IRREVERSIBLE NUCLEAR DISARMAMENT

Conditional reversibility as a condition of irreversibility: the case of the US and the end of nuclear testing

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Cover photo: Preparation for an underground nuclear test at the Nevada Test Site in the 1990s as the diagnostic cables are installed.

Introduction

This paper examines the role of conditionality in irreversibility as a function of arms reduction and prohibition agreements. It unpacks the paradoxical idea of 'reversible irreversibility' as a phenomenon that negotiators of disarmament agreements are likely to encounter. In doing so, it engages with the familiar concept of 'hedging' in nuclear studies as a means of generating sufficient support for an agreement amongst sceptical domestic veto players by providing reassurance in the form of a plausible reversal pathway. The paper uses the US experience of ending nuclear testing through the negotiation of the Comprehensive Test Ban Treaty (CTBT) to illustrate this process.

'Reversible irreversibility'

Controlling the means of violence has a rich history of bilateral, regional and multilateral treaties, agreements, codes of conduct, confidence-building measures and organisations. The logic of these developments to dampen security dilemmas by building confidence, predictability and transparency has long been attractive.[1] But inescapable uncertainty about intentions generates both fear of transgressions that could be militarily disadvantageous as well as a politics of fear whereby concerns are politicised and manipulated for international and domestic political gain.[2] This can be especially so if some domestic actors are formal or de facto veto players in disarmament decisions (for example, the US Senate's role in ratifying treaties).

The politics of fear of transgression and vulnerability is often driven by prevailing belief systems about threats, intentions, and imagined consequences of different choices and the domestic politics of competing interpretations of and subsequent responses to security dilemmas, much of which is rooted in beliefs about degrees of trust or mistrust. Belief systems are, as James Lebovic has shown, essential to understanding nuclear arms control processes and choices.[3] A collective *belief* in the need to insure against Soviet/Russian cheating through an insurance hedge became

[1] This is rooted in the logic of dampening the security dilemma whereby "a relative decrease in a state's capabilities can increase its security by revealing its benign motives, which will in turn reduce the adversary's insecurity and decrease its need for aggressive policies. Facing a more secure and less hostile opponent, the first state will become more secure as well". Montgomery E. (2006). Breaking out of the Security Dilemma: Realism, Reassurance, and the Problem of Uncertainty. *International Security*, 31: 2, p. 161.

[2] See Wheeler N. & Booth K. (2007). *The Security Dilemma: Fear, Cooperation and Trust in World Politics* (Palgrave Macmillan, Basingstoke).

[3] Lebovic J. (2013). *Flawed Logics: Strategic Arms Control from Truman to Obama* (Johns Hopkins University Press, Baltimore).

embedded in the culture of US arms control and this idea is likely to feature in future nuclear disarmament agreements.

Fear of harm, coercion, loss of prestige or political capital generates incentives for some sort of 'insurance' or 'hedge' against the risk of transgression of agreed commitments by negotiating partners. As Ruzicka and Keating put it, "hedging strategies allow states to self-insure against possible defection or opportunism by other states, allowing them to act more securely in a risky environment because the possible 'worse-case' outcomes are both anticipated and accounted for".[4] Hedging can involve formal processes negotiated in agreements, especially when there are significant asymmetries of power prompting smaller powers to hedge against exploitation, for example through opt-out clauses, sunset clauses, requirements for referenda, joint decision-making processes with veto opportunities, and so on. States also pursue hedging strategies unilaterally through measures not prohibited in an agreement, such as developing relationships with other states to avoid dependencies and coercion, sustaining or building up armed forces, diversifying trade relations, and so on.[5] Hedging is compounded by the extreme political sensitivity of nuclear weapons policy and planning that results in the conservatism of nuclear policy communities and resistance to policy change. [6]

Acton and Perkovich made this point in their 2008 study of 'Abolishing Nuclear Weapons', in which they note that nuclear-armed states "might insist, at least for an intermediate period, on retaining the capacity to reconstitute nuclear arsenals. The desire to hold on to some such capacity is likely to be at least as strong in democracies as in non-democracies, with opposition parties and lobby groups in democracies liable to challenge any government that appeared ready to agree to eliminate the last nuclear weapons. It would be easy for opposition groups to exploit public wariness about disarmament by decrying the absence of a robust capability to reconstitute nuclear forces rapidly; governments might well be inclined to pre-empt such criticisms by making reconstitution capabilities a condition of agreeing to multilateral disarmament."[7]

The act of hedging can, however, generate its own security dilemma because it allows for the possibility of future transgressions even if there is no intention to do so at the time of a negotiation. But what if a 'hedge' as a plausible pathway to reversal is *necessary* for the negotiation of an agreement in the first place - an agreement

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[4] Keating V. & Ruzicka J. (2014). Trusting relationships in international politics: No need to hedge. *Review of International Studies,* 40: 4, p. 761.
[5] Stiles, K. (2018) Trust and Hedging in International Relations (Ann Arbor: University of Michigan Press).
[6] Nolan J. (1999). *An Elusive Consensus: Nuclear Weapons and American Security after the Cold War* (Brookings Institution Press, Washington D.C.), p. 105.
[7] Perkovich G. & Acton J. (2008) Chapter Five: Hedging and Managing Nuclear Expertise in the Transition to Zero and After. *The Adelphi Papers* 48: 396, p. 99.

intended to *dilute* a broader security dilemma by constraining or even eliminating specific means of violence? As Cliff et al observe: "Counter-intuitively, one can also make the argument that the ability to reverse disarmament positively contributes to efforts to achieve nuclear abolition. If disarmament was irreversible then nuclear-armed states may be more reluctant to pursue it. After all, they would be doing so knowing that they could never go back on abolition if at some point in the future they deemed it necessary or desirable to do so."[8]

How should both the possibility of reversal and the motivation of negotiating partners to purposefully plan for that possibility be interpreted? If it is interpreted as actual or latent bad faith, then the response will likely be to harden negotiating positions making an agreement more difficult, or to withdraw from a negotiation process altogether.[9] What is required, then, is for a desire for a plausible pathway to reversal to be understood as means to reach an agreement that has been negotiated and entered into in good faith. Such situations can be characterised as having sufficient 'generalised trust' in the good faith of negotiating parties and the ability of partners to deliver on commitments entered into in order to actually negotiate an agreement, but insufficient trust to negate fears of transgression.[10] Indeed, Andrew Kydd defines trust in international politics as "a belief that the other side prefers mutual cooperation to exploiting one's own cooperation, while mistrust is a belief that the other side prefers exploiting one's cooperation to returning it."[11]

This is not to say that 'reversible irreversibility' *will* define future nuclear disarmament processes, but that it could, and that it could do so in different ways depending on the perceived value of nuclear weapons amongst negotiating parties and domestic political constituencies during a disarmament process.

