Assuring destruction forever: 2015 EDITION

REACHING CRITICAL WILL OF THE
WOMEN'S INTERNATIONAL LEAGUE FOR
PEACE & FREEDOM

Photo: Reuters / Yuriko Nakao

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Edited by Ray Acheson

Research and writing by John Ainslie, Merav Datan, Hans Kristensen, Greg Mello, Zia Mian, Pavel Podvig, M.V. Ramana, Trish Williams-Mello, Hui Zhang

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Fly Moskito

Introduction

Ray Acheson, Greg Mello, and Trish Williams-Mello

Article VI of the nuclear Non-Proliferation Treaty (NPT) obligates all states parties to "undertake to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament." Nuclear weapon modernisation is the qualitative aspect of the "nuclear arms race". Forty-five years ago the NPT required this practice to end "at an early date," an outcome the Treaty paired with "good faith" progress toward nuclear disarmament. The NPT, especially as unanimously and authoritatively interpreted by the International Court of Justice, requires nuclear disarmament.[1] The illegitimacy of nuclear weapons is a foundation of the NPT.

Yet as the chapters in this volume show, all of the nuclear-armed states are modernising their nuclear arsenals, and some are continuing to expand them.[2] China, the Democratic People's Republic of Korea, France, India, Israel, Pakistan, Russia, the United Kingdom, and the United States collectively possess approximately 15,650 nuclear weapons.[3]

Modernisation is driven largely by the quest for military advantage. Nuclear "deterrence" requires the threat of the use of nuclear weapons to be credible, and preparations for such use, legitimate. Modernisation, especially if new "military characteristics" are created, refreshes the perceived utility and credibility of nuclear use, both technically and politically. At the same time, modernisation, and specifically the investments necessary for it, is also a legitimacy-making exercise. The greater the investment and sacrifices necessary, the greater the perceived legitimacy of nuclear weapons in national policies.

Like other machines, nuclear warhead components and delivery systems do age, fail, or become incompatible with other modernised weapon system components. Having a nuclear weapon system at all implies modernisation and new capabilities to a greater or a lesser degree, sooner or later. Most weapon system components must eventually be replaced, and decades-old components will invariably be replaced by modern ones. These must sometimes be produced in one-of-a-kind facilities, which themselves must be renewed. Obsolete technologies will not be, and often cannot be, used. Meanwhile some of the skills involved are unique to the nuclear weapons enterprise and require years of training. Maintaining nuclear weapons means that these skills must be developed, maintained, and transmitted to new workers, which in turn implies some kind of continuous real work, certainly including evaluation, design, maintenance, production of some sort, and dismantlement. In short, maintenance, replacement, and upgrading are synonymous with long-continued possession of nuclear weapons.

Thus modernisation is inevitable as long as nuclear weapons exist. The only way to avoid modernisation is to prohibit and eliminate the weapons.

There is no comprehensive, explicit legal prohibition of the possession or use of nuclear weapons. And no treaty governs the total number of deployed nuclear warheads, their alert status, the number of maintained, working nuclear warheads held in reserve, the total number of warheads in the retired inventory or in a firm dismantlement queue, the number of warheads actually dismantled, or the number of reusable nuclear components held in inventory from those warheads. There are no treaty-based qualitative restraints on nuclear weapon system technology.

The programmes and policies of the nuclear-armed states are designed to perpetuate their possession of these weapons into the indefinite future. Internationally, these governments have backed the interests that sustain these programmes by adopting inflexible political positions against pursuing initiatives to ban and eliminate nuclear weapons, or even in most cases to discuss the humanitarian impact of nuclear weapons. They have argued that any activities not explicitly found within the 2010 NPT Action Plan will distract and detract from "progress" on the actions articulated in that plan – which are based on steps that have been on the international agenda since the 1950s.[4] However, most of the incremental steps that have been agreed to have not been implemented. And actions such as modernisation have actually resulted in steps backwards.

Failure by the nuclear-armed states to meet their legal obligation to end the nuclear arms race and eliminate their arsenals must be met with resolve for concrete action by non-nuclear-armed states so as to avoid further entrenchment of the indefinite possession of nuclear weapons.[5] All governments have the responsibility to prevent a humanitarian tragedy.

We know that nuclear weapons represent just a tragedy.

The immediate effects of even a single nuclear weapon detonation are horrifying and overwhelming. One detonation will cause tens of thousands of casualties and inflict immediate and irreversible damage to infrastructure, industry, livelihoods, and human lives. The effects will persist over time, devastating human health, the environment, and our economies for years to come. These impacts will wreak havoc with food production and displace entire populations.[6]

The existence of nuclear weapons generates great risk. There have been many instances of near-misses and potential accidental nuclear detonations.[7] There have also been a number of recent reports of the declining operational atmosphere and disturbing behaviour of those in supposed "command and control" of these arsenals.[8] Furthermore, the policies of "nuclear deterrence" and military doctrines of nuclear-armed states and their allies require preparations for the use of nuclear weapons. The potential use of nuclear weapons in a conflict between their possessors or in pre-emptive or retaliatory strikes against others is not a threat of the past.

Nuclear weapons waste money. The money spent on nuclear weapons not only detracts from the resources available to tackle ecological, social, economic, and energy crises, but also reinforces the institutions that benefit from weapons and war. The maintenance and modernisation of nuclear weapons undermine development and the achievement of global economic and social equality.

The overwhelming majority of states have rejected nuclear weapons. They do not see them as instruments of security but rather of mutual destruction. Yet unlike the other weapons of mass destruction, nuclear weapons have not been categorically banned. Now is the time to address this anomaly, which has been allowed to persist for far too long.

Notes:

1. *Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion of 8 July 1996*, International Court of Justice, 105(2)F, http://www.icj-cij.org/docket/files/95/7495.pdf.
2. The Democratic People's Republic of Korea is not included in this study due to lack of publicly available information on its programme.
3. "Status of World Nuclear Forces 2015," Federation of American Scientists, 1 April 2015 (when accessed 2 April 2015), http://www.fas.org/programs/ssp/nukes/nuclearweapons/nukestatus.html.
4. Statement to the high-level meeting on nuclear disarmament on behalf of France, the United Kingdom, and the United States, delivered by the United Kingdom, New York 26 September 2013; Statement to the UNGA First Committee on behalf of France, the United Kingdom, and the United States, delivered by France, New York, October 2013; Statement to the UNGA First Committee by Russia, 22 October 2013.
5. *A treaty banning nuclear weapons*, Reaching Critical Will and Article 36, April 2014.
6. For details, please see *Unspeakable suffering: the humanitarian impact of nuclear weapons*, Reaching Critical Will of the Women's International League for Peace and Freedom, 2013.
7. Eric Schlosser, *Command and Control: Nuclear Weapons, the Damascus Accident, and the Illusion of Control*, New York: Penguin Books, 2013.
8. "Key findings on nuclear force troubles," Associated Press, 27 January 2014, bigstory.ap.org/article/key-findings-nuclear-force-troubles.

Executive summary

Photo: Library of Congress / US Government

China

Hui Zhang

Current status

There are various estimates on the size of China's nuclear arsenal. Some estimates suggest China currently has approximately 190 nuclear warheads including approximately 120 operationally deployed nuclear missiles and approximately 70 warheads stored for its submarine-launched ballistic missiles and bombers. Each of those nuclear ballistic missiles carries a single warhead, which are normally separated from the missiles.[1] The Federation of American Scientists argues that China has a total stockpile of 250 nuclear weapons.[2] In April 2013, China published a new white paper that gives an overview of China's military strategy. As in previous defence papers and other official documents the white paper does not reveal any basic information on the size of China's current nuclear capability or nuclear arsenal.[3] Unlike the other nuclear weapon states, which are maintaining their current arsenal levels or are slowly decreasing, China is believed to be slowly increasing the size of its nuclear weapons arsenal.[4]

China has not declared publically that is has ended the production of highly enriched uranium (HEU) and plutonium for nuclear weapons, though it is believed that China stopped production of HEU in 1987 and plutonium by 1990. China's military inventory would be about 18±4 tons of weapon-grade HEU and 1.8±0.5 tons of weapon-grade plutonium.[5]

Modernisation

Beijing is concerned with maintaining what it sees as a "limited" and "effective" nuclear arsenal and its modernisation programme has focused on increasing the "survivability" of its land-based strategic missiles. China is phasing out its older missiles and replacing them with new ones in order to increase their range and sophistication.[6] Meanwhile, recently China has sped up the modernisation of its sea-based strategic force. China has replaced its first generation ballistic nuclear missile-carrying submarines.[7] US missile "defence" plans will be a major driving forcing for China's nuclear weapon modernisation, as some Chinese officials are concerned that even a limited missile "defence" system could neutralize China's nuclear force.

China was reported to be phasing out its older missiles, DF-3A and the DF-4, and replacing them with new DF-21 and DF-31In addition, China has deployed four other nuclear-capable ballistic missiles, the DF-5A, DF-31, DF-31A, and JL-2.[8] These developments in missile capability will both increase the range and sophistication of land-based systems and nuclear-powered ballistic missile submarines. Estimates as the end of 2014 indicate that China has about 120 land-based nuclear ballistic missiles that can carry one warhead each. A 2014 US DoD report states that China may be developing a new road-mobile ICBM known as the Dong Feng-41 (DF-41), possibly capable of carrying multiple independently targetable re-entry vehicles (MIRVs).[9] China also has additional warheads for their submarine launched ballistic missiles (SLBMs) as well as bombs for air delivery. Some analysts have argued that China is currently modernising its sea-based strategic force in order to secure a second-strike force.[10]

Economics

It is difficult to estimate the cost of China's nuclear weapon force, however, assuming that China consistently maintains 5% of its overall military expenditure for its nuclear weapons programme,[11] China would have spent between US$6.6 and $13billion on its nuclear programme in 2014.

International law and doctrine

China has signed but not ratified the Comprehensive nuclear Test Ban Treaty (CTBT). Most estimates assume China will ratify the CTBT only after the United States does. China officially supports the commencement of negotiations of a fissile materials cut-off treaty (FMCT) at the Conference on Disarmament, but US plans to develop its missile "defence" capabilities will likely affected China's willingness to participate in FMCT negotiations. If China remains concerned about US missile "defence," it could seek to develop more fissile materials to fuel additional ICMBs. In terms of disarmament, China is bound by article VI of the NPT to negotiate the elimination of its arsenal, though has consistently demanded the US and Russia reduce their arsenals first.

Public discourse

China is one of the least transparent of the nuclear-armed states. There is scant public debate about nuclear weapons in China. After US President Obama outlined his "vision" of a nuclear weapon free world, an online survey conducted by the People's Daily newspaper indicated that 51% of respondents wanted nuclear disarmament while 49% did not.[12] Beijing believes the transparency of its own nuclear strategy and nuclear doctrine is more important than that of its force posture. Further, China contends the opacity of its force posture can serve to enhance the "deterrence effect" of its smaller nuclear force, which is helpful for maintaining "strategic stability". However, a certain level of nuclear transparency measures, including nuclear strategic intentions and nuclear capabilities, are seen as necessary to maintain nuclear "strategic stability" among nuclear-armed states.

France
Hans Kristensen

Current status

France possesses approximately 300 nuclear warheads, approximately 290 of which are deployed or operationally available for deployment on short notice.[13] Its delivery vehicles consist of approximately 40 aircraft assigned a total of 54 cruise missiles; and four nuclear-powered ballistic missile submarines (at least two of which are always fully operational) equipped with nuclear-armed long-range ballistic missiles.[14] Former president Nicolas Sarkozy stated in 2008 that the French nuclear "arsenal will include fewer than 300 nuclear warheads" and that it "has no other weapons beside those in its operational stockpile."[15] But in February 2015, President François Hollande stated that the stockpile included 300 warheads for 48 SLBMs and 54 cruise missiles.[16] France is no longer thought to be producing fissile materials for nuclear weapons. It is believed to have an estimated six tons of plutonium and 26±6 tons of highly enriched uranium.[17]

Modernisation

France is replacing its remaining M45 sea-launched ballistic missile with the more capable M51 on its four Triumphant-class submarines. Starting in 2016, one year later than planned, the M51 will receive a new nuclear warhead, known as the TNO (Tête Nucléaire Océanique). In February 2015, President François Hollande announced a decision to develop a SLBM to arm a next-generation SSBN of about the same size as the current Triumphant-class SSBN.[18]

Holland also declared that studies have been carried out for a next-generation air-launched cruise missile,[19] tentatively known as ASN4G.[20] Half of the land-based nuclear bomber force has been upgraded to Rafale, and by 2018 the Rafale will also replace the remaining Mirange 2000Ns at Istres Air Base. That same year, the first two of a fleet of 12 Phoénix-class Airbus tankers will be deployed at Avon Air Base.

President Hollande also declared in 2015 that he had "instructed the Atomic Energy Commission [CEA] to prepare the necessary adaptations of our nuclear warheads ahead of the end of their operational life."[21]

Economics

The French government has indicated that it spends approximately US$4.6 billion on its nuclear forces each year,[22] though a report from Global Zero estimates that the total cost for 2011 was approximately $6 billion.[23] The 2015 budget envisions $3.8 billion for nuclear weapon equipment.[24]

International law and doctrine

Despite France's obligation to pursue negotiations toward nuclear disarmament, President Hollande declared in 2015 that "the time of the nuclear deterrent is not a thing of the past. There can be no question of lowering our guard, including in that area."[25] Moreover, Hollande said it is French policy that, "If the level of other arsenals, particularly those of Russia and the United States, were to fall one day to a few hundred weapons, France would respond accordingly, as it always has. But today, that scenario is still a long way off."[26] These statements, together with the pledge to continue to modernise French nuclear forces, appears to be in conflict with France's obligations under the NPT to negotiate disarmament.

Public discourse

There is scant debate in France over the composition or cost of its nuclear forces.

India

M.V. Ramana

Current status

India is estimated to have 90–110 nuclear warheads.[27] It is also developing a range of delivery vehicles, including land- and sea-based missiles, bombers, and submarines. There are no official estimates of the size of India's stockpile of fissile materials, though it is known that India produces both HEU for its nuclear submarines and plutonium for weapons. India is estimated to have a stockpile of 3.2 ± 1.1 tons of HEU as of the end of 2014.[28] With regard to plutonium, India is estimated to have a stockpile of 0.59 ± 0.20 tons of weapon-grade plutonium by the end of 2014.[29] There has been speculation that India has used reactor-grade plutonium in its nuclear weapons, in which case, the nuclear arsenal could potentially be much larger: as of the end of 2014, between 2.0 to 4.4 tons of reactor-grade plutonium is estimated to have been separated from its power reactors.[30] Its fast breeder reactor programme also provides another potential source of producing weapon-grade plutonium; however, construction of the first Prototype Fast Breeder Reactor has experienced a series of delays and it is now expected to be commissioned only in late 2015 or early 2016, about six years after the initial projection.[31]

Modernisation

The primary focus of modernisation has been on increasing the diversity, range, and sophistication of nuclear delivery vehicles. The latest of the missiles in this series is the three-stage, 5,000 kilometer range Agni V, which is fired from what is described as a canister rather than a fixed concrete launch pad.[32] The significance of this firing mode is explained by the former Director General of the Defense Research and Development Organization (DRDO), "In the second strike capability, the most important thing is how fast we can react. We are working on cannisterised systems that can launch from anywhere at any time."[33] Agni V is scheduled for further tests and induction into the armed forces is projected for 2017.[34] The DRDO has also been developing the Nirbhay cruise missile, which had its first successful test in October 2014.[35] The first test of a 3000 kilometer range submarine launched ballistic missile named K-4 was carried out in March 2014.[36] India is in the process of deploying its first nuclear submarine, Arihant, which began "sea acceptance trials" in December 2014, having earlier "passed its harbor acceptance trials."[37] There is evidence from satellite images that the current uranium enrichment plant at Rattehalli capacity is being expanded.[38] The nuclear establishment is in the process of building a new complex in the eastern city of Vishakhapatnam, which will host two research reactors, including one that "will be similar in design to the existing Dhruva research reactor" that is used to produce plutonium for weapons.[39]

Economics

The expansion of India's nuclear and missile arsenals are part of a larger military build-up and consistently-increasing military spending. However, there is no reliable public estimate on nuclear weapon spending in India. The Defense Budget for 2015 saw an eleven percent increase in defense spending.[40] In 2014, India achieved the dubious distinction of being the largest arms importer in the world.[41] Increasing defense expenditure and spreading the wealth around has been an interest of both the military (especially retired military leaders) and the corporate sector.[42] Private corporations have benefitted from the expected boost in defense manufacture under the Modi government. Many of the companies saw their stock prices go up significantly when the Hindu Nationalist Bharatiya Janata Party won the elections in 2014.[43]

International law and doctrine

Dating back to 2003, India's official nuclear doctrine is very brief and gives little detail on what it envisions for its nuclear arsenal.[44] However, a draft report from the National Security Advisory Board released a few years earlier is far more detailed.[45] It calls for India's nuclear forces to be deployed on a triad of delivery vehicles of "aircraft, mobile land-based missiles and sea-based assets" that are structured for "punitive retaliation" so as to "inflict damage unacceptable to the aggressor".

Since the 1974 nuclear test, the Indian government's focus in arms control diplomacy has been to resist signing onto any international treaties that impose any obligations on its nuclear arsenal. This allows the government to maintain that it is a responsible member of the international community because it has not breached any agreement. It also interprets this as meaning there are no legal constraints on any modernisation activities that may affect the quantity or quality of its nuclear weapons. However, its activities may not be in complete concordance with international law; the 1996 advisory opinion of the International Court of Justice maintained that the obligation for disarmament is not restricted to signatories of the NPT.

Public discourse

By and large, the discourse surrounding development, modernisation, and expansion of the nuclear arsenal involves jubilation about India becoming a militarily powerful state. Media articles often obsess over how few countries possess one or the other of the many destructive capabilities – nuclear submarines, anti-satellite weapons, submarine launched ballistic missiles, and so on – and extol India for becoming just the third or sixth or whatever country to achieve the dubious status of acquiring these armaments. Like national security elites everywhere, Indian security policy makers have used secrecy as a weapon to quash independent questions, increasingly clamping down on the reporting of various details arbitrarily deemed secret.

Israel
Merav Datan

Current status

Estimates about the size of the arsenal are based on the power capacity of the nuclear reactor near Dimona. Experts and analysts outside of Israel estimate that Israel's current nuclear force ranges from 60-80 weapons at the low end to over 400 at the high end. The most recently cited figure is 80 warheads.[46] It is assumed that Israel has a triad of delivery systems: land, air, and sea. It is estimated that, Israel could have produced approximately 840 kg of weapons-grade plutonium.[47] Estimates of HEU production are even more difficult to make though public information suggests Israel has a uranium enrichment programme.[48] A recent estimate has assumed Israel possesses approximately 300 kg of HEU.[49]

Modernisation

In light of current and planned nuclear capabilities, it seems that the country is continuing to "enhance" its triad of delivery systems.[50] Nuclear weapons modernisation is related to modernisation activities in the security sector generally, including in areas of information technology, advanced military technology, and outer space technology. In September 2014, Israel received the fourth of six German-made submarines.[51] Theses submarines are reportedly nuclear capable.[52]

Economics

There is no reliable public estimate on nuclear weapon spending in Israel.

International law and doctrine

Israel has not signed or ratified the NPT and interprets this as meaning it is not bound by the article VI disarmament obligation. Israel has signed but not ratified the CTBT, citing concern with the as-yet incomplete development of the verification regime and potential abuse of this regime; Israel's status in the policy making organs of the Treaty; and concerns with the regional security situation in the Middle East.[53] It is party to a number of non-proliferation-related agreements, on the basis of which it projects itself domestically and internationally as a responsible non-proliferant. Its position of opacity means it has no public nuclear weapon doctrine.

Public discourse

The policy of opacity entails a nuclear weapons capability about which "everyone knows" (domestically and internationally) and an umbrella of secrecy covering the physical and doctrinal elements of this capability. The secrecy surrounding Israel's nuclear programme has taken on a life of its own at the domestic level with Israelis practicing self-censorship on a wide range of nuclear issues. At the same time, a discourse does exist at the academic level and increasingly in the media, driven in large part by debate over Iran's nuclear programme. This discourse relies primarily on foreign sources. Historically, public opinion polls have indicated support for the nuclear option though a new survey has indicated that 65% of Israelis would prefer a nuclear weapon free Middle East to the current situation.[54]

Photo: U.S. Air Force photo

Pakistan
Zia Mian

Current status

As of the end of 2014, Pakistan was believed to have on the order of 130 nuclear weapons, an almost ten-fold increase from the year 2000. The growth of the arsenal appears to have been steady for most of the past decade but it may begin to increase at a faster rate in coming years as additional plutonium becomes available from the production reactors that came online in 2013 and 2014 and new missile systems move from development to deployment. Pakistan has a number of short-range, medium, and longer-range road-mobile ballistic missiles as well as ground-launched, air-launched and possibly sea-launched cruise missiles in various stages of development that are capable of delivering a nuclear warhead. It is estimated that Pakistan could have a stockpile of 3 tonnes of weapon-grade HEU and almost 200 kilograms of plutonium by the end of 2014. It continues to block talks on a fissile material cut-off treaty at the United Nations Conference on Disarmament.

Modernisation

Pakistan is moving from an arsenal based wholly on HEU to greater reliance on lighter and more compact plutonium-based weapons, which is made possible by a rapid expansion in plutonium production capacity. As of the end of 2014, it has four plutonium-production reactors in operation and a third reprocessing plant being commissioned or possibly operating. Pakistan's arsenal is moving from aircraft-delivered nuclear bombs to include nuclear-armed ballistic and cruise missiles and from liquid-fueled to solid-fueled medium-range missiles. In early 2015, it tested its newest ballistic missile – with a maximum range of 2750 km. A long-term concern now driving Pakistan's nuclear programme is the US policy of cultivating a stronger strategic relationship with India to counter the rise of China. This may tie the future of Pakistan and India's nuclear weapons to the emerging contest between the United States and China.

Economics

There is almost no information about the funding of Pakistan's nuclear weapons programme. It is clear that a significant fraction of Pakistan's financial resources go to its nuclear weapons, but that this cost is not a large share of its overall military spending. Assuming that like overall military spending, nuclear weapons spending, has kept pace with increases in gross domestic product, Pakistan may spend an estimated US$4 billion a year on nuclear weapons. Despite extensive foreign military assistance, Pakistan's effort to sustain its conventional and nuclear military programmes has come at increasingly great cost to the effort to meet basic human needs and improve living standards and the country continues to rely on extensive bilateral and international economic aid.

International law and doctrine

Pakistan is not a signatory to the NPT nor has it signed the CTBT and it appears to recognize no legal obligation to restrain or end its nuclear weapons and missile programme. The government has, however, said it supports negotiation of a nuclear weapons convention. Pakistan has blocked negotiations of a fissile material cut-off treaty at the Conference on Disarmament, arguing that it would only further entrench asymmetries between the nuclear-armed weapon states. In 2014 Pakistan proposed the outline for an fissile material cut-off treaty that seemed intended to create a rough parity in fissile material stockpiles with India and is unlikely to be accepted by other states. Pakistan has indicated it would allow talks to start if were granted an exemption from the nuclear trade sanctions imposed by the Nuclear Suppliers Group as India has been.

Public discourse

The government has sought to create a positive public image of the nuclear weapons programme, often by linking it to national pride and identity. Pakistan's major political parties support the nuclear weapons programme. The central thrust of most public debate about Pakistan's nuclear weapons is the struggle with India, with Pakistan's nuclear weapons seen as a response to India's.

