1989). *The Meaning of the Nuclear Revolution*, pp. 104, 182.

meanings can become normalised, and this can lead to the redundancy and even stigmatisation of previously accepted practices. Some norms of behaviour can become embedded in organisations and social institutions into which actors are socialised, leading to an internalisation of these norms such that norm adherence becomes habitual, uncontested and conflated with an actor's sense of identity over a period of time.

This doesn't imply the meaning of nuclear weapons can flip-flop around depending on what we make of them from one day to the next. The meanings assigned to nuclear weapons have become deeply embedded in strategic cultures and national identity conceptions and nested in other deeply embedded, shared understandings of the state, security and violence in world politics.[111] Meanings like these can become so well-embedded that they can become naturalised, or reified, and confront us as 'social facts' that are resistant to change.[112] Dislodging, transforming or transcending some meanings can be really difficult if they become "so internalized that we no longer think seriously about alternative behaviors".[113]

Nevertheless, it is the social constructedness of these meanings that allows for the *possibility* of change. The LTS and actor-network scholarship has surprisingly little to say about systems of meaning and the ways in which changes in these systems can stabilise or destabilise socio-technical systems. However, there is a good scholarship on how the systems of meaning that constitute nuclear weapons can change such that they are reframed as unnecessary, illegitimate or unacceptable instruments of statecraft.

Systems of meaning and discourse

Systems of meaning are especially important when it comes to nuclear weapons because the world of nuclear deterrence and nuclear war is so abstract. In fact, language is really all we have for our understandings, given that we have zero experience of an actual nuclear war and that there are no widely accepted empirical

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[111] Karchner defines strategic culture as a set of "shared beliefs, assumptions, and modes of behaviour, derived from common experiences and accepted narratives (both oral and written), that shape collective identity and relationships to other groups, and which determine appropriate ends and means for achieving security objectives." Kartchner K. (2006). Summary Report of the 'Comparative Strategic Culture: Phase II Kickoff Workshop. Defense Threat Reduction Agency Advanced Systems and Concepts Office, Washington D.C. 13 February. Cited in Lantis J. (2006). *Strategic Culture: From Clausewitz to Constructivism* (Washington, DC: Defense Threat Reduction Agency Advanced Systems and Concepts Office, 2006), p. 16

[112] Dueck C. (2004). Ideas and Alternatives in American Grand Strategy, 2000-2004. Review of International Studies, 30: 4, pp. 521-24; Checkel J. (1997). Ideas and International Political Changes: Soviet/Russian Behavior and the End of the Cold War (New Haven: Yale University Press), pp. 9-10.

[113] Finnemore M. & Sikkink K. (1998). International Norm Dynamics and Political Change. *International Organization* 52: 2, p. 913.

truths about nuclear weapons and nuclear deterrence.[114] In particular, we have no empirical data on the conditions under which nuclear deterrence breaks down, on the functioning of nuclear deterrence in a nuclear war, or the effects of nuclear detonations in war (though we can model these). Empirical studies on the efficacy of nuclear deterrent threats in crises and the role of nuclear weapons in war prevention remain contested and statistical analyses are inconclusive.[115] Lawrence, for example, argued that in the nuclear age theorising strategy and policy "has been beset by an extraordinary problem: the lack of any data" and that the key issues for nuclear strategy are interpretative and contestable.[116] Robert Jervis also argued that in the absence of an actual nuclear war, many arguments about nuclear strategy simply cannot be verified and nuclear strategy has therefore remained hypothetical and based on certain sets of logic rather than evidence.[117]

Jervis goes on to argue that the absence of empirical evidence has allowed much greater scope for the power of ideas and concepts to shape perceptions of nuclear reality. He argues that on key issues such as the credibility of nuclear threats there is no reality to be described independent of policy-makers' beliefs about it and that doctrines and beliefs shape rather than describe reality.[118] He also argues that the construction of problems affecting nuclear strategy by analysts and policy-makers has been quite arbitrary.[119] Policy-makers acknowledge this too, such as Walter Slocombe, former Under Secretary of Defense for Policy for President Clinton, who noted that "Discussion of nuclear weapons is almost entirely done in theoretical and conceptual terms. This has an important influence on how nuclear weapons decisions are made".[120] All of this means that the systems of meaning that constitute nuclear weapons in a particular socio-historical context are crucial to understanding the possibilities for change.