The US experience

The concept of a nuclear 'hedge' emerged in the US in the early 1990s driven by two perceived needs: first to guard against a resurgent Russia; and second to guard against the failure of a warhead type as the Cold War legacy arsenal was consolidated and modernised. The hedge concept was formally codified in the 1994 Nuclear Posture Review based on a strategy to redeploy a reserve stockpile of operational nuclear weapons and plutonium pits and reconstitute a START I nuclear arsenal within a three-year timeframe as US nuclear forces steadily reduced to START II levels over

[8] Cliff, D., Elbahtimy H. & Persbo A. (2011). *Irreversibility in Nuclear Disarmament* (VERTIC, London), p. 12.
[9] Larkin B. (2008). *Designing Denuclearization: An Interpretive Encyclopedia* (Transaction Publishers, London), p. 78.
[10] Rathbun B. (2011). Before Hegemony: Generalized Trust and the Creation and Design of International Security Organizations. *International Organization* 65: 2: 243–73.
[11] Kydd. A. (2005). *Trust and Mistrust in International Relations* (Princeton University Press, Princeton), p. 6.

the 1990s, as envisaged at the time. The second driver of the hedge concept was the state of the US nuclear weapons production complex. With the closure of a number of sites and the loss of key capabilities such as nuclear testing, plutonium pit production, tritium operations and uranium component fabrication, the US no longer had the ability to develop and produce existing or new warheads. A hedge was therefore deemed a crucial insurance against the failure of a warhead-type that could affect a large proportion of the operational nuclear stockpile and undermine US nuclear posture. The hedge concept evolved in the 2000s to encompass a responsive 'warm' nuclear weapons production complex able to design, test, and manufacture (or re-manufacture) nuclear weapons relatively quickly.[12]

US Special Representative for Nuclear Nonproliferation, Christopher Ford, discussed some of these points in 2007 in a speech in Nagasaki. He said "the potential availability of countervailing reconstitution would need to be a part of deterring 'breakout' from a zero-weapons regime". This possibility has already been "incorporated explicitly into U.S. nuclear weapons planning as a way to provide a 'hedge' against a technical surprise or geopolitical risk". Moreover, Ford argued that "The possibility of countervailing reconstitution…is already promoting disarmament" through a responsive US nuclear weapons complex that has enabled a reduction both in deployed nuclear weapons and in non-deployed nuclear weapons retained as a hedge. In addition, Ford asserted that a plausible reversal pathway "could make nuclear disarmament seem less potentially threatening… thereby helping to achieve

[12] This has continued to the present. The Obama administration's 2013 "Report on Nuclear Employment Strategy of the United States" reiterates the hedge strategy. The Trump administration's 2018 Nuclear Posture Review stated that "An effective, responsive, and resilient nuclear weapons infrastructure is essential to the U.S. capacity to adapt flexibly to shifting requirements". This included exploring "approaches for rapid prototyping, develop options for modifying warheads to increase flexibility and responsiveness, examine the potential for retired warheads and components to augment the future hedge stockpile" and "reduce the time required to design, develop,and initially produce a warhead, from a decision to enter full-scale development" (p. 63). Congress mandated NNSA to develop a "Stockpile Responsive Program" in 2016 to " identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons" See https://www.govinfo.gov/app/details/USCODE-2015-title50/USCODE-2015-title50-chap42-subchapII-partA-sec2538b. and Appendix D in "Fiscal Year 2022 Stockpile Stewardship and Management Plan Report to Congress", Department of Energy, March 2022 at https://www.energy.gov/sites/default/files/2022-03/FY%202022%20SSMP%20March%202022.pdf. The Biden administration's 2022 Nuclear Posture Review also discusses "A resilient and adaptive nuclear security enterprise" stating that "we must re-establish, repair, and modernize our production infrastructure, and ensure it has appropriate capabilities and sufficient capacity to build and maintain modern nuclear weapons in a timely manner. The nuclear security enterprise must be able to respond in a timely way to threat developments and technology opportunities, maintain effectiveness over time" (p. 23). For a critique of the 'responsive complex' concept, see Boyd D. (2014). Hedging Nuclear Deterrence: Reserve Warheads or a Responsive Infrastructure? *Strategic Studies Quarterly* , 8: 2, pp. 96-114.

the elimination of nuclear weapons".[13] This was reiterated in President Obama's 2010 Nuclear Posture Review that said revitalising the US nuclear weapons production complex would allow further stockpile reductions, and that "in a world with complete nuclear disarmament, a robust intellectual and physical capability would provide the ultimate insurance against nuclear break-out by an aggressor".[14]

Reversible irreversibility, then, is certainly a feature of US strategic culture when it comes to nuclear arms control and potential disarmament, one that frames nuclear disarmament around a set of assumptions of the continuing value of nuclear weapons in some form that might necessitate their redevelopment and redeployment. The US experience with the CTBT and the end of explosive nuclear testing in the 1990s illustrates this process and its central dynamics. It is a case where a good faith commitment to an irreversible change is conditional upon some degree of reversibility reassurance. The case shows how irreversibility in relation to nuclear testing was understood and negotiated domestically in the United States over the post-Cold War period, with a particular emphasis on the administrations of George H. W. Bush, Bill Clinton and George W. Bush. It also shows how planning for the possibility of reversing an end to nuclear testing was necessary to reassure domestic political sceptics and how this planning evolved over time.

In the US, this took two main forms: conditional irreversibility based on capability hedging; and conditional irreversibility based on technology substitution. The former is a hedging strategy to reverse a change in capability that can encompass the reconstitution or reproduction of material things, practices, institutions, competencies, and so on. Potential reversal is justified in terms of i) threat perceptions, and ii) erosion of core competencies. The latter is based on substituting a prohibited material capability with a non-prohibited material capability. This can take the form of: i) using different means to achieve the same outcome, for example replacing some nuclear weapons with modern conventional weapons that can hold the same types of targets at risk, or using a science and technology programme to validate the integrity of the warhead stockpile and substitute for live nuclear testing; and ii) using different means to achieve a modified outcome, for example, developing missile defences to provide 'insurance' against cheating on a nuclear disarmament agreement. This is how US President Ronald Reagan framed investment in the Strategic Defense Initiative in the 1980s, stating that "SDI is America's insurance policy that the Soviet Union would keep the commitments made at Reykjavik. SDI is America's security guarantee if the Soviets should – as they have done too often in the past – fail to comply with their solemn

[13] Ford C. (2007). Disarmament and Non-Nuclear Stability in Tomorrow's World. Remarks to Conference on Disarmament and Nonproliferation Issues. Nagasaki, Japan, August 31. Available at <https://2001-2009.state.gov/t/isn/rls/rm/92733.htm>.
[14] (2010). Nuclear Posture Review. The White House: Washington, D.C., pp. 38, 42.

commitments", the commitments at Reykjavik being to pursue the complete elimination of nuclear weapons.[15]

A final issue to note is the passage of time. A 'capability insurance' condition that enables a state to commit to irreversibility in good faith can be understood to make sense within the logic of strategic inter-state competition in which nuclear weapons *could* re-emerge. This is the same logic within which the practice of nuclear deterrence is currently seen to make sense by nuclear-armed states. However, nuclear disarmament presupposes *to some degree* a significant reduction in the perceived value of nuclear weapons and the security logic of nuclear deterrence sufficient to enable nuclear-armed states to relinquish their nuclear arsenals. This is likely to be accompanied by delegitimising moves. As the value and legitimacy of nuclear weapons and nuclear deterrence diminish, incentives for sustaining a 'capability insurance' are also likely to diminish, and this is likely to occur over a period of time as nuclear weapons-capable states acclimatise to a world without nuclear weapons.