Russian Federation
Pavel Podvig

Current status

Russia is estimated to have a total stockpile of 8000 nuclear warheads, of which about 4300 are believed to be in active stockpile.[55] In the New START data exchange Russia reported that in September 2014 it had 528 operationally deployed launchers and 1643 nuclear warheads.[56] The actual number of delivery systems and warheads in the strategic arsenal is somewhat higher, mostly because New START does not accurately account for warheads associated with strategic bombers. According to best estimates based on data exchange under New START and other expert assessments, Russia has, as of March 2015, 489 operational strategic launchers – 305 ICBMs, 128 SLBMs, and 66 bombers. It has about 1900 strategic warheads associated with these launchers –1166 on ICBMs, 512 SLBM warheads, and about 200 nuclear weapons that could be delivered by bombers.[57] Russia is estimated to have about 670±120 tons of HEU and 128±8 tons of weapon-grade plutonium (plus 50 tons of reactor-grade plutonium).[58]

Modernisation

President Putin announced in November 2013 that Russia should replace its Soviet-built arsenals with modern weapons to counter new evolving threats.[59] Under this process, Russia will allocate about $700 billion to a broader military rearmament, which will include 400 new ICBMs and eight SSBNs.[60] Russia's modernisation plans indicate that it is determined to maintain parity with the United States in terms of number of warheads and delivery systems. Most of the currently operational ICBMs are being retired but new multiple-warheads missiles are being deployed to replace them. One new solid-propellant ICBM is undergoing flight tests.[61] The government also made a commitment to development of a new multiple-warhead liquid-fuel ICBM, which is supposed to be ready for deployment in 2018.[62] Russia is also upgrading its SSBN fleet with a planned construction of eight new submarines of Project 955 Borey class, carrying 16 Bulava missiles.[63] In 2013 the first two Borey submarines formally joined the Russian Navy (although none of the submarines has ballistic missiles on board).[64] Russia is working on an overhaul of its current strategic bomber fleet and is also reported to have started preliminary work on a new-generation strategic bomber.[65]

Economics

Modernisation of the nuclear arsenal is part of a broader rearmament programme that is expected to spend about US$700 billion on various military systems in 2011-2020. About 10% of these funds will be spent on strategic force modernisation.[66] Financial constraints could affect the scale of these plans, though the rearmament effort appears to have strong support of the political leadership and public, so significant cuts to the modernization programme are unlikely. This situation may change if political environment in Russia would allow an open discussion of government spending priorities and the role of nuclear weapons in the national security policy, but so far this discussion has been very limited. In 2015 Russia was supposed to approve a new long-term rearmament programme. This programme, initially estimated to cost about 56 trillion rubles, was scaled down in 30 billion rubles. Then, as it was increasingly clear the budget may not support a programme of this size, its approval was postponed until 2018.[67]

International law and doctrine

Official documents of the Russian government do not question Russia's right to possess nuclear weapons, though they also recognize its responsibilities as an NPT nuclear weapon state including to pursue a world free of nuclear weapons as a means of achieving security for all. Official policy assumes the right of first use of nuclear weapons, though the policy has a limited range of scenarios under which this would be considered. Both Russia and the United States consider their bilateral arsenal reductions to contribute toward the goal of article VI of the NPT. Russia's position on nuclear weapons is directly linked to a number of security concerns, such as US ballistic missile defence, US advantage in terms of conventional weapon systems, NATO expansion, and in the long run, China's position in the region.[68] The last Russian military doctrine published was released in February 2010. It indicates that Russia could respond to the use of any weapon of mass destruction with the use of nuclear weapons or even conventional weapons.[69] In February 2012 the Chief of the Russian General Staff, Nikolai Makarov, said that Russia would use nuclear weapons in response to any imminent threat to its national security.[70]

Public discourse

Public opinion in Russia tends to support the nuclear status of the country – according to a poll conducted in 2006, 76 percent of all the respondents believed that Russia "needs nuclear weapons."[71] More than half of the population consider nuclear weapons to be the main guarantee of the security of the country and about 30 percent of respondents believe that nuclear weapons play an important, although not a decisive, role. To a large extent, the lack of critical assessment of the role of nuclear weapons is a result of the lack of an open and informed discussion of national security priorities and policies that would involve independent voices. While there are non-governmental research organisations that are involved in the discussion of defence policies, there are no independent public organizations that would have nuclear weapons related issues on the agenda.

United Kingdom
John Ainslie

Current status

In January 2015 the UK had 120 operationally available nuclear warheads. This is part of a larger stockpile of between 180 and 225 warheads. There are four Vanguard class submarines, three of which are normally armed. Each armed submarine carries eight Trident D5 missiles and a total of 40 nuclear warheads. It is estimated that the UK has 3.2 tons of separated plutonium in its military stockpile. In 2002 the UK had 21.6 tons of highly enriched uranium.

Modernisation

The Trident warhead is being upgraded to a new Mk4A specification. The Mk4A version will be in service until the 2040s. The modernised warhead will have a new fuzing system, which will enhance its capability and make it more effective against hardened targets. In 2019 the UK is due to make a decision on the production of a new warhead which would replace the Mk4A. The Atomic Weapons Establishment is conducting research into new components for a future warhead. The US will supply the UK with upgraded Trident D5LE missiles and with modernised fire control and navigation systems. These changes will improve the performance of Trident. In 2016 the UK will make the Main Gate decision on the construction of three or four new ballistic-missile submarines, which are scheduled to enter service in 2028. The new vessels will each have 12 missile tubes. This leaves open the possibility that the number of missiles carried could be increased. The submarines will have a new PWR3 reactor, which is being developed with US support. Almost all of the UK's facilities for developing and building nuclear warheads are being rebuilt or refurbished. There is close collaboration with US modernisation programmes. Future hydrodynamic research will be conducted at a new facility in France.

Economics

The through-life cost of the Trident replacement programme is in the region of £100 billion. Submarine and related construction costs are £25 billion. Running costs would be £59 billion. In addition a large part of the £21 billion Nuclear Warhead Capability Sustainment Programme should be assigned to Trident replacement. The UK defence budget is facing cuts, possibly as high as 41%. Other defence expenditure may be substantially reduced in order to fund Trident replacement.

International law and doctrine

Mohammed Bedjaoui, former President of the International Court of Justice has said that a nuclear attack by a system like the UK's Trident force would be illegal in all circumstances. The UK's extensive modernisation programmes are an indication of the country's intention to retain nuclear weapons indefinitely, contrary to legal obligations. The close collaborations with the US and French programmes are contrary to the spirit of the NPT.

Public discourse

The Labour and Conservative parties both support replacing the current Trident submarines with a similar system. The Liberal Democrats have a similar approach, except they argue that there is no longer a requirement to keep one submarine on patrol at all times. The Scottish National Party is opposed to Trident and to its replacement. Moving the UK's nuclear force from Scotland would be very difficult. Opposition to nuclear weapons in Scotland continues to have a significant impact on UK politics even though Scotland did not vote for independence in 2014. While some information is in the public domain there are major gaps in the UK's transparency. The Mk4A warhead modernisation programme has been largely concealed from the public and parliament. The upgrade of nuclear warhead facilities has been presented as if it was unrelated to the replacement of Trident.

United States
Greg Mello and Trish Williams-Mello

Current status

As of 1 April 2015 the United States deployed 1,597 strategic warheads on 785 strategic delivery vehicles on or in 898 deployed and non-deployed launchers.[72] In all the United States possesses at least 7,100 warheads including deployed strategic warheads, non-strategic warheads, operational warheads not deployed, and including a minimum of 2,340 intact but "retired" warheads. An unknown number of retired warheads are in "managed retirement" or "war reserve" status.[73]

The US strategic "triad" consists of: 447 Minuteman III intercontinental ballistic missiles (ICBMs) carrying 447 warheads with the capacity for additional warheads to be uploaded; 14 Ohio-class submarines each with 24 launch tubes for Trident D5 submarine-launched ballistic missiles (SLBMs) carrying about 1,152 warheads with an upload capacity of more than that many warheads again; and 96 nuclear capable strategic bombers, 20 B2As and 76 B-52Hs. Of these heavy bombers, 60 (44 B-52Hs and 16 B-2As) have been assigned nuclear roles.[74] Each heavy bomber is counted as one warhead under New START, although up to 20 warheads on cruise missiles can be deployed on a single B-52H and up to 16 nuclear gravity bombs can be carried on each B-2.[75] The active US stockpile also includes about 500 non-strategic weapons, with about 180 deployed at NATO air bases in Europe for delivery by US F-15Es, F-16s, and host country F-16s and Tornado aircraft.[76]

The US has produced or acquired approximately 850 metric tons (MT) of highly-enriched uranium (HEU) and 112 MT of weapon-grade plutonium, of which 609 MT and 95 MT remain, respectively (current HEU stock is exclusive of HEU in spent naval reactor fuel).[77]

Modernisation

The US government is officially committed to modernising its nuclear bombs and warheads; the submarines, missiles, and aircraft that carry them; and the laboratories and plants that design, maintain, and manufacture nuclear weapons. US policy and budget documents all manifest an intent to keep some thousands of nuclear weapons in service for the foreseeable future, together with the capability to bring stored weapons back into service and to design and manufacture new weapons should they be desired.

However, there is a great difference between modernisation aspirations on the one hand and practical accomplishment on the other. Over the past two years, virtually all the warhead and infrastructure modernisation projects in the Department of Energy (DOE) have experienced serious cost overruns and schedule delays that have eroded congressional and military support and caused the DOE to downscale or indefinitely defer several projects in question.

Economics

Nuclear weapon costs occur in both the DOE and DoD budgets. The DOE budget request for fiscal year 2016 includes $8.847 billion for nuclear weapons activities, not including $283 million in related administrative costs. This is a proposed 10% increase from 2015, an annual growth rate exceeded only twice in US history (1962 and 1982).[78] It is higher in constant dollars than the last peak in nuclear warhead spending for development, testing, and production under President Reagan in 1985.[79] Current budget projections entail continuous cost increases through 2040.[80]

Over the past years there have been many reports and studies on the cost of the US nuclear programme and possible options for savings.[81] In December 2013 the Congressional Budget Office (CBO) published an authoritative report assessing the projected costs of the US nuclear forces for the 2014-2023 timeframe, utilising long-term cost databases maintained by CBO and with full access to Department of Defense data.[82] This study was updated in January 2015.[83] According to CBO, maintaining and modernising the current US stockpile will cost $348 billion over the 2015–2024 decade, including about $79 billion for modernisation sensu stricta, exclusive of any abnormal cost overruns (which are in fact normal at DOE). Since most modernisation efforts are still in the initial phase, annual costs are expected to generally increase over the decade and continue to increase afterward.[84]

International law and doctrine

More than four decades after the United States signed and ratified the NPT, it retains a nuclear arsenal large enough to end civilization in short order. None of its recent bilateral reduction agreements with Russia fundamentally change the character of nuclear weapon deployments. The US has signed but not ratified the CTBT; ratification was rejected by the US Senate in 1999 even after a bargain was made to modernize its nuclear weapons infrastructure in exchange for ratification. The Obama administration has stated that CTBT ratification "remains a top priority for the United States."[85] If the past is any guide, an attempt to obtain consent for ratification from the Senate is likely to be accompanied by new programmatic and funding commitments to the nuclear weapons establishment.

The US 2010 Nuclear Posture Review (NPR) states that the US will keep relying on its nuclear weapons as an important part of its national security and will also do this for the foreseeable future.[86] On 19 June 2013 President Obama announced in Berlin that his administration would, together with its NATO allies, seek "bold reductions in US and Russian tactical nuclear weapons in Europe."[87] On the same day, however, the US administration published a report on President Obama's new guidance on the employment of nuclear weapons.[88] Among other things, the report reaffirmed that "as long as nuclear weapons exist," the United States will maintain a "safe, secure and effective arsenal for its protection and that of its allies."[89] At the third conference on the humanitarian impact of nuclear weapons, hosted by Austria in December 2014, the US representative stated that his government "does not support efforts to move to a nuclear weapons convention, a ban, or a fixed timetable for elimination of all nuclear weapons."[90]

Public discourse

In the broader populace, there is little debate about US nuclear weapons policies or spending. The absence of a disarmament movement has made progress on an ambitious abolition agenda unlikely. What public discussion there is about US nuclear weapons policy is dominated by specialists and is skewed towards drumming up fear of nuclear weapons coming into the possession of non-nuclear weapon states or non-state actors rather than pointing to the very real dangers posed by nuclear weapons held as central elements of national security policies in the hands of the world's most powerful states. In the United States, disarmament remains an abstract aspiration; the pursuit of global military dominance backed by constantly modernised nuclear weapons remains the concrete reality.

Notes:

1. See, e.g. "China's National Defense in 2008," Information Office of the State Council of the People's Republic of China, January 2009, http://www.china.org.cn/government/whitepaper/node_7060059.htm.
2. Kristensen. H & Norris. R, "Chinese nuclear forces, 2013," Bulletin of the Atomic Scientists, November 2013, p. 80.
3. "The Diversified Employment of China's Armed Forces," Information Office of the State Council of the People's Republic of China, 19 April 2013, http://eng.mod.gov.cn/Video/2013-04/19/content_4443469.htm.
4. Kristensen. H & Norris. R, "Chinese nuclear forces, 2013", Bulletin of the Atomic Scientists, November 2013, p. 79.
5. See details in: Hui Zhang, "Chapter 7: China," *Global Fissile Material Report 2010: Balancing the Books: Production and Stocks*, Princeton, NJ: Princeton University, 2011, http://belfercenter.ksg.harvard.edu/files/Hui-Zhang-China-Chapter-Global-Fissile-Materials-Report.pdf; Hui Zhang, "China's HEU and Plutonium Production and Stocks," *Science & Global Security* 19, no. 1, January–April 2011, pp. 68–89, http://belfercenter.ksg.harvard.edu/files/huizhangSGS2011.pd; International Panel of Fissile Materials (IPFM), *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament*, October 2013, p. 13, http://fissilematerials.org/library/gfmr13.pdf.
6. Zhang.H, "China's Nuclear Weapons Modernization: Intentions, Drivers, and Trends", Kennedy School of Government Harvard University, July 2012, p. 4 http://belfercenter.ksg.harvard.edu/files/ChinaNuclearModernization-hzhang.pdf.
7. "Annual Report to Congress – Military and Security Developments Involving the People's Republic of China 2014," Office of the Secretary of Defense, 24 April 2014, http://www.defense.gov/pubs/2014_DoD_China_Report.pdf.
8. Kristensen. H & Norris. R, "Chinese nuclear forces, 2011," *Bulletin of the Atomic Scientists*, November 2011, p. 81.
9. "Annual Report to Congress – Military and Security Developments Involving the People's Republic of China 2014," Office of the Secretary of Defense, 24 April 2014, http://www.defense.gov/pubs/2014_DoD_China_Report.pdf.
10. Zhang.H, "China's Nuclear Weapons Modernization: Intentions, Drivers, and Trends", *op.cit.*
11. See, e.g. Brigadier Vijai K Nair, "China's Nuclear Strategy and Its Implications For Asian Security," *China Brief*, Vol 4, Issue 3, 4 February 2004, http://www.jamestown.org/single/?no_cache=1&tx_ttnews%5Btt_news%5D=26259.
12. For instance, Guo Qiang, "US' nuke-free world plan stirs debate," *Global Times*, 24 September 2009.
13. *Speech by Nicolas Sarkozy, President of the French Republic, Presentation of Le Terrible in Cherbourg*, 21 March 2008, p. 8. A copy of the French version is available here: http://www.elysee.fr/president/root/bank/pdf/president-1944.pdf
14. Status of World Nuclear Forces, Federation of American Scientists (FAS), June 2011.
15. *Speech by Nicolas Sarkozy, President of the French Republic, Presentation of Le Terrible in Cherbourg*, 21 March 2008, p. 8. A copy of the French version is available here: http://www.elysee.fr/president/root/bank/pdf/president-1944.pdf
16. Speech by François Hollande, *Visit to the Strategic Air Forces*, 25 February 2015, p. 9, http://basedoc.diplomatie.gouv.fr/vues/Kiosque/FranceDiplomatie/kiosque.php?fichier=baen2015-02-25.html.
17. For estimates of French fissile material production and status, see: *Global Fissile Material Report 2011: Nuclear Weapons and Fissile Material Stockpiles and Production*, International Panel on Fissile Materials, 2011; *Global Fissile Material Report 2011: Balancing the Books: Production and Stocks*, International Panel on Fissile Materials, 2010; both reports are available at http://www.fissilematerials.org; International Panel of Fissile Materials (IPFM), *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament*, October 2013, pp. 12-13, p. 18, http://fissilematerials.org/library/gfmr13.pdf.
18. Speech by François Hollande, *Visit to the Strategic Air Forces*, 25 February 2015, http://basedoc.diplomatie.gouv.fr/vues/Kiosque/FranceDiplomatie/kiosque.php?fichier=baen2015-02-25.html.
19. Ibid.
20. JeanYves Le Drian, Defense Minister, Closing Remarks – Symposium for 50 Years of Deterrence, 20 November 2014, http://www.defense.gouv.fr/ministre/prises-de-parole-du-ministre/prises-de-parole-de-m.-jean-yves-le-drian/discours-de-cloture-du-colloque-pour-les-50-ans-de-la-dissuasion.
21. Speech by François Hollande, *Visit to the Strategic Air Forces*, 25 February 2015, http://basedoc.diplomatie.gouv.fr/vues/Kiosque/FranceDiplomatie/kiosque.php?fichier=baen2015-02-25.html.
22. National Assembly, Defense Committee, *AVIS, PRÉSENTÉ AU NOM DE LA COMMISSION DE LA DÉFENSE NATIONALE ET DES FORCES ARMÉES, SUR LE PROJET DE loi de finances pour 2012 (n° 3775), TOME VII, DÉFENSE ÉQUIPEMENT DES FORCES – DISSUASION, PAR M. FRANÇOIS CORNUT-GENTILLE*, 25 October 2011, http://www.assemblee-nationale.fr/13/pdf/budget/plf2012/a3809-tVII.pdf.
23. Bruce G. Blair and Matthew A. Brown, *Nuclear Weapons Cost Study*, Global Zero Technical Report, June 2011, p. 1, http://www.globalzero.org/files/scott/Global%20Zero%20Cost%20Study,%20June%202011.pdf.
24. Ministry of Defense, Project de Loi de Finances 2015, 2014, http://www.defense.gouv.fr/sga/le-sga-en-action/budget-finances-de-la-defense/budget.
25. Speech by François Hollande, *Visit to the Strategic Air Forces*, 25 February 2015, http://basedoc.diplomatie.gouv.fr/vues/Kiosque/FranceDiplomatie/kiosque.php?fichier=baen2015-02-25.html.
26. Ibid.
27. Hans M. Kristensen and Robert S. Norris, "Worldwide Deployments of Nuclear Weapons, 2014," *Bulletin of the Atomic Scientists* 70, no. 5 (2014): 96–108, doi:10.1177/0096340214547619.
28. IPFM, *Global Fissile Material Report 2015* (Princeton: International Panel on Fissile Materials, forthcoming 2015).
29. *Ibid.*
30. Ibid.
31. C. Shivakumar, "PFBR Plant May Go Critical by Mid-Year," *New Indian Express*, February 4, 2015, http://www.newindianexpress.com/cities/chennai/PFBR-Plant-May-Go-Critical-by-Mid-year/2015/02/04/article2651524.ece..
32. M. Somasekhar, "Agni-V: A Game Changer in India's Missile Technology," *The Hindu Business Line*, January 31, 2015, http://www.thehindubusinessline.com/news/science/agniv-a-game-changer-in-missile-technology/article6842427.ece.
33. Shiv Aroor, "My Job Is to Speed up India's Nuclear Strike Time, DRDO Chief Says," *Daily Mail India*, July 3, 2013, http://www.dailymail.co.uk/indiahome/indianews/article-2355107/Dr-Avinash-Chander-My-job-speed-Indias-nuclear-strike-time-DRDO-chief-says.html.
34. TNN, "Nuclear-Capable Agni-IV Test-Fired Successfully, Has China in Sight," *The Times of India*, December 3, 2014, http://timesofindia.indiatimes.com/india/Nuclear-capable-Agni-IV-test-fired-successfully-has-China-in-sight/articleshow/45355075.cms.
35. Rishi Iyengar, "India Tests First Nuclear-Capable Cruise Missile," *Time*, October 17, 2014, http://time.com/3515183/india-tests-nirbhay-cruise-missile/.
36. Daily Bhaskar, "3,000 Km-Range SLBM Successfully Test-Fired by DRDO," *Daily Bhaskar*, May 13, 2014, http://daily.bhaskar.com/news/NAT-TOP-3000-km-range-slbm-successfully-test-fired-by-drdo-4611759-NOR.html; TNN, "India Tests New Underwater Nuclear Missile."
37. TNN, "INS Arihant Embarks on Its First Sea Trials," *The Times of India*, December 16, 2014, http://timesofindia.indiatimes.com/city/visakhapatnam/INS-Arihant-embarks-on-its-first-sea-trials/articleshow/45529440.cms.
38. Brian Cloughley and Robert Kelley, "India Increases Its Uranium Enrichment Programme," *IHS Jane's 360*, June 20, 2014, http://www.janes.com/article/38957/india-increases-its-uranium-enrichment-programme.
39. "Unstarred Question No. 1398," Rajya Sabha, 22 August 2013, dae.nic.in/writereaddata/parl/mansoon2013/rsus1398.pdf .
40. PTI, "Budget 2015: Defence Allocation Increased by Nearly 11 per Cent," *The Economic Times*, February 28, 2015, http://economictimes.indiatimes.com//articleshow/46407292.cms.
41. Ibid.
42. Deepak Kapoor, "Defence Modernisation: Make in India and Private Sector," *India Strategic*, March 2015, http://www.indiastrategic.in/topstories3695_Defence_Modernisation.htm.
43. Defence Radar, "Modi Booster for Indian Defence Companies," *Defenceradar News*, June 16, 2014, http://defenceradar.com/2014/06/16/modi-booster-for-indian-defence-companies/.
44. *Press Release: Cabinet Committee on Security reviews progress in operationalizing India's nuclear doctrine,* Prime Minister's Office, Government of India, 2003.
45. NSAB, *Draft Report of National Security Advisory Board on Indian Nuclear Doctrine,* New Delhi: National Security Advisory Board, 1999.
46. Stockholm International Peace Research Institute (SIPRI), *SIPRI Yearbook 2013: Armaments, Disarmament and International Security - Summary,* Stockholm, 2013, p. 13. See also H. M. Kristensen and R. S. Norris, Global nuclear weapons inventories, 1945–2013, *Bulletin of the Atomic Scientists,* September 2013, p. 80.
47. *Global Fissile Material Report 2013: Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step Toward Disarmament*, International Panel on Fissile Materials, October 2013, p. 18.