Reframing and national identity

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[114] See, for example, Pelopidas, B. (2015). A Bet Portrayed as a Certainty: Reassessing the Added Deterrent Value of Nuclear Weapons. In Shultz G. and Goodby J. (Eds.) *The War that Must Never Be Fought: Dilemmas of Nuclear Deterrence* (Hoover Institution Press, Stanford), pp. 5-56.
[115] However, there is substantial empirical evidence demonstrating the role of luck in non-nuclear outcomes, 'normal accidents' and nuclear weapons complexes, the multiple reasons why states do and don't seek nuclear weapons, the effects of nuclear testing, and how and why people, groups and organisations respond in crises.
[116] Lawrence P. (1988). Strategic Beliefs, Mythology and Imagery. In Little, R. and Smith, S. (Eds.) *Belief Systems and International Relations* (Basil Blackwell Inc, Oxford), pp. 140, 162.
[117] Jervis R. (1989), *The Meaning of the Nuclear Revolution: Statecraft and the Prospect of Armageddon* (Cornell University Press, Ithaca), pp. 104, 182.
[118] Jervis (1989), *The Meaning of the Nuclear Revolution*, pp. 38, 183.
[119] Jervis R. (1984), *The Illogic of American Nuclear Strategy* (Cornell University Press, Ithaca), p. 54.
[120] Slocombe W. (2006). Democratic Control of Nuclear Weapons Policy Paper No. 12, Geneva Centre for the Democratic Control of Armed Forces, Geneva, p. 7.

Social scientists refer to processes of reinterpretation as 'reframing': the process of moving from one set of shared understandings that constitute a practice (like nuclear deterrence) to another set of understandings that constitutes the practice differently. Framing is a social process that involves 'meaning construction' because frames "help to render events or occurrences meaningful and thereby function to organize experience and guide action".[121] Two of the sociologists who developed frame theory, Robert Benford and David Snow, describe framing as "'conscious strategic efforts by groups of people to fashion shared understandings of the world and of themselves that legitimate and motivate collective action".[122] Framing is an important part of producing and sustaining socio-technical systems, and studies show that 'system builders' often purposefully frame systems and their core technologies through discourses that connect them to broader rhetorical or ideological agendas.[123]

Reframing can be contentious because "it involves the generation of interpretive frames that not only differ from existing ones but that may also challenge them".[124] Reframing is often based on active efforts to reassess the value, necessity and legitimacy of a practice. STS scholars like Stegmeier see reframing as an important part of 'discontinuation governance' insofar as "The discontinuation of governance practices… is seen as the discontinuing of a particular way of solving a policy or a governance problem as the result of a changed framing (formulation, perception) of a problem or solution".[125] Moreover, delegitimisation can be central to reframing. In their study of coal phase-out, Markard et al. argue that "the struggle over phase-out policies is also very much a struggle over the legitimacy of the focal practice or technology… Only if the established technology loses its legitimacy can we expect widespread societal and political support to enact phase-out policies".[126]

Shared understandings of national identity are important components of systems of meaning.[127] This is because the discourses that convey those meaning don't just shape what we say; they tell us about actors and their identities (they 'produce' them),

