The costs of nuclear disarmament

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Executive Summary

This paper considers the financial costs of nuclear disarmament with respect to both the dismantlement and destruction of nuclear warheads and associated delivery systems as well as to verification of nuclear disarmament. There is a large lacuna in countless studies of nuclear disarmament specifically addressing its costs. As such data on what disarmament is likely to cost is scarce, and the discussion about costing nuclear disarmament has not yet evolved beyond the philosophical level. The principle recommendation of this paper is therefore that the ICNND commission a group of independent experts to engage in a detailed, full-scale study of the costs of nuclear disarmament.

This study, despite the paucity of data, nonetheless reaches a number of conclusions about how to begin thinking about costing nuclear disarmament, most notably the following:

- The costs of disarmament will largely be borne by the nuclear weapon states, including verification costs
- The cost of dismantling and destroying nuclear weapons is more accurately attributed to being a normal part of weapon life cycles rather than to nuclear disarmament
- The costs of disarmament pale in comparison to the financial burden of deploying, maintaining and upgrading nuclear arsenals in perpetuity and
- A multilateral verification regime will be a bargain given the benefits of a world free of nuclear weapons.

Nuclear disarmament is not an inexpensive process, but if it is agreed to be a goal that will vastly improve international security then the costs are not so high that they should be anything more than a secondary concern.

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Introduction

Two types of financial costs need to be considered in thinking about nuclear disarmament.[1] The first relates to the dismantlement of nuclear weapons, delivery systems and associated facilities and the disposition of nuclear weapons-related materials, notably fissile material. The second type of costs are those related to the monitoring and verification of nuclear disarmament. This study examines both.

How global nuclear disarmament will proceed is still largely an unknown. At this early stage, the costs are thus impossible to calculate. All that can be done now is to indicate orders of magnitude, identify the types of activities that will incur a cost that would not otherwise be borne and consider the question of who pays for what. As progress is made towards nuclear disarmament and a clearer picture emerges of how 'getting to zero' is likely to unfold and how it will be verified, it will become easier to calculate the likely costs and to answer these related questions definitively.

The nuclear weapon states ultimately need to undertake cost studies for the dismantlement of their own arsenals. Only they—and in some cases not yet even they—know the costs of researching, developing and deploying nuclear weapons, as well as what it will take to dismantle them and their associated weapons complexes. Meanwhile, estimating the costs of multilateral involvement in verifying nuclear disarmament must await more detail on the nature and extent of that involvement, in particular the role of a multilateral nuclear disarmament organization, whether it is the International Atomic Energy Agency (IAEA) or a future Nuclear Disarmament Commission.

There have been non-governmental efforts to map out global disarmament, including the Draft Nuclear Weapons Convention compiled by several non-governmental organizations and tabled in its original version by Costa Rica in 1997.[2] In addition, Global Zero—an international initiative dedicated to the phased, verified elimination of nuclear weapons—has published a *Global Zero Action Plan* which also lays out a framework for nuclear disarmament.[3] None of these plans deal with the question of costs in any detail. Nonetheless they illustrate the key point that the financial costs of disarmament are likely to be spread over decades and that different costs will be

[1] The authors would like to acknowledge the advice and assistance of consultant Dr Ian Davis, Dr Rebecca Johnson of the Acronym Institute, Mr Miles Pomper of the James Martin Center for Nonproliferation Studies and Mr Stephen Schwartz of the James Martin Center for Nonproliferation Studies, among the many others who contributed to this research. Any inaccuracies remain the sole responsibility of the authors.

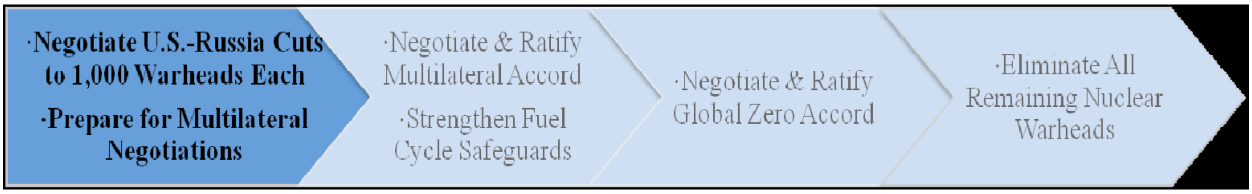
[2] International Association of Lawyers Against Nuclear Arms, International Network of Engineers and Scientists Against Proliferation and International Physicians for the Prevention of Nuclear War (IPPNW), *Securing Our Survival (SOS): The case for a Nuclear Weapons Convention*, IPPNW, Cambridge, Mass., 2007.

[3] Global Zero, *Global Zero Action Plan*, 29 June 2009, http://www.globalzero.org/files/pdf/gzap_3.0.pdf (accessed 16 September 2009).

incurred at different stages of the process. Notably, dismantlement and disposition costs will come in the early stages, along with strengthening of nuclear safeguards, while verification costs will ramp up as the process nears zero and becomes politically and strategically more sensitive.

Illustrative timetables such as that below from Global Zero provide some guidance as to what the process might look like and how long it will take.

PHASE 1: 2010-2013 PHASE 2: 2014-2018 PHASE 3: 2019-2023 PHASE 4: 2024-2030



Source: Global Zero Action Plan

The Global Zero plan is rather ambitious, calling for the complete elimination of nuclear weapons by 2030. This paper will assume that the path to disarmament will be something similar to the *Global Zero Action Plan*, although it will not restrict discussion of costs to the plan's 20-year time-frame. The plan may however be somewhat misleading in appearing to suggest, perhaps, that the culmination of the process will mean zero costs. This is far from being the case. In fact verification is likely to be required in perpetuity.

The Data Challenge

Data that could be used to determine the likely costs of nuclear disarmament is scarce, in large part because the information is classified or otherwise unobtainable. Examples include the past costs of dismantling nuclear weapons and weapons production facilities and the ongoing cost of storing weapons-grade fissile material. Most nuclear weapon states, even those with parliamentary oversight and public accountability mechanisms, keep this information secret or tightly held. Among the five nuclear weapon states recognized by the 1968 Nuclear Non-Proliferation Treaty (NPT), the United Kingdom tends to be the most transparent, while China is the least.