The US and the end of nuclear testing

The negotiation of a test ban treaty to ban all nuclear tests had been at the top of the international nuclear arms control and disarmament agenda for decades. The hundreds of massive thermonuclear tests conducted by the United States and Soviet Union in the 1950s led to major protests across the world against testing and the radioactive fallout they produced. The US and Soviet Union responded in 1963 by negotiating the Limited (or Partial) Test Ban Treaty (LTBT/PTBT) that banned nuclear explosions in the atmosphere, in space, and under water. A second treaty, the Threshold Test Ban Treaty (TTBT) negotiated in 1974, banned underground nuclear weapons tests with an explosive force of more than 150 kilotons. A further agreement extended this limit to nuclear explosions for peaceful purposes through the 1976 Peaceful Nuclear Explosions Treaty (PNET).

Negotiation of a comprehensive treaty banning *all* nuclear tests remained a top priority for many non-nuclear weapon states. It was a cause of deep consternation at the 1990 NPT Review Conference and pressure mounted to negotiate a treaty in order to ensure a successful extension of the NPT at its pivotal Review and Extension

[15] Reagan, R. (1986). Address to the Nation on the Meetings With Soviet General Secretary Gorbachev in Iceland. October 13. https://www.reaganlibrary.gov/archives/speech/address-nation-meetings-soviet-general-secretary-gorbachev-iceland

Conference in 1995.[16] Momentum gathered in the UN and in August 1993 the Conference on Disarmament (CD) formally gave its Ad Hoc Committee on a Nuclear Test Ban a mandate to negotiate a comprehensive treaty. A few months later in November the UN General Assembly unanimously approved a resolution calling for negotiation of a CTBT and negotiations began in earnest in the CD the following January.

The US debate

In the United States, nuclear testing became a particularly contentious subject. In the early 1990s, the George H. W. Bush administration and its supporters in Congress were adamant that continued nuclear testing was essential, arguing that ending testing would undermine confidence in the reliability of the stockpile as warheads aged and forces were reduced.[17] Moreover, testing was needed to incorporate the latest safety and security features into new weapons and to avoid future technological surprise by retaining the capability and expertise to design, develop, test and deploy new warheads.[18] Computing capabilities were judged insufficient to replace physical testing and in fact the number of tests needed to be *increased* to "maintain sufficient confidence in the experienced judgement of weapon designers".[19] The Bush administration did ratify the 1974 TTBT and the 1976 PNET, but insisted, along with weapons laboratory directors and supporters in Congress, that as long as the US deployed nuclear weapons it would need to test them.[20] The prudent course was to

[16] U.S. Arms Control and Disarmament Agency (1995). Annual Report of the U.S. Arms Control and Disarmament Agency, Washington, D.C. For example, Representative Ed Markey stated that the 1990 NPT Review Conference "broke down without issuing a final declaration because the United States refused to commit to negotiating a CTB by 1995" and that without a US commitment to a CTBT, the NPT itself would be in jeopardy. Markey, E. (1990). In Support of the Bosco Amendment. Congressional Record (Extension of Remarks). 19 September. United States Congress, Washington, D.C., p. E2934.

[17] Barker, R. (1990). Statement of Robert B. Barker, Assistant to the Secretary of Defense (Atomic Energy). Senate Committee on Armed Services hearing on "National Security Implications of Nuclear Testing Agreements", September 17, p. 43; Cheney, R. B. (1992). Prepared Statement by Richard B. Cheney, Secretary of Defense. Senate Committee on Armed Services hearing on "Military implications of START I and START II", July 28. p. 16.

[18] Barker, R. (1992). Prepared Statement by Robert B. Barker, Assistant to the Secretary of Defense (Atomic Energy). 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.

[19] Barker, R. (1990). Statement of Robert B. Barker, Assistant to the Secretary of Defense (Atomic Energy). Senate Committee on Armed Services hearing on "National Security Implications of Nuclear Testing Agreements", September 17, p. 46.

[20] Reed, T. (1992). Statement of Thomas C. Reed. House of Representatives Committee on Armed Services hearing on "Regional Threats and Defense Options for the 1990s", April 8, p. 401.

assess the verification of these two treaties before eventually negotiating a comprehensive agreement to ban all further tests.[21]

Many in Congress disagreed with the administration and argued that a CTBT was required immediately in order to stabilise the nuclear arms competition, support the arms reduction process, and reinforce the NPT.[22] Test ban supporters argued that the US should end nuclear testing for a year and proceed with a limited programme of tests solely for ensuring the reliability and safety of nuclear weapons rather than the development of new warheads.[23] By the end of 1990 both the House and the Senate expressed clear support for a CTBT. As pressure mounted, Bush set out a new testing policy in July 1992 that imposed further limits on the number, purpose and yield of future tests but did not support a complete end to nuclear testing.[24] In response, Congress passed the Nuclear Testing Moratorium Act in August that imposed a nine-month nuclear testing moratorium and limited testing to no more than six per year after the moratorium with a view to negotiating a CTBT by September 1996.[25]

Bill Clinton entered the White House in 1993 committed to a CTBT and a review of current testing policy.[26] After an interagency presidential policy review, Clinton reiterated his commitment to a CTBT and extended the testing moratorium for a further year, through to at least September 1994.[27] This is the point at which conditions began to enter the debate, including the possibility of reversal and this was framed by negotiations on the scope of the testing prohibition.

Scope of the prohibition

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[21] Barker, R. (1991). Prepared Statement of Robert B. Barker, Assistant to the Secretary of Defense (Atomic Energy). Hearing before the Senate Committee on Armed Services hearing on “Department of Defense Authorization for Appropriations for Fiscal Years 1992 and 1993 Part 7: Strategic Forces and Nuclear Deterrence”, May 9, p. 81; Lehman, R. F. (1990). Statement of Robert F. Lehman, Director, U.S. Arms Control and Disarmament Agency. Senate Committee on Armed Services hearing on “National Security Implications of Nuclear Testing Agreements”, September 17, p. 15.
[22] Fascell, D. B. (1990). Conference Report on H.R. 4739, National Defense Authorization Act for Fiscal Year 1991. *Congressional Record (House of Representatives),* October 24, p. H13516.
[23] Mitchell, G. (1992). Energy and Water Development Appropriations Act. *Congressional Record (Senate),* August 3, p. S11171.
[24] Cheney, R. B. (1992). Prepared Statement by Richard B. Cheney, Secretary of Defense. Senate Committee on Armed Services hearing on "Military implications of START I and START II", July 28, p. 17.
[25] Isaacs, J. (1992). Reports: Nuclear Testing: the Senate that can say No. *Bulletin of the Atomic Scientists*, 48: 8 (October); Lakimets, V. & Suleimenov, O. (1992). New Tests Means New Nukes. *Bulletin of the Atomic Scientists,* 48: 8 (October).
[26] Clinton, W. J. (1993). The President's Radio Address, July 3, 1993. *Weekly Compilation of Presidential Documents,* 29: 27, pp. 1229-1296.
[27] (1996). *Comprehensive Test Ban Treaty Chronology During Clinton Administration, September 10, 1996,* The White House, Washington, D.C.