48. IISS, p. 132, citing David Albright, "ISIS Estimates of Unirradiated Fissile Material in De Facto Nuclear Weapon States, Produced in Nuclear Weapons Programs," Institute for Science and International Security (ISIS), Washington, 2003 (revised 2005); ISIS, Israeli Military Stocks of Fissile Material As of Late 2003 (revised 2005), http://isis-online.org/isis-reports/detail/israeli-military-stocks-of-fissile-material-as-of-late-2003/.
49. *Global Fissile Material Report 2013: Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step Toward Disarmament*, International Panel on Fissile Materials, October 2013, p. 11.
50. BASIC, p. 28.
51. "Israel to receive fourth Dolphin-class submarine from Germany within days," *The Jerusalem Post*, 3 September 2014, http://www.timesofisrael.com/fourth-advanced-german-submarine-en-route-to-israel/
52. Secret Cooperation: Israel Deploys Nuclear Weapons on German-Built Submarines, *Der Spiegel*, 3 June 2012, http://www.spiegel.de/international/world/israel-deploys-nuclear-weapons-on-german-submarines-a-836671.html
53. Explanation of vote by Israel on the Comprehensive Nuclear-Test-Ban Treaty (L.29), UN General Assembly First Committee on Disarmament and International Security, New York, 4 November 2013, http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/1com/1com13/eov/L29_Israel.pdf.
54. Yitzhak Benhorin, "We'll give up nukes if Iran does same," *Yediot Ahronot*, 1 December 2011, http://www.ynetnews.com/articles/0,7340,L-4155677,00.ht
55. H. M. Kristensen and R. S. Norris, "Russian Nuclear Forces, 2014," *Bulletin of the Atomic Scientists* 70, no. 2 (March 3, 2014): 75–85, doi:10.1177/0096340214523565.
56. "New START "New START Treaty Aggregate Numbers of Strategic Offensive Arms," *U.S. Department of State*, 1 January 2014, http://www.state.gov/t/avc/rls/219222.htm
57. Russian strategic forces in January 2014, RussianForces.org, 15 January 2014.
58. International Panel of Fissile Materials (IPFM), *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament*, October 2013, pp. 10-11, p. 20, http://fissilematerials.org/library/gfmr13.pdfl.
59. President Putin, Meeting on implementing state armament programme for nuclear deterrence, July 26, 2012, Sochi, http://eng.news.kremlin.ru/news/4220
60. "Putin Vows to Pursue Enormous Military Rearmament Campaign", The Nuclear Threat Initiative, 12 February 2012.
61. "Deployment of new solid-propellant ICBM expected in 2015," RussianForces.org, 1 November 2013, http://russianforces.org/blog/2012/11/deployment_of_new_solid-propel.shtml
62. "New ICBM contract reportedly went to Makeyev Design Bureau," RussianForces.org, 14 May 2011, http://russianforces.org/blog/2011/05/new_icbm_contract_reportedly_w.shtml.
63. The Project 955 submarine is also reported to be able to carry long-range cruise missile. For more information see: "Project 955 submarines to carry long-rage cruise missiles", RussianForces.org, 11 January 2013.
64. Yuri Dolgorikiy and Alexandr Nevskiy submarines arrive in Gadzhievo, RussianForces.org, 30 December 2013.
65. Podvig. P, "Russia," In Assuring destruction forever: nuclear weapon modernization around the world, Reaching Critical Will, 2012, pp. 60-61 and "Modernization of Tu95MS bombers", RussianForces.org, 20 September 2012.
66. "Russia to spend $70 billion on strategic forces by 2020," RussianForces.org, 11 February 2011, http://russianforces.org/blog/2011/02/russia_to_spend_70_billion_on.shtml
67. Дмитрий Бутрин and Иван Сафронов, "Вооружения вступили в бой с возражениями," *Газета "Коммерсантъ,"* 19 February 2015.
68. Kearns. I, "Beyond the United Kingdom: Trends in the Other Nuclear Armed States", British American Security Information Council (BASIC), November 2011, p. 16.
69. "Text of Newly-Approved Russian Military Doctrine", Carnegie Endowment, February 2010.
70. "Putin pledges 400 ICBMs for Russia in ten years", RIANovosti, 20 February 2012.
71. Ildar Akhtamzyan, Opinion Poll "Attitudes in the Russsian Federation towards WMD Proliferation and Terrorism," PIR Center Report, Moscow: Human Rights Publishers, 2006, pp. 16–17.
72. "New START Treaty Aggregate Numbers of Strategic Offensive Arms," *U.S. Department of State*, 1 April 2015, http://www.state.gov/t/avc/rls/240062.htm.
73. "US nuclear forces, 2015," Hans M. Kristensen and Robert S. Norris Bulletin of the Atomic Scientists, March 2015, pp. 107-119. http://bos.sagepub.com/content/71/2/107.full.pdf+html. The Government Accountability Office (GAO), with access to classified stockpile data unavailable to Kristensen and Norris, says there are "several thousand" intact, retired warheads. "Nuclear Weapons: Actions Needed by NNSA to Clarify Dismantlement Performance Goal," GAO-14-449, 30 April, 2014. http://www.gao.gov/products/GAO-14-449. See "U.S. claims of nuclear weapons retirement, dismantlement "may be misleading" – GAO," Los Alamos Study Group, 1 May 2014, http://www.lasg.org/press/2014/press_release_1May2014.pdf.
74. Kristensen and Norris, *op. cit.* Kristensen and Norris say there are 93 B-52H bombers, but the Air Force lists a total B52 inventory of only 76 planes. "FY 2016 Budget Overview, Appendix, A-37," United States Air Force, February 2015, http://www.saffm.hq.af.mil/shared/media/document/AFD-150210-042.pdf. The Congressional Research Service also says there are 76 B-52s. "CRS Insights, Budget Highlight: Air Force Long Range Strike Bomber," Gertler, Jeremiah, 2 July 2014, http://fas.org/sgp/crs/weapons/IN10095.html. All US ICBMs have been de-MIRVed as of 16 June 2014. "Last Malmstrom ICBM reconfigured under treaty," *Air Force Times* 19 June 2014, http://archive.airforcetimes.com/article/20140619/NEWS04/306190038/Last-Malmstrom-ICBM-reconfigured-under-treaty. US SLBMs could in theory deliver up to 2,688 W76-0, W76-1, and W88 warheads at 8 warheads per missile.
75. "Weapons Carriage Capability of the B-52H," B-52 Stratofortress Association [accessed 24 March 2015], http://www.stratofortress.org/current-operations.htm; Kristensen and Norris, op. cit.
76. Kristensen and Norris, *op. cit.*
77. *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament, Seventh annual report of the International Panel on Fissile Material, October 2013*, p. 11. http://ipfmlibrary.org/gfmr13.pdf; "The United States Plutonium Balance, 1944-2009," U.S. Department of Energy, 26 June 2012, http://www.lasg.org/technical/PU_rpt_rev_26Jun2012.pdf.
78. "Administration's nuclear warhead design, production budget larger than Reagan and Bush, again," Los Alamos Study Group, 2 February 2015, http://www.lasg.org/press/2015/press_release_2Feb2015.html.
79. [17] Ibid.
80. "FY2016 SSMP," DOE *op. cit.*
81. See for example: Rumbaugh, R. and Cohn, N., "Resolving Ambiguity: Costing Nuclear Weapons," June 2012: http://www.stimson.org/images/uploads/research-pdfs/RESOLVING_FP_4_no_crop_marks.pdf; Tom Collina,"U.S. Nuclear Modernization Programmes," Arms Control Association, August 2012, http://www.armscontrol.org/factsheets/USNuclearModernization;"What Nuclear Weapons Cost Us," Ploughshares Fund, September 2012, http://www.ploughshares.org/sites/default/files/resources/What%20Nuclear%20Weapons%20Cost%20Us%20Final%20(100212).pdf; Wolfsthal, J.B., Lewis, J., and M. Quint, *op. cit.*
82. "Projected Costs of U.S. Nuclear Forces, 2014 to 2023," CBO, 19 December 2013, http://www.cbo.gov/sites/default/files/cbofiles/attachments/12-19-2013-NuclearForces.pdf.
83. "Projected Costs of U.S. Nuclear Forces, 2015 to 2024," CBO, 22 January 2015 with supplementary tables, https://www.cbo.gov/sites/default/files/cbofiles/attachments/49870-NuclearForces.pdf (main report), https://www.cbo.gov/publication/49870 (includes links to tables).
84. CBO, 2013 and 2015. CBO's 2015 estimates show a slight peak in 2022 but DOE's more recent FY2016 SSMP does not. Full-scale DoD procurements for all the new delivery platforms come only after 2024.
85. Rose Gottemoeller, Acting Under Secretary for Arms Control and International Security, remarks, "The Obama Administration's Second Term Priorities for Arms Control and Nonproliferation," Geneva Centre for Security Policy, March 20, 2013.
86. "Nuclear Posture Review report", Department of Defense United States of America, April 2010, p. 1.
87. Remarks by the President Obama at the Brandenburg Gate – Berlin, Germany, The White House Office of the Press Secretary, 19 June 2013, http://www.whitehouse.gov/the-press-office/2013/06/19/remarks-president-obama-brandenburg-gate-berlin-germany.
88. "Report on Nuclear Employment Strategy of the United States – Specified in Section 491 of 10 U.S.C.", US Department of Defense, 12 June 2013, http://www.defense.gov/pubs/ReporttoCongressonUSNuclearEmploymentStrategy_Section491.pdf.
89. "Report on Nuclear Employment Strategy of the United States – Specified in Section 491 of 10 U.S.C.", US Department of Defense, 12 June 2013, http://www.defense.gov/pubs/ReporttoCongressonUSNuclearEmploymentStrategy_Section491.pdf.
90. Intervention during Session I, Vienna Humanitarian Impact of Nuclear Weapons Conference, "Impact of Nuclear Weapons Explosions" delivered by Ambassador Adam Scheinman, Special Representative of the President for Nuclear Nonproliferation, 8 December 2014, http://vienna.usmission.gov/141208nwe.html.

Photo: U.S. Air Force photo/Master Sgt. Kevin J. Gruenwald

China
Hui Zhang

Since its first nuclear explosion in 1964, China has maintained what it describes as a "minimum deterrent" and a no-first use (NFU) pledge.[1] As its 2010 White Paper on Defense states, China upholds capacity for "counterattack in self-defense and limited development of nuclear weapons," and aims to build "a lean and effective nuclear force capable of meeting national security needs." The White Paper asserts that China "has always exercised the utmost restraint in the development of nuclear weapons, and has never participated in any form of nuclear arms race, nor will it ever do so. It will limit its nuclear capabilities to the minimum level required for national security."[2]

Unlike previous White Papers on Defense, China's 2012 edition did not reiterate China's long-standing NFU policy, which sparked a debate over whether China was changing its nuclear doctrine.[3] However, in April 2013 Colonel Yang Yujun, a spokesman for China's Ministry of Defense, said that the policy had not changed, explaining that while all former White Papers were comprehensive and detailed China's nuclear policy in sections on "national defense policy" and "arms control," the 2012 edition adopted a " thematic" model and focused specifically on the employment of China's armed forces, without addressing nuclear policy in detail.[4]

The NFU policy has been consistently embraced by top Chinese leaders from Mao Zedong onwards. For this reason, China currently maintains a smaller and simpler nuclear arsenal with a lower alert status than what is thought to be required for a first-use option. The Second Artillery Corps, the military unit in control of China's strategic missile forces, conducts war planning and training under the assumption that China will use its nuclear forces only to retaliate.[5]

In the Chinese calculus, the "minimum acceptable" nuclear force is one that is able to survive a first nuclear strike and overcome a "missile defence" system to reach its designated targets. The number of the "minimum" nuclear warheads would be relatively constant. However, the total number of warheads required to support an "effective" nuclear force is changeable, depending on a number of factors, including estimates about the survivability of Chinese missiles.

China's officials have never declared the specific number of weapons needed for its "minimum nuclear force". Mao Zedong stated, "In any case, we won't build more atomic bombs and missiles than others." He also said that "a few atomic bombs are enough (for China). Six are enough."[6] While six warheads is likely not be the specific number in the mind of Chinese leaders, a "minimum nuclear force" with approximately ten warheads capable of reaching a target country may be considered enough to inflict what would be considered "unacceptable damages" to "deter" a nuclear first-strike.[7]

Many Chinese officials and nuclear weapons experts have emphasised that China's nuclear modernisation will be conducted under the guidelines of a nuclear policy that stresses the principles of counterattack in self-defence and the avoidance of an arms race. Under China's NFU doctrine and the goal of maintaining a "lean and effective" nuclear force, China initiated a nuclear modernisation program in the 1980s aimed at increasing the "survivability, reliability, and safety" ability of its nuclear arsenal.

In 1978, Deng Xiaoping provided the guidance for the future development of China's nuclear force. He emphasized that China's strategic weapons "should be updated (gengxin) and the guideline [for their development] is few but effective (shao er jing). Few means numbers and effectiveness should increase with each generation."[8]

China's nuclear modernisation has focused on the quality rather than the quantity of its nuclear arsenal during the past three decades. Specifically, China's nuclear modernisation has sought to increase the survivability of its nuclear force by replacing older, liquid-fueled missiles with solid-fueled, mobile ballistic missiles and by constructing deep underground tunnels that can act as missile bases.[9] Since the Taiwan Strait crisis of 1996, the Second Artillery Corps has modernised and significantly increased the size of its arsenal of conventionally armed missiles (in particular, the medium-range, mobile DF-21C and DF-21D missiles). There has been, however, no obvious corresponding increase in nuclear warheads.

Recently, Western governments and media outlets have expressed growing concerns about Chinese nuclear buildup, in particular, Beijing pursuing nuclear parity with the United States and Russia after the New Strategic Arms Reduction Treaty was signed in 2010. Such voices were amplified when Georgetown University professor Phillip Karber released a study indicating the 3,000-mile-long network of underground tunnels – sometimes called China's "underground great wall" – could host as many as 3,000 nuclear weapons.[10] However, any expansion of the Chinese nuclear arsenal would still be constrained by its inventory of fissile materials, which at present would not support an arsenal of more than 1,000 warheads.[11]

China will likely continue to modernise its nuclear force in order to maintain a "reliable" second-strike retaliatory capability. China's nuclear modernisation has been mainly in response to the advance of military capabilities of other countries, particularly the United States. US missile "defence" plans will be a major driver for China's nuclear weapon modernisation.[12] However, China's nuclear modernisation program will likely continue to be guided by its nuclear policy and thus the nuclear force will likely be kept at the minimum level Beijing feels is required to "deter" a nuclear attack.

Status of China's nuclear forces

Based on China's minimum deterrence policy and Western government and non-government estimates, this author estimates China has a total inventory of approximately 190 nuclear warheads. This includes approximately 120 operationally deployed nuclear missiles (mainly landbased nuclear ballistic missiles, of which approximately 35-40 can reach the continental United States), and approximately 70 warheads stored for its submarine-launched ballistic missiles (SLBMs), bombers and retired warheads (see table 1). Each of those nuclear ballistic missiles carries a single warhead, which are normally separated from the missiles. This estimate is significantly lower than other appraisals. The Federation of American Scientists estimates that China has a total stockpile of 250 nuclear weapons by mid-2014,[13] which is 10 warheads more than its estimates in 2011.[14] It should be noted that when I presented my earlier estimates in 2012 in China, Chinese nuclear weapons experts responded that my number could be still higher than the real case.[15] China could have the smallest arsenal of nuclear weapons among the five original nuclear-armed states.

China's Nuclear Force, 2014

TYPE	NATO DESIGNATION	YEAR DEPLOYED	RANGE (KILOMETERS)	YIELD (KILOTONS)	NUMBER OF WARHEADS
LAND-BASED BALLISTIC MISSILES					
DF-5A	CSS-4	1990S	13,000+	4,000-5,000	<20
DF-31A	CSS-10 Mod 2	2007	11,200+	200-300	15-20
DF-4	CSS-3	1980	5,400+	3,300	10
DF-31	CSS-10 Mod 1	2006	7,200+	200-300?	10
DF-3 A	CSS-2	1971	3,00+	3,300	5
DF-21	CSS-5 Mods 1/2	1991	1,750+	200-300	60
SUBTOTAL:					120
SUBMARINE-LAUNCHED BALLISTIC MISSILES					
JL-2	CSS-NX-4	?	7.400	200-300?	36
BOMBERS					
H-6	B-6	1965	3,100	-	20
SUBTOTAL:					~176a

Note:[a] Estimates of more than 10 additional warheads include those for retired JL-1, for a total inventory of approximately 190 warheads.

Delivery systems

Quantitative

Given that China has no reliable operational air-based or sea-based nuclear force, China's nuclear modernisation has focused on increasing the survivability of its land-based strategic missiles. Before 2011, the US Defense Department had consistently reported that China has 20 DF-5A missiles-liquid-fueled, two-stage, silo-based intercontinental ballistic missiles (ICBMs).[16] The 2013 Air Force report estimates China has about 20 DF-5As [17] Given that one focus of China's modernisation programme is to replace these older, liquid-fueled ICBMs with the new, solid-fueled, road-mobile DF-31As, it can be expected that, as the DF-31A continues to be deployed in the coming years, some DF-5As will be replaced. But China's underground great wall project – initiated in 1985 and aimed at increasing the survivability of land-based missiles by shielding them in deep tunnels – could motivate China not to replace all the DF-5As quickly. Thus, I estimate that China could have less than 20 DF-5As.

According to the 2013 Air Force report, China deploys more than 15 DF-31As. FAS estimated that China had deployed around 20 DF-31as of 2013. Here I assume China has approximately 15–20 DF-31As. Thus, China could have approximately a total of 35–40 long-range ICBMs that could reach the continental United States. As more DF-31As are deployed, more DF-5As would be phased out. The total number of missiles, however, should not change significantly without a significant expansion and development of US missile "defence" programmes.

China also has shorter-range missiles intended for regional "deterrence," including the DF-4, a liquid-fueled, two-stage ICBM. It is being replaced by the new, solid-fueled, road-mobile DF-31. I assume that China has approximately ten DF-4s and ten DF-31s, as I did in 2012. The main target of the DF-4 during the Cold War was Moscow. Given that China and Russia have improved their relations significantly, China has no strategic reason to greatly increase the number of missiles it fields in this category. It can be expected that as more DF-31s are deployed, more DF-4s would be replaced. The total number of two kinds of missiles (i.e. a total around 20 warheads), however, should not change significantly. It should be noted that the 2013 Air Force report and 2013 FAS estimates have a similar total number for both missiles.

Moreover, China is phasing out its oldest and near-retired DF-3As. The liquid-fueled, single-stage, medium-range DF-3A is being replaced by the DF-21. The 2011 DoD report estimated China has 5–20 DF-3As.[18] Most of the DF-3As could be replaced by the DF-21s. The DF-21 family is the most important MRBM system of the Second Artillery for regional nuclear deterrence. This family includes the DF-21 (CSS-5 Mod 1), DF-21A (CSS-5 Mod2), DF-21C, and DF-21 D. However, only the DF-21 and DF-21A are for nuclear missions. China began seriously deployment of the DF-21 in 1991. After its deployment for two decades, the DF-21 could replace most of those DF-3As. The 2011 DoD report estimated China had 75-100 missiles of the whole DF-21 family, including conventional-mission missiles as well. The 2013 Air Force Report estimates China has less than 100 DF-21s and DF 21As. The 2013 FAS estimate is around 80 DF-21s that are nuclear capable, an increase of 20 warheads from the 2011 FAS estimates.

There is no evidence to show that China has a rationale to significantly increase its DF-21s with nuclear missions during such a short period. Given the increasing tensions with its neighbors over the East China Sea and South China Sea issues since 2012, China could increase its DF-21 missiles aimed at "deterring" potential military conflicts. Most likely, the new increase in the DF-21 family is contributed to its conventional missions. The Second Artillery has emphasized its dual missions (nuclear and conventional) since the early 2000s. A Project 2049 Institute study indicates that although China has deployed significant numbers of missiles in the DF-21 family, many of them carry conventional armaments.[19] A conservative estimate would give China no more than 60 DF-21s that are nuclear capable by 2014.

In addition, a 2014 US DoD report states that China may be developing a new road-mobile ICBM known as the Dong Feng-41 (DF-41), possibly capable of carrying multiple independently targetable re-entry vehicles (MIRVs).[20] In August 2014 it was reported that China Shaanxi Provincial Environmental Monitoring Center website made a news report about a military facility in the province developing DF-41 ICBMs. The report was taken down shortly after getting public attention.[21] Also, China is reportedly working a hypersonic glide vehicle (HGV) able to carry nuclear warheads at a speed above Mach10 through US missile "defences".[22] These developments could be indicative of Chinese reactions to US missile "defence" developments.

Submarine-launched ballistic missiles

The People's Liberation Army Navy started to operate its sole Xia-class SSBN (Type-092) in early 1980.[23] It is equipped with 12 JL-1 SLBMs. Each JL-1 missile has a single warhead and a rage of 1700 km. However, it is reported that the Xia-class has never conducted a deterrent patrol. According to the 2014 DoD report, this old, first generation Xia was replaced with the second generation Jin-class SSBN (Type-094). The 2014 DoD report states that three JIN-class SSBNs are currently operational, and up to five may enter service before China proceeds to its next generation SSBN (Type 096) over the next decade. The Jin-class SSBN can carry 12 JL-2 SLMBs with a much longer range (7400km, a modification model of DF-31) than that of JL-1. As the DoD report emphasizes, the JIN-class and the JL-2 will give the PLA Navy its first "credible" sea-based nuclear weapon. Recently, it is reported China conducted another flight test of its new JL-2 submarine-launched ballistic missile in January 2015. China is likely to conduct its first patrols with the JIN-class SSBN in 2015.[24] It can be expected that, after its three-decade modernisation programme, with a focus on increasing the survivability of its land-based missiles, China will speed up the modernisation of its sea-based strategic force to secure a second-strike force in the coming years. Indeed, China's 2011 Defense White Paper states that "the PLA Navy endeavors to accelerate the modernisation of its integrated combat forces, enhances its capabilities in strategic deterrence and counterattack, and develops its capabilities in conducting operations in distant waters and in countering non-traditional security threats."[25]

Bombers

China's air-based nuclear force is the weakest leg of its nuclear triad. China's aged strategic bomber force consists of about 20 Hong-6 bombers, each of which has a combat radius of approximately 3,000 kilometers and carries one bomb. However, China's small arsenal of strategic bombers mainly has symbolic meaning.

China could have no rationale to have a larger air-based nuclear force. Given their relatively short operating range and poor ability to overcome missile "defences," those bombers would be very difficult to fly into an enemy's territory to destroy "strategic countervalue targets," e.g. cities. Moreover, during the Cold War, the major target of those bombers was the Soviet Union/Russia. However, the relationship between China and Russia has recently improved significantly. Thus, there is no rationale to expend its air-based force due to geopolitical considerations.

Tactical nuclear weapons

There have been rumours for many years that China has tactical nuclear weapons. In 1988, China tested a one- to five-kiloton nuclear device with an enhanced radiation yield, or a "neutron bomb."[26] However, the deployment of tactical nuclear weapons is not consistent with China's no-first-use policy. Chinese nuclear experts have argued that the neutron bomb test was aimed at understanding its effects for "defensive" purposes. In practice, while it would not be difficult for China to field tactical weapons, it currently does not.

Fissile materials

It is believed that China stopped production of highly enriched uranium (HEU) in 1987 and of plutonium by about 1990. All its previous military production facilities have been closed, converted, or are being decommissioned.[27]

China has produced HEU for weapons in two complexes: the Lanzhou gaseous diffusion plant (GDP) (Plant 504) and the Heping GDP (Plant 814). The Lanzhou GDP began operations in 1964 and ended HEU production in 1979. The Lanzhou GDP produced an estimated 1.1 million separative work units (SWU). The Heping GDP, a "Third Line" facility that began operating in 1970 and stopped production of HEU in 1987, produced an estimated 3 million SWU. Together, the Lanzhou and Heping gaseous diffusion plants therefore produced roughly 4.1 million SWU, enough to make about 21 tons of weapon-grade HEU. Taking into account HEU and separative work consumed by research and naval reactors, tritium production reactors, used in nuclear tests, and lost in waste, the total amount of weapon-grade HEU in China's stockpile is estimated to be 18±4 tons.[28]

China has produced plutonium for weapons at two nuclear complexes. The first is the Jiuquan Atomic Energy Complex in Gansu province (Plant 404). This site includes China's first plutonium reactor and the associated reprocessing facilities. The Jiuquan reactor began operation in 1966 and stopped plutonium production in 1984. The second is the Guangyuan plutonium production complex, located at Guangyuan in Sichuan province (Plant 821), a "third line" plant backing up the Jiuquan complex that also included a plutonium reactor and reprocessing facility. The reactor began operation in 1973 and stopped plutonium production in 1989.

China's two plutonium production reactors produced an estimated 2±0.5 tons of weapon-grade plutonium. After considering plutonium consumed in nuclear tests, the total amount of weapon-grade plutonium in China's current inventory would be 1.8±0.5 tons available for weapons. Hence, China could have the smallest military stockpile of HEU and plutonium available for weapons among the five NPT nuclear-armed states.

Economics

It is difficult to estimate the cost of China's nuclear weapon force. Chinese experts of nuclear weapons believe China invests at a very low level for its nuclear weapon programmes.[29]

China's officially announced military budget of 808 billion yuan (about 132 billion USD) for 2014 is an increase of 12.2 percent over the 720 billion yuan authorized in 2013. Chinese military officials stated that the new increased defense spending was mainly used to update weapons and equipment, to improve the living and training conditions of officers and soldiers, and to reform the military system.[30] Responding to some countries' concerns, Chinese officials explained that China's military budget accounts for 1.4 percent of its GDP, which is smaller than the world average level of 3 percent, and only about one fourth of US military budget.[31]

Beijing insists that it coordinates its military modernisation with national economic development. As stated in its 2010 White Paper, "China adheres to the principle of coordinated development of national defense and economy. In line with the demands of national defense and economic development, China decides on the size of defense expenditure in an appropriate way, and manages and uses its defense funds in accordance with the law."[32]

However, some foreign analysts suspect that the Chinese official data does not represent the real Chinese military-related spending. The Stockholm International Peace Research Institute estimated that total Chinese military spending is about 55 per cent higher than the total central and local military budget.[33]

It is even much more difficult to estimate the spending on nuclear forces without knowing the specific portion of the overall military budget dedicated to nuclear weapons. Assuming that China consistently maintains five percent of its overall military expenditure for its nuclear weapons programme, as suggested by an Indian analyst,[34] China would thus have spent between $6.6 and $13 billion on its nuclear programme in 2014. A report by Global Zero estimated that China's core nuclear cost to be $6.4 billion in 2011, and its full cost to be $7.6 billion.[35]

International law and doctrine

China signed the Comprehensive nuclear Test Ban Treaty (CTBT) in 1996 but has not yet ratified it, partly because it was rejected by the US Senate in 1999. Some Chinese nuclear experts argue that the US should take a lead to ratify the treaty. They suggest that if US does not ratify the treaty, this may send a signal to Chinese officials and experts that if even the US – with over one thousand nuclear tests – still lacks confidence on having a safe and reliable arsenal, the Chinese arsenal, with only about 40 tests, might require more testing.[36]

In practice, the CTBT will constrain China's nuclear modernisation the most among the NPT nuclear-armed states. China conducted only 45 tests before its moratorium commitment in 1996. This leaves China with a very limited number of tested warhead designs certified for deployment. The lack of test data would limit China's ability to further develop new and smaller warheads. Most likely, Beijing's ratification of the CTBT will follow Washington's ratification of the Treaty.