Sometimes relevant information is contained within aggregate figures on military spending or nuclear energy programs as a whole, peaceful as well as military. But such figures are impossible to disaggregate. Even when a specific line item is possible to discern, further details are often unavailable. For instance occasionally a figure for the cost of dismantling a particular type of redundant nuclear warhead is available, but it is usually unclear as to how many warheads were disposed of, under what conditions, and what costs are considered part of a dismantlement process. It is also usually unclear whether parts of weapons systems or materials could be economically salvageable for other purposes and whether the costs of using a particular facility for the dismantlement process is factored in (often the facility used to build nuclear weapons will also be used to disassemble them). It would be difficult even for officials with access to all of the available information regarding a particular weapons complex to be able to accurately assess how much it would cost to dismantle it.

In conducting this research we contacted many of the foremost experts on nuclear disarmament and verification. Many of the responses were thoughtful and provided rational arguments about how to begin thinking about costing nuclear disarmament, but few pointed to cold, hard data—even data in orders of magnitude, much less specifics. The discussion about costs has not yet, unfortunately, advanced beyond the philosophical level, despite decades of rumination about nuclear disarmament by hundreds of experts inside and outside of government. As an example, one of the most recent books on nuclear disarmament, *Abolishing Nuclear Weapons: a Debate*, involving 18 contributors, mentions the cost issue only once (in Patricia Lewis' chapter on verification).[4] Similarly, a study by George Perkovich and James Acton for the International Institute for Strategic Studies devotes just one and a half pages out of 130 to the question of 'how much and who should pay?'.[5] As far as is known the Nuclear Threat Initiative, in all of its detailed work on nuclear disarmament has not yet considered the cost issue. The 1996 Canberra Commission devoted just one page to costs.[6]

It may be instructive to consider why this inattentiveness to costs should be the case, especially when it is assumed by some observers that cost will be a significant, continuing excuse for postponing nuclear disarmament. The first reason is the lack of transparency indicated above. However, freedom of information laws in the Western nuclear weapon states should have made some information easier to obtain by determined researchers than in the past. A second reason may be the complexity of the steps required for nuclear disarmament, including the lack of detail about how the process will unfold and about which states will be involved at which stage. A further factor is the sheer variation in the nuclear arsenals of the possessor states, ranging from the handful of weapons that North Korea is suspected of having to the still large American and Russian arsenals. A final reason may be that such studies have in the past appeared pointless since nuclear disarmament appeared so unlikely.

From the perspective of those advocating nuclear disarmament the lack of sound cost estimates for achieving it should be viewed as a barrier to achieving their goal, since

[4] Patricia Lewis, 'Verification, compliance and enforcement' in George Perkovich and James M. Acton (eds), Abolishing Nuclear Weapons: a Debate', Carnegie Endowment for International Peace, Washington DC, pp. 238-239.
[5] George Perkovich and James M. Acton, *Abolishing Nuclear Weapons*, Adelphi Paper no. 396, Routledge for the International Institute of Strategic Studies, London, 2008, pp. 67-68.
[6] Report of the Canberra Commission on the Elimination of Nuclear Weapons, National Capital Printers, Canberra, August 1996, p. 95.

such uncertainty may be used by opponents as yet another reason for opposing disarmament. The ICNND may wish to help remove such an obstacle—probably one of the easiest to remove—by commissioning a full-scale study by the world's leading experts.

Traditionally it has not been states involved in reducing their own nuclear weapons which have worried unduly about the cost. Having decided on cuts they have simply found the resources to achieve the task. The real debate over costs will come when multilateral mechanisms are being contemplated to verify the nuclear disarmament process. As in the case of both the International Atomic Energy Agency (IAEA) and the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO), financial issues can be significant sources of controversy, both in their own right, and as proxies for unresolved substantive issues.

The Costs of Disarmament 1: Dismantling and Disposition of Nuclear Weapons, Weapons Systems, Associated infrastructure and Materials

This section will examine, to the extent possible, the costs of dismantling and destroying nuclear weapons, weapons systems and associated infrastructure.

Disarmament activities likely to incur significant financial costs

The various activities that will have to be funded include, but are not limited to, the following:

- De-mating of nuclear weapons and their delivery systems (notably land-based and submarine-based)
- Decommissioning, dismantling and destruction of delivery systems and launch platforms, including strategic bombers, submarines and ballistic missiles of varying ranges (minus those that can legitimately be converted to conventional weapons delivery)
- Construction of secure, verification-friendly storage and dismantlement facilities in nuclear weapon states that do not possess them
- Removal of nuclear weapons to secure, verified storage and/or dismantlement facilities
- Verified dismantlement of nuclear weapons and disposition of non-fissile and fissile components
- Decommissioning and razing of nuclear weapon research and production facilities (although some research facilities might be devoted to verification and/or peaceful nuclear research)
- Decommissioning and razing of uranium enrichment facilities, plutonium production reactors and plutonium reprocessing plants unless these are to be used for peaceful purposes and placed under IAEA safeguards

- Construction of high-level nuclear waste repositories for defence-related nuclear waste if the state does not already possess such a facility or if other arrangements cannot be made
- Return to zero readiness and permanent closure of nuclear test sites and associated facilities.

Existing studies

As indicated already, there have been no studies to date that have assessed comprehensively the costs of nuclear disarmament. Two studies have, however, sought to partially tackle the issue and these are considered below.

Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940

A study by Stephen Schwartz *et al* published in 1998 deserves an honourable mention for opening the discussion on how much nuclear weapons cost—both to keep and to get rid of. The authors delve into the costs of nuclear weapons, including building, deploying and dismantling them.[7] The study approaches the question of disarmament from the angle of reducing nuclear weapons expenditures in the aftermath of the Cold War rather than that of complete nuclear disarmament, so some of the challenging questions about how to dismantle the nuclear weapons complex writ large (along with the costs of verification) are not addressed directly. However, the study does reveal how challenging it is to account for nuclear weapons costs, especially on the disarmament side, particularly with respect to the difficult question of the disposition of excess fissile material.