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[121] See Benford R. & Snow D. (2000). Framing processes and social movements: an overview and assessment. *Annual Review of Sociology* 26, p. 614.
[122] McAdam D., McCarthy J. & Zald M. (Eds) (1996). *Comparative Perspectives on Social Movements: Political Opportunities, Mobilizing Structures, and Cultural Framings* (Cambridge University Press: New York), p. 6.
[123] Sovacool B., Lovell, K. & Ting M. (2018). Reconfiguration, Contestation, and Decline: Conceptualizing Mature Large Technical Systems. *Science, Technology and Human Values* 43: 6, p. 1072.
[124] See Benford & Snow (2000). Framing processes and social movements, p. 614.
[125] Stegmeier P. (2023). Conceptual Aspects of Discontinuation Governance, p. 88.
[126] Markard, J. Isoaho K. & Widdel L. (2023). Discourse around Decline: Comparing the debates on Coal Phase-out in the UK, Germany and Finland. In Koretsky Z., Stegmaier P., Turnheim B. & van Lente H. (Eds.) *Technologies in Decline: Socio-Technical Approaches to Discontinuation and Destabilisation* (Routledge: London), p. 120.
[127] Weldes J. (1996). Constructing National Interests. *European Journal of International Relations* 2: 3, pp. 275-318.

they shape accepted ('normalised') ways of being and acting in the world with terms like 'civilised' and 'rogue', and they marginalise or silence others.[128] Social scientists have long been interested in the social processes of collective identity formation through representations of the 'self' and 'others', how these are constructed in relation to one another, how collective identities shape understandings of collective interests, and how these understandings legitimise some ways of knowing, being and acting in relation to something (like nuclear weapons) and delegitimise others.[129] Shared identities provide common understandings of who 'we' are and how 'we' should act and, at a fundamental level, a government or policy elite cannot know what it wants and therefore what its interests are until it knows what it is, i.e. until it defines its identity in relation to others.[130] In fact, Dunne argues in relation to the UK that "to understand how it can be in our interest to retain a nuclear deterrent capability . . . one needs to understand how a particular account of identity makes such calculations possible".[131] The argument here is that a 'nuclearised' national identity conception generates a 'common sense' national interest in retaining nuclear weapons. Embedding nuclear disarmament will likely require a 'denuclearisation' of shared ideas of national identity within a society, especially its policy elite.

Cases of reframing nuclear weapons

The meaning of nuclear weapons has long been subject to discursive contestation between competing frames. Most recently, core actors within the 'humanitarian initiative on nuclear weapons' that led to the negotiation of the TPNW sought to reframe nuclear weapons and nuclear deterrence as illegitimate and nuclear disarmament as an urgent humanitarian imperative.[132] Reframing has also led to important changes in nuclear systems of meaning *within* countries in relation to shared understandings of what sort of state the state in question *is,* how security is understood, and how threats are interpreted.

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[128] See Fierke K. (2001). Critical Methodology and Constructivism. In Fierke K. & Jorgensen K. (Eds), *Constructing International Relations: The Next Generation* (Armonk, NY: ME Sharpe) and Weldes J., Laffey M. & Gusterson H.(Eds). *Cultures of Insecurity: States, Communities and the Production of Danger* (Minneapolis, MN: University of Minnesota Press); Milliken J. (1999). The Study of Discourse in International Relations: A Critique of Research and Methods. *European Journal of International Relations*, 5: 2, pp. 225-254

[129] Doty R. (1993). Foreign Policy as Social Construction: A Post-Positivist Analysis of U.S. Counterinsurgency Policy in the Philippines. *International Studies Quarterly 37*, pp. 297–320

[130] Wendt A. (1992). Anarchy Is What States Make of It: The Social Construction of Power Politics. *International Organization* 46, pp. 397.

[131] Dunne T. (2004). 'When the shooting starts': Atlanticism in British security strategy. *International Affairs* 80: 5, p. 904.

[132] Løvold M., Fihn B. & Nash T. (2013). Humanitarian perspectives and the campaign for an international ban on nuclear weapons. In Borrie J. & Caughley T. (Eds) *Viewing nuclear weapons through a humanitarian lens* (UNIDIR, Geneva), p. 146.

Nina Tannenwald examined the role of socially constructed meanings in her analysis of a normative 'nuclear taboo' against nuclear use in the US. She shows how a normative prohibition against the use of nuclear weapons emerged during the Cold War, how this shaped what was considered legitimate and illegitimate, and how it became institutionalised through various agreements and practices.[133] She traces the evolution of the non-use norm from Hiroshima, through the Korean War, the Vietnam War and shows that by the time of the 1991 Gulf War, US society "had come to see nuclear use as contrary to their perceptions of themselves" as a moral, civilised nation.[134] This is an important example of how the meanings that constitute nuclear weapons (how we 'know' them) can change over time within a society in relation to ideas about the state.