China's position on a fissile material cut-off treaty (FMCT) is that the treaty would be "conducive to preventing nuclear weapons proliferation and promoting nuclear disarmament." China advocates for "the Conference on Disarmament (CD) in Geneva to negotiate and conclude at an early date a multilateral, non-discriminatory and internationally and effectively verifiable FMCT, based on a comprehensive and balanced program of work acceptable to all."[37]

Although Beijing supports FMCT negotiations, the reference to ''a comprehensive and balanced program of work acceptable to all" could mean a consideration of space weapons issues. Indeed, due to its concerns about US missile "defence" and potential space weapon technology, China strongly indicated its preference to simultaneously address both the FMCT and a treaty on the prevention of an arms race in outer space (PAROS) during the early 2000s. In recent years, China's position has not demanded simultaneous negotiations, though it continues to promote a draft treaty on preventing space weaponisation along with Russia. If Beijing remains concerned about US missile "defences" and space weapons programmes, it might decide to build more ICBMs for maintaining its "deterrence" posture, which might require more plutonium and HEU to fuel those weapons. A calculation of this measure would undermine possible Chinese support for FMCT negotiations.

China's official policy has long called for "the complete prohibition and thorough destruction of nuclear weapons," which it reiterated in its 2010 White Paper on Defense. Furthermore, the White Paper stated that to "attain the ultimate goal of complete and thorough nuclear disarmament, the international community should develop, at an appropriate time, a viable, long-term plan with different phases, including the conclusion of a convention on the complete prohibition of nuclear weapons."

Beijing maintains that "countries possessing the largest nuclear arsenals bear special and primary responsibility for nuclear disarmament" and thus they "should further drastically reduce their nuclear arsenals in a verifiable, irreversible, and legally-binding manner, so as to create the necessary conditions for the complete elimination of nuclear weapons."[38] However, Beijing does not state when China itself would participate in the process of nuclear reductions or elimination. Many Chinese analysts believe Beijing may wish to wait until the United States and Russia reduce their stockpiles to no more than about 1,000 total

Photo: Flickr/Crown Copyright,

warheads each. Then, China may need to reveal the size of its nuclear force as a way to create the necessary confidence for the United States and Russia to continue their reductions.

While an arsenal of 1,000 total warheads would still be a substantial amount of weapons, many Chinese experts and analysts suspect the United States and Russia would never intend to reach even that level. In practice, they believe that to move toward deeper reductions, both countries should devalue the role of nuclear weapons in their national security strategies and foreign policies. Instead, both are modernising their nuclear arsenals. Further, in the wake of Ukraine crisis, Chinese experts worry that the deteriorating US-Russian relations will harm their cooperation on possible further nuclear weapon reductions.

Some Chinese officials and analysts are skeptical of the true intentions behind President Barack Obama's vision of a nuclear weapon free world, which he articulated in an April 2009 address in Prague. They argue this rhetoric aims to constrain China's nuclear modernisation process.[39] For instance, to respond to US missile "defence" deployments, China's officials may want to build more warheads to maintain what they determine to be an "effective deterrent" capability. Such an expansion could run into pressure generated by the downsizing trend of Russian and US arsenals. As Moscow and Washington move toward deeper cuts, both capitals could also push Beijing to be more transparent about its arsenal. Given the asymmetric nature of the US/Russian and Chinese nuclear arsenals, Beijing believes the transparency of its own nuclear strategy and nuclear doctrine is more important than that of its force posture. Further, China contends the opacity of its force posture can serve to enhance the "deterrence effect" of its smaller nuclear force, which is helpful for maintaining "strategic stability".

However, a certain level of nuclear transparency measures, including nuclear strategic intentions and nuclear capabilities, are seen as necessary to maintain nuclear "strategic stability" among nuclear-armed states. In order to defuse theories about the "threat of China," China should release more information about its nuclear weapon programme. The CCTV report of the existence of the "underground great wall" has shown the world that China has a real and reliable retaliatory counterattack capability. As Beijing develops a more "survivable" nuclear force, the government should become more open about its nuclear programmes.

Public discourse

There is scant public debate about nuclear weapons in China. After US President Obama outlined his "vision" of a nuclear weapon free world, an online survey conducted by the People's Daily newspaper indicated that 51% of respondents wanted nuclear disarmament while 49% did not.[40]

Notes:

1. Information Office of the State Council of the People's Republic of China, "China's National Defense in 2010," March 2011, www.gov.cn/english/official/2011-03/31/content_1835499.htm.
2. "China's National Defense in 2010," op. cit.
3. James Acton, "Is China Changing Its Position on Nuclear Weapons?" *New York Times*, April 18, 2013. http://www.nytimes.com/2013/04/19/opinio is-china-changing-its-position-on-nuclear-weapons.html?_r=1&
4. http://news.china.com.cn/live/2013-04/26/content_19698408.htm
5. See more in Hui Zhang, "China's Perspective on a Nuclear –Free World," *The Washington Quarterly*, 32 (2010) 2: pp.139–155, http://www.twq.com/10april/docs/10apr_Zhang.pdf.
6. John Lewis and Xue Litai, 1994. *China's Strategic Seapower: The Politics of Force Modernization in the Nuclear Age.* Stanford University Press, p. 232.
7. Hui Zhang, "Nuclear Modernization in China," in *Assuring Destruction Forever: Nuclear Weapon Modernization around the World*, edited by Ray Acheson, published by Reaching Critical Will, a project of the Women's International League for Peace and Freedom, March 2012.
8. Selection of Deng Xiaoping's discussions on army building in the new period, (Beijing: Bayi Publisher, 1993), p. 99.
9. Hui Zhang, "The Defensive Nature of China's 'Underground Great Wall'," *Bulletin of Atomic Scientists, 16* January 2012.
10. Phillip A. Karber, "Strategic Implications of China's Underground Great Wall," Georgetown University, [26] September 2011, http://www.fas.org/nuke/guide/china/Karber_UndergroundFacilities-Full_2011_reduced.pdf.
11. Zhang, "The Defensive Nature of China's 'Underground Great Wall'," op.cit.
12. Hui Zhang, "China's Nuclear Weapons Modernization: Intentions, Drivers, and Trends," Kennedy School of Government Harvard University, July 2012, p. 4, http://belfercenter.ksg.harvard.edu/files/ChinaNuclearModernization-hzhang.pdf.
13. Hans Kristensen and Robert Norris, "Worldwide deployments of nuclear weapons, 2014," *Bulletin of the Atomic Scientist*, 70(5), 2014, p. 97. See also, Hans Kristensen and Robert Norris, "Chinese nuclear force, 2013," *Bulletin of the Atomic Scientist*. 69(6), 2013. It should be noted that FAS's 10 warheads more is incurred by an increase of 20 DF-21s and a decrease of 10 warheads of other land-based missiles. In particular, its estimate of the number of missiles (including DF-4s, DF-5As, DF-31s and DF-31As) that can strike US territory is decreased by as many as 12.
14. Hans Kristensen and Robert Norris, "Chinese nuclear force, 2011," *Bulletin of the Atomic Scientist*. 67(6), 2011.
15. Communications with Chinese nuclear weapons experts in Beijing, November 2013.
16. "*Report to Congress: Military and Security Developments Involving the People's Republic of China 2010,*" Office of the Secretary of Defense, 2010, http://www.defense.gov/pubs/pdfs/China_Military_Power_Report_2010.pdf.
17. *National Air and Space Intelligence Center, Ballistic and Cruise Missile Threat*, 2013, http://www.25af.af.mil/shared/media/document/AFD-130710-054.pdf.
18. "*Report to Congress: Military and Security Developments Involving the People's Republic of China 2011,*" *op. cit.*
19. Mark A. Stokes, *"China's Nuclear Warhead Storage and Handling System,"* Report of Project 2049 Institute, 12 March 2010, http://project2049.net/documents/chinas_nuclear_warhead_storage_and_handling_system.pdf.
20. "Annual Report to Congress – Military and Security Developments Involving the People's Republic of China 2014," Office of the Secretary of Defense, 24 April 2014, http://www.defense.gov/pubs/2014_DoD_China_Report.pdf.
21. AFP, "China 'confirms new generation long range missile," The Telegraph, 1 August 2014, http://www.telegraph.co.uk/news/worldnews/asia/china/11005061/China-confirms-new-generation-long-range-missiles.html.
22. "China confirms hypersonic missile carrier test," Reuters, 15 January 2014, http://www.reuters.com/article/2014/01/16/us-china-missile-idUSBREA0F03R20140116.
23. John Lewis and Xue Litai, *op. cit*.
24. Bill Gertz, "China conducts JL-2 sub missile test," *The Washington Times*, 18 February 2015, http://www.washingtontimes.com/news/2015/feb/18/inside-the-ring-china-tests-nuclear-missile-for-su/?page=all#pagebreak.
25. "China's National Defense in 2011," Information Office of the State Council of the People's Republic of China, 2011.
26. Hui Zhang, "How US restraint can keep China's nuclear arsenal small," *Bulletin of the Atomic Scientists*, July/August 2012, 68, pp. 73 – 82, bos.sagepub.com/content/68/4/73.full.
27. See details in: Hui Zhang, "Chapter 7: China," *Global Fissile Material Report 2010: Balancing the Books: Production and Stocks*, Princeton, NJ: Princeton University, 2011, http://belfercenter.ksg.harvard.edu/files/Hui-Zhang-China-Chapter-Global-Fissile-Materials-Report.pdf; Hui Zhang, "China's HEU and Plutonium Production and Stocks," *Science & Global Security* 19, no. 1, January–April 2011, pp. 68–89, http://belfercenter.ksg.harvard.edu/files/huizhangSGS2011.pdf.
28. This is an update from my earlier estimate of 16±4 tons (see Zhang, "Chapter 7: China," op.cit. and Zhang, "China's HEU and Plutonium Production and Stocks", *op.cit*.). The major update is incurred by the operation started date of Heping GDP. Previous estimates assumed the plant started operation in 1975. Based on new Chinese information, it began operating on 25 June 1970 (see: Wang Zhaofu, "60 Years of New China's Nuclear Energy Development Key Events," China *Nuclear Energy*, No.5, 2009, http://www.china-nea.cn/html/2009-11/4239.html). Thus, based on following assumptions – a) From 1970–74, a linear increase from 50,000 to 100,000 SWU per year at a tails assay of 0.3 percent; b) From 1975–79, a linear increase from 100,000 to 230,000 SWU per year at a tails assay of 0.3 percent; c) From 1980–87 the plant operated at 230,000 SWU per year at a tails assay of 0.3 percent - the Heping GDP would have produced 3 million SWU, sufficient to produce about 15 tons of HEU.
29. Hu, "The Road toward China's Nuclear Weapons," *op. cit.*
30. Li Zhi, "Military budgets: US is four times of Chinese, Japanese per capita spending is higher than Chinese," China.com.cn (in Chinese), 7 March 2014. http://news.china.com.cn/2014lianghui/2014-03/07/content_31701334.htm
31. *Ibid.*
32. "China's National Defense in 2010," *op. cit.*
33. See, e.g. Sam Perlo-Freeman, "Mar. 2014: Deciphering China's latest defence budget figures," Stockholm International Peace Research Institute, March 2014, http://www.sipri.org/media/newsletter/essay/perlo-freeman-mar-2013.
34. See, e.g. Brigadier Vijai K Nair, "China's Nuclear Strategy and Its Implications for Asian Security," *China Brief*, Vol 4, Issue 3, 4 February 2004, http://www.jamestown.org/single/?no_cache=1&tx_ttnews%5Btt_news%5D=26259.
35. See details in Bruce G. Blair and Matthew A. Brown, "Nuclear Weapons Cost Study," Global Zero Technical Report, June 2011, http://www.globalzero.org/files/scott/Global%20Zero%20Cost%20Study%2C%20June%202011.pdf. Core costs refer to researching, developing, procuring, testing, operating, maintaining, and upgrading the nuclear arsenal (weapons and their delivery vehicles) and its key nuclear command-control-communications and early warning infrastructure; full costs add unpaid/deferred environmental and health costs, missile defenses assigned to defend against nuclear weapons, nuclear threat reduction, and incident management. Not included are air defences, submarine warfare, and nuclear weapons-related intelligence and surveillance expenses.
36. Communications with Chinese nuclear experts in Beijing, July 2013.
37. "Negotiation on the Fissile Material Cut-off Treaty," Ministry of Foreign Affairs of the People's Republic of China, 27 May 2010,
38. China 2008 National Defense document, http://www.gov.cn/english/official/2009-01/20/content_1210227_16.htm.
39. See, e.g. Hui Zhang, "China's Perspective on a Nuclear –Free World," *op.cit.*
40. For instance, Guo Qiang, "US' nuke-free world plan stirs debate," *Global Times*, 24 September 2009.


Photo: Defense Image Database/Tam McDonald

France
Hans M. Kristensen

France spends about a third of its defence budget on nuclear forces. Like all of the other nuclear-armed states, France is in the middle of a broad modernisation of its nuclear forces involving submarines, aircraft, missiles, warheads, and production facilities. And studies of next-generation weapon systems have begun.

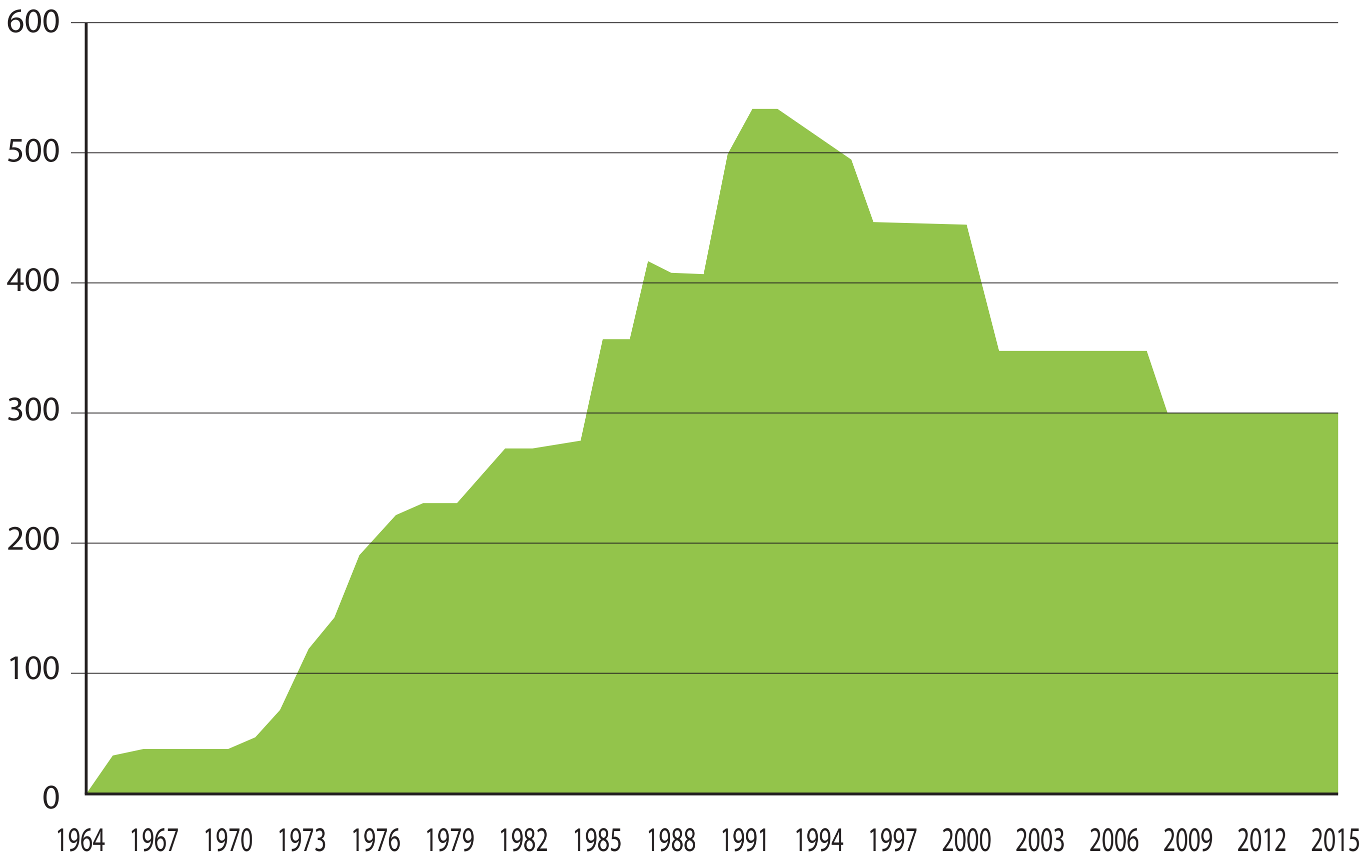
Having reducing its air-delivered nuclear forces by one-third in 2008, France does not appear to have plans to reduce its nuclear forces for the foreseeable future. The Hollande government has rejected further cuts and reaffirmed the existing nuclear posture. The absence of plans or negotiations for further reductions are, especially when considered in context with its substantial nuclear modernisation, in conflict with France's obligations under the nuclear Non-Proliferation Treaty to pursue additional reductions of nuclear weapons.

Status of French nuclear forces

As of early 2015, France possessed a stockpile of an estimated 300 nuclear warheads. Nearly all of these warheads are deployed or operationally available for deployment on short notice. A small number of additional warheads are in maintenance or awaiting dismantlement.

The current forces level is the result of recent adjustments made to the posture following former President Nicolas Sarkozy's announcement on 21 March 2008, that the "arsenal" would be reduced to "fewer than 300 warheads" by cutting one of three nuclear bomber squadrons.[1] This posture was reaffirmed by President François Hollande on 25 February 2015, when he declared that France has a stockpile of 300 warheads for "three sets of 16 submarine-based missiles and 54 ASMPA delivery systems."[2]

The 300-warhead stockpile is, Sarkozy declared in 2008, "half of the maximum number of warheads we had during the Cold War."[3] The peak occurred in 1991-1992 at end of the Cold War, and the size of today's stockpile is about the same as in 1984 (see Figure 1), although the composition is significantly different.



The roughly 300 nuclear warheads in the current French nuclear weapons stockpile correspond to about half of the peak stockpile size at the end of the Cold War, and about equal to the stockpile size in 1984.

Delivery systems

France's nuclear posture is based on two types of delivery vehicles: aircraft and ballistic missiles (see Table 1). The aircraft exist in two forms: land- and sea-based fighter-bomber jets.

DELIVERY VEHICLE	NO. OPERATIONAL	YEAR DEPLOYED[a]	RANGE (KILOMETERS)[b]	WARHEAD X YIELD (KILOTONS)	WARHEADS
LAND-BASED AIRCRAFT					
Mirage 2000 NK3 /ASMPA	20	1988/2009	2,750	1 TNA X Variable to 300	20
Rafale F3/ASMPA	20	2008/2010	2,000	1 TNA X Variable to 300	20
CARRIER-BASED AIRCRAFT					
Rafale F3/ASMPA	10	2010/2011	2,000	1 TNA X Variable to 300	10
SLBM[c]					
M45	16	1997	>5,000	up to 6 TN75 x100[d]	80
M51.1	32	2010	>6,000	up to 6 TN75 x100[e]	160
M51.2	n.a.	2016	>6,000+	up to 6 TN75 x150	n.a.
M51.3	n.a.	(2020)	?	?	n.a.
TOTAL	**98**				**~300**

a For aircraft, the first number is for the aircraft, the second is for when the ASMPA first became operational with that aircraft.

b For aircraft the number listed is maximum range without refueling. Combat range is shorter but is extended by air refueling from tanker aircraft. The maximum range of the ASMPA is 500 kilometers. For SLBM ranges, see: French Navy, "Missiles balistiques stratégiques (MSBS)," updated 11 March 2015, http://www.defense.gouv.fr/marine/decouverte/equipements-moyens-materiel-militaire/missiles/missiles-balistiques-strategiques-msbs

c Three sets of missiles are available for three of four SSBNs in the operational cycle.

d Compared with its predecessor, the M4, the M45 carries "higher-performance TN75 nuclear warheads (stealthier RV and penetration aids)."

e The M51.1, which first became operational on the Terrible in late-2010, has "significantly greater range and payload capacity, as well as greater accuracy" than the M45. Payloads on individual missiles may vary significantly depending on mission.

Land-based aircraft

The land-based aircraft are organized under the Strategic Air Forces (Forces Aériennes Stratégiques, or FAS), which operates two nuclear-capable fighter-bombers in two squadrons: the Mirage 2000N K3 with the 2/4 "La Fayette" squadron at Istres Air Base in southern France, and the Rafale F3 with the 1/91 "Gascogne" squadron at Saint Dizier Air Base about 190 km east of Paris. Approximately 40 aircraft (20 of each type) are thought to be assigned a total of 40 ASMPA cruise missiles.

The Mirage 2000N K3, which first entered operations in 1988, carries two pilots and has an unrefueled combat range of approximately 1480 km. The standard nuclear strike configuration is with the ASMPA on the centerline pylon and two 1700-liter fuel tanks under the wings. The remaining Mirage 2000Ns at Istres will be replaced by the Rafale in 2018.

The two-seater Rafale F3 nuclear version, which first entered service in 2009 at Saint Dizier airbase, has an unrefueled combat range 1850 km. As with the Mirage 2000N, the standard nuclear strike configuration for the Rafale F3 is with the ASMPA on the centerline pylon and two fuel tanks under the wings. Initially projected at 294 aircraft (232 for the Air Force and 60 for the Navy), the Rafale programme has been scaled back significantly to 132 aircraft for the Air Force (and 48 Ms for the Navy).

France operates a fleet of 14 Boeing-produced C-135FR tankers to refuel its nuclear strike aircraft. The tankers are organized under the 0/93 Bretagne squadron at Istres airbase. The C-135FR is being replaced with 12 new Phénix (Airbus 330) tankers, the first two in 2018.

The ASMPA is a nuclear enhanced medium-range air-to-ground missile with a ramjet engine and a maximum range of 500 km. The missile carries the new TNA warhead with an estimated maximum yield of 300 kilotons, although lowers yield options are thought to be available. MBDA Missile Systems states that the TNA is a "medium energy thermonuclear charge, a concept validated during the last nuclear testing campaign [in 1995-1996]. Simulators have proven its effective operation."[6] Although validated by live nuclear tests, the French Ministry of Defence states that the TNA is the only nuclear warhead that has been designed and certified by simulation rather than nuclear tests.[7]

Following initial design development in 1997, the ASMPA production contract was awarded in 2000 to Aerospatiale Matra Missiles at a value of more than five billion French Francs ($1 billion).[8] Aerospatiale Matra Missiles later merged with other companies to form the MDBA, the current producer of ASMPA. The 2015 budget includes 26.6 million ($29 million) for maintaining ASMPA reliability.

The ASMPA first became operational on 1 October 2009, on the Mirage 2000Ns of the 3/4 "Limousin" Fighter Squadron (since re-designated as the 2/4 "La Fayette" squadron) at Istres airbase in southern France. The ASMPA was declared operational on the Rafale F3s of the 1/91 "Gascogne" Fighter Squadron during a ceremony at Saint-Dizer airbase (Air Base 113) on 1 July 2010. Production and delivery of the ASMPA and its TNA warhead was completed in 2011. The warheads for the ASMPAs are thought to be stored at the two bases as well as the Avord Air Base 200 km south of Paris.