Schwartz *et al* estimate the cost of dismantling American nuclear weapons between 1940 and 1990 at $40.6 billion.[8] Of this total, 47.2 percent ($19.2 billion) was for plutonium disposition—making it one of the most expensive parts of the process.[9] The authors also caution that these numbers reflect dismantlement costs in an era when warheads were being replaced rather than retired, which limited the amount of surplus material that needed to be permanently disposed of.[10] In these instances the material taken out of a warhead to be retired was often held for future use in a replacement weapon.

Complete nuclear disarmament would, in contrast, entail the additional cost of disposal of weapons grade material to render it unusable for a nuclear weapon. The options for such material disposition are numerous and include ‘burning’ it in fast reactors, using plutonium in mixed-oxide (MOX) fuel for civilian power reactors, blending high-enriched uranium (HEU) down also for civilian power reactor use, or vitrification with other fission products as waste. These options vary wildly in their

[7] Stephen I. Schwartz *et al*, *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940*, Brookings Institution Press, Washington DC, 1998.
[8] All figures in this paper are, unless otherwise specified, converted to and expressed in 2008 USD.
[9] Schwartz *et al*, p. 326.
[10] Schwartz *et al*, p. 328.

potential cost.[11] Disposing of all of the fissile material from large nuclear programs will be costly. Most of such states will already have facilities for handling, storage and long-term if not permanent disposal of such material, not just from their military programs but from their civilian nuclear power programs. In such cases the additional expense may not be as great as might be expected.

The Schwartz study was intended to be a blueprint for researchers elsewhere to also conduct an 'atomic audit' of their countries' nuclear weapons programs, but no others took the initiative. A logical first step in determining nuclear disarmament costs is for researchers working closely with government and military officials to undertake a rigorous study of what it would take for their country to disarm, along with the costs. So far none of the nuclear weapon states have taken this step.

Costs of Disarmament—Disarming the Costs: Nuclear Arms Control and Nuclear Rearmament

Another useful study is Susan Willet's, published by the United Nations Institute for Disarmament Research (UNIDIR) in 2003.[12] The study confines itself to examining the costs of the 1991 Strategic Arms Reduction Treaty (START I) between the US and Soviet Union. Signed by the two parties just five months before the Soviet Union collapsed, the agreement required significant reductions in strategic nuclear delivery vehicles—including Intercontinental Ballistic Missiles (ICBMs), Submarine-Launched Ballistic Missiles (SLBMs) and strategic bombers—as well as nuclear warheads. In 1991 the US had 1,876 strategic delivery vehicles deployed and 11,966 nuclear warheads, while the Soviet Union had 2,354 delivery vehicles deployed and 10,980 nuclear warheads.[13] START required that the two former superpowers reduce their arsenals to 1,600 strategic delivery vehicles and 6,000 warheads each.[14] In total START thus called for the dismantling of 1,030 delivery vehicles and 10,946 warheads. This was no small undertaking and gives some indication of the scale of disarmament that would be required now. As of 2006, according to the Natural Resources Defense Council (NRDC), there were globally approximately 27,000 nuclear warheads remaining, about 14,500 of which are considered to be in reserve or retired and awaiting dismantlement in the US and Russia.[15]

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[11] Schwartz *et al*, pp. 347-352.

[12] Susan Willett, *Costs of Disarmament – Disarming the Costs: Nuclear Arms Control and Nuclear Rearmament*, UNIDIR, Geneva, 2003.

[13] SIPRI, *SIPRI Yearbook 1991: World Armaments and Disarmament*, Oxford University Press, New York, 1991, pp. 16, 18.

[14] US Department of State, "Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Reduction and Limitation of Strategic Arms," 1991, http://www.state.gov/www/global/arms/starthtm/start/start1.html#ArtI (accessed 18 September 2009).

[15] Robert S. Norris and Hans M. Kristensen, 'Global nuclear stockpiles, 1945-2006', *Bulletin of the Atomic Scientists*, July/August 2006, http://thebulletin.metapress.com/content/c4120650912x74k7/fulltext.pdf (accessed 18 September 2009).

Although the Willet study largely confines itself to the cost of START and does not extrapolate these to the costs of getting to zero, it does provide some sense of the character and costs of complete global nuclear disarmament. The study estimates that START actually resulted in net economic savings for the US, taking into consideration the one-time costs of dismantlement, recurring costs of verification and the savings accrued from cutting the US arsenal. The one-time costs, including destruction of equipment and facilities, restructuring of forces and bases, initial inspections to verify declarations and setting up facilities for site inspections, were $2.1 billion.[16] Recurring costs of START include verification and monitoring costs from 1991 to 2001 of $681.4 million.[17] Savings accrued from cuts in US forces resulting from START reductions are estimated at $7.5 billion.[18] Because of the breakup of the Soviet Union, the US also spent approximately $2.9 billion between 1991 and 2001 to support implementation of START nuclear dismantlement activities in Russia and other former Soviet republics.[19] Even so, the US on balance saved approximately $1.8 billion dollars as a result of the START agreement.

No comparable study appears to have been done on the costs of the 1987 Intermediate-range Nuclear Forces (INF) Agreement between the US and the Soviet Union, which mandated the withdrawal of INF missiles from Europe, the dismantlement of the missiles and launch sites, and ongoing verification of non-production of new intermediate-range missiles. The verification provisions for START I were in part modelled on this agreement, with the exception of continuous on-site monitoring of missile production facilities, which is labour-intensive and therefore expensive. In addition, there were presumably additional costs incurred in dismantling facilities away from the two parties' home territories, although there were also ultimately cost savings from no longer having to maintain such facilities abroad.

The START agreement naturally does not embody all of the costs that will need to be taken into consideration when implementing a global disarmament regime—such as the costs of a multilateral verification agency. It does, however, indicate that arms control is not always as expensive as it may appear. Susan Willett correctly identifies the START agreement as a useful reference point to begin thinking about the costs of future disarmament agreements.