Other examples include the shift in meanings in states that have relinquished nuclear weapons or nuclear weapons programmes. A number of studies have looked at the case of Ukraine's post-Soviet experience. Christopher Stevens argues that the emergence of a widely shared independent Ukrainian national identity that framed Kyiv (the 'self") in relationship to Russia and Europe (key 'others') in particular ways was key to the elite's decision to relinquish the country's Soviet nuclear arsenal.[135] Scott Sagan similarly argues that "numerous pro-NPT Ukrainian officials insisted that renunciation of nuclear weapons was now the best route to enhance Ukraine's international standing" and confirm its new identity as a full and responsible member of the international community.[136] William Long and Suzette Grillot explore the cases of Ukraine and South Africa and argue that beliefs about what sort of country each was and wanted to be played a major role in the formation of preferences about nuclear weapons.[137]

Similarly, Aida Abzhaparova examined the construction of a post-Soviet national identity in Kazakhstan that was antithetical to the retention of Soviet nuclear weapons. Here, the "new" identity of Kazakhstan was constructed in binary opposition to the "old" Soviet identity such that "Kazakhstan is represented as 'democratic,' 'peace loving,' 'non-nuclear' in opposition to the Soviet rule which was 'totalitarian,' 'cruel,' 'aggressive,' and 'nuclear.'[138] Becoming non-nuclear became essential to a new post-Soviet national identity. Through a process of 'de-Sovietisation', nuclear weapons

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[133] Tannenwald N. (1999). The Nuclear Taboo: The United States and the Normative Basis of Nuclear Non-Use. *International Organization*, 53: 3, p. 434.
[134] Ibid., p. 460.
[135] Stevens C. (2008). Identity Politics and Nuclear Disarmament: The Case of Ukraine. *Nonproliferation Review* 15, pp. 43–70.
[136] Sagan S. (1996). Why Do States Build Nuclear Weapons? Three Models in Search of a Bomb. *International Security* 21, p. 81.
[137] Long W. & Grillot S. (2000). Ideas, Beliefs, and Nuclear Policies: The Cases of South Africa and Ukraine. *Nonproliferation Review* 7, pp. 24-40.
[138] Abzhaparova A. (2011). Denuclearisation Practices of Kazakhstan: Performing Sovereign Identity, Preserving National Security. *Review of International Studies* 37, p. 1,543.

were framed as a danger to the material security *and* identity of Kazakhstan as a newly sovereign state rather than as valuable assets and a guarantor of security.

In the UK, the Scottish National Party articulated a particular representation of an independent Scottish 'self' that was constituted in part by its rejection of nuclear weapons. This was juxtaposed against a Westminster 'other' that continued to place a very high value on nuclear weapons, notably in the context of the 2014 Scottish independence referendum.[139] As SNP leader Nicola Sturgeon put it in 2014, "Just think about it—as the world's newest country, one of the first things an independent Scotland will have the chance to do is rid itself of weapons of mass destruction. I cannot think of any more powerful statement we can make to the world about what kind of country we will be, and what our place in the world will be".[140]

Shifts in systems of meaning in relation to nuclear weapons are often enabled by changes in the wider structure of norms in international society and how conforming with those norms relate to shared ideas of national identity. The norm of non-proliferation embodied by the NPT was key to the shift in the meaning of nuclear weapons in Ukraine, Kazakhstan, Belarus and South Africa. More broadly, Harald Muller and Andreas Schmidt show in their overview of what they call 'de-proliferation' that decisions by states that had the ability to develop nuclear weapons and had taken steps down that path but then abandoned them were shaped in large part by the emergence of the non-proliferation norm in the NPT after 1970.[141]