Following the announcement by President Sarkozy in 2008 that the air-based nuclear posture would be reduced by one-third, the Strategic Air Force has been significantly reorganised in recent years. Of the three nuclear fighter-bomber squadrons that existed in 2008, two have been disbanded, one transferred, and an earlier disbanded squadron has be re-established at a new location. Of the two squadrons previously based at Luxeuil airbase, one (1/4 Dauphine) was disbanded in 2010 and the other (2/4 La Fayette) was moved to Istres airbase where it replaced the 3/4 Limousin squadron in 2011. Two squadrons now remain: the 2/4 "La Fayette" squadron at Istres airbase near Marseille and the 1/91 "Gascogne" squadron at Saint Dizier airbase east of Paris (see Table 2).

Although the ASMPA became operation in 2009, France has already started design development of a next-generation air-launched nuclear cruise missile. The new missile will have increased range and stealth features.

Along with reorganization and modernisation of the aircraft and their weapons, the nuclear custodial units have also been reorganized. The nuclear weapons custodial unit at Istres has been converted to ASMPA, and the nuclear weapons unit at Luxeuil has been disbanded. The nuclear weapons custodial unit at Saint Dizier that previously provided ASMP support to one of the two nuclear squadrons that used to be at Luxeuil, has now been converted to ASMPA to support the new 1/91 Gascogne squadron at Saint Dizier.

The airbase at Avord (BA 702) continues to provide nuclear support to the fighter squadrons. The base has a nuclear weapons storage area managed by a nuclear weapons custodial unit and recently converted to the new ASMPA missile.

Due to the relatively short range of the Mirage 2000N and Rafale aircraft, France's air-base nuclear weapons depend on refueling aircraft. The current tanker fleet , the

BASE	2008	2015
Avord (BA 702)	14.004 DAMS	91.532 DAMS
Istres (BA 125)	3/4 Limousin Sq Mirage 2000N K3/ASMP 11.004 DAMS	2/4 La Fayette Sq Mirage 2000N K3/ASMPA 11.004 DAMS
Luxeuil (BA 116)	1/4 Dauphine Sq Mirage 2000N K3/ASMP 2/4 La Fayette Sq Mirage 2000N K3/ASMP 13.004 DAMS	No nuclear units but might serve as dispersal base
Saint Dizier (BA 113)	18.004 DAMS*	1/91 Gascogne Sq Rafale F3/ASMPA 18.004 DAMS
Key: ASMP = Air-Sol Moyenne Portee; ASMPA = Air-Sol Moyenne Portee Amélioré; BA – Base Aériennes; DAMS = Dépôt Atelier de Munitions Spéciales (special weapons depot); Sq = Squadron.		

Photo: Flickr/Todd Lappin

US-supplied KC-135, is based at Istres airbase, one of the two nuclear airbases. Under current plans, the KC-135 will be replaced with the multi-role Airbus 330 tanker-transport, known as A330 MRTT Phoenix. A total of 12 A330s have been ordered at a cost of Euro 3 billion ($3.3 billion) with first delivery in 2018.[9]

Sea-based aircraft

The aircraft carrier Charles de Gaulle (R91) is equipped to carry ASMPA cruise missiles for delivery by Rafale MF3 fighter-bombers organized under the 12F squadron. This mission was previously performed by the Super Étandard, but the Rafale MF3 is taking over this mission and the Super Étandard is scheduled to be retired in 2016. The first of 10 Rafale F3s was delivered in 2014 and the last will be delivered in 2017 at a cost of 240 million ($261.9 million).

When not deployed on the carrier, the air wing is based at Landivisau in northern France. When deployed, the Charles de Gaulle does not carry nuclear weapons under normal circumstances. Its complement of ASMPA missiles is probably stored at one of the air bases, probably Istres airbase.

Management of the ASMPA cruise missile for the Rafale MF3 on the Charles de Gaulle carrier is supported by the centre d'expérimentations pratiques et de réception de l'aéronautique navale (the center for practical experiments and integration of naval aviation, CEPA/10S) at Istres airbase (AB 125).

According to the French Navy, the Nuclear Naval-Air Force (FANU) based on the carrier is "[l]ess powerful" than the nuclear submarines "but more conspicuous" and "boasts great flexibility in terms of positioning and in demonstrating the power of the aircraft carrier."[10]

Suggestions in 2013 that the carrier-based nuclear capability be retired[11] were rejected by the Hollande government, which decided to retain the force.[12]

Sea-launched ballistic missile submarines

France operates four Triomphant-class nuclear-powered ballistic missile submarines (SSBNs) equipped with nuclear-armed long-range ballistic missiles (SLBMs). The fleet, which is known as the FOST (La Force Océanique Stratégique), is based at the Ile Longue peninsula near Brest.Of the four SSBNs, at least two are always fully operational, one of them at sea on "deterrent patrol". A patrol reportedly lasts about 10 weeks.[13]

Ballistic missiles for non-deployed submarines or stored onboard the submarine at the Ile Longue base or in unique silos at the base. The warheads, if not loaded on the missiles, are at the weapons storage facility near Saint-Jean approximately four kilometers south of the Ill Longue.

The French SSBN force is in the middle of an upgrade from the M45 to the M51 missile. Currently, one of the four SSBNs is equipped to carry the M45, two carry the M51, and one is undergoing conversion to the M51.

The M45 entered service in 1997, has a range of more than 4000 km and can carry up to six TN75 thermonuclear warheads. The TN75 was proof tested during France's final nuclear test series at Mururoa in 1995–1996.

The current version of the M51 is known as M51.1. It first became operational on Le Terrible in late-2010. The production contract was awarded to EADS Astrium SPACE Transportation in 2004 at a price of Euro 3 billion ($3 billion).[14] The 2015 budget includes Euro 610.9 million ($666.6 million) to maintain and modify the M51, and another Euro 190.9 million ($208.3 million to adapt the M51 for the next-generation SSBN.[15]

The M51.1 carries the same warhead (TN75) as the M45, but the M51.1 reportedly has "significantly greater range and payload capacity, as well as greater accuracy."[16] Increasing the payload makes little sense today so the M51 probably carries the same number of warheads as its predecessor, or less, to maximize countermeasures and range.[17]

SSBN	2015	2018	2020
Le Triomphant (S 616)	M51.1/TN75	M51.2/TNO	M51.2/TNO
Le Téméraire (S 617)	M45/TN75	M51.2/TNO	M51.2/TNO
Le Vigilant (S 618)	M51.1/TN75	M51.1/TN75	M51.2/TNO
Le Terrible (S 619)	M51.1/TN75*	M51.1/TN75	M51.3/TNO?

Note: Only three sets of missiles and warheads are produced. The forth SSBN will be in overhaul at any given time.
* The Terrible became operational with the M51 SLBM in December 2010.

Conversion of the remaining three SSBNs to the M51 has happened during their normal maintenance and refueling cycles. Conversion of the final boat (Téméraire) is planned for completion in 2018.[18]

From 2016, the modified M51.2 will be introduced on the Triomphant, which will carry a new warhead known as the TNO (Tête Nucléaire Océanique).[19] The development contract was awarded to EADS Astrium Space Transportation in the third quarter of 2010. Work on a third version of the M51, known as M51.3, began in 2014 and is scheduled for deployment around 2020, possibly on the Terrible.

Operation of the SSBN force reportedly costs more than $2 billion (Euro1.5 billion) per year,[20] and a French audit report in 2010 found that the unit wcost of the SSBNs had increased by more than 50 percent.[21]

Although not nuclear-armed themselves, Rubin-class nuclear-powered attack submarines play an important part in the nuclear mission by providing protection to SSBNs deploying on patrol.[22] The Rubin-class will be replaced in this mission by the Barracuda-class starting in 2018.

Fissile materials

France is no longer thought to be producing fissile materials for nuclear weapons. Large quantities produced during the Cold War are more than sufficient for the current warhead level. Plutonium production at the Marcoule facility ceased in 1992 with an estimated six tons remaining. HEU production ended in 1996 with an estimated 26 tons remaining, and the HEU production plant at Pierrelatte has been dismantled.[23]

The nuclear weapons complex

France's nuclear weapons complex is managed by the DAM (Direction des Applications Militaires), a department within the Nuclear Energy Commission (Le Commissariat à L'énergie Atomique et aux Énergies Renouvelables, CEA). DAM is responsible for research, design, manufacture, operational maintenance, and dismantlement of nuclear warheads. Of CEA's 15,000 employee, more than 4,700 are working for the DAM. In 2010, the DAM received Euro 1.7 billion ($1.9 billion) of the Euro4.2 billion allocated to CEA. Following the decision to end nuclear testing in 1996, France has reorganized its nuclear weapons centers. Today, DAM operates six sites (see Table 4).

NAME OF FACILITY	LOCATION (COORDINATES)	ROLE
Centre d'Etudes de Valduc (CEA Valduc)	Burgundy (47°34'37.02"N, 4°52'6.79"E)	Warhead production and dismantlement. Hydrodynamic test center added from 2014.
DAM-Ile-de-France (CEA Bruyères-le-Châtel)	Ile-de-France (48°35'40.53"N, 2°12'0.30"E)	Warhead design research and computer simulation.
Centre d'Etudes de Ripault (CEA Ripault)	Centre (47°17'26.05"N, 0°40'13.66"E)	Research and production of non-nuclear components, including high explosives.
Centre d'Études Scientifiques et Techniques d'Aquitaine (CESTA)	Aquitaine (44°38'46.70"N, 0°47'42.20"W)	Design of equipment for nuclear weapons, reentry vehicles, and coordinates the development of nuclear warheads. The site is the location of the Mejoule facility designed to study the fusion process of secondaries.
Centre d'Etudes de Vaujour-Moronvilliers (CEA Moronvilliers)	Champagne-Ardenne (49°14'5.32"N, 4°19'16.88"E)	Airix x-ray machine used to study hydrodynamic behavior of pre-fission implosion of primary. Airix being moved to Valduc.
Centre d'études de Gramat (CEA Gramat)	Midi-Pyrénées (44°44'23.44"N, 1°44'3.05"E)	National center for studying vulnerability of nuclear weapons systems to nuclear effects.

Warhead design and simulation of nuclear warheads take place at the DAM-Ile-de-France (Bruyères-le-Châtel) Centre approximately 30 kilometers south of Paris. The centre houses Tera 100, a super computer that went into operation in July 2010. The previous generation super computer, Tera 10, is also located at the centre, which employs about half of the people affiliated with the military section (DAM) of the CEA.

The Valduc Center (Centre d'Etudes de Valduc, or CEA Valduc) is responsible for nuclear warhead production, maintenance, and dismantlement. It is located approximately 30 kilometers northwest of Dijon and is undergoing expansion to accommodate new facilities resulting from the 2010 French-British defence treaty. The AIRIX x-ray radiography facility is being moved to Valduc from the Moronvilliers center to become operational in 2014. A second radiography facility will be added by 2019, and a third by 2022 to form the Epure facility.

The CESTA (Centre d'Études Scientifiques et Techniques d'Aquitaine) near Le Barp is responsible for the design of equipment for nuclear weapons, reentry, and coordinates the development of nuclear warheads. The site is also the location of the new Megajoule laser, France's equivalent of the US National Ignition Facility. Construction of Megajoule, which will study the thermonuclear process in warhead secondaries, began in 2005 and was scheduled for completion in 2014. A smaller Laser Integration Line (LIL) laser has been operating at CESTA since 2002 to validate the Megajoule design. The Megajoule reportedly costs Euro 3.5 billion ($3.8 billion).[24] CESTA was established in 1965 and employs 970 people.

The Vaujour-Moronvilliers Centre 60 kilometers east of Reims includes the Airix x-ray pulse machine established in 2000 to study the pre-fission hydrodynamic behavior of imploding high explosives in a nuclear warhead primary. The results are used to validate warhead simulation computer codes. Airix was scheduled to be re-established at Valduc in 2014.

The Gramat Centre (Centre d'études de Gramat) is responsible for hardening nuclear weapons against radiation. The centre was transferred to the CEA in 2010.

Combined, warhead simulation costs account for approximately Euro 505 million ($551 million) in the 2015 budget.[25]

Naval nuclear propulsion

In addition to nuclear weapons production, France spends considerable resources on building nuclear propulsion for naval vessels that carry the nuclear weapons. France currently has 11 nuclear-powered naval vessels in operation: four Triumphant-class ballistic missile submarines, six Rubis-class attack submarines, and one Charles de Gaulle-class aircraft carrier. Although nuclear-powered attack submarines are not nuclear-armed, they play an important role in the nuclear posture by protecting SSBNs on patrol. Construction of a replacement for the Rubin-class is underway, known as the Barracuda-class, at a price of more than Euro 8.6 billion ($9.4 billion) for six boats, with the first unit expected in 2017.[26]

Construction of nuclear-powered vessels happens at the naval shipyard in Cherbourg on the English Channel. Development and testing of the nuclear reactors takes place at CEA Cadarache center north of Toulon. Production of the reactors happens near Nantes at the naval propulsion factory of DCNS (Direction des Constructions Navales), the manager of the naval shipyard at Cherbourg. Refueling of the nuclear-powered vessels takes place at the naval shipyard in Toulon. The fuel-life of French naval reactor cores is probably 6 to 8 years.

Economics

Assessing the total cost of French nuclear forces is difficult. There is no detailed official public nuclear budget and reports vary depending on sources and cost categories counted. France is generally thought to spend about a third of its annual military budget on the nuclear mission. The 2015 military budget includes Euro 2.6 billion ($2.8 billion) for nuclear forces, Euro 93 million ($101.5 million) for SSBN infrastructure, and Euro 450 million ($491 million) for operations,[27] for a total of at least Euro 3.1 billion ($3.4 billion) for nuclear-related costs. If adding other items, according to one assessment, annual spending on the nuclear forces comes to Euro 3.9 billion ($4.2 billion) in the 2014-2019 plan, up from Euro 2.8 billion ($3 billion) in the 2003-2008 defense plan and Euro 3.8 billion ($4.1 billion) in 2009-2014.[28]

International law

Although the French government will insist that its recent reduction of the land-based air-delivered nuclear force is consistent with France's obligations under article VI of the nuclear Non-Proliferation Treaty to pursue nuclear reductions, its rejection of additional reductions and its ongoing modernisation of its nuclear forces might be seen as being out of sync with those obligations.

If France were to change this policy and reduce its nuclear forces further, the most likely first option would be to phase out the carrier-based nuclear capability. An additional step could be to eliminate the air-delivered ASMPA nuclear cruise missile altogether. In addition to strengthening France's arms control saving record, doing so would save scarce military resources and free the bomber squadrons of the unnecessary burden of nuclear weapons certifications and operations to focus on the more relevant conventional mission.

Phasing out the carrier- and sea-based nuclear cruise missiles would still leave France with a robust and capable sea-based nuclear strike force sufficient to "deter" nuclear attack on France.

Public discourse

Although there is some debate in France over the composition and cost of the nuclear forces, it is not a very prominent debate. The nuclear defense establishment is very insulated and views the future of the "force de frappe" as beyond public debate. When defence officials in 2013 rejected a proposal from a private institute to phase out the nuclear strike mission on France's single aircraft carrier, civilian sources warned of a pro-nuclear defence lobby imposing an artificial "consensus" about French nuclear doctrine. "It's locked down," a defence expert said. Anyone who questions the deterrent doctrine is subject to "eviction or ridicule".[29]

Not surprisingly, President François Hollande announced in February 2015 that he had decided to retain the carrier-based nuclear capability, upgrade the last remaining Mirage 2000N squadron to Rafale, begin future upgrades of the M51 SLBM, commission design studies for a new class of SSBNs to replace the current Triumphant-class submarines, and develop a new and improved air-launched cruise missile.[30]

Hollande rejected additional reductions for the foreseeable future. "If the level of other arsenals, particularly those of Russia and the United States, were to fall one day to a few hundred weapons, France would respond accordingly, as it always has," he said but added: "But today, that scenario is still a long way off."[31]

Notes:

1 *Speech by Nicolas Sarkozy, President of the French Republic, Presentation of Le Terrible in Cherbourg*, 21 March 2008, p. 8. A copy of the French version is available here: http://www.elysee.fr/president/root/bank/pdf/president-1944.pdf. For an overview of French nuclear forces in 2008, see: Robert S. Norris and Hans M. Kristensen, "French nuclear forces, 2008," Nuclear Notebook, *Bulletin of the Atomic Scientists*, September 2008, http://bos.sagepub.com/content/64/4/52.full.pdf+html.

2. Speech by François Hollande, *Visit to the Strategic Air Forces*, 25 February 2015, p. 9, http://basedoc.diplomatie.gouv.fr/vues/Kiosque/FranceDiplomatie/kiosque.php?fichier=baen2015-02-25.html.

3 *Speech by Nicolas Sarkozy, President of the French Republic, Presentation of Le Terrible in Cherbourg*, *op. cit.*

4. "French MSBS Programmes (Submarine-Launched Ballistic Missiles)," EADS, 13 June 2005, http://www.eads.com/eads/int/en/news/press.en_20050613_MSBS.html

5. Ibid.

6 *ASMPA: Air-To-Ground Missile, Medium Range, Enhanced*, MBDA Missile Systems, n.d., http://www.mbda-systems.com/mediagallery/files/asmpa_ds.pdf. The yield of the TNA warhead is not known but the yields of the devices detonated in the South Pacific during the 1995–1996 probably provide a clue; the yields ranged from less than 20 to 120 kilotons. The last test conducted on 27 January 1996, had a yield of 120 kilotons. *Fifteenth Anniversary of France's Last Nuclear Test*, CTBTO Preparatory Commission, 27 January 2011, http://www.ctbto.org/press-centre/highlights/2011/fifteenth-anniversaryof-frances-last-nuclear-test/.

7. Le General D'Armee Aerienne Jean-Paul Paloméros, Chef D'Etat- Major de L'Armee de L'Air, *ORDRE DU JOUR N°7*, 1 July 2010, http://www.defense.gouv.fr/content/download/76218/679550/file/01-07-10 - Allocution sur le couple Rafale - ASMPA.pdf.

8. "The Vesta ramjet completes its development phase with a successful series of tests," *MBDA Missile Systems*, Press Release, 12 March 2001, http://www.mbdasystems.com/mediagallery/#/news/2530.

9. "France orders 12 "Phoenix" aerial refuellers from Airbus for €3 Billion," Defense Update, 21 November 2014, http://defense-update.com/20141121_a330_mrtt.html#.VRIct4rF_wQ.

10. French Navy, "Navy action regarding this strategic function," 18 July 2011, http://www.defense.gouv.fr/english/navy/missions2/deterrence.

11. Pierre Tran, "French Cuts Spur Debate on Nuke Deterrence Budget," Defense News, 8 January 2013, http://archive.defensenews.com/article/20130108/DEFREG01/301080002/French-Cuts-Spur-Debate-Nuke-Deterrence-Budget

12. Speech by François Hollande, *Visit to the Strategic Air Forces*, 25 February 2015, p. 6, http://basedoc.diplomatie.gouv.fr/vues/Kiosque/FranceDiplomatie/kiosque.php?fichier=baen2015-02-25.html.

13. "Propulsion nucléaire: Quand la flotte veille au grain," CEA, n.d. [accessed 6 February 2012], http://www.cea.fr/defense/propulsion_nucleaire/quand_la_flotte_veille_au_grain.

14. "Contract for the production of the M51 Weapon System," *EADS*, 23 December 2004, http://www.eads.com/eads/int/en/news/press.en_20041223_m51.html.

15. French Government, *Budget Général: Mission Ministérielle, Project Annuels De Performances, Annex au Project de Loi de Finance Pour Defence*, 2015, p. 327, http://www.performance-publique.budget.gouv.fr/sites/performance_publique/files/farandole/ressources/2015/pap/pdf/PAP_2015_BG_defense.pdf.

16. "French MSBS Porgrammes (Submarine-Launched Ballistic Missiles)," EADS, 13 June 2005, http://www.eads.com/eads/int/en/news/press.en_20050613_MSBS.html.

17. Some unofficial sources estimate the M51 range a much higher: 8,000-10,000 kilometers. See: Nicolas Pillet, "Le Terrible a tiré avec succès un M-51!," *Aeroplans*, 28 January 2010, http://www.aeroplans.fr/Europespace/terrible-tir-m51.html; the article appears to draw upon this wiki-type web site: "Missile M51," http://fr.goldenmap.com/Missile_M51.

18. "Adaptation au M51 des SNLE," French Ministry of Defense, 3 December 2010, http://www.defense.gouv.fr/dga/equipement/dissuasion/adaptation-au-m51-des-snle/.

19. "M51 - Missile mer-sol balistique stratégique," French Ministry of Defense, 14 June 2011, http://www.defense.gouv.fr/dga/equipement/dissuasion/m51-missile-mer-sol-balistique-strategique/.

20. National Assembly, *op. cit.*

21. "French Audit Report Reveals Weapon Prices, A400M Details," 18 March 2010, http://www.defense-aerospace.com/article-view/feature/112431/french-auditor-reveals-weapon-prices%2C-a400m-details.html.

22. The F67-class frigate was also used to protect SSBNs. The last of the class, *Touraille*, was retired in June 2011. Some of the new FREMM-class frigates might inherit the SSBN protection mission.

23. For estimates of French fissile material production and status, see: *Global Fissile Material Report 2011: Nuclear Weapons and Fissile Material Stockpiles and Production*, International Panel on Fissile Materials, 2011; *Global Fissile Material Report 2011: Balancing the Books: Production and Stocks*, International Panel on Fissile Materials, 2010; both reports are available at http://www.fissilematerials.org.

24. "Laser mégajoule, des essais nucléaires en laboratoire," Le Figaro, 25 February 2015, http://www.lefigaro.fr/sciences/2015/02/25/01008-20150225ARTFIG00305-laser-megajoule-des-essais-nucleaires-en-laboratoire.php; CEA, "Le Laser Mégajoule: Des retombées pour l'industrie," 6 December 2010, http://www-lmj.cea.fr/fr/installation/des_retombees_pour_l_industrie.htm.

25. French Government, *Budget Général: Mission Ministérielle, Project Annuels De Performances, Annex au Project de Loi de Finance Pour Defence*, 2015, p. 349, http://www.performance-publique.budget.gouv.fr/sites/performance_publique/files/farandole/ressources/2015/pap/pdf/PAP_2015_BG_defense.pdf.

26. For background and status of the Barracuda program, see: "France's Future SSNs: The Barracuda Class," *Defense Industry Daily*, 11 December 2011, http://www.defenseindustrydaily.com/frances-future-ssns-the-barracuda-class-02902/.

27. French Government, *Budget Général: Mission Ministérielle, Project Annuels De Performances, Annex au Project de Loi de Finance Pour Defence*, 2015, http://www.performance-publique.budget.gouv.fr/sites/performance_publique/files/farandole/ressources/2015/pap/pdf/PAP_2015_BG_defense.pdf.

28. Jean-Marie Collin, "Dissuasion nucléaire : l'obstination française," GRIP, 19 February 2015, p. 2, http://www.grip.org/sites/grip.org/files/BREVES/2015/EC_2015-02-19_FR_JM-COLLIN.pdf. For 2011 estimates, see also: Bruce G. Blair and Matthew A. Brown, *Nuclear Weapons Cost Study*, Global Zero Technical Report, June 2011, p. 1, http://www.globalzero.org/files/scott/Global%20Zero%20Cost%20Study,%20June%202011.pdf; National Assembly, *op. cit.*

29. Pierre Tran, "French Cuts Spur Debate on Nuke Deterrence Budget," Defense News, 8 January 2013, http://archive.defensenews.com/article/20130108/DEFREG01/301080002/French-Cuts-Spur-Debate-Nuke-Deterrence-Budget.

30. Speech by François Hollande, *Visit to the Strategic Air Forces*, 25 February 2015, pp. 6, 7, http://basedoc.diplomatie.gouv.fr/vues/Kiosque/FranceDiplomatie/kiosque.php?fichier=baen2015-02-25.html.

31. Speech by François Hollande, *Visit to the Strategic Air Forces*, 25 February 2015, p. 9, http://basedoc.diplomatie.gouv.fr/vues/Kiosque/FranceDiplomatie/kiosque.php?fichier=baen2015-02-25.html.