The British experience

As one of the original three nuclear weapon states, with a long history of managing nuclear weapons, in addition to achieving relative transparency about its operations, the UK experience is worth reviewing for clues about costs. The UK's Ministry of Defence publishes an estimate of the costs of all of its nuclear liabilities in its annual report, giving some indication of what the prospective costs of dismantling British nuclear weapons could be. These nuclear liabilities are costs that have not yet been

[16] Willett, p. 106.
[17] Willett, p. 106.
[18] Willett, p. 106.
[19] Willett, p. 106.

incurred, so they are only estimates and will likely be spread out over at least ten years.

Member of Parliament Paul Flynn requested a breakdown of these costs in the House of Commons in 2006, leading to further information about the relative costs of various disarmament activities. Some of the more revealing line items—in 2006 GBP, with converted 2008 USD figures in brackets—are as follows:[20]

- £3,394 million ($6,769 million) – Costs associated with decommissioning, care and maintenance of redundant facilities (the conditioning, retrieval and storage of contaminated materials); research and development; and the procurement of capital facilities to handle the various waste streams.
- £2,132 million ($4,252 million) – Decontamination and decommissioning of Naval Test Reactor and waste disposal.
- £1,052 million ($2,098 million) – Costs associated with the research, development and construction of the NIREX Deep Waste Repository.
- £935 million ($1,864 million) – Storage of nuclear materials.
- £504 million ($1,005 million) – Berthing and decommissioning of out of service submarines.
- £146 million ($291 million) – Dismantlement of warheads.

The breakdown reveals that the costs of decommissioning various facilities are likely to account for a large portion of disarmament costs, while warhead and storage costs will be less expensive. The UK numbers, however, are only reflective of current nuclear liabilities, and do not accurately reflect the scale of a complete disarmament initiative. To put these numbers in perspective, it cost £1,500 million to recently refurbish the offices of the UK Ministry of Defence.[21] These disarmament numbers are thus relatively modest compared to the normal spending of governments .

Costs of fissile material disposition

An important and inevitably expensive part of the disarmament process will be the disposition of the fissile materials used in nuclear devices, notably HEU and plutonium.[22]

HEU can be down-blended to low-enriched uranium (LEU) and used in a power reactor, so the solution in the case of uranium weapons is obvious. Indeed the US/Russian Megatons to Megawatts program is already disposing of surplus former Soviet HEU in this way. The US purchases the material, thereby offsetting to some extent the past cost of production and of its removal from Soviet nuclear weapons. Under a complete nuclear disarmament regime such use of HEU could be said to offset some of the costs of disarmament, although the economic benefit of using

[20] House of Commons, Hansard, 24 July 2006, column 779W.

[21] David JC MacKay, *Sustainable Energy – without the hot air*, UIT, Cambridge, 2009, p. 219.

[22] Tritium is also essential to modern nuclear weapons but is not of such concern in terms of disposition since it has a half-life of only 12.3 years.

downblended HEU in power reactors is zero compared with using natural uranium or LEU produced directly. Nonetheless there is an incalculable nonproliferation benefit in removing as much HEU from circulation as possible.

Plutonium disposition, in large part because there is still great uncertainty about it, is more challenging and hence the costs less easily calculable. The options for plutonium disposition are numerous and vary significantly in their costs, but all are expensive. Schwartz *et al* estimated the cost of several plutonium disposition options, the more likely of which are examined below.[23]

Disposition option	Cost estimate for disposition of 50 metric tons of plutonium (2008 USD)
New burner reactors	$8.2 billion
Convert to MOX then use in existing light-water reactors (LWR)	$425 million[24] (requires MOX facility)
Converted to MOX then used in dedicated advanced light-water reactor	$4.5 billion to $7.8 billion (requires MOX facility)
Vitrification with fission products	$1.4 billion (maximum)

According to the *Global Fissile Material Report 2008* there is currently a global total of 500 tons of plutonium, about half of which is military.[25] Plutonium disposition looks to be one of the more costly steps of nuclear disarmament, but not unreasonably so given the benefits of a world potentially free of separated plutonium and its associated proliferation risks.

There is, indeed, a danger that states with plutonium stockpiles from dismantled weapons will come to see the material as a resource that is of use in fast breeder reactors which breed more plutonium than they consume. This would increase the amount of plutonium worldwide, creating greater proliferation risks as well as increasing the costs of verifying that such plutonium was not being diverted to military uses. In addition, the economics of fast breeder reactors and the so-called plutonium economy have always been questionable.[26] The cheapest option in the long

[23] Schwartz *et al*, pp. 349-350.

[24] These are the incremental costs of using MOX fuel instead of LEU, and 'This does not include the costs of modifying reactors using MOX fuel, licensing proceedings, subsidies to electric utilities for using MOX fuel, and long-term waste disposal issues associated with the higher plutonium content of spent fuel resulting from MOX irradiation'. See Schwartz *et al*, p. 348.

[25] International Panel on Fissile Materials, *Global Fissile Material Report 2008*, http://www.fissilematerials.org/ipfm/site_down/gfmr08.pdf (accessed 17 September 2009).

[26] See 'Breeder reactors', chapter 12, Report of the Nuclear Energy Policy Study Group, *Nuclear Power Issues and Choices*, Ballinger Publishing Co., Cambridge, Mass., pp. 335-364 and Richard L. Garwin and

term is therefore likely to be vitrification with fission products to make the plutonium unusable for nuclear weapons, followed by long-term deposition in deep geological repositories.

Such deep geological repositories are expensive, but states with nuclear energy programs are already seeking to build them for disposing of high-level nuclear waste from nuclear power plants, so the costs will be partly met by countries' civilian nuclear energy sectors. In the US military nuclear waste is already deposited in a geological repository just outside of Carlsbad, New Mexico. Currently work on its proposed Yucca Mountain facility for civilian nuclear waste is suspended pending a resolution of the entire issue of what to do with such waste, even though nuclear utilities have for years been contributing to a fund for such purposes. In 2008 the US Department of Energy (DOE) increased the lifetime cost estimate for the proposed Yucca Mountain facility in Nevada to $98.5 billion, up 43 percent from its previous estimate in 2001 of $68.8 billion.[27] There may be political controversy in the Western nuclear weapon states about using a civilian facility for military high-level nuclear waste, necessitating the construction of a separate one.