The negotiation of the scope of the CTBT eventually led to a 'zero-yield' prohibition banning any nuclear test that generated explosive yield. Some states, including the US, wanted a looser prohibition with opt-out clauses formalised in the treaty text. A looser prohibition was advocated by the P5 through what they called "activities not prohibited". This would permit weapon tests for safety and reliability purposes, low-yield and hydronuclear tests, laboratory experiments, simulations and peaceful nuclear explosions in order to maintain nuclear weapon design, production and maintenance capabilities.[28] France suggested that nuclear-armed states should have the right to conduct a safety test every 5 or 10 years.[29] The US sought to build in an opt-out clause from the treaty at the first review conference 10 years after entry into force. Clinton eventually supported a zero-yield test ban despite pressure from the US Department of Defense, Department of Energy and the national laboratories to allow continued testing of nuclear weapons with an explosive force equivalent to 1 kiloton.[30] It was reported that the nuclear weapons laboratories favoured a 15-year plan based on 15 tests for safety and reliability up to 1996, 5 years of testing below 1 kiloton, 5 years of no testing and then a review.[31]

Others wanted a stricter prohibition to limit the potential for any future tests. The G-21 opposed the idea of safety tests and Sweden and Germany went further by advocating a prohibition of nuclear test preparations. Iran, supported by a number of other states, went further still by pushing for nuclear testing sites to be closed and testing infrastructure destroyed. Indonesia proposed a prohibition on "testing through super-computer simulation", whilst India pushed back against 'sub-critical tests' (see below), saying that "as the PTBT drove testing underground, we do not wish the CTBT to drive testing into the laboratories by those who have the resources to do so." Instead, the CTBT should leave "no loophole for activity, either explosive based or non- explosive based, aimed at the continued development and refinement of nuclear weapons".[32] The latter three proposals were ultimately unsuccessful, with the US pushing back that test sites were important national research laboratories and that prohibiting preparations and simulations would be very difficult to verify.[33]

In the absence of opt-out clauses, the US and other nuclear-armed states pursued unilateral measures within the bounds of the treaty to reverse the commitment to end nuclear testing should the need arise. The tighter the prohibition, the greater the

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[28] Johnson R. (2009). Unfinished Business: The Negotiation of the CTBT and the End of Nuclear Testing (UNIDIR, Geneva), p. 58.
[29] Ibid., p. 61.
[30] Smith, R. J. (1993). White House Studies Nuclear Test Limits. *Washington Post,* April 30.
[31] Mitchell, G. (1993). Senate Concurrent Resolution 9 - Urging The President to Negotiate a Comprehensive Nuclear Weapons Test Ban. *Congressional Record (Senate),* February 4, p. S1494.
[32] Johnson R. (1996). CTB negotiations - Geneva Update No. 25. *Disarmament Diplomacy* 1 (January). http://www.acronym.org.uk/old/archive/textonly/dd/dd01/index.htm
[33] For detail, see Johnson (2009) *Unfinished Business*, pp. 62-3.

perceived set of risks, and the stronger the incentives to seek formal and informal pathways to reversal. The negotiation process was therefore in part about setting the parameters for reversibility.

As negotiations unfolded, France conducted a series of tests in the South Pacific in 1995 and 1996 and then pledged to dismantle the test facilities, which it did. The US, however, along with China and Russia retained their nuclear tests sites in Nevada, Lop Nur in Xinjiang, and the islands of Novaya Zemlya respectively. The principal Soviet test site at Semipalatinsk in Kazakhstan was closed in 1989 and in the process of being dismantled.[34]

'Safeguards'

President Clinton knew that his administration would face severe difficulties in persuading the Republican-controlled Senate to ratify the CTBT and the process leading up to the vote on ratification in 1999 was divisive and contentious.[35] In order to assuage domestic critics of the CTBT and ensure the safe, secure and reliable operation of the US nuclear arsenal in an era of no nuclear testing, the Clinton administration set out a series of 'safeguards' as conditions for ratification. These were:[36]

A. Continuation of a robust science-based Stockpile Stewardship Program.
B. Maintenance of modern nuclear laboratory facilities and programmes to attract and retain nuclear weapons expertise.
C. Maintenance of the basic capability to resume nuclear tests if needed.
D. Continuation of a comprehensive programme to improve CTBT monitoring capabilities, operations and intelligence on global nuclear weapons programmes.
E. An annual stockpile certification process embodied in domestic law. This required the Secretaries of Defense and Energy – advised by the Nuclear Weapons Council, the directors of the nuclear weapons laboratories, and STRATCOM – to certify to a high degree of confidence that the stockpile is safe and reliable, and, if not, whether testing is necessary.[37]
F. Acceptance that the President, in consultation with the Congress, would be prepared to withdraw from the CTBT to conduct whatever testing might be

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[34] Ibid., p. 149.
[35] Medalia, J. (2004). Nuclear Testing and Comprehensive Test Ban: Chronology Starting September 1992. Congressional Research Service, Washington, D.C.
[36] See Clinton, W. J. (1998). Remarks at Los Alamos National Laboratory in Los Alamos, New Mexico February 3, 1998. *Weekly Compilation of Presidential Documents,* 34: 6, pp. 175-225.
[37] Clinton, W. J. (1997). Message to the Senate Transmitting the Comprehensive Nuclear Test-Ban Treaty and Documentation, September 22, 1997. *Weekly Compilation of Presidential Documents,* 33: 39, pp. 1371-1429.

required if a major problem arose with the safety or reliability of a nuclear weapon-type that the Secretaries of Defense and Energy consider to be critical to the US arsenal.[38]

Clinton initiated the science-based Stockpile Stewardship Program (SSP) in 1995 to ensure the safety and reliability of the US nuclear stockpile under a CTBT in order to neutralise opposition to the treaty.[39] The programme's primary rationale was to develop an understanding of the functioning of all aspects of nuclear weapons and the behaviour of the materials involved as they aged; maintain the capability to identify problems in nuclear warheads; repair any problems; and certify the repairs or replace warheads that could not be repaired – all without nuclear testing.[40] The SSP would also allow the nuclear weapons complex to maintain a cutting edge technological capability and train and retain a highly capable nuclear weapons workforce.[41] The programme was to be implemented through the construction of a host of sophisticated and expensive facilities.[42]

Readiness to reverse nuclear testing restrictions has been a staple of US planning, beginning with a series of safeguards implemented by President Kennedy in 1963 during the negotiation of the PTBT in order to win the support of members of

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[38] Reis V. (1997). Testimony Before the Senate Committee on Governmental Affairs, International Security, Proliferation, and Federal Services Subcommittee. Prepared Statement of: Victor H. Reis, Assistant Secretary of Energy for Defense Programs. 27 October.