India

M.V. Ramana

The 2014 elections in India brought the Hindu Nationalist Bharatiya Janata Party (BJP), under the leadership of Narendra Modi, back into power. In his election manifesto, Modi, an authoritarian politician, promised to "revise and update" India's nuclear doctrine and "make it relevant to [the] challenges of current times."[1] When it last came to power, in 1998, the BJP fulfilled an election campaign pledge by ordering nuclear weapon tests, the first since 1974, and its then leader Atul Vajpayee proudly proclaimed India to be a nuclear-armed state.[2] The first months of the Modi government have not seen a public statement of a new nuclear doctrine, but there has been a significant increase in military expenditure and plans for ambitious new programmes, especially nuclear submarines.

Indian officials increasingly claim to have realized a nuclear strategy they call "credible minimum deterrence," while recognizing that some technical and military capabilities still need to be acquired.[3] As of mid-2014, the Nuclear Notebook of the Bulletin of the Atomic Scientists estimated that India has 90 to 110 nuclear weapons.[4] It has the capability to deliver these weapons using airplanes and land-based missiles, and there are plans for submarine-launched missiles. Questions about the state of India's nuclear weapon capabilities and planning have focused less on the hardware of the arsenal and more on aspects such as the operational requirements for being able to use the weapons and the state of planning for the execution of nuclear war. Occasionally, however, there are questions about the reliability both of the nuclear warheads (described in the 2012 report) and the missiles.[5]

Status of India's nuclear forces

India's nuclear arsenal is still in the development stage, rather than being modernised. Programmes are largely aimed at developing and deploying new delivery systems that would be more capable of attacking cities and their populations at greater distances, one goal being to target major population centres in China. The testing of these systems is a highly visible, well publicised activity in complete contrast to the near absence of official information about other aspects of the nuclear arsenal, including technical aspects of the weapons themselves, their command and control, and plans for their use. Although there is evidence of efforts aimed at increasing coordination between the scientific agencies that control the nuclear weapons and the different wings of the military that control the delivery systems to enable more effective operationalisation of India's nuclear forces, there is little detail available publicly.

Delivery systems

Following the lead of other nuclear-armed states, Indian policy makers desire the ability to deliver their nuclear weapons using airplanes, ballistic missiles launched from land, and submarine-launched missiles, even though the official nuclear doctrine dating back to 2003 does not call for such a triad.[6] However, Indian nuclear planning has largely relied on an earlier document, with no official status, known as the draft nuclear doctrine released by the National Security Advisory Board in 1999.[7] This calls for India's nuclear forces to be deployed on a triad of delivery vehicles of "aircraft, mobile land-based missiles and sea-based assets" that are structured for "punitive retaliation" so as to "inflict damage unacceptable to the aggressor". The reference to "sea-based assets," a relatively vague term that was not explained, may have reflected either secrecy or uncertainty about progress on the ballistic missile submarine project and in principle allows for different kinds of naval nuclear weapon systems to be acquired.

Aircrafts are India's oldest nuclear delivery system. Indeed, until 1998, the Indian Air Force was the only military service with a nuclear role and had modified some of the aircraft it had imported from France to deliver the weapons.[8] Currently, the Indian Air Force has several aircraft that are capable of delivering nuclear weapons, the Mirage 2000-H, the Jaguar IS/IB, and the Sukhoi-30.[9] However, the Air Force is modernising its fleet and some of these will likely be replaced by other aircraft.[10] Nuclear planners would like, in particular, "long range bombers with a capability to deliver cruise missiles or nuclear capable standoff air to surface missiles."[11]

The naval leg of the triad has been the focus of much attention in recent years. India is in the process of deploying its first nuclear submarine, Arihant. Although much delayed, the submarine began what were described as "sea acceptance trials" in December 2014, having earlier "passed its harbor acceptance trials."[12] The delay is explained as being due to the caution on the part of the safety regulatory authority.[13] However, it is reported that a second nuclear submarine is ready and a third vessel is under construction.[14] Another nuclear fuel core to reload the Arihant submarine after it has been in service for some years is reportedly also "ready for shipping".[15]

The Arihant submarine is intended to carry up to 12 ballistic missiles each armed with one nuclear warhead. Currently, this missile is the B05, also known as the K-15, with a range of 700 to 750 kilometers. Testing of the missile started sometime in the late 2000s and the B05 missile has by now been tested over a dozen times.[16] The first four tests of the system were kept a secret and India publicly announced only the successful fifth test, in February 2008.[17] Many of the early tests, however, might have been tests of subsystems rather than the full missile.[18] The K-15/B05 missile will reportedly be test fired from the Arihant during the submarine's sea-acceptance trials.[19]

Naval planners want submarine launched missiles with longer ranges than K-15/B05 to be deployed. Vice Admiral Ravi N. Ganesh, who headed the Indian nuclear submarine building programme for four years, states "the INS Arihant and her successors will need to be armed with missiles of at least intermediate ballistic missile range (3,000 - 5,500km). Until a missile with this range becomes operational, India's sea-based deterrent must clearly be considered to be in a developmental stage."[20]

The process of building such longer range missiles has started. The first test of a 3000 kilometer range submarine-launched ballistic missile named K-4 was carried out in March 2014.[21] There were reports that the missile's gas-booster was tested earlier.[22] K-4 is believed to be capable of carrying a warhead weighing up to 2 tons and uses solid propellant. The Arihant submarine is reported to be capable of carrying four of these (as compared to twelve of the shorter range K-15 missiles).[23]

The expansion of the nuclear arsenal to the sea will result in a significant shift in India's nuclear posture. Thus far, to the extent that there is any public clarity of the fact, India is believed to keep its nuclear weapons separate from the delivery vehicles. Once there are operational submarines armed with nuclear weapons at sea, both the delivery vehicle and the weapons will be on the same platform.[24]

In February 2015, the government also approved the construction of six nuclear powered attack submarines.[25] The proposal is still in its very early stages and even the navy's technical requirements for these submarines are yet to be drafted.[26] The timing of the announcement may have to do with the defence establishment taking advantage of the more militaristic outlook of the Modi government; the programme is estimated to cost about 1 trillion Rupees ($16 billion in nominal exchange terms).[27] Development of such a naval capability appears to be part of a larger naval competition with China, with control of the Indian Ocean being a particular area of contention.[28]

While the naval leg of the triad is still under development, the land- and air-based legs have been in place for a while. The main land-based nuclear delivery system is the Agni series of missiles. Work on the Agni started as part of the Integrated Guided Missile Development Programme in 1983, but the missile has been substantially redesigned since the 1998 nuclear tests.[29] The latest of the missiles in this series is the three-stage, 5,000 kilometer range Agni V, which is fired from what is described as a canister rather than a fixed concrete launch pad.[30]

The significance of this firing mode is explained by the former Director General of the Defense Research and Development Organization (DRDO), Avinash Chander, who said in July 2013, "In the second strike capability, the most important thing is how fast we can react. We are working on cannisterised systems that can launch from anywhere at any time."[31] Being in a canister also allows for the missile to be transportable by truck on the road system and thus harder to locate. Agni V is scheduled for further tests and induction into the armed forces is projected for 2017.[32] This schedule may slip; in 2012, when the Agni V missile was first tested, V. K. Saraswat, the head of DRDO, the agency that developed the missile, announced: "We are going to conduct two more tests and those will be validation tests ... and then the production of this system will start. It is going to take a year maximum" and that the missile would be inducted into the armed forces in "the next two years," i.e. by 2014.[33]

The Agni IV missile with only two stages and a slightly shorter range is also still under testing before being deployed. Its latest test, in December 2014, involved the "users," the Strategic Forces Command that is in charge of the nuclear arsenal, and the missile was reportedly flown in "its full deliverable configuration".[34] Compared to the earlier Agni missiles, Agni IV is described as lighter in weight and capable of transporting a "payload with re-entry heat shield"; in other words, it could carry a nuclear weapon that would be expected to survive the high temperatures it would encounter as it re-enters the atmosphere in the last leg of its ballistic trajectory.[35] According to the Indian Ministry of Defense 2013-14 Annual Report, the Agni IV "missile is now ready for induction and its serial production will begin shortly."[36]

The Agni III also had roughly the same range as Agni IV but it was reportedly about three times as heavy.[37] It has undergone a number of tests, including one in December 2013 by "personnel of Strategic Forces Command" as part of "regular user training".[38] Likewise, the Agni II, with a range of 2000 to 2500 kilometers, and Agni I, with a range of 700 kilometers, have also been tested several times, including by the Strategic Forces Command.[39] Finally, there is the series of Prithvi missiles, which have a shorter range and are regularly tested by Strategic Forces Command, most recently in February 2015.[40]

According to India's Ministry of Defense, the Agni I, II, and III missiles "are already in the arsenal of the Armed Forces".[41] The International Institute for Strategic Studies estimates that the military possesses about 80 to 100 Agni I missiles and 20–25 Agni II missiles, and about 30 Prithvi I and Prithvi II missiles.[42]

In addition to these ballistic missiles, the DRDO has also been developing a cruise missile. The first successful test of the Nirbhay cruise missile took place in October 2014.[43] An earlier test failed and the flight had to be terminated mid-course.[44] With a reported range of 1000 km, the Nirbhay is said to be capable of delivering a small nuclear warhead.[45] The Nirbhay is now reportedly being adapted for being launched from the Russian Su-30MKI aircraft.[46]

For the future, the DRDO is said to be developing a longer range Agni VI. In addition to the longer range, DRDO's plans for this missile to be capable of carrying four or six warheads that would be aimed at different targets: what are called multiple independently targetable re-entry vehicles or MIRVs.[47] The unnamed DRDO missile technologist who spoke about the MIRV design to the media made it clear that the government had not yet sanctioned the Agni VI MIRV project, but the DRDO had already "done all the enabling studies, finalized the missile's design and started working on the engineering part."[48]

Another of the DRDO's more ambitious plans is to explore the possibility of using the capabilities of the Agni series of missiles, especially Agni V, to develop an anti-satellite (ASAT) weapon. In a public interview the head of the DRDO was clear that the development of an ASAT weapon was not something the Government had ordered, saying, "India does not believe in weaponization of space. We are only talking about having the capability. There are no plans for offensive space capabilities."[49] At the same time, the DRDO is also working on mini-satellites that would be used to identify military targets on the ground.[50]

Finally, there are plans to develop and deploy a ballistic missile defence (BMD) system. India's interest in BMD started in the 1990s with the DRDO starting conceptual studies, combined with discussions with Israel and Russia about air defence.[51] India has come a long way since then and is now reported to be planning the deployment of a BMD system around cities, possibly starting with Delhi and Mumbai.[52] In its first phase, the system will aim to counter incoming missiles of 2000 kilometer range, while stopping missiles with up to 5000 kilometer range would be attempted in the second phase.[53]

A key component of the BMD system is the Prithvi interceptor missile, which has been tested a number of times. The more recent tests have been conducted in the exo-atmosphere (altitude above 40 km) whereas the earlier ones were in the endo-atmosphere (altitude below 40 km).[54] In most cases, the results have been described as successful, although as in the United States, many of these tests are perhaps scripted and thus the interception may not have been in a very realistic situation.

In the cases of all these advanced systems, it is clear that there is a significant push from the military research establishment to develop these technologies, presumably in the hope that the government will agree to provide funding and thereby ensure continued work, if not expansion, for these laboratories.

Hawkish retired military personnel have picked up on these ideas and have added to the chorus. For example, the former Commander in Chief of the Strategic Forces Command has called publicly for the "development [of] MIRV and MaRV [Manoeuvering re-entry vehicles] capability" arguing, "MIRV does provide a system to increase the number of targets destroyed by one delivery vehicle, overcome missile interception defences, deliver more on a single missile, thereby reducing the delivery vehicles. However, the disadvantage of MIRV delivery missile loss does worry planners with small arsenals. MaRV is required to overcome missile interception defences, ensure assured strike and it also improves deterrence. Other aspects for future development are improved guidance systems, miniaturization, bigger SSBNs, antisatellite capability, space based sensors, earth penetrating systems and host of new technology required to overcome protection/ defensive systems."[55] There is evidently no end to the weapons desired by these hawks.

Fissile materials

India's nuclear weapons are based on plutonium. Although the country produces highly enriched uranium (HEU), the other fissile material commonly used in nuclear weapons, all the HEU produced in the country is believed to be earmarked for the nuclear submarine programme described earlier.

India has historically produced weapon-grade plutonium at two production reactors, CIRUS and Dhruva, both at the Bhabha Atomic Research Centre (BARC), in Mumbai.[56] The CIRUS reactor was shut down in December 2010, after 50 years of operation, and all the spent fuel from the reactor has been reprocessed to separate out the plutonium contained.[57] BARC is the primary location where most of the nuclear weapons work in the country is carried out. Besides the reactors, the site is also home to the Trombay reprocessing plant.[58] Metallurgical activities involving plutonium are carried out in the same complex.[59]

Because of overcrowding on the BARC site, a second nuclear site is being built in the city of Vishakhapatnam on the Eastern Coast of India. Among the important facilities being planned for this site are two new reactors, with power levels of 125 MWt and 30 MWt. According to the Indian government, construction of these reactors is "scheduled to commence" before 2017.[60]

On the basis of the limited amount of information available about the operations of these multiple facilities and reasonable assumptions, and after accounting for material that would have been used in nuclear weapons tests and other purposes, India is estimated to have a net stockpile of weapon-grade plutonium of 0.59 ± 0.20 tons as of the end of 2014.[61] The upper estimate includes the possibility that some of the power reactors in the country that are primarily meant for producing electricity have also produced limited amounts of weapon-grade plutonium.[62] The current stockpile of weapon-grade plutonium could suffice to produce about 100 warheads (assuming 5 kilograms per weapon).

There is also the possibility of using reactor-grade plutonium to make nuclear weapons. While there is no official confirmation of this possibility, there has been ample speculation that one of the devices tested in 1998 used reactor-grade plutonium.[63] If this is the case, then the nuclear arsenal could potentially be much larger. The estimated stockpile of separated plutonium from power reactors is 2.0 to 4.4 tons of plutonium as of the end of

2014.[64] Assuming that about eight kilograms of the material is required for a weapon, this stockpile could be used to make 250 to 550 weapons.

Officially, however, this stockpile of reactor-grade plutonium is intended for use as fuel for India's planned fast breeder reactors.[65] While it may consume reactor grade plutonium, the fast breeder program provides a potential source of weapon-grade plutonium. During the negotiations and public debates surrounding the nuclear deal that was negotiated with the United States, the DAE strenuously insisted on keeping outside of international safeguards the Prototype Fast Breeder Reactor (PFBR) being constructed at Kalpakkam in southern India. The PFBR can produce about 140 kilograms (kg) of weapon-grade plutonium every year if it operates at 75% efficiency.[66] This is sufficient for fabricating nearly 30 weapons every year and would represent a major increase in weapons production capacity. However, the PFBR has been repeatedly delayed and is now currently scheduled to start operating at full power ("commercialized") late in 2016.[67] When construction of the PFBR began in 2004, the commissioning date was projected to be 2010.[68]

The HEU used to fuel nuclear submarines comes from the Rare Materials Plant in Rattehalli, Mysore (Karnataka). The HEU is said to be enriched to a level between 30 and 45% of uranium-235, much less than weapon-grade uranium. Assuming an enrichment level of 30%, India is estimated to have a stockpile of 3.2 ± 1.1 tons of HEU as of the end of 2014.[69]

India's HEU production capability is being increased. Based on satellite imagery, in June 2014, the defence magazine IHS Jane's identified new buildings at the Rattehalli plant showing that the plant was being expanded.[70] A second enrichment facility called the Special Material Enrichment Facility has been proposed in Chitradurga, again in the state of Karnataka. According to officials, this facility will be used for both production of HEU for the submarine and for low enriched uranium to be used as nuclear reactor fuel.[71] However, there are no power reactors in the country that require low enriched uranium from Indian enrichment plants.[72] Thus, it is likely that the initial, if not primary, purpose of the second facility will be to produce HEU for military purposes.

The proposal to set up the Chitradurga enrichment plant as well as other military testing facilities in the area has been challenged by local villagers and environmentalists.[73] In a rare development, the National Green Tribunal, the country's top legal authority on environmental issues, ordered a stop to construction in August 2013. Although BARC has fenced up the area and is continuing preparatory activities, a strong opposition movement has so far not allowed actual construction.

The role of other countries

India's modernisation programmes and the larger militarisation project involve active commercial dealings and exchanges of technology with other countries. Its nuclear weapons programme owes much to Canada and the United States and the first ballistic missile, Prithvi, is based in part on reverse-engineering a Soviet missile.[74] In recent years, the main area of joint activity is the development of the BMD system.

For a decade or more, India's interest in developing a BMD system has found enthusiastic approval within some sections of the US nuclear policy making elite. For example, Ashley Tellis, who served as Senior Adviser to the US ambassador to India in the early 2000s, lauded the "dramatic new acceptance of strategic defenses as conducive to stability on the part of New Delhi" as "both an example of, and a means toward, the steady improvement in US-Indian ties."[75] US interest in engaging India on BMD even spilled over to NATO, and in 2011 a top NATO official even offered to cooperate with India on BMD.[76] Despite this interest on both sides, efforts by DRDO to work with Raytheon in the United States had not "come to fruition" under earlier governments, but there is an expectation among defence analysts that this is more likely under the current BJP government.[77]

The proposed plans for joint work on BMD need to be seen against a larger backdrop of India joining with the United States in an anti-China alliance, a long-held BJP goal. During the visit to New Delhi by President Barack Obama in January 2015, the two countries agreed on a "Joint Strategic Vision for the Asia-Pacific and Indian Ocean Region" as well as various military cooperation agreements. As pointed out by analyst and peace activist Praful Bidwai, these agreements aim to "recruit India into a partnership with the US to contain China's military and economic power in what pro-US enthusiasts term the 'Indo-Pacific', as part of the US 'pivot' to Asia."[78]

On the US side, the appointment of Ashton Carter as Secretary of Defense might prove significant. During a 2012 visit to India when he was still Deputy Defense Secretary, Carter spoke to the Confederation of Indian Industries, which represents the interests of Indian corporations, and termed BMD "an important potential area for our future cooperation," stressing that cooperation meant working on co-development of projects.[79]

The other country that is significant when it comes to Indian BMD plans is Israel. Though India has traditionally been a supporter of Palestinian rights and did not have diplomatic ties with Israel, things have changed substantially since in the last two decades.[80] India's defence relationship with Israel has also changed during this period. According to former Israeli Ambassador to India, during the Kargil war in 1999, "Israel came to India's assistance when India was in great need and brought about the turnaround in the situation on the ground."[81] These ties have been strengthened since the 2003 visit of Israel's Prime Minister

Ariel Sharon to India.[82] An important component of those ties revolved around plans to jointly build an integrated anti-missile system that was announced in February 2014.[83] The proposed missile "defence" programme is to involve Rafael and Israel Aircraft Industries in Israel and DRDO, Bharat Dynamics Limited, and Bharat Electronics Limited in India. It would consist of India's Prithvi missile in combination with an Israeli mobile radar system, quite likely the Green Pine radar. The Israeli Green Pine radar was originally developed for Israel's Arrow anti-ballistic missile system. India has imported Green Pine radars in the past and has since, with Israeli help, produced what it calls the Swordfish radar.[84]

Under the BJP, India is in the process of forming a much closer military alliance with Israel.[85] Even as Chief Minister of Gujarat, Prime Minister Narendra Modi forged strong ties with Israeli businesses, which invested heavily in the state. In February 2015, the Israeli Defense minister Moshe Ya'alon visited India and offered to share "cutting-edge weapons technologies" and the two countries are "close to finalising contracts for two additional Phalcon AWACS (airborne warning and control systems) and four aerostat radars, together worth well over $1.5 billion"; India already has three Phalcon AWACS early-warning radar suites dating back to 2004 when the BJP was last in power.[86]

The third country that plays a key role in India's modernisation activities is Russia. Russian help with the Arihant submarine may have been crucial. As detailed by Praful Bidwai, "the core of the Arihant technology … came from Russia. Scores of Russian engineers were sent to India to aid the Department of Atomic Energy (DAE) and the Defence Research & Development Organisation (DRDO). It was the Russians who supplied the vital designs, precision equipment based on their VM-5 reactor, and the technology of miniaturising the reactor."[87]

Russia also gave on lease a nuclear attack submarine that India has deployed.[88] The lease period is 10 years at a cost of nearly $1 billion.[89] This submarine does not carry nuclear weapons but has likely been deployed with the Arihant during its tests. In December 2014, India decided to lease another nuclear submarine from Russia, again in the same class and with the same conditions, including not using it as a platform for nuclear weapons.[90]

Russia is also reportedly the source of the engine for the Nirbhay cruise missile.[91]

Economics

Indian nuclear arsenal development has been going hand in hand with an expansion of the military industrial complex. In the case of the nuclear weapons related infrastructure, this is especially true of the missile and submarine programmes. Since the very beginning, a large number of private and government companies – approximately 40 in the late 1990s – have been involved in manufacturing components for the missiles.[92] Likewise, several large Indian corporate conglomerates, such as the Tatas and Larsen & Toubro have been involved in manufacture of the Arihant submarine.[93]

Interest in increasing military expenditure and spreading the wealth around has been an interest of both the military (especially retired military leaders) and the corporate sector.[94] Private corporations have benefitted from the expected boost in military manufacture under the Modi government. Many of the companies saw their stock prices go up significantly when the BJP won the elections in 2014.[95]

Bharat Dynamics, the government company that integrates the different components of the Agni missiles developed by the DRDO, is setting up at least three new facilities in the states of Telengana, Andhra Pradesh, and Maharashtra, the last at a cost of Rs. 10 billion.[96]

India's costly nuclear and missile development is only part of the story. There is a larger military build-up going on and that is reflected in increasing expenditures. The budget for 2015 saw an 11% increase in military spending.[97] This follows a consistent pattern of increases over the last decade as shown in the table below.[98]

Table 1: Military Expenditure (local currency, current prices for calendar years)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Military Expenditure (bn Rs)	917	1017	1085	1168	1436	1874	2108	2316	2523	2777
Military Expenditure (bn constant 2011 US $)	33.9	36.1	36.2	36.7	41.6	49	49.2	49.6	49.5	49.1

Source: Stockholm International Peace Research Institute

In 2014, India achieved the dubious distinction of being the largest arms importer in the world. Its "imports of major arms rose by 111 percent between 2004-08 and 2009-13, and its share of the volume of international arms imports increased from 7 to 14 percent," with the result that "imports are now almost 3 times as high as those of the second and third largest arms importers – China and Pakistan."[99]

International law and doctrine

Ever since the 1974 nuclear test, the Indian government's focus in arms control diplomacy has been to resist signing onto any international treaties that impose any obligations on its nuclear arsenal. This allows the government to maintain that it is a responsible member of the international community because it has not breached any agreement. Indeed, in a press statement from 18 May 1998, Jaswant Singh, a senior government official and a key strategist for the Bharatiya Janata Party, stressed precisely this when he said, "In undertaking these tests, India has not violated any international treaty obligations."[100] Since then India has held fast to the position that even though it has a moratorium on nuclear tests, it will not sign the Comprehensive Test Ban Treaty nor the nuclear Non-Proliferation Treaty. Neither has it agreed to a freeze on fissile material production pending the negotiation of a fissile material treaty.

The official nuclear doctrine of India issued in January 2003 states that the country's policy is to build and maintain "a credible minimum deterrent". It then goes on to warn: "nuclear retaliation to a first strike will be massive and designed to inflict unacceptable damage."[101] Unacceptable damage, in plain English, means that these nuclear weapons would be dropped on cities, each killing hundreds of thousands or even millions of innocent people.

Public discourse

By and large, the discourse surrounding development, modernisation, and expansion of the nuclear arsenal involves jubilation about India becoming a militarily powerful state. Media articles often obsess over how few countries possess one or the other of the many destructive capabilities – nuclear submarines, anti satellite weapons, submarine launched ballistic missiles, and so on – and extol India for becoming just the third or sixth or whatever country to achieve the dubious status of acquiring these armaments.