Currently experience with long-term deep geological waste sites is limited. Only Finland and Sweden are close to constructing one and France and the UK are investigating them (for civilian nuclear waste). Since the facilities for military and civilian waste are identical, the experience in building and operating the latter will be applicable to military sites and could result in industrial learning and cost savings over time. No information is available about the arrangements for storing and disposing of nuclear weapons production waste and excess fissionable material in China, India, Israel, North Korea and Pakistan, or the costs involved.

Other considerations in assessing the cost of disarmament

Variability of costs

How much the nuclear disarmament process costs will vary country by country. The older nuclear weapon states' arsenals and delivery systems have been cut dramatically since the end of the Cold War, notably those of the US and Russia, but also those of France and the UK. These states are better equipped to dismantle their nuclear weapons more cost effectively because they already have experience in doing so, along with the necessary facilities. In addition such states already had experience in dismantling older redundant first generation nuclear weapon systems that were replaced in their entirety. In a sense such states have already experienced the process and borne the costs of what would have been complete nuclear disarmament had they not replaced the old systems with new ones.

Georges Charpak, *Megatons to Megawatts: the Future of Nuclear Power and Nuclear Weapons*, University of Chicago Press, Chicago, 2001, pp. 127-152.

[27] 'Yucca Mountain cost estimate rises to $96 billion', *World Nuclear News*, 6 August 2008, http://www.world-nuclear-news.org/newsarticle.aspx?id=20196 (accessed 18 September 2009).

States with smaller nuclear arsenals that have remained relatively constant or have grown since they were first deployed—those of India, Israel, North Korea and Pakistan—are in a different situation, as may be China. Dismantlement facilities are expensive, so states with historically static nuclear arsenals that have not required such facilities will be at a comparative disadvantage when the time comes for dismantlement and disposition. There are, however, options for multilateral cooperation, including financial assistance to these states.

Weapon life cycles

For the older, more sophisticated nuclear weapon states, the weapon life cycle concept is critical to understanding what marginal costs may be accurately attributable to disarmament versus what are appropriately attributable to the construction, maintenance, dismantlement and disposition of nuclear weapons and their delivery systems in their normal life cycle. The US and the Soviet Union went through several generations of nuclear weapons and delivery systems before the end of the Cold War halted their nuclear arms race. The dismantlement and destruction of retired weapons, as well as the costs of environmental clean-up associated with them should not be considered costs of disarmament. Rather these are costs of armament as they are a normal part of weapon life cycles incurred irrespective of arms control agreements or other disarmament initiatives. These costs should normally be amortized over the lifetime of the weapon system's deployment. There are a large number of warheads in reserve or in retirement yet to be dismantled as a result of previous arms control agreements that will also need to be dismantled. The costs of doing so are, however, legacy costs that should also be attributed to weapon life cycles and not disarmament.

Costs of verifiability and speed

If an agreement requires that weapons are dismantled and destroyed in a particular way so that the process is verifiable—as was the case with START I and the INF agreement, for example—those costs are properly attributed to disarmament.[28] Another consideration in costing nuclear disarmament is how quickly it is expected to proceed. Urgency is not without a price. If rapid progress is expected, the costs are substantially higher than if the process is drawn out over several decades. Not only do total costs increase as a result of the demand for larger dismantlement capabilities and storage requirements, but the short-term financial burden placed on states is more difficult to bear than if the process were more gradual. Any costs associated with dismantling weapons sooner than their normal life cycles would dictate should be attributed to nuclear disarmament. The question that should be asked when determining if a cost is attributable to a weapon life cycle or disarmament is thus 'would the cost be incurred in the absence of a disarmament initiative?'

The cost of non-disarmament

The alternative to nuclear disarmament—maintaining or increasing existing stockpiles—is not without its costs as well. For the nuclear weapon states, the one-off

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[28] Willett, p. 24.

cost of dismantling their arsenals (even including the continuing cost of verification) is insignificant compared to the costs of maintaining a nuclear arsenal indefinitely. The costs of building and deploying the US nuclear arsenal from 1940 to 1990—according to Schwartz *et al*—was $4,762 billion.[29] This number does not include the costs of targeting and controlling nuclear weapons; defending against them; nuclear waste management and remediation; or reparations to those victimized by nuclear weapons testing or working in weapons laboratories. From the perspective of the nuclear weapon states, the one-time costs of disarmament will pale in comparison to the costs of continuing to deploy, maintain and upgrade nuclear weapons in perpetuity. The question then becomes one of whether the recurring costs of disarmament—verification, nonproliferation efforts and other measures—are higher than the recurring costs of maintaining and upgrading a nuclear arsenal. Given the enormous cost of nuclear weapons to date the answer is 'probably not'.

Keeping nuclear weapons also involves an opportunity cost. Money invested in developing, deploying and dismantling nuclear weapons is money that cannot be invested in other priority areas, be they conventional military forces, domestic programs or foreign aid. If the cost of disarming is less than the cost of maintaining nuclear weapons—as it undoubtedly would be in the long-run—the nuclear weapon states need to also consider the additional benefits they receive from being able to divert financial resources from costly nuclear programs.

A potential issue in some nuclear weapon states is that they may not be able to afford to safely and securely dismantle their nuclear arsenals. Some states will undoubtedly require assistance in doing so—from other nuclear weapon states and non-nuclear weapon states—if they prove willing but unable participants in nuclear disarmament. The G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction is intended for exactly this purpose, and has been effective in securing nuclear material in the former Soviet Union since 2002. The Global Partnership has a budget of $10 billion over 10 years, with contributions made by all of the G8 states and a select handful of others. It is set to expire in 2012, but extension beyond then is certainly possible, and desirable. The Global Partnership would be an effective mechanism to assist those nuclear weapon states unable to pay for nuclear disarmament on their own.