[39] Paine, C. (2004). Weaponeers of Waste. Natural Resources Defense Council, Washington, D.C., p. 5.

[40] Collina, T. and Kidder, R. (1994). Shopping Spree Softens Test-Ban Sorrows. *Bulletin of the Atomic Scientists,* 50: 4; Hecker, S. S. (1997). Prepared Statement by Dr. Siegfried S. Hecker, Director, Los Alamos National Laboratory. Senate Committee on Armed Services hearing on "Department of Defense Authorization for Appropriations for Fiscal Year 1998 and the Future Years Defense Program", March 19, p. 207

[41] Charles Curtis, Under Secretary of Energy, listed four such competencies: nuclear science and technology; dynamic experimentation, advanced sensors and instrumentation; theory, advanced computation, modelling and simulation of complex systems; and advanced manufacturing and process technology. Curtis, C. (1994). Prepared Statement by Charles B. Curtis, Under Secretary of Energy. Senate Committee on Armed Services hearing on "Department of Defense Authorization for Appropriations for Fiscal Year 1995 and the Future Years Defense Program", May 3.

[42] These included the National Ignition Facility (NIF) designed to create very brief, contained thermonuclear reactions; a Dual Axis Radiographic Hydrotest Facility (DARHT) to allow nuclear scientists to 'see' inside the explosion of the first stage of a thermonuclear weapon; a more sophisticated facility, the Advanced Hydrotest Facility; the Jupiter Facility for testing weapons effects; the Atlas Facility for simulating weapon environments; a Contained Firing Facility; a Process and Environmental Technology Laboratory; a High-Explosive Pulsed-Power Facility; an Accelerated Strategic Computing Initiative to build the most powerful computers in the world at the national laboratories to simulate nuclear explosions; See U.S. Department of Energy (1996). Final Environmental Impact Statement for the Nevada Test Site and OffSite Locations in the State of Nevada. Volume 1, Appendix A, "Description of Projects and Activities".

Congress and the Joint Chiefs of Staff.[43] The Clinton administration continued this approach with a requirement for the Department of Energy to maintain the capability to conduct an underground test within twenty-four to thirty-six months of a decision to do so set out in Presidential Decision Directive-15 in 1993. This meant maintaining the required infrastructure, personnel, skills and knowledge to conduct nuclear tests through dynamic experiments, (including sub-critical experiments) hydrodynamic tests, and exercises.[44] The US nuclear weapons laboratories maintained a permanent presence at the test site and assigned technical staff to the Test Readiness programme managed by the National Nuclear Security Administration (NNSA). Together with staff at the Nevada Test Site (since renamed the Nevada National Security Site), they were required to conduct annual assessments of test readiness and support NNSA in its biannual report to Congress on essential workforce skills, capabilities, and infrastructure requirements to support test readiness.[45] The Nevada Test Site conducted training exercises to practice the skills and processes necessary to conduct a nuclear test and maintained a roster of retirees with experience of nuclear testing to be called upon should testing resume.[46]

Contestation of knowledge

However, critics argued that the SSP was a high risk strategy with no guarantee that the new technologies would work well enough to replace knowledge previously gained through nuclear testing and that confidence in the reliability and safety of the nuclear

[43] These were: 1) Continue underground nuclear testing "vigorously and diligently"; 2) Maintain a posture of readiness to resume testing in the environments prohibited by the treaty; 3) Expand and improve facilities for the detection of possible violations of the treaty; 4) Maintain "strong weapons laboratories in a vigorous program of weapons development"; 5) Pursue "its programs for the further development of nuclear explosives for peaceful purposes by underground tests". Kennedy, J. F. (1963). Letter to Senate Leaders Restating the Administration's Views on the Nuclear Test Ban Treaty. 11 September. https://www.presidency.ucsb.edu/documents/letter-senate-leadersrestating-the-administrations-views-the-nuclear-test-ban-treaty. For more detail, see Frankel M., Scouras J. and Ullrich G. (2021). Tickling the Sleeping Dragon's Tail: Should We Resume Nuclear Testing? Johns Hopkins Applied Physics Laboratory https://www.jhuapl.edu/Content/documents/DragonsTail.pdf

[44] (1993). Presidential Decision Directive. NSC-15. 3 November. The White House. Washington, D.C. https://irp.fas.org/offdocs/pdd/pdd-15.pdf

[45] Government Accountability Office (2007). Nuclear Weapons: Annual Assessment of the Safety, Performance, and Reliability of the Nation's Stockpile. GAO-07-243R. https://www.gao.gov/assets/gao-07-243r.pdf.

[46] Reis, V. (1997). Prepared Statement of Dr. Victor Reis. House Committee on Appropriations Subcommittee on Energy and Water Development hearing on "Energy and Water Development Appropriations for 1997".

stockpile would inevitably decline.[47] Despite the safeguards set out by Clinton, a group of Republican Senators successfully led the Senate in its rejection of the treaty in October 1999.[48]

This represented a contestation of knowledge and political ideology about security, arms control and the state. The effects of a treaty like the CTBT can never be known for certain in advance, providing political space for best case and worst case prognoses that can draw on different sources of expert analysis and judgement. This resolved into a discursive 'techno-political' contestation. For example, critics of the CTBT argued that a credible US nuclear deterrent threat required ongoing nuclear tests to ensure the safety, reliability and security of US nuclear weapons.[49] They pointed to the 1990 Report of the Panel on Nuclear Weapons Safety of the Committee on Armed Services (the Drell Commission) that recommended a series of limited tests to improve the safety, security and reliability of nuclear warheads.[50] Arguments in favour of continued nuclear testing for safety and reliability purposes were backed by five former Secretaries of Defense, two former chairmen of the Joint Chiefs of Staff, five previous directors of the Central Intelligence Agency, former Secretary of State Henry Kissinger, former National Security Advisor Brent Scowcroft, former Ambassador to the United Nations Jeanne Kirkpatrick, and former Assistant to the Secretary of Defense for Atomic Energy Robert Barker.[51]

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[47] Bailey, K. C. (1998). Prepared Statement of Dr. Kathleen C. Bailey. Senate Committee on Governmental Affairs hearing on "The Comprehensive Test Ban Treaty and Nuclear Nonproliferation", March 18; Joseph, R. & Lehman, R. (1998). U.S. Nuclear Policy in the 21st Century. *Strategic Forum*, No. 145 (August); Robinson, C. P. (1999), Statement of C. Paul Robinson, Director, Sandia National Laboratories. Senate Committee on Armed Services hearing on "Comprehensive Test Ban Treaty", October 7. For a more recent critique, see Hopkins, John C. and Sharp, David H., "The Scientific Foundation for Assessing the Nuclear Performance of Weapons in the U.S. Stockpile Is Eroding," Issues in Science and Technology 35, no. 2 (Winter 2018). https://issues.org/byline/david-h-sharp/.