There has been some limited debate over how large India's nuclear arsenal should be. The argument for restraint has been primarily based on trying to hold planners to the nuclear doctrine, which calls for a "credible minimum deterrent," and makes the case that the Indian arsenal "has already gone way over the minimum required to 'inflict unacceptable damage' on any rational government, be it Pakistan or China."[102]

Without getting into the problematic nature of qualifiers like "unacceptable" and "rational," for those who see the number of nuclear weapons as already large enough to achieve "deterrence," the main aims of further weapons development should be to build delivery systems that are capable to inflicting damage either in geographical regions so far not reachable (e.g. longer range missiles) or from platforms that are more difficult to attack (i.e. submarines).

Many strategic analysts and media commentators also link "deterrence" to the establishment of a clear resolve and will to use military force in non-nuclear contexts, often making reference to terrorist events or border events.[103] As one strategist asked, "Would India really destroy Lahore, if one of our army brigades which have entered Pakistan is struck by a small nuclear weapon? A country that did not retaliate after the Mumbai terror attack in 2008, does not look like one that would destroy a city of 6 million, just like that. There is certainly an issue of credibility here."[104]

Like national security elites everywhere, Indian security policy makers have used secrecy as a weapon to quash independent questions, increasingly clamping down on the reporting of various details arbitrarily deemed secret. In August 2014, a leading television channel, NDTV, carried a news report about the Arihant submarine, where, in passing, it briefly mentioned something about the communication system used and that the Prime Minister was shown images of the submarine. This set off a furious reaction from the government's National Security Advisor, who wrote a stern letter to the Indian Cabinet terming the information "classified" and stating that obtaining such information was an offence under the "Official Secrets Act," and calling for "firm action".[105]

In August 2014, on the eve of a visit to Japan, Indian Prime Minister Modi declared, "There is no contradiction in our mind between being a nuclear weapon state and contributing actively to global nuclear disarmament and non-proliferation. India remains strongly committed to universal, non-discriminatory, global nuclear disarmament."[106] For anyone but those completely taken in by the ideological propaganda that pervades elite nuclear weapons discourse, the contradiction between the Indian nuclear modernisation activities and what might count as active contribution to nuclear disarmament is all too obvious. This trajectory needs to change. The only source of resistance to the ongoing buildup of the nuclear arsenal and the larger process of militarisation is the peace movement. This movement needs strengthening and our support.

Notes:

1. Elizabeth Roche, "BJP Manifesto Says Will Revise India's Nuclear Doctrine," *Livemint*, 7 April 2014, http://www.livemint.com/Politics/xno41g9Q3UYykz-Phv3guXP/BJP-election-manifesto-says-will-revise-Indias-nuclear-doct.html.
2. The role of the BJP and its ideology in conducting these tests is explained by political analyst and peace activist Achin Vanaik: "The basic credo and incessant refrain of the BJP and the Sangh is to 'make India strong'. It is not a coincidence nor a mere matter of contingent compulsions that it was during the reign of a BJP-led coalition government in 1998 that tests were carried out to make India a declared nuclear weapons power." See Achin Vanaik, *After the Bomb: Reflections on India's Nuclear Journey* (Hyderabad: Orient Blackswan, 2015).
3. This is exemplified in the comments of Shyam Saran, then the Chief of the National Security Advisory Board of the country: "since January 2003, when India adopted its nuclear doctrine formally at a meeting of the Cabinet Committee on Security, it has taken a series of graduated steps to put in place a triad of land-based, air-delivered and submarine-based nuclear forces to conform to its declared doctrine of no-first use and retaliation only. Currently, at least two legs of the triad are fully operational." See Shyam Saran, "Weapon That Has More than Symbolic Value," *The Hindu*, 4 May 2013.
4. Hans M. Kristensen and Robert S. Norris, "Worldwide Deployments of Nuclear Weapons, 2014," *Bulletin of the Atomic Scientists* 70, no. 5 (2014): 96–108, doi:10.1177/0096340214547619.
5. Gaurav Kampani, "The Nuclear Conundrum," *The Hindu Business Line*, 11 September 2013, http://www.thehindubusinessline.com/todays-paper/tp-opinion/the-nuclear-conundrum/article5113977.ece; M. V. Ramana, "India," in *Assuring Destruction Forever: Nuclear Weapon Modernization Around the World*, ed. Ray Acheson (New York: Reaching Critical Will, 2012), 34–43.
6. PMO, *Press Release: Cabinet Committee on Security Reviews Progress in Operationalizing India's Nuclear Doctrine* (Prime Minister's Office, Government of India, 2003).
7. NSAB, *Draft Report of National Security Advisory Board on Indian Nuclear Doctrine* (New Delhi: National Security Advisory Board, 1999). The National Security Advisory Board describes itself as consisting "of senior retired officials, civilian as well as military, academics and distinguished members of civil society drawn from and having expertise in Internal and External Security, Foreign Affairs, Defence, Science & Technology and Economic Affairs". See http://nsab.gov.in/?1001. It is a purely advisory body.
8. Gaurav Kampani, "New Delhi's Long Nuclear Journey," *International Security* 38, no. 4 (2014): 79–114, doi:10.1162/ISEC_a_00158.
9. Lt Gen. B.S. Nagal, "Perception and Reality," *Force India*, October 2014, http://www.forceindia.net/PerceptionandReality.aspx.
10. Gp Capt B. Menon, "Fifth Generation Fighter Aircraft for the Indian Air Force," *Indian Defence Review*, June 2013, http://www.indiandefencereview.com/news/fifth-generation-fighter-aircraft-for-the-indian-air-force/.
11. Lt Gen. B.S. Nagal, "Checks and Balances," *Force India*, June 2014, http://www.forceindia.net/Checks_and_Balances.aspx.
12. TNN, "INS Arihant Embarks on Its First Sea Trials," *The Times of India*, 16 December 2014, http://timesofindia.indiatimes.com/city/visakhapatnam/INS-Arihant-embarks-on-its-first-sea-trials/articleshow/45529440.cms.
13. S Anandan, "INS Arihant May Be of Limited Utility," *Hindu*, 21 December 2014.
14. S Anandan, "Second Nuclear Submarine Headed for Year-End Launch," *Hindu*, 14 January 2012, http://www.thehindu.com/news/national/article2798864.ece.
15. Sekhar Basu, "Founder's Day Address 2014," *Bhabha Atomic Research Centre*, 30 October 2014, 14, http://www.barc.gov.in/presentations/fddir14.pdf.
16. Pallava Bagla, "India Test Fires Missile from under Sea, Completes Nuclear Triad," *NDTV.com*, 28 January 2013, http://www.ndtv.com/india-news/india-test-fires-missile-from-under-sea-completes-nuclear-triad-511545.
17. T. S Subramanian, "Strike Power," *Frontline*, 28 March 2008.
18. Cmde Ranjit B Rai, "The inside Story of SLBM K-15," *Indian Defence Review*, 11 February 2013, http://www.indiandefencereview.com/spotlights/the-inside-story-of-k-15/.
19. TNN, "India Tests New Underwater Nuclear Missile," *The Times of India*, 26 March 2014, http://timesofindia.indiatimes.com/india/India-tests-new-underwater-nuclear-missile/articleshow/32694060.cms.
20. Ravi Ganesh, "Political Stability First, Strategic Stability Second," *The Interpreter*, 14 October 2014, http://www.lowyinterpreter.org/post/2014/10/14/Stabilising-role-of-SSBNs.aspx.
21. Daily Bhaskar, "3,000 Km-Range SLBM Successfully Test-Fired by DRDO," *Daily Bhaskar*, 13 May 2014, http://daily.bhaskar.com/news/NAT-TOP-3000-km-range-slbm-successfully-test-fired-by-drdo-4611759-NOR.html; TNN, "India Tests New Underwater Nuclear Missile."
22. T. S Subramanian, "DRDO Plans Another K-15 Missile Launch," *The Hindu*, 29 January 2011, http://www.thehindu.com/news/cities/Chennai/article1134320.ece.
23. Pallava Bagla and Vishnu Som, "This Is INS Arihant, First Made-in-India Nuclear Submarine," *NDTV.com*, 20 August 2014, http://www.ndtv.com/india-news/ndtv-exclusive-this-is-ins-arihant-first-made-in-india-nuclear-submarine-651097.
24. W. P. S Sidhu, "Whose Finger on the Nuclear Trigger at Sea?," *Livemint*, 4 August 2013, http://www.livemint.com/Opinion/rkEybO3sf1wA2vWbxXr0GM/Updating-Indias-nuclear-doctrine.html; W. P. S Sidhu, "Updating India's Nuclear Doctrine," *Livemint*, 27 April 2014, http://www.livemint.com/Opinion/rkEybO3sf1wA2vWbxXr0GM/Updating-Indias-nuclear-doctrine.html.
25. Rajat Pandit, "Govt Approves Construction of 7 Stealth Frigates, 6 Nuclear-Powered Submarines," *The Times of India*, 18 February 2015, http://timesofindia.indiatimes.com/india/Govt-approves-construction-of-7-stealth-frigates-6-nuclear-powered-submarines/articleshow/46281364.cms.
26. This is despite an earlier plan dating back to 1999, which envisaged induction of 12 new submarines by 2012, and another dozen submarines by 2030. Rajat Pandit, "Move to Fast-Track Two Submarine Projects Gathers Steam," *The Times of India*, 14 July 2014, http://timesofindia.indiatimes.com/india/Move-to-fast-track-two-submarine-projects-gathers-steam/articleshow/38342676.cms.
27. N. C. Bipindra, "India Said to Approve Expansion of Submarine Fleet," *Bloomberg.com*, 18 February 2015, http://www.bloomberg.com/news/articles/2015-02-18/india-said-to-approve-priciest-naval-expansion-in-five-years.
28. Abhijit Singh, "'Blue-Water' Navies in the Indian Ocean Region," *The Diplomat*, 21 January 2015, http://thediplomat.com/2015/01/blue-water-navies-in-the-indian-ocean-region/.
29. The early Agni missile used both solid and liquid propellants and was never deployed.
30. M. Somasekhar, M., "Agni-V: A Game Changer in India's Missile Technology," *The Hindu Business Line*, 31 January 2015, http://www.thehindubusinessline.com/news/science/agniv-a-game-changer-in-missile-technology/article6842427.ece.
31. Shiv Aroor, "My Job Is to Speed up India's Nuclear Strike Time, DRDO Chief Says," *Daily Mail India*, 3 July 2013, http://www.dailymail.co.uk/indiahome/indianews/article-2355107/Dr-Avinash-Chander-My-job-speed-Indias-nuclear-strike-time-DRDO-chief-says.html.
32. TNN, "Nuclear-Capable Agni-IV Test-Fired Successfully, Has China in Sight," *The Times of India*, 3 December 2014, http://timesofindia.indiatimes.com/india/Nuclear-capable-Agni-IV-test-fired-successfully-has-China-in-sight/articleshow/45355075.cms.
33. Murali Krishnan, "Indian Military Makes Strategic Stride with the Agni-V," *Deutsche Welle*, 19 April 2012, http://www.dw.de/indian-military-makes-strategic-stride-with-the-agni-v/a-15894820.
34. TNN, "Nuclear-Capable Agni-IV Test-Fired Successfully, Has China in Sight," *op. cit.*
35. ibnlive, "India Test-Fires 4,000 Km-Range Nuclear Capable Agni-IV Missile," *IBNLive.Com*, 20 January 2014, http://ibnlive.in.com/news/india-test-fires-4000-kmrange-nuclear-capable-agniiv-missile/446570-3-234.html.
36. MoD, *Annual Report 2013-2014* (New Delhi: Ministry of Defence, Government of India, 2014), 86.
37. T S Subramanian, "Missile Power," *Frontline*, 6 March 2015, http://www.frontline.in/other/data-card/missile-power/article6904798.ece.
38. Y. Mallikarjun, "Agni-III Test-Fired by SFC Personnel," *Hindu*, 23 December 2013.
39. PTI, "Nuclear-Capable Agni-II Missile Test Fired," *Hindustan Times*, 9 November 2014, http://www.hindustantimes.com/india-news/nuclear-capable-agni-ii-missile-test-fired/article1-1284108.aspx; PTI, "India Successfully Conducts Maiden Night Test of Agni Missile," *NDTV.com*, 12 April 2014, http://www.ndtv.com/india-news/india-successfully-conducts-maiden-night-test-of-agni-missile-557066.
40. PTI, "India Successfully Test Fires Nuclear Capable Prithvi-II Missile," *Daily News & Analysis*, 19 February 2015, http://www.dnaindia.com/india/report-india-successfully-test-fires-nuclear-capable-prithvi-ii-missile-2062319.
41. MoD, *Annual Report 2013-2014*, 86.
42. IISS, "Chapter Six: Asia," *The Military Balance* 115, no. 1 (2015): 248, doi:10.1080/04597222.2015.996361.
43. Rishi Iyengar, "India Tests First Nuclear-Capable Cruise Missile," *Time*, 17 October 2014, http://time.com/3515183/india-tests-nirbhay-cruise-missile/.
44. PTI, "India Test-Fires Nuclear-Capable Nirbhay Cruise Missile," *The Times of India*, 17 October 2014, http://timesofindia.indiatimes.com/india/India-test-fires-nuclear-capable-Nirbhay-cruise-missile/articleshow/44845526.cms.

45. James Hardy, "India Successfully Tests Nirbhay Cruise Missile," *IHS Jane's Defence Weekly*, 16 October 2014.
46. TASS, "Integration of Air-Based Cruise Missile with Su-30MKI Fighter Completed in India," *Russia & India Report*, 3 February 2015, http://in.rbth.com/economics/2015/02/03/integration_of_air-based_cruise_missile_with_su-30mki_fighter_compl_41149.html.
47. T. S. Subramanian, "Agni-VI All Set to Take Shape," *The Hindu*, 4 February 2013, http://www.thehindu.com/news/national/agnivi-all-set-to-take-shape/article4379416.ece.
48. Ibid.
49. Rajat Pandit, "After Agni-V Launch, DRDO's New Target Is Anti-Satellite Weapons," *The Times of India*, 21 April 2012, http://timesofindia.indiatimes.com/india/After-Agni-V-launch-DRDOs-new-target-is-anti-satellite-weapons/articleshow/12763074.cms.
50. Cenan Al-Ekabi et al., *Yearbook on Space Policy 2012/2013: Space in a Changing World* (Heidelberg: Springer, 2015), 128.
51. Bharath Gopalaswamy, "Missile Defense in India," *Bulletin of the Atomic Scientists*, 27 February 2009, http://thebulletin.org/missile-defense-india.
52. PTI, "Delhi, Mumbai to Be First Provided with Missile Defence Shield," *The Economic Times*, 24 June 2012, http://economictimes.indiatimes.com//articleshow/14370434.cms.
53. Y. Mallikarjun, "India to Conduct Complex Interceptor Missile Test," *Hindu*, 14 April 2014.
54. Ibid.
55. Nagal, "Checks and Balances," *op. cit.*
56. Weapon-grade plutonium refers to plutonium that has low concentrations of the higher isotopes of plutonium, especially plutonium-240. This is in contrast to reactor-grade plutonium that has greater concentrations of these higher isotopes. The latter is less desirable for use in nuclear weapons, but it is possible to use reactor-grade plutonium to make nuclear weapons.
57. Sekhar Basu, "Founder's Day Address 2013," *Bhabha Atomic Research Centre*, 30 October 2013.
58. C. V. Sundaram, L. V. Krishnan, and T. S. Iyengar, *Atomic Energy in India: 50 Years* (Mumbai: Department of Atomic Energy, Government of India, 1998).
59. P R Roy and C Ganguly, "Plutonium Metallurgy in India," *Bulletin of Materials Science* 6, no. 5 (September 1984): 923–58.
60. V Narayanasamy, *Unstarred Question No. 1398: Nuclear Science Research Programme* (New Delhi: Rajya Sabha, 22 August 2013), http://dae.nic.in/writereaddata/parl/mansoon2013/rsus1398.pdf.
61. IPFM, *Global Fissile Material Report 2015* (Princeton: International Panel on Fissile Materials, forthcoming 2015).
62. Power reactors, when they first start operations, do discharge some spent fuel with low concentrations of higher isotopes of plutonium; this is what allows these to be sources of weapon-grade plutonium.
63. Raj Chengappa, *Weapons of Peace: The Secret Story of India's Quest to Be a Nuclear Power* (New Delhi: Harper Collins, 2000); R. Ramachandran, "Pokharan II: The Scientific Dimensions," in *India's Nuclear Deterrent: Pokharan II and Beyond*, ed. Amitabh Mattoo (New Delhi: Har Anand Publications, 1999), 34–61; George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999).
64. IPFM, *Global Fissile Material Report 2015*.
65. M. V. Ramana, "India and Fast Breeder Reactors," *Science and Global Security* 17, no. 1 (2009): 54–67; M. V. Ramana and J. Y. Suchitra, "Slow and Stunted: Plutonium Accounting and the Growth of Fast Breeder Reactors," *Energy Policy* 37 (2009): 5028–36.
66. Alexander Glaser and M. V. Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," *Science and Global Security* 15 (2007): 85–105.
67. C. Shivakumar, "PFBR Plant May Go Critical by Mid-Year," *New Indian Express*, 4 February 2015, http://www.newindianexpress.com/cities/chennai/PFBR-Plant-May-Go-Critical-by-Mid-year/2015/02/04/article2651524.ece.
68. T. S. Subramanian, "A Milestone at Kalpakkam," *Frontline*, 19 November 2004, http://www.frontline.in/static/html/fl2123/stories/20041119003210200.htm.
69. IPFM, *Global Fissile Material Report 2015*.
70. Brian Cloughley and Robert Kelley, "India Increases Its Uranium Enrichment Programme," *IHS Jane's 360*, 20 June 2014, http://www.janes.com/article/38957/india-increases-its-uranium-enrichment-programme.

T S Subramanian, "'In the Event of a Nuclear Incident, Victims Must Get Prompt Compensation,'" *The Hindu*, 26 September 2010, http://www.thehindu.com/todays-paper/tp-opinion/in-the-event-of-a-nuclear-incident-victims-must-get-prompt-compensation/article616499.ece.

71. Indian power reactors are largely based on the use of natural uranium without any enrichment. In the case of those reactors that do use low enriched uranium, there are contracts with foreign vendors to supply the necessary fuel. Plans to build indigenous reactors that will require low enriched uranium are still nascent. IE, "Work Begins on India's First Light Water Reactor after Smaller Version," *Indian Express*, 7 January 2015, http://indianexpress.com/article/india/india-others/work-begins-on-indias-first-light-water-reactor-after-smaller-version/.
72. Saswati Mukherjee, "Storm Brewing on Chitradurga Grasslands," *The Times of India*, 23 May 2013, http://timesofindia.indiatimes.com/city/bengaluru/Storm-brewing-on-Chitradurga-grasslands/articleshow/20218647.cms.
73. M. V. Ramana, "La Trahison Des Clercs: Scientists and the India's Nuclear Bomb," in *Prisoners of the Nuclear Dream*, ed. M.V. Ramana and C. Rammanohar Reddy (New Delhi: Orient Longman, 2003), 206–44.
74. Ashley J. Tellis, "The Evolution of U.S.-Indian Ties: Missile Defense in an Emerging Strategic Relationship," *International Security* 30, no. 4 (2006): 113–51, doi:10.1162/isec.2006.30.4.113.
75. PTI, "NATO Offers Missile Defence Cooperation to India," *Hindu*, 4 September 2011, http://www.thehindu.com/news/national/nato-offers-missile-defence-cooperation-to-india/article2424128.ece.
76. Vivek Raghuvanshi, "India To Push Joint Weapons Development During US Visit," *Defense News*, 28 September 2014, http://archive.defensenews.com/article/20140928/DEFREG03/309280012/India-Push-Joint-Weapons-Development-During-US-Visit.
77. Praful Bidwai, "Modi's Costly Embrace," *The News International, Pakistan*, 31 January 2015, http://www.thenews.com.pk/Todays-News-9-299134-Modis-costly-embrace.
78. PTI, "Potential for Cooperation with India to Develop BMD: US," *Business Standard*, 23 July 2012; Jay Menon, "U.S. Eyes Missile Defense Work With India," *Aviation Week & Space Technology*, 13 August 2012, http://aviationweek.com/awin/us-eyes-missile-defense-work-india.
79. Priyamvada Gopal, "India's Forgotten Solidarity with Palestine," *Al Jazeera English*, 6 August 2014, http://www.aljazeera.com/indepth/opinion/2014/08/india-forgotten-solidarity-with-p-2014848848765551.html.
80. Seema Sirohi, "'The Secret Part Of Indo-Israel Defence Ties Will Remain A Secret,'" *Outlook*, 18 February 2008, http://www.outlookindia.com/article/The-Secret-Part-Of-IndoIsrael-Defence-Ties-Will-Remain-A-Secret/236728.
81. Vijay Prashad, "Shalom Modi: India and Israel Look to Deepen Ties Following Victory of the Hindu Right," *Mondoweiss*, accessed 10 March 2015, http://mondoweiss.net/2014/05/shalom-following-victory. Ariel Sharon was the first Israeli leader to come to India.
82. Tamir Eshel, "India, Israel to Build Anti-Missile System," *Defense Update*, 7 February 2014, http://defense-update.com/20140207_india-israel-build-anti-missile-system.html#.VPOY_ik-Dw4.
83. Strategic Studies, "Air Defense: India Buys Israeli Tech To Stop Hostile Missiles," *Indian Strategic Studies*, 7 March 2014, http://strategicstudyindia.blogspot.com/2014/03/air-defense-india-buys-israeli-tech-to.html.
84. As Anat Bernstein-Reich, president of the Israel-India Friendship Association and vice president of the Israel-Asia Chamber of Commerce, put it: Modi "understands that Israel needs India for political reasons as a strategic ally… [and he] will want to keep Israel close to him and not at a distance." Sean Savage, "With New Indian Leader Narendra Modi, Israel Sees Brighter Horizon in the East," *JNS.org*, 2 June 2014, http://www.jns.org/latest-articles/2014/6/2/with-new-indian-leader-narendra-modi-israel-sees-brighter-horizon-in-the-east.
85. TNN, "Israel Offers Top-Notch Military Technologies for 'Make in India' Endeavour," *The Times of India*, 20 February 2015, http://timesofindia.indiatimes.com/india/Israel-offers-top-notch-military-technologies-for-Make-in-India-endeavour/articleshow/46307051.cms.
86. Praful Bidwai, "Sinking Billions into Nuclear Weapons," *Rediff News*, 3 August 2009, http://news.rediff.com/column/2009/aug/03/sinking-billions-into-nuclear-weapons.htm.
87. Sudhi Ranjan Sen, "Nuclear-Powered Submarine INS Chakra Joins Indian Navy," *NDTV.com*, 4 April 2012, http://www.ndtv.com/india-news/nuclear-powered-submarine-ins-chakra-joins-indian-navy-474877.
88. Sudhi Ranjan Sen, "India to Lease a Second Nuclear Submarine From Russia," *NDTV.com*, 16 December 2014, http://www.ndtv.com/india-news/india-to-lease-a-second-nuclear-submarine-from-russia-714039.
89. Ibid.
90. Hardy, "India Successfully Tests Nirbhay Cruise Missile," *op. cit.*
91. Prabhu Dandriyal, "Truth of Agni Missile Program," *Corruption In DRDO*, 2 February 2015, http://corruptionindrdo.com/2015/02/03/truth-of-agni-missile-programme.