Conversion

There are numerous variables to consider about the ultimate fate of the resources—facilities, equipment, material and personnel—that would be a by-product of nuclear disarmament. In some cases the cost of disarmament may be offset by conversion or re-employment. Some facilities may be converted to peaceful applications, while in the case of others—such as a dedicated plutonium production reactor—there is little choice but to dismantle it and absorb the costs. How much of a nuclear weapons program can be diverted to peaceful uses is dependent on the composition of each

[29] Schwartz *et al*, pp. 32, 104.

state's program, the practicality of certain peaceful applications and the negotiated provisions of the disarmament treaty that mandates complete nuclear disarmament. The difficulty and cost of verifying conversion and subsequent non-diversion, as opposed to complete dismantlement, may be a critical factor.

Perverse costs of the nuclear disarmament process

Putting a price tag on nuclear disarmament is not easy to do given the numerous outstanding questions about how the process will play out. There are several potential 'pathways to zero', but most acknowledge that years of unilateral or bilateral disarmament steps are needed before complete nuclear disarmament can be achieved. The US and Russia have rightfully taken the lead. As this paper was being written the two former superpowers were working to negotiate a follow-on to START I, which expires in December 2009. The START follow-on is seen to be a logical first step towards global disarmament given the disproportionately large size of the US and Russian nuclear arsenals. Cost data for even this immediate step of the START follow-on in the disarmament process is not known.

However, in August 2009 a bipartisan group of US Senators urged President Obama to provide a '10-year financing assessment for bolstering the nation's nuclear arsenal' that, in their view, necessarily goes hand in hand with a START replacement.[30] This historically familiar 'twin track' approach of rebuilding while disarming argued that, 'The plan should come with estimates on how much could be spent to update the U.S. nuclear complex and to ensure that personnel are ready to develop new weapons that might be needed in the future'.[31] This bipartisan response to the START replacement shows that costing the disarmament process is further confounded by the costs of upgrading remaining, albeit shrunken, nuclear arsenals, as well as the costs of maintaining the option of testing and building new weapons should the 'need' arise.

The argument here is that if the US is to further reduce its nuclear arsenal, it needs to ensure that the weapons that remain constitute a credible and effective deterrent. While contestable in reality, this argument may be sufficiently powerful politically as to raise the costs of disarmament by compelling spending on nuclear readiness at the same time.

Advocates of virtual disarmament, whereby states would keep intact a certain level of capacity for quickly reassembling a nuclear arsenal in the case of breakout by another state, also foresee high levels of spending on readiness. Such costs, while not validly attributable to nuclear disarmament, will nonetheless factor into decisions about the overall financial implications of a move to zero, as perceived by each nuclear weapon state—as this US example demonstrates.

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[30] "Senators Urge Obama to Include Cost Estimates With START Replacement," *Global Security Newswire*, 4 August 2009.

[31] 'Senators Urge Obama…'

The Costs of Disarmament 2: Verification
Verification of nuclear disarmament is the second key element in considering the cost of nuclear disarmament. Verification costs will consist of two components: unilateral and multilateral.

Unilateral verification costs
The first component of verification costs results from the verification activities that states choose to undertake unilaterally. One reality of the verification regime for complete nuclear disarmament is that major powers, particular former nuclear weapon states, will not be comfortable with just a multilateral verification regime, no matter how powerful is it. They will use their own intelligence and information gathering activities to monitor the actions of other states. Verification in this case will comprise the intelligence-gathering and analysis apparatus of such states, including technical measures such as reconnaissance satellites and other remote monitoring devices known as national technical means (NTM). Costs in this case are directly determined by each individual state as a result of political, strategic and financial considerations. These will inform a decision about what resources the state is prepared to dedicate to providing itself with additional reassurance about the compliance of other states with their nuclear disarmament obligations. A particular concern will be to detect early signs of 'breakout'.

In addition to purely unilateral measures, there may also be cooperative verification arrangements between pairs or larger groupings of nuclear weapon states. One can envisage that the US, Russia and China, and India and Pakistan, may wish to establish their own cooperative verification arrangements which may involve cost-sharing. One of the original features of the multilateral Chemical Weapons Convention was to be an arrangement whereby the US and the Soviet Union established a bilateral verification mechanism to monitor destruction of their respective chemical weapons stockpiles. While this did not eventuate it is a possible model for nuclear disarmament.

Under START I, the use of existing NTM, coupled with cooperative measures, went a long way towards reassuring the two former superpowers that the treaty was being implemented and in keeping the verification costs relatively low. Of course global nuclear disarmament will require something more robust that will increase the costs compared to the START agreement, but NTM will continue to be an important part of any verification regime. In addition to supporting states' own analysis of compliance with a nuclear disarmament regime, NTM is also likely to be made available to the multilateral side of the verification regime. This would build on the current situation in which the IAEA receives limited intelligence information from member states in detecting non-compliance with nuclear safeguards and the NPT. This arrangement is at no cost to the multilateral enterprise and is thus a free benefit. Under a nuclear disarmament regime the cost of NTM and other national intelligence gathering activities will continue to be absorbed by the wealthy, mostly former nuclear-armed nations, thereby reducing the costs of verification that would need to be assumed by non-nuclear weapon states.

For those states with significant NTM and other intelligence assets the question will not be how much verifying nuclear disarmament *per se* costs, but what the marginal cost of verifying nuclear disarmament will be, in addition to all of the other tasks that such assets are used for. There may be additional technologies and human assets that are judged necessary for verifying nuclear disarmament in particular, but by and large it is likely that existing assets will simply be extended and improved and the costs absorbed in regular budgetary processes for intelligence-gathering activities.

Multilateral Verification

The second component of verifying compliance with a nuclear-free world will be a multilateral verification regime. While there is still a great deal of uncertainty about the possible character of a such a regime, there are some general elements that can be foreseen.