[48] Kimball, D. (1999). How the U.S. Senate Rejected CTBT Ratification. *Disarmament Diplomacy,* 40 (September/October).

[49] Warner, J. (1999). Comprehensive Test Ban Treaty. *Congressional Record (Senate)*, October 6, p. S11672

[50] The Commission argued that tests were needed to incorporate fire-resistant pits (FRP), insensitive high explosives (IHE) and enhanced nuclear detonation safety (ENDS) into US nuclear weapon systems. It recommended that all nuclear weapons in the stockpile be equipped with ENDS and that all nuclear bombs and cruise missiles loaded on aircraft be equipped with IHE and FRPs. Spratt, J. (1993). Nuclear Testing Moratorium. *Congressional Record (Extension of Remarks),* September 29, p. E2278.

[51] Warner, J. (1999). Comprehensive Test Ban Treaty. *Congressional Record (Senate),* October 6, p. S11672; Abraham, S. (1999). Comprehensive Nuclear Test Ban Treaty. *Congressional Record (Senate),* October 14, p. S12630; Kirkpatrick, J. (1999). Prepared Statement of Jeane K. Kirkpatrick. Senate Committee on Foreign Relations hearing on "Final Review of the Comprehensive Test Ban Treaty", October 7; Barker, R. (1992). Prepared Statement by Robert B. Barker, Assistant to the Secretary of Defense (Atomic Energy). 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. pp. 48-49.

CTBT supporters in Congress, on the other hand, rejected the argument that nuclear tests were essential for ensuring the safety, security and reliability of US nuclear weapons. They pointed to the 1995 report by the JASON group of US nuclear scientists that concluded confidence in the US nuclear stockpile was high and no further nuclear testing was needed unless major problems were encountered in an existing stockpile design.[52] Supporters included Secretary of Defense William Cohen, JCS chairman Henry Shelton, Secretary of Energy Bill Richardson and Secretary of State Madeleine Albright.[53] These serving officials were also joined by four former chairmen of the Joint Chiefs of Staff, General John Shalikashvili, General Colin Powell, General David Jones, and Admiral Bill Crowe, who all endorsed the test ban.[54]

Scientific and technical analysis could not 'prove' the case either way and so building the political coalition necessary to secure ratification required reassurance through the six safeguards that encompassed both the SSP and a plausible pathway to reversal.

Sub-critical experiments

Part of the process for 'reversible irreversibility' was a programme of sub-critical experiments (SCEs) at the Nevada Test Site as part of the Stockpile Stewardship Program. The Congressional Research Services defines SCEs as experiments involving "chemical high explosives and fissile materials in configurations and quantities such that no self-sustaining nuclear fission chain reaction can result. In these experiments, the chemical high explosives are used to generate high pressures that are applied to the fissile materials."[55] SCEs are controversial but deemed permissible by the US under the CTBT because they do not generate a nuclear chain reaction. Critics argue that they undermine the CTBT by enabling the development of new warhead designs.

SCEs are conducted 1,000 feet underground at the U1A complex of tunnels. They are used to assess warhead performance, safety and reliability, monitor nuclear warhead components as they age, certify plutonium pits, and support the development of

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[52] (1995). National Defense Authorization Act for Fiscal Year 1996. *Congressional Record (Senate),* August 4, pp. S11368- S11369.
[53] Albright, M. (1999). Prepared Statement of Madeleine K. Albright. Senate Committee on Foreign Relations hearing on "Final Review of the Comprehensive Test Ban Treaty", October 7; Cohen, W. and Shelton, H. (1999). Joint Prepared Statement by William S. Cohen an Gen. Henry H. Shelton. Senate Committee on Armed Services hearing on "Comprehensive Test Ban Treaty", October 6; Richardson, B. (1999). Prepared Statement by Secretary Bill Richardson. Senate Committee on Armed Services hearing on "Comprehensive Test Ban Treaty", October 7.
[54] Clinton, W. J. (1998). Remarks at Los Alamos National Laboratory in Los Alamos, New Mexico February 3, 1998. *Weekly Compilation of Presidential Documents,* 34: 6, pp. 175-225.
[55] Medalia J. (2005). Nuclear Weapons: Comprehensive Test Ban Treaty. Congressional Research Service, Washington D.C. 11 March.

warhead computational and modelling capabilities.[56] SCEs also play a key role in sustaining the test site in a state of readiness to resume nuclear testing.[57] In 2021, NNSA stated that "DOE/NNSA is continuing to leverage subcritical experiments for test readiness, as they are challenging, multi-disciplinary efforts that enhance the technical competency of the nuclear security enterprise workforce."[58]

George W. Bush and enhancing test readiness

The George W. Bush administration expressed considerable scepticism about the nuclear testing moratorium in place since 1992, the viability of the CTBT and NNSA's ability to sustain and modernise the US nuclear arsenal without full nuclear testing. In 2001 both Secretary of Defense Donald Rumsfeld and Secretary of State Colin Powell reiterated Republican opposition to ratification of the treaty and concerns about verification and the safety and reliability of the US stockpile.[59] Under Secretary of State for Arms Control and International Security, John Bolton, reportedly said that the CTBT was "profoundly misguided and potentially dangerous" and an "unenforceable treaty with illusory protections".[60] The Bush administration stated that it would not resubmit the CTBT for consideration by the Senate but that it would adhere to the testing moratorium and had no reason or plans to conduct any new nuclear tests.[61] White House Press Secretary Ari Fleischer said on 10 January 2002 that President Bush had not ruled out testing "to make sure the stockpile, particularly as it is reduced, is reliable and safe. So he has not ruled out testing in the future, but there are no plans to do so."[62]

However, the administration's 2001 Nuclear Posture Review made a number of changes to US nuclear posture, including a revitalised nuclear weapons production complex that the administration considered to have atrophied since the end of the Cold War.[63] This included a plan to reduce the time required to conduct a nuclear test

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[56] (2005). The Nevada Test Site: Desert Annex of the Nuclear Weapons Laboratories. Western States Legal Foundation. Information Bulletin Summer. http://www.wslfweb.org/docs/nts2005.pdf.
[57] U.S. Department of Energy, National Nuclear Security Administration, Fiscal Year 2001 Stockpile Stewardship Plan, 2000, obtained by the Western States Legal Foundation via the Freedom of Information Act, p. 31-2.
[58] (2022). "Fiscal Year 2022 Stockpile Stewardship and Management Plan Report to Congress", Department of Energy, March, p. 4-30.
[59] Isaacs, J. (2001). The Ones to Watch. *Bulletin of the Atomic Scientists,* 57: 2; Lortie, B. (2001). Setting the Scene. *Bulletin of the Atomic Scientists,* 57: 2.
[60] Kennedy, E. (2001). Nomination of John Robert Bolton of Maryland to be Under Secretary of State for Arms Control and International Security - Resumed. *Congressional Record (Senate)*, May 8, p. S4455.
[61] Wolfowitz, P. (2001). Deputy Secretary Wolfowitz Interview with Radio Correspondents, June 29, 2001, U.S. Department of Defense, Washington, D.C.; Spector, L. (2002). Ambassador Linton Brooks on U.S. Nuclear Policy. *Non-Proliferation Review,* 9: 3, pp. 1-7
[62] Pincus W. (2002). U.S. Aims for 3,800 Nuclear Warheads. *Washington Post*, 10 January.
[63] Rumsfeld, D. (2002). Annual Report to the President and the Congress. U.S. Department of Defense, Washington, D.C. chapter 7.

to 18 months by September 2005.[64] The NPR also established the Advanced Concepts Initiative to re-establish advanced warhead concepts teams disbanded in the 1990s at the three nuclear weapons laboratories to train weapons designers and examine options for earth penetrating warheads and low-yield warheads.