We also see shifts at the national level *within* nuclear weapons policies. The emergence of the CTR agenda outlined above represents a reframing of Soviet nuclear weapons as a different type of threat to be addressed by different means with successor states to the Soviet Union that were understood as having, and understood themselves to have, different identities to the Soviet Union in terms of the state, the NATO threat and nuclear weapons. A more granular example is the reframing of the meaning of MIRVed Russian missiles in 2001 by the Bush administration. Under Clinton, 'de-MIRVing' the Russian ICBM fleet was interpreted as essential for 'strategic stability' because they were deemed destabilising in a crisis. The Bush administration decided otherwise, in part by reframing the relationship with Russia and strategic nuclear arms control.[142] The Bush administration declared "a new strategic framework"

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[139] Ritchie N. (2016). Nuclear identities and Scottish independence. *Nonproliferation Review*, 23: 5-6, pp. 653-675

[140] (2014). Sturgeon: It's now or never for a nuclear-free Scotland. *Herald*, April 5.

[141] Muller & Schmidt (2010). The Little Known Story of Deproliferation. See also Rublee M. (2009). *Nonproliferation Norms: Why States Choose Nuclear Restraint* (Athens: The University of Georgia Press), pp. 27–28.

[142] The George W. Bush administration took a simplified approach in the Strategic Offensive Reductions Treaty (SORT) or Moscow Treaty signed in 2002 that jettisoned the detailed counting and verification processes in START I and START II.

with Russia, stating "we don't need arms control negotiations to reduce our weaponry in a significant way"[143] or to "narrowly regulate every step we each take, as did Cold War treaties founded on mutual suspicion and an adversarial relationship"[144], and shifted the meaning of 'strategic stability' from one focused on an adversarial relationship to one based on cooperation to meet the new strategic threats from WMD-armed 'rogue' states and terrorist groups.[145] As result of this reframing, the meaning of Russia's MIRVed ICBMs changed very quickly. For Secretary of Defense Donald Rumsfeld, "Russia's deployment of MIRVs has little impact on US national security under current conditions…Since neither the US nor its allies nor Russia view our strategic relationship as adversarial we no longer view the deployment of MIRVed ICBMs as destabilising to this new relationship".[146]

Stigmatisation as the acme of irreversibility

These examples show that systems of meaning that constitute nuclear weapons in particular ways can change. Changes in systems of meaning don't explain everything, they are only part of the story of why people and states do what they do. Nonetheless, systems of meaning are especially important in the politics of nuclear weapons and it is a change in systems of meaning that currently value, legitimise and necessitate nuclear weapons that will be part of the process not just of getting to a disarmament process, but of maximising its irreversibility.

We can, however, go a step further and consider the process of stigmatisation. Here, I suggest that reframing a previously accepted practice as prohibited to the extent that the practice becomes stigmatised would maximise the irreversibility of the prohibition. The social changes required for a state like the UK, for example, to re-legitimise and resume previously accepted practices like slavery, genocide, chemical warfare and so on, would be considerable and are difficult to imagine (though it is, of course, always possible). Stigmatisation is a powerful process: when a society collectively labels a practice, object, discourse or characteristic as illegitimate it moves it beyond the realm of 'normal' and acceptable behaviour within that society. When illegitimacy is rooted in moral revulsion then that practice can become stigmatised. This is a process of separation, one that discriminates between those actors that engage in

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[143] Bush G. W. (2001). The President's News Conference with President Vladimir Putin of Russia. The White House, Washington, D.C. November 13.
[144] Bush G. W. (2002). Message to the Senate Transmitting the Treaty Between the United States of America and the Russian Federation on Strategic Offensive Reductions. The White House, Washington, D.C. June 20.
[145] Bush G. W. (2001). The President's News Conference with President Vladimir Putin of Russia in Genoa. The White House, Washington, D.C. July 22.
[146] Rumsfeld D. (2002). Questions and Responses. Senate Committee on Armed Services hearing on "The National Security Implications of the Strategic Offensive Reductions Treaty". July 25, p. 48.

unacceptable behaviour and those that do not.[147] A stigma therefore shapes actors' identities in terms of whether they are the sort of actor that accepts or conforms to prohibitionary norms and therefore what counts as appropriate behaviour in relation to that identity, or whether they are an actor that does not.[148] A stigma therefore constitutes a powerful prohibitionary norm. It cannot prevent perpetration of a prohibited act if the means remain available, but it can mobilise and legitimise punishment of non-conformity through shaming, moral opprobrium, sanction, and exclusion insofar as possible.