A multilateral verification regime will most likely involve an international agency tasked with carrying out monitoring and verification activities, similar to the IAEA. Unlike the IAEA it is likely to have universal membership, since it would be too great a risk to leave any state out of a nuclear disarmament obligation. An accounting system for nuclear material—similar to but more extensive and sophisticated than the existing IAEA system—is a likely component. It would cover all nuclear materials anywhere, since all of it will be deemed for peaceful purposes, with the possible exception of fuel for nuclear-powered submarines (although this too would need to be subject to some type of verification arrangement). Significant data exchanges and/or reporting is yet another likely feature of a new regime.

Finally, it is, according to one author, 'universally understood' that a verification regime will require on-site inspections (OSI).[32] These are likely to take many forms, including baseline inspections to determine the veracity of state declarations, routine inspections (both announced and unannounced) and challenge inspections. While deemed essential, they also tend to be costly compared with technological monitoring systems. The existing verification system for the CTBT would need to be completed and continuously improved in order to ensure that no state ever again tests a nuclear device.

The essential tools for verifying nuclear disarmament multilaterally thus already exist, although verification research should be ramped up and pursued indefinitely in a nuclear weapon-free world, so those costs also need to be factored in.

The outstanding question for determining the cost of multilateral verification is 'how much is enough'? During negotiations on a nuclear weapon convention states will

[32] Bruce D. Larkin, *Designing Denuclearization: An Interpretive Encyclopedia*, Transaction Publishers, New Brunswick and London, 2008, p. 257.

need to decide what mix of verification tools is required multilaterally, bearing in mind likely synergistic effects both among multilateral tools and NTM, and crucially how much they are collectively willing to pay. As in all negotiations on arms control verification there will be crucial trade-offs between comprehensiveness, intrusiveness and cost. The more extensive and intrusive the verification, the greater the likelihood of higher costs. There is a point, however, at which spending more on verification will bring only marginal gains in verifiability.[33] For example, it would be extremely expensive to continuously monitor every chemical plant in the world to ensure that it was not producing chemical weapons, even though high levels of verifiability would be achieved. Much cheaper and sufficiently effective verification is possible through declarations, data analysis and random inspections.

The principle of non-discrimination in multilateral verification arrangements may increase costs as it requires the application of the same level of verification to all parties, regardless of whether they are likely to be treaty violators or not. The basis for such a verification system is, therefore, not intentions, but potential or actual capabilities. It is not yet clear whether a nuclear disarmament verification regime would focus intensified verification on the former nuclear weapon states given that they are the most likely to retain residual virtual capabilities, or indeed whether all highly developed countries with nuclear weapons potential might be subject to greater scrutiny. On past experience such discrimination may be politically unacceptable to some states (one can imagine India, Pakistan and Brazil being particularly sensitive on this point). It may in any case be unnecessary given that the former nuclear weapon states and other advanced states will be monitoring each other closely. Nonetheless, decisions about application of the principle of non-discrimination will have an important bearing on the ultimate costs of the multilateral system.

Costing the multilateral verification regime

Perhaps one of the greatest bargains in global governance since the formation of the UN is the IAEA. Given the importance of the agency's task of detecting non-compliance with nuclear safeguards and with the NPT its cost is small. In 2009, the Agency's regular budget is $428.7 million. In addition it has set a goal of $121.4 million in voluntary contributions that are considered necessary for the agency to function. With these rather modest funds the IAEA applies nuclear safeguards at 1099 facilities worldwide, almost all in non-nuclear weapon states.

Since the nuclear weapon states have significantly more peaceful and military nuclear facilities than the non-nuclear weapon states, a verification regime even at the current level of intensity, applied to all states in a nuclear disarmed world will have greater demands put on it, and thus a greater cost. It is unlikely the current level of safeguards

[33] The Verification Research, Training and Information Centre (VERTIC) and the United Nations Institute for Disarmament Research (UNIDIR), *Coming to Terms with Security: A Handbook on Verification and Compliance*, UNIDIR, Geneva, 2003, pp. 13-14.

intensity will be deemed sufficient, even if all states were to adopt an Additional Protocol.

Given the uncertainty about how much verification will be deemed enough, it is impossible at this stage to make precise estimates of the size of the organization, the nature and size of the inspectorate and the types of technologies that will be deemed necessary. But even assuming an increase that is an order of magnitude higher—five times the current IAEA budget—the costs of verification are manageable at roughly $2.1 billion annually. To put this number in perspective, the annual operating budget for the city of Ottawa in 2009 is $1.9 billion. Given the benefits of a nuclear weapon-free world, a $2.1 billion dollar operating budget for a verification agency—be it the IAEA or another designated agency—is perfectly justifiable and attainable. These costs will presumably need to be borne in perpetuity. By comparison the London Olympics in 2012 are estimated to cost at least £9 billion ($14.7 billion), while the cost of decommissioning all of the UK's nuclear power plants is estimated at £70 billion ($114 billion). More relevant to nuclear disarmament is 'the cost of not making nuclear weapons', as David McKay engagingly puts it, namely the US Department of Energy's stockpile stewardship program to maintain the nuclear stockpile *without* nuclear testing and *without* large-scale production of new weapons: $4.5 billion per year.[34]

The costs of future multilateral verification are likely to be allocated in a manner similar to the way costs for the IAEA and most other UN agencies are allocated. The UN scale of assessment is thus the best predictor of how much individual states would need to contribute. In the $2.1 billion example, and assuming the current UN scale of assessments is used, the following table shows how much key states would be responsible for contributing annually.

Country	Multiplier	Contribution (USD millions)
United States	22.00%	$462.0
Japan	19.47%	$408.8
Germany	8.66%	$181.9
United Kingdom	6.13%	$128.7
France	6.03%	$126.6
China	2.05%	$43.1
Mexico	1.88%	$39.5
Australia	1.59%	$33.4
Russia	1.10%	$23.1
Saudi Arabia	0.71%	$15.0
Norway	0.68%	$14.3
India	0.42%	$8.8

[34] MacKay, p. 220.