This reflected the conclusion of the Foster Panel to Assess the Reliability, Safety, and Security of the United States Nuclear Stockpile that reported in March 2002. The report stated that 2-3 years from a decision to a test was too long and that "test readiness should be no more than three months to a year".[65] In testimony before a House Armed Services Committee panel. Foster stated that "prudence requires that every President have a realistic option to return to testing, should technical or political events make it necessary." In fact, the 2-3 year time frame was already looking problematic and in September 2002 a report by DOE's Office of Inspector General found that while Clinton's PDD-15 requires DOE to be able to restart underground testing within three years, that ability was "at risk": "Specifically, key aspects of the Department's testing process and infrastructure had experienced significant degradations in the last decade, including a decline in the number of employees with testing experience; the deterioration of necessary systems and equipment; the inability to keep pace with new technology; and, delays in updating required safety studies".[66]

However, the Bush administration did not make this a legal requirement and Clinton's PDD-15 requirement to be able to test within 2-3 years remained in force. Nevertheless, in 2017, NNSA published a new interpretation of PDD-15 as follows: "6 to 10 months for a simple test, with waivers and simplified processes; 24 to 36 months for a fully instrumented test to address stockpile needs with the existing stockpile; 60 months for a test to develop a new capability".[67]

The challenge of sustaining readiness

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[64] Brooks, L. (2004). Statement of Ambassador Linton F. Brooks, Under Secretary for Nuclear Security and Administrator, National Nuclear Security Administration. Senate Committee on Appropriations, March 24. The 2001 Nuclear Posture Review was classified but J. D. Crouch, Assistant Secretary of Defense for International Security Policy, presented an unclassified "Special Briefing on the Nuclear Posture Review" on 9 January 2002.

[65] Foster, J. (2002). Prepared Statement of John S. Foster, Jr., Panel to Assess the Reliability, Safety and Security of the United States Nuclear Stockpile. Senate Committee on Foreign Relations hearing on "Examining the Nuclear Posture Review", May 16.

[66] (2002). U.S. Department of Energy. Office of Inspector General. Office of Audit Services. National Nuclear Security Administration's Test Readiness Program, Audit Report, September, p. 1. https://www.energy.gov/sites/default/files/igprod/documents/CalendarYear2002/ig-0566.pdf.

[67] Fiscal Year 2018 Stockpile Stewardship and Management Plan Report to Congress. Department of Energy. November 2017, p. 3-26. https://www.energy.gov/sites/default/files/2017/11/f46/fy18ssmp_final_november_2017%5B1%5D_0.pdf.

Nevertheless, the US has struggled to sustain a robust test readiness posture. This is part of a wider challenge of revitalising the Cold War nuclear weapons production complex over the past 30 years. A detailed report on the resumption of nuclear testing in 2021 by the Johns Hopkins Applied Physics Laboratory concluded that the US would struggle to conduct a nuclear test in the time-frames currently required. The authors note that nuclear test teams have long since dispersed since the last test in 1992 and that "the associated firsthand knowledge base has atrophied. Moreover, most of the equipment, facilities, and supporting infrastructure have long since fallen into disuse and would have to be reconstituted".[68] They set out the scale of task of conducting an underground nuclear test:

> "While testing a nuclear weapon underground is an extreme exercise of big science, it is also in part an art. And it is not only the device designers who are part of the art but also other uniquely accomplished technical specialists who may not be as familiar to the public. Every individual underground test is unique in terms of geology, undetected rock faults, unexpected vagaries of weapon performance, containment challenges, stemming and grouting, grounding and shielding, data acquisition design, and various emplacement issues. Although the experienced and expert national laboratory personnel conducted over eight hundred underground nuclear tests, they did not all contend with containment failures or data acquisition failures to the same degree…At its peak during the Cold War, there were over seven thousand personnel on-site at the Nevada Test Site and over one hundred thousand personnel as part of the supporting industrial infrastructure nationwide. These are mostly gone. According to the NNSA, much, if not most, of the equipment and technology required for nuclear testing in the past has not been adequately maintained, is obsolete, or has been sold or salvaged. More important, the knowledge needed to conduct a nuclear test, which comes only from testing experience, is all but gone too. In the words of John C. Hopkins, retired associate director of LANL, 'In sum, there is essentially no test readiness. The whole testing process—whether to conduct one test or many— would in essence have to be reinvented, not simply resumed.' Given that assessment, some have questioned our current capability to satisfy the two to three-year timeline mandated by Presidential Decision Directive 15."[69]

Geoffrey Steeves (USAF) unpacks the costs, complexities and challenges of a resumption of nuclear testing based on the type of test required on spectrum from a hydronuclear test to a full experimentation test for a new warhead design.[70] He also notes that "the US lacks personnel—specifically geophysicists, physicists, and engineers with hands-on experience—to perform not only these tests but also some

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[68] Frankel et al (2021). Tickling the Sleeping Dragon's Tail, p. 38.
[69] Ibid., p. 39. Hopkins is cited from Hopkins, J. (2016). Nuclear Test Readiness. *National Security Science*, December, pp. 9-16. https://www. lanl.gov/discover/publications/national-security-science/2016-december/_assets/docs/NSS-dec2016_ nuclear-test-readiness.pdf.
[70] Steeves G. (2020). Ready, Set, Getting to Go: US Nuclear Test Readiness Posture. *Strategic Studies Quarterly*, Fall, p. 26.

of the essential associated experimentation".[71] Steeves argues that the organisational, technical, and logistical challenges to be overcome to conduct a nuclear test are significant, requiring successful "integrating 15 specialties as part of an entire system to conduct an underground nuclear test… containment, security, assembly, storage and transportation, insertion, emplacement and stemming, timing and control, arming and firing, diagnostics, test control centre activities, post-shot drilling, nuclear design, weapons engineering, test integration, and nuclear chemistry. All these specialized areas either complement or are in addition to the aforementioned challenges in that they represent a unique level of complexity".[72]