The stigmatisation of a practice often occurs when it is aligned with other stigmatised practices in a society. We saw something like this in the Global South as the nuclear age unfolded after 1945.[149] Newly-independent countries across Asia, Africa and Latin America embraced nuclear disarmament by embedding nuclear weapons within a much longer tradition of collective resistances to European colonialism, imperialism and racism and framing disarmament in terms of peace, economic development and economic and social justice in world politics.[150] The anti-colonial struggle gathered momentum at the turn of the 20th century through a host of transnational movements and international conferences on racism, solidarity, Pan-Africanism, and anti-colonialism, including Afro-Asian women's internationalism.[151] After 1945, nuclear weapons were aligned in these movements with illegitimate, discredited, *stigmatised* practices of racism, colonialism, and imperialism.[152] The seminal event was the gathering of 29 newly-independent states in Bandung, Indonesia, for a conference of decolonised African, Asian and Middle Eastern states to discuss the condition of world politics and the struggle against colonialism and white supremacy, development, peaceful coexistence and disarmament.[153]

The conference's Final Communique "discussed the problems of dependent peoples and colonialism and the evils arising from the subjection of peoples to alien subjugation, domination and exploitation", declared that "colonialism in all its

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[147] Adler-Nissen R. (2014). Stigma Management in International Relations: Transgressive Identities, Norms, and Order in International Society. *International Organization* 68: 1, pp. 147-176.
[148] Price R. (1995). A Genealogy of the Chemical Weapons Taboo. *International Organization* 49: 1, p. 87.
[149] Namboodiri P. K. S (1983). Nonalignment and Disarmament. *Strategic Analysis*, 6: 12, p. 747.
[150] Pham Q. & Shilliam R. (2016). Reviving Bandung. In Pham Q. & Shilliam R (Eds.) *Meanings of Bandung: Postcolonial Order and Decolonial Visions* (London: Rowman & Littlefield), p. 7.
[151] Armstrong E. (2016). Before Bandung: The Anti-Imperialist Women's Movement in Asia and the Women's International Democratic Federation. *Signs: Journal of Women in Culture and Society*, 41: 2, pp. 305-331.
[152] Persaud R. (2016). The Racial Dynamic in International Relations: Some Thoughts on the Pan-African Antecedents of Bandung. In Pham Q. & Shilliam R (Eds.) *Meanings of Bandung: Postcolonial Order and Decolonial Visions* (London: Rowman & Littlefield).
[153] Hongoh J. (2016). The Asian-African Conference (Bandung) and Pan-Africanism: the challenge of reconciling continental solidarity with national sovereignty. *Australian Journal of International Affairs*, 70: 4, p. 381.

manifestations is an evil which should speedily be brought to an end" and unequivocally called for nuclear disarmament: "Disarmament and the prohibition of the production, experimentation and use of nuclear and thermonuclear weapons of war are imperative to save mankind and civilisation from the fear and prospect of wholesale destruction. It considered that the nations of Asia and Africa assembled here have a duty towards humanity and civilisation to proclaim their support for disarmament and for the prohibition of these weapons and to appeal to nations principally concerned and to world opinion, to bring about such disarmament and prohibition."[154]

Conclusion

The purpose of this report has been to think about what maximising irreversibility might mean in a world without nuclear weapons that still looks something like this world. The starting point is that disarmament is a condition rather than an end state and that irreversibility is therefore a spectrum on which a state can be more or less 'disarmed'. The argument here is that maximising irreversibility means: 1) the practical undoing of a nuclear weapons complex as a socio-technical system leading to structural disarmament as strong decline kicks in; 2) a shift in the system of meanings that constitute nuclear weapons in previously nuclear-armed societies, including in relation to shared ideas of national identity, and perhaps to the point of stigmatisation; and 3) allowing for the passage of time, which will be an important factor in allowing these processes to take hold and become embedded.