South Africa	0.29%	$6.1
Indonesia	0.14%	$3.0
Pakistan	0.06%	$1.2

There are a number of assumptions used in this estimate that will undoubtedly prove inaccurate as decisions are made about disarmament verification. The $2.1 billion yearly price tag may be too low depending on the verification model used. The UN assessment scale furthermore may not be the best mechanism to distribute costs, particularly given some apparent contradictions such as Japan and Germany paying a large share while an economically rising nuclear weapon state like China pays much less. It may be that in the negotiations on a final disarmament regime the states that developed nuclear weapons are required to pay more, regardless of whether they are considered developed or not on the basis that if they were well off enough to squander money on nuclear weapons they are well off enough to pay for disarmament. The numbers above are thus potential orders of magnitude only, intended to give a rough estimate for what multilateral verification might cost.

Although the costs of safeguarding peaceful nuclear facilities increases over time as more of them are built, for military nuclear facilities this will not be the case. As nuclear weapons complexes are dismantled or diverted to other uses, the burden on a potential verification agency should decrease rather than increase. It is not difficult to envision a scenario in a nuclear-free world in which in the long-run, as confidence increases that the former nuclear weapon states (or perhaps just some of them) are complying, that the demands for verification will decrease.

However, if the projected revival in the use of nuclear energy for generation of electricity occurs[35] so will the demands on the existing IAEA safeguards system in order to ensure that there is no diversion to military purposes. Of particular concern is the possibility that increasing numbers of states will begin enriching uranium and reprocessing plutonium for fuelling their power reactors. The multilateralisation of the sensitive parts of the nuclear fuel cycle and/or a ban on reprocessing of plutonium for any purpose (civil or military) would have varying cost implications for the multilateral verification regime. Multilateral facilities would still need to be safeguarded, although perhaps less intensively than a series of national facilities.

Nuclear disarmament will also require national authorities to oversee national involvement in multilateral verification work or in other collaborative efforts with other states. The former US On-Site Inspection Agency (OSIA)—whose activities now fall under the Defense Threat Reduction Agency (DTRA)—is a good example of this. The OSIA's mission was to conduct US inspections of foreign facilities,

[35] For detailed analysis of the so-called nuclear energy revival see Nuclear Energy Futures Project, Canadian Centre for Treaty Compliance and Centre for International Governance Innovation (CIGI), www.cigionline.org

territories and events, beginning mainly with the INF Treaty.[36] It did so by organizing, training, equipping and deploying inspection, monitoring and escort teams.[37] The total budget for the OSIA in 1998, its final year before being consolidated into the DTRA, was (in 2008 USD) $98.9 million.[38] The verification activities of the US were extensive, so this number is not necessarily reflective of what will be needed in other countries, particularly in non-nuclear weapon states, but it is an indication of what can be expected.

Ultimately how much verification will cost comes down to the intrusiveness question germane to every verification initiative. More intrusive verification measures—such as on-site inspections—are more costly than less intrusive verification measures—such as data exchange or declarations. It currently seems likely that states will require rather intrusive verification, especially in the early stages of disarmament, but there is still much uncertainty about whether that will be true in the long-term.

Conclusions and recommendations

Data specific to the costs of dismantling nuclear weapons and of a potential verification regime is scarce, so the information available for compiling this study was limited. It nonetheless provides an overview of some of the cost data that is publically available and discusses considerations that need to be taken into account when seeking to cost nuclear disarmament and a verification regime to accompany it.

More work clearly needs to be done to permit an accurate cost analysis of nuclear disarmament. The first step would be for research to be undertaken in each of the nuclear weapon states aimed at estimating what it would cost for that state to dismantle its own nuclear weapons and associated capabilities. Such studies could emulate Schwartz *et al*'s *Atomic Audit*, but with an emphasis on complete nuclear disarmament by each state.

Second, the discussion about how nuclear disarmament would be verified needs to make headway before it will be possible to determine accurately the costs of verification. States—particularly the nuclear weapon states—need to begin discussing what they would require of a verification regime. In the meantime they should emulate the British and begin studies on what verification measures might be applied in the case of their own weapon systems. In the late 1990s the Atomic Weapons Establishment at Aldermaston was directed by the UK Secretary of State for Defence to conduct an 18-month study to identify the technologies, skills and techniques

[36] US Department of Defense, On-Site Inspection Agency: Operation and Maintenance, Defense-Wide, FY 2000/2001 Biennial Budget Estimates, [N.D]. http://www.defenselink.mil/comptroller/defbudget/fy2000/budget_justification/pdfs/01_Operation_and_Maintenance/fy00pb_osia.pdf (accessed 18 September 2009).
[37] US Department of Defense.
[38] US Department of Defense.

required to verify nuclear weapons reductions and to what extent the UK had such capabilities. This study was published in 1998 and reported to the UN.[39]

Third—and this is this report's principal recommendation to the ICNND—is that it commission a group of independent experts to engage in a detailed study of the costs of nuclear disarmament of the type that was not possible in this report. If there is a large lacuna in the countless studies of nuclear disarmament to date it is in respect of the costs. Such a study is likely to take a number of years and involve an array of experts from a variety of fields, including the following:

- Finance and budgetary specialists
- Defence economists
- Military personnel
- Nuclear disarmament experts
- Scientists and technicians
- Verification experts.

Nuclear disarmament is not inexpensive, but the costs pale in comparison to the consequences—both economic and otherwise—of the continuation of a discriminatory international system based on the threat of nuclear annihilation. If nuclear disarmament is agreed to be a goal that will vastly improve international security, then the costs are not so high that they should be anything more than a secondary concern. What does seem clear is that the nuclear weapon states will inevitably bear most of the financial burden in moving towards a nuclear-free world and that the financial burdens placed on the non-nuclear weapon states will be light, especially considering the security benefits they will accrue. The subject of the cost of nuclear disarmament is nonetheless a void in the research on nuclear disarmament that needs to be filled in order to advance the discussion about nuclear disarmament beyond the philosophical to the practical.

[39] Atomic Weapons Establishment, *Confidence, Security & Verification: The challenge of global nuclear weapons arms control*, 1998.