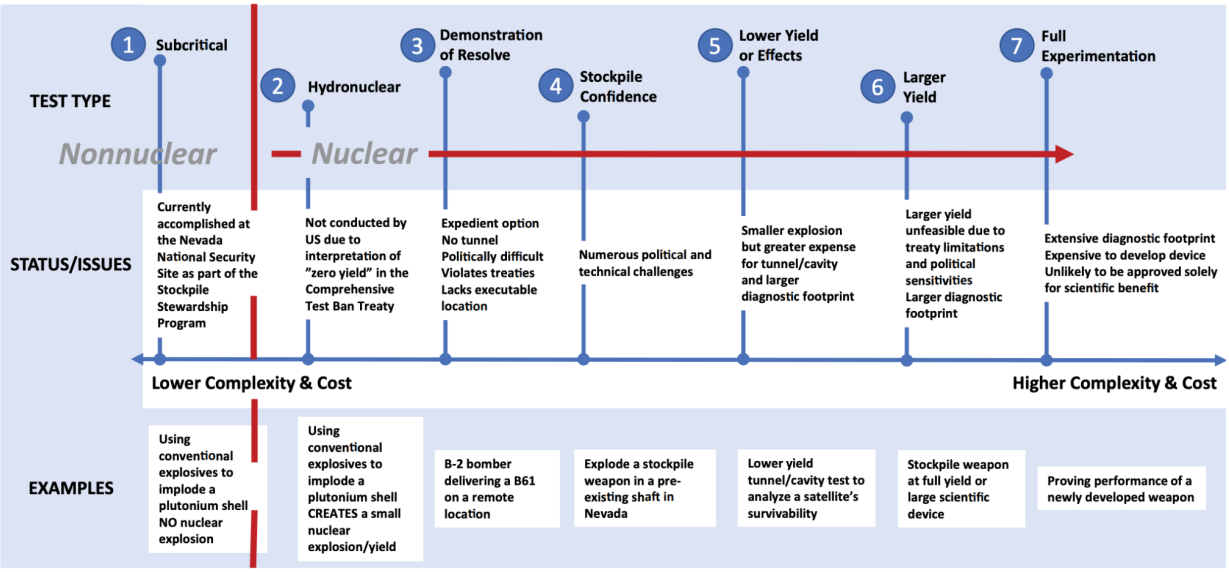

Figure from Steeves G. (2020). Ready, Set, Getting to Go: US Nuclear Test Readiness Posture. *Strategic Studies Quarterly*, Fall, p. 26.

In addition, the regulatory environment for worker, public, and environmental safety has expanded considerably over the past 30 years, and these would need to be reviewed to ensure compliance before any resumption of nuclear testing.[73] Moreover, the DoD Defense Science Board reported in 1998 that "there is no practical alternative for success in Stockpile Stewardship" because a return to limited nuclear testing would require "a massive expansion of the planned plutonium and uranium processing (primary and secondary production) capability that went with limited, underground nuclear testing".[74]

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[71] Ibid., p. 35.
[72] Ibid., p. 36. For further detail on the test process, see https://nuke.fas.org/guide/usa/nuclear/testing.htm.
[73] Ibid., p. 36.
[74] (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. 52. https://apps.dtic.mil/sti/pdfs/ADA433328.pdf

Both Steeves and former UK Foreign Office arms control expert, John Walker, highlight the challenges of the degradation of specialised equipment for nuclear testing. Walker notes that specialist drilling teams were needed to prepare the borehole for a nuclear test and extensive safety reviews were needed to ensure there would be no inadvertent release of radioactivity. In the US "the Containment Evaluation Panel was a rigorous and thorough process. Such reviews considered in detail the device yield, depth of burial, geology, hydrology, characteristics of the soil and rock, location of the emplacement site (including the proximity to and the success of previous test locations), closure methods, stemming design, and drilling and construction history. Drill-back operations are required to recover samples from the melt puddle for device diagnostics; this takes place after the temperature of the cavity has cooled. The post-shot hole is as small in diameter as possible and is drilled at an angle to allow the drill rig to be positioned safely away from surface ground-zero. All of this requires careful planning, resources and highly specialised expertise and is one of the more visible aspects of a nuclear weapons programme".[75]

Steeves also notes that "the equipment required to safely conduct underground testing has atrophied severely. The ability to emplace a [test] rack or canister has been compromised as the large crane capable of handling this load was salvaged and the wire ropes and pipes required to lower the test device need pull testing to ensure viability. While the remaining unused racks and canisters are helpful for instructional purposes, they may be of limited utility to conduct an immediate test as racks are developed specifically for each test and aren't interchangeable. The specially designed gas-blocked cables that prevent radioactive material from releasing into the atmosphere have been baking in the Nevada desert for almost 30 years, and there is no longer a manufacturer to supply replacements."[76]

Conclusion

The US experience of the end of nuclear testing is instructive. It shows how uncertainty, belief systems, domestic politics and techno-political contestation incentivised the development of a plausible pathway to reversing the commitment entered into in good faith by the Clinton administration to permanently end explosive nuclear testing. In this case, the irreversibility of the commitment was conditional upon capability hedging through the test readiness programme *and* the success of technology substitution through the SSP, with reversal pre-emptively justified by a

[75] Walker, J. (2015). Nuclear Firewall: Weaponisation and Militarisation. Unclassified Working Paper prepared for the Carnegie Endowment for International Peace Nuclear Firewall project, 11 June. Head, Arms Control and Disarmament Research Unit, Foreign and Commonwealth Office. Copy provided by author, January 2023, p. 9.
[76] Steeves (2020). Ready, Set, Getting to Go, p. 35.

change in the nuclear threat perceived by the US and/or an erosion of core competencies judged to require a resumption of nuclear testing to rectify.

However, the case also highlights the serious challenges of sustaining a plausible reversal pathway over time (see the report for this project on *Unmaking Nuclear Weapon Complexes*). Despite continuous concerns over the post-Cold War period about the ability of NNSA to resume nuclear testing within the 2-3 years mandated in PDD-15, it seems that challenges remain.

This suggests that in a nuclear disarmament agreement we can expect serious techno-political contestation incentivising plausible pathways to reversal, the parameters for which will be conditioned by the scope of the prohibition agreements negotiated. This could take the form of conditional irreversibility through capability hedging and/or through technology substitution. This will need to be anticipated by the negotiating parties. However, sustaining plausible pathways to reversal over time will be difficult, not least since getting to a disarmament negotiation will require a degree of devaluing and likely delegitimation of nuclear weapons and nuclear deterrence that can be expected to erode any pathway to reversal over time.

PROJECT ON IRREVERSIBLE NUCLEAR DISARMAMENT

Working papers

Joelien Pretorius. **Staying the course: Lessons from South Africa for irreversibility of nuclear disarmament**. March 2023. York IND Working Paper#1.

Nick Ritchie. **Conditional Reversibility as a Condition of Irreversibility: The Case of the US and the End of Nuclear Testing.** March 2023. York IND Working Paper#2.

Mikhail Kupriyanov. **Prohibition Treaties and Irreversibility**. March 2023. York IND Working Paper#3.

Research Reports

Nick Ritchie. *Irreversibility and Nuclear Disarmament: Unmaking Nuclear Weapons Complexes.* March 2023. York IND Research Report#1.

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