For example, a state in which the nuclear weapons socio-technical system as to all intents and purposes completely come apart and in which the unacceptability of nuclear weapons has been normalised within society will find it very difficult indeed to reverse the disarmament process. On the other hand, a state in which substantial parts of the socio-technical system remain functioning and connected and the value and legitimacy of nuclear weapons still have salience will find it easier to reverse. Nevertheless, producing the paradigmatic nuclear weapon comprising a two-stage boosted thermonuclear weapon delivered by long-range ballistic missile will be very difficult once the socio-technical system that currently produces and maintains such weapons starts to come apart. Producing a basic nuclear weapon capability might be easier, especially given modern technology, manufacturing processes, materials science, computing capabilities and prior knowledge of nuclear weapons systems, providing of course that the state has access to sufficient weapon-grade fissile materials.[155] But as the US experience of the 1990s shows, it takes a lot of political, intellectual, organisational and fiscal work to sustain a nuclear weapons socio-

[154] Available at: https://issafrica.s3.amazonaws.com/site/uploads/BANDUNG55.PDF.
[155] See MacKenzie D. (1999). Theories of Technology and the Abolition of Nuclear Weapons.

technical system. Once that goes, and it could go very quickly, the possibility of reversal through a sustained state of 'readiness' diminishes considerably.

Finally, these processes will require the invention of 'nuclear disarmament governance' and 'strategic social construction'[156] to reframe the systems of meaning that constitute nuclear weapons. This will involve creativity, collective agency, contingency, contestation and contradiction and, because of this, 'irreversibility' cannot be *guaranteed* as part of a disarmament process. However, by expanding our gaze to include irreversibility as structural disarmament and irreversibility as social change, we can see how a strong or deep form irreversibility is conceivable.

Future research

The frameworks set out here could be developed further by applying them to a hypothetical case of UK nuclear disarmament. The UK would make an excellent case study of a nuclear weapons complex as a LTS in terms of the scope of the socio-technical system, its actors and social groups, its rules and regimes, its network of interconnections that would need to be destabilised, core ideas that would need to be dislodged, practices that would need to be discontinued, and governance processes that would need to be invented for a disarmament process to unfold sufficiently to become practically irreversible. This is because the UK nuclear weapons complex has been reduced significantly since the end of the Cold War to the point at which Walker categorises it as a 'threshold' nuclear-armed state "since it is close to the boundary between armament and disarmament and seems closer to it than any other nuclear weapon state".[157] The UK nuclear weapons complex is for example, reliant upon a single warhead (Holbrook), a single warhead production site (AWE Aldermaston), a single means of delivery (Trident II D5 built by Lockheed Martin and leased from the US), a single delivery vehicle (SSBN), and single SSBN manufacturer at a single site (BAe Systems at Barrow), a single submarine nuclear reactor supplier and production site (Rolls Royce at Raynesway), and a single SSBN maintenance site (HMNB Devonport). In addition, the superposition of the UK's nuclear reactor-building LTS with its nuclear weapons programme (including the production of naval nuclear reactors for its SSBN fleet) opens up questions about where a nuclear weapons LTS end and a nuclear reactor-building LTS begins.

Useful work could also be done by applying these frameworks to the denuclearisation of individual armed services in nuclear-armed states. For example, the denuclearisation of the US Army and the UK's Royal Air Force.

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[156] Finnemore M. & Sikkink K. (1998). International Norm Dynamics and Political Change. *International Organization* 52: 2, pp. 887-917.
[157] Walker W. (2010). The UK, Threshold Status and Responsible Nuclear Sovereignty. *International Affairs* 86:2, p. 447.

PROJECT ON IRREVERSIBLE NUCLEAR DISARMAMENT

Working papers

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