Notes:

92. Josy Joseph, “Private Sector Played a Major Role in Arihant,” *Daily News & Analysis*, 27 July 2009, http://www.dnaindia.com/india/report-private-sector-played-a-major-role-in-arihant-1277435.
93. Deepak Kapoor, “Defence Modernisation: Make in India and Private Sector,” *India Strategic*, March 2015, http://www.indiastrategic.in/topstories3695_Defence_Modernisation.htm.
94. Defence Radar, “Modi Booster for Indian Defence Companies,” *Defenceradar News*, 16 June 2014, http://defenceradar.com/2014/06/16/modi-booster-for-indian-defence-companies/.
95. Faisal Malik, “Rs 1,000 Crore Missile Unit in Amaravati,” *Asian Age*, 7 February 2015, http://www.asianage.com/mumbai/rs-1000-crore-missile-unit-amravati-857; Bureau, “V Udaya Bhaskar Appointed CMD of Bharat Dynamics,” *Hindu Business Line*, 5 February 2015, http://www.thehindubusinessline.com/companies/v-udaya-bhaskar-appointed-cmd-of-bharat-dynamics/article6860151.ece.
96. PTI, “Budget 2015: Defence Allocation Increased by Nearly 11 per Cent,” *The Economic Times*, 28 February 2015, http://economictimes.indiatimes.com//articleshow/46407292.cms.
97. SIPRI, “Military Expenditure Database,” *SIPRI Military Expenditure Database*, 2014, http://www.sipri.org/research/armaments/milex/milex_database.
98. Ibid.
99. Jaswant Singh, “Press Statement by Shri Jaswant Singh Deputy Chairman, Planning Commission,” in M. L. Sondhi (ed.) *Nuclear weapons and India’s national security*, New Delhi: Har-Anand Publications, 2000.
100. *Press Release: Cabinet Committee on Security reviews progress in operationalizing India’s nuclear doctrine, op. cit*.
101. R. Rajaraman, “Minimum Deterrent and Large Arsenal,” *The Hindu*, 2 July 2014.
102. Ibid.
103. Manoj Joshi, “Updating India’s Nuclear Posture,” *Observer Research Foundation*, 9 April 2014, http://orfonline.org/cms/sites/orfonline/modules/analysis/AnalysisDetail.html?cmaid=65296&mmacmaid=65297.
104. Deepak Sharma and Akshay Singh, “Government Wants Crackdown on Violation of Official Secrets Act,” *Mail Today*, 30 December 2014, http://indiatoday.intoday.in/story/official-secrets-act-media-nsa-ajit-doval-ins-arihant-ajit-kumar-seth-aaj-tak/1/410485.html.
105. Indrani Bagchi, “India Not Revisiting Its Nuclear Doctrine, Modi Assures Japan,” *The Times of India*, 30 August 2014, http://timesofindia.indiatimes.com/india/India-not-revisiting-its-nuclear-doctrine-Modi-assures-Japan/articleshow/41231521.cms.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Israel
Merav Datan

In the case of Israel, far more is known about its approach to modernisation in the most general terms and in the military context than about its approach to nuclear weapons. Whatever factual information is publicly available relies on sources outside of Israel. The analysis below will first explore relevant foreign sources in an effort to summarise the factual information available regarding Israel's nuclear weapons programme and plans for its modernisation. It will then draw on relevant domestic sources in order to provide a broader context for these issues.

According to foreign sources

Since 1970, when the New York Times published revelations based on US intelligence assumptions, it has been widely assumed that Israel possesses nuclear weapons. Because Israel has never officially confirmed or denied having nuclear weapons[1], the scope and nature of its nuclear arsenal is based on the assessments of foreign sources, which vary widely. Based on available foreign information, the current status and modernisation plans of Israel's nuclear programme are outlined below.

Nuclear weapons

Estimates about the size of the arsenal are based on the power capacity of the nuclear reactor near Dimona (which, like the overall program, is subject to secrecy and uncertainty) ranging from 24MWt to 70MWt or more[2] and on assumptions about production that in turn are based on speculation, scientific calculations, and unconfirmed revelations dating back to 1986.[3]

Experts and analysts outside of Israel estimate that Israel's current nuclear force ranges from 60–80 weapons at the low end to over 400 at the high end. The most recently cited figure is 80 warheads.[4]

Fissile materials

It is estimated that, Israel could have produced approximately 840 kg of weapons-grade plutonium.[5] Estimates of highly enriched uranium (HEU) production are even more difficult to make, though public information suggests Israel has a uranium enrichment programme.[6] A recent estimate has assumed Israel possesses approximately 300 kg of HEU.[7]

Delivery systems

The Sdot Micha Air Force Base is believed to host nuclear-tipped missiles.[8] It is also assumed that Israel has a triad of delivery systems: land, air, and sea.[9] Specifically, Israel is believed to have deployed a cumulative total of 100 Jericho-I (500 km range) and Jericho-II (1,500 km range) ballistic missiles, both of which are nuclear capable as well as mobile by land or rail. The range of the Jericho-II and its 1,000 kg payload "make it well suited for nuclear delivery."[10] Israel's space-launch rocket, the Shavit, which is similar to the Jericho-II, could "also be conceivably modified to deliver a nuclear weapon, thus granting Israel the ability to deploy an intercontinental ballistic missile if there were ever a political desire to do so,"[11] although there is no indication of such a desire at this time. In terms of modernisation, Israel is currently developing a new ballistic missile, the Jericho-III, which is believed to have a maximum range of 4,000–6,500km.[12]

Israel's aircraft capabilities give it the option of using its F-16 Falcons or F-15 Eagles to deliver nuclear weapons. Both have a range of 2,500 km.[13] As of late 2008, Israel was believed to have well over 200 Falcons, which it had purchased from the United States, although "it is assumed that only a fraction of this number will have the modifications, trained crews, and practiced procedures necessary to make them suitable for the nuclear mission."[14] Israel's 87 Eagle fighter and ground attack aircraft were more recently purchased from the US, which itself designated the F-15E Strike Eagle for delivery of nuclear weapons, an indication that Israel could do the same.[15]

Israel's sea-launched nuclear capability is based on three Dolphin-class submarines that were bought from Germany, all of which were received and deployed by the year 2000.[16] These submarines are believed to be armed with dual-capable cruise missiles that were developed in Israel, with each missile having an estimated range of 1,500 km.[17] Reports claiming that these submarines are armed with modified US Harpoon anti-ship missiles (some of which could have been modified to deliver nuclear weapons to land targets) have been denied, but "[i]n 2003, in an interview with the Los Angeles Times, Israeli and American officials announced that Israel had deployed U.S. supplied Harpoon ASCMs on its Dolphin submarines and modified the missiles to carry nuclear warheads."[18] In September 2014, Israel received the fourth of six German-made submarines.[19] Theses submarines are reportedly nuclear capable.[20] In light of current and planned nuclear capabilities, "it seems clear that the country is continuing to enhance its own triad of land, sea, and air launched nuclear systems."[21]

Infrastructure

The Israel Atomic Energy Commission (IAEC), "among the most secretive organisations in Israel," is the government agency that oversees the country's nuclear activities.[22]

All factual information about its operations, including budget, organisational structure, relations with other military and defence organizations, and parliamentary oversight, is classified.[23] The IAEC is chaired directly by the prime minister and operates "to a certain extent under a dual identity," serving both as the government agency that executes national nuclear policy and as a body staffed by nuclear scientists that carries out Israel's nuclear research. The IAEC also represents Israel in international nuclear fora.[24]

sThe IAEC oversees the operation of Israel's two national nuclear-research facilities. The Negev Nuclear Research Center, located near the southern desert town of Dimona, "includes working units for a full array of nuclear-weapons-related activities, from uranium conversion, fuel fabrication and uranium enrichment, to a plutonium-production reactor and reprocessing mechanisms, and possibly weapons-specific facilities" and is reportedly believed to serve as "Israel's national laboratory in the nuclear field."[25] As noted above, estimates vary regarding the reactor's capacity. The original capacity of 24MWt was reportedly expanded to 40MWt and later to 70MWt.[26]

The Soreq Nuclear Research Center, located approximately 40km south of Tel Aviv, was purchased from the US as part of the "Atoms for Peace" programme. It was originally constructed as a 1MWt light-water research reactor and later expanded to 5MWt. It is the only facility in Israel under IAEA safeguards. According to the Soreq website:

Its R&D activities include laser and electro optics, nuclear medicine, radiopharmaceutics, non-destructive testing, space components characterization and testing, crystal growth, development of innovative radiation detectors and sophisticated equipment for contraband detection. It offers radiation protection training, and operates personal dosimetry service. It is a major distributor of radio-pharmaceuticals for medical diagnostics and therapy.[27]

In sum, Israel is assumed to have "full fuel-cycle capabilities"[28] but specific details and current information is not available. It is also assumed that other nuclear activities related to weaponisation are "carried out in other secret facilities."[29] It is further believed that "Israel is upgrading its deterrence capabilities."[30]

Policy

The secrecy surrounding Israel's nuclear activities serves the policy of nuclear "ambiguity" or "opacity".[31] Nuclear opacity has been defined as a situation in which "a state's nuclear capability has not been acknowledged, but is recognized in a way that influences other nations' perceptions and actions."[32] In Israel's case, this policy was the product of a compromise with the United States that emerged during the years leading up to conclusion of the nuclear Non-Proliferation Treaty (NPT), the period during which Israel was reportedly developing its first nuclear weapons.[33] The NPT was opened for signature in 1968 and entered into force in 1970.

Israel had reportedly completed its first nuclear device by May 1967.[34] Despite US pressure, in 1968 Israel informed the US that because of its security needs, it could not sign the NPT at that time. A nuclear option was seen as an existential necessity. In 1969 Israeli Prime Minister Golda Meir and US President Richard Nixon reached a secret agreement that laid the foundation for a tacit "don't ask, don't tell" policy between the two states with respect to Israel's nuclear-weapons capability.[35] The US accepted that Israel felt a security-based need to have a nuclear-weapons capability, and Israel agreed not to undermine the NPT by openly declaring its nuclear capability. The secrecy surrounding Israel's nuclear programme is an outgrowth of this compromise.

According to domestic sources

The policy of opacity has shaped and circumscribed Israel's non-proliferation, arms control, and disarmament policies. Despite this opacity, however, Israel does participate publicly in some non-proliferation activities and agreements. In fact, Israel is generally supportive of the non-proliferation regime, and particularly in recent years, has made efforts to be recognized as a technologically advanced, mature state committed to the "spirit of the NPT".[36]

Interest in participating in international nuclear activities (including an India-like exception to Nuclear Supplier Group guidelines) and a recurring but fledgling interest in exploring nuclear energy options have informed this new approach. Similarly, domestic discourse, though far from democratically free and open, exists but is also circumscribed by the policy of opacity.

International law and doctrine

Israel has signed but not yet ratified the Comprehensive nuclear Test Ban Treaty (CTBT), citing concern with the as-yet incomplete development of the verification regime and potential abuse of this regime; Israel's status in the policy making organs of the Treaty; and concerns with the regional security situation in the Middle East.[37] It actively participates in verification activities of the CTBT Organization Preparatory Committee. Israel is a signatory or party to a number of non-proliferation-related (safety and security) agreements, including the Vienna Convention on Civil Liability for Nuclear Damage, the Convention on the Physical Protection of Nuclear Material, the Convention on Early Notification of a Nuclear Accident, the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, Convention on Nuclear Safety, the Revised Supplementary Agreement Concerning the Provision of Technical Assistance by the IAEA, and a Safeguards Agreement applicable to the Soreq nuclear facility.[38]

On the basis of the above legal commitments, in combination with its NPT non-party status and its emphasis on security and secrecy surrounding nuclear activities, Israel projects itself both domestically and internationally as a responsible non-proliferant (in the sense of not supplying nuclear technology to others but, rather, having an interest in sharing safety and security expertise). Not having signed the NPT, Israel is not bound by its article VI disarmament obligations under a strict treaty-based interpretation of international law, which is the prevalent view in this context. Arguments based on customary international law that posit a universal obligation to disarm have not gained ground or drawn attention (or a rebuttal) within Israel, but they would likely be countered by the argument that Israel is not bound by agreements that it has not signed (a view consistent with Israel's general approach to international legal norms and obligations) and has, in fact, systematically rejected. The "persistent objector" exception to a customary international legal norm would likely be invoked in the event that customary international law is given consideration. In this context, any modernisation of nuclear weapons would not be perceived by Israel as a conflict with international legal commitments.

Public discourse

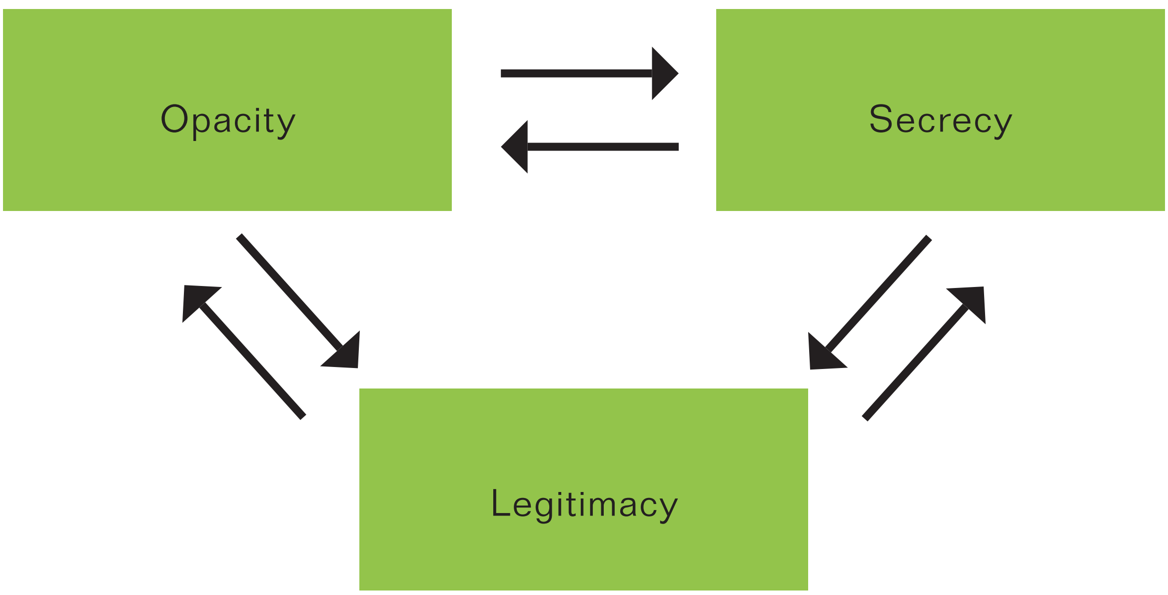
The domestic discourse on nuclear issues is characterized by what has been termed the "enigma of opacity": ignorance is a qualification for speaking on nuclear issues.[39] Anyone who "knows" cannot speak openly about the issues, while anyone who speaks must first profess ignorance by asserting reliance on foreign sources.

At the basis of nuclear policy is the question of legitimacy (Israel's right to exist). Perceived existential threats informed, drove, and shaped the development of a nuclear programme. US-led non-proliferation efforts shaped the further development of this secrecy. Yet the concept of nuclear "deterrence" requires that others (the target audience) be aware of Israel's capability. Thus it relies on foreign sources and indirect references because a strictly secret nuclear programme would have no deterrent value. This interaction between secrecy and opacity is further shaped by questions of Israel's legitimacy or right to exist. On the one hand, Israel still perceives nuclear deterrence as a guarantor of its existence, that is, opacity as an existential issue. On the other hand, international criticism of Israeli nuclear policy, which is unique in the global arena, feeds into and reinforces challenges to Israel's legitimacy. The trilateral interplay among these issues – opacity, secrecy, and legitimacy – is represented in the figure below.

One presumably unintended consequence of the internalised secrecy within Israeli society is that the phrase "according to foreign sources" has come to imply sensitive and secret information about internal domestic issues. It is ironic and perhaps unique among nations that the term "foreign sources" in Israel refers to "our own innermost secrets".

The policy of opacity entails a nuclear weapons capability about which "everyone knows" (domestically and internationally, with the former reliant on the latter) and an umbrella of secrecy covering the physical and doctrinal elements of this capability. The nuclear-capable aspect of opacity, which is perceived as provocative or in violation of international law by Israel's critics, is projected within Israel as a policy of restraint, of which secrecy is an element: Israel does not advertise its nuclear capability; Israelis do not conduct parades celebrating their nuclear capabilities (unlike other countries); secrecy is the alternative to open declaration of a nuclear option, which would be provocative. This is the prevalent perception.

The secrecy surrounding Israel's nuclear programme, which has its origins in the US-Israel compromise discussed above, has taken on a life of its own at the domestic level. The origins of opacity are no longer the driving force as Israelis practice self-censorship on a wide range of nuclear



issues. At the same time, a discourse does exist at the academic level and, increasingly, in the media, driven in large part by debate over Iran's nuclear programme and the best response. This discourse relies on foreign sources as a factual foundation, but that has not prevented a relatively open discourse at the elite level within the contours of academic and think-tank dialogue. For example, the Institute for National Security Studies (Israel's foremost security think tank) addresses "the Obama vision" of nuclear disarmament from an Israeli perspective (generally regarding this vision as unrealistic).[40]

It has frequently been asserted that Israel views its nuclear programme as a "sacred national insurance policy"[41] and even critics of the policy in its current form have asserted that "for a state born out of the Holocaust and surrounded by the hostile Arab world, not to [acquire a nuclear weapons capability] would have been irresponsible."[42]

A somewhat superficial but nevertheless telling example illustrates the difference between Israel's domestic and international discourses as well as the potential for change within Israeli policy. Following the 2011 and first-ever IAEA forum on a nuclear weapons free zone (NWFZ) in the Middle East, which Israel had resisted for 11 years, an editorial was published in the newspaper *Ha'aretz*[43] observing that, in the words of a participating Israeli delegate "the sky didn't fall on us." The secrecy born of the policy of opacity had bred a fear of discussing the issues that turned out to be unfounded. What is most telling about this editorial, however, is that despite a faithful translation between the Hebrew and English versions, the headlines differed.[44]

In English the editorial was entitled "Israel is clinging dearly to its policy of nuclear ambiguity" and the subheading went on to state, "Israel has never claimed that there is no possibility it will change its nuclear policy one day. But for Israel that's a vision for the distant future."[45] The Hebrew version was identical expect for the headline, which directly translates as "Disarmament, But Not Now."[46] *Ha'aretz* is a daily newspaper published in both Hebrew and English, and not surprisingly, the emphasis in coverage differs slightly: a foreign-language target audience is not likely to seek an Israeli newspaper for coverage of news that has no direct bearing on Israel, whereas Hebrew-language readers are more likely to rely on Ha'aretz if it is their newspaper of choice for coverage of any news, domestic or foreign. What is telling in the case of the editorial mentioned above is the difference in emphasis when the same editorial is packaged for foreign vs. domestic consumption. In the former case the emphasis is on maintenance of the old nuclear policy, and the words "clinging dearly" imply a near-desperate tone (not actually reflected in the body of the editorial). In the latter case the emphasis is on disarmament, a relatively new idea for a domestic audience.

Weapon of mass destruction free zone

The goal of a nuclear weapon free zone (NWFZ) or weapons of mass destruction free zone (WMDFZ) in the Middle East is not a new idea among Israel's diplomatic representatives, however. Israel has joined the consensus UN General Assembly resolution on a Middle East NWFZ since 1980, but with reservations. As stated in Israel's most recent explanation of vote on this resolution:[47]

A credible [regional security] process is also closely connected to the widely agreed principle that the establishment of any NWFZ, or WMDFZ as is in the case of the Middle East, must be based on arrangements freely arrived at. This requires that regional states have to fully commit themselves to open and direct communication channels, to genuine engagement and the acknowledgement of the threats and challenges facing other regional partners. They have to recognize all regional states' right to exist and the need to build a spirit of conciliation rather than of confrontation. In the final analysis, this is an incremental process, where one building block must be placed on top of the other, in a stable and sustainable manner.

During the UN General Assembly meetings Israel annually asserts that "it remains committed to a vision of the Middle East developing eventually into a zone free of Chemical, Biological, and Nuclear weapons as well as ballistic missiles" but that these issues can only be "realistically addressed within the regional context." A NWFZ, or a WMDFZ (which, as Israel notes, is unprecedented) "must be based on arrangements freely arrived at through direct negotiations between the states of the region and those directly concerned, applying a step by step approach."[48]

On 23 November 2012, the United States announced the indefinite postponement of the conference to establish a Middle East WMDFZ, a decision that has been criticized by the Arab states of the region and co-convener of the conference, the Russian Federation. Subsequently, the Finnish facilitator, Ambassador Jakoo Laajava, has convened five multilateral consultations in preparation for such a conference, in which Israel has participated on senior or authoritative level.[49] As of 1 April 2015 no further meetings have been held, nor has a date for the conference been announced.

Notes:

1. International Institute for Strategic Studies, *Nuclear Programmes in the Middle East: In the Shadow of Iran,* London, 2008, p. 124 (hereinafter "IISS").
2. Ibid., p. 130.
3. Before the revelations by former Dimona nuclear technician Mordechai Vanunu were published in the London *Sunday Times* in 1986 it was generally estimated that Israel had two to three dozen nuclear weapons. Ibid., p. 130
4. Stockholm International Peace Research Institute (SIPRI), *SIPRI Yearbook 2013: Armaments, Disarmament and International Security - Summary,* Stockholm, 2013, p. 13. See also H. M. Kristensen and R. S. Norris, Global nuclear weapons inventories, 1945–2013, *Bulletin of the Atomic Scientists,* September 2013, p. 80.
5 *Global Fissile Material Report 2013: Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step Toward Disarmament*, International Panel on Fissile Materials, October 2013, p. 18.
6. IISS, p. 132, citing David Albright, "ISIS Estimates of Unirradiated Fissile Material in De Facto Nuclear Weapon States, Produced in Nuclear Weapons Programs," Institute for Science and International Security (ISIS), Washington, 2003 (revised 2005); ISIS, Israeli Military Stocks of Fissile Material As of Late 2003 (revised 2005), http://isis-online.org/isis-reports/detail/israeli-military-stocks-of-fissile-material-as-of-late-2003/.
7. *Global Fissile Material Report 2013: Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step Toward Disarmament*, International Panel on Fissile Materials, October 2013, p. 11.
8. IISS, p. 131.
9. BASIC, p. 28.
10. IISS, pp. 132-133, citing Joseph Cirincione, *Deadly Arsenals: Nuclear, Biological, and Chemical Threats*, second edition, Washington, 2005, p. 261.
11. IISS, p. 133, citing "Nuclear Weapons Database: Israeli Nuclear Systems," Center for Defense Information, updated May 2002, http://www.cdi.org/issues/nukef&f/database/isnukes.html.
12. IISS, p. 133.
13. Ibid.
14. BASIC, p. 28.
15. Ibid., citing International Institute for Strategic Studies, *The Military Balance,* Washington, 2011, p.314.
16. BASIC, p. 27, citing Robert S. Norris, William M. Arkin, Hans M. Kristensen and Joshua Handler, "Israeli nuclear forces, 2002," *Bulletin of the Atomic Scientists* ,September/October 2002, p.75.
17. BASIC, p. 28, quoting Norris et al., ibid., p.75: "In June 2002, former Pentagon and State Department officials told the *Washington Post* that Israel was arming three diesel-powered submarines with cruise missiles capable of carrying nuclear warheads."
18. BASIC, p. 28, n. 125, quoting Nuclear Threat Initiative, *Israel Profile*, http://www.nti.org/e_research/profiles/Israel/Nuclear/index.html.
19. "Israel to receive fourth Dolphin-class submarine from Germany within days," *The Jerusalem Post*, 3 September 2014, http://www.timesofisrael.com/fourth-advanced-german-submarine-en-route-to-israel/
20. Secret Cooperation: Israel Deploys Nuclear Weapons on German-Built Submarines, *Der Spiegel*, 3 June 2012, http://www.spiegel.de/international/world/israel-deploys-nuclear-weapons-on-german-submarines-a-836671.html
21. BASIC, p. 28.
22. IISS, p. 129.
23. Ibid.
24. Ibid., p. 130.
25. Ibid.
26. Ibid.; ISIS Reports, *Israeli Military Stocks of Fissile Material As of Late 2003, Revised 2005*, http://isis-online.org/isis-reports/detail/israeli-military-stocks-of-fissile-material-as-of-late-2003/.
27. http://www.soreq.gov.il/default_EN.asp.
28. IISS, p. 131.
29. Ibid.
30. Ibid., p. 119. See also BASIC, *op. cit.*
31. Historically the term most frequently used was "ambiguity" but in recent years "opacity" has gained currency. The latter is closer to the Hebrew term (*amimut*), which implies something "unclear" or "opaque." Avner Cohen has advocated use of the term "opacity" (originally in 1987-88 in an article with Benjamin Frankel), and this term has been increasingly accepted in recent years, particularly in academic circles. See Avner Cohen, *Israel and the Bomb*, New York, 1998.
32. Cohen, p. 2.
33. Cohen, pp. 277–321.
34. IISS, p. 122. Cohen, p. 275.
35. IISS, p. 123. See also Cohen, pp. 277-321; Seymour M. Hersh, *The Samson Option: Israel's Nuclear Arsenal and American Foreign Policy*, New York, 1991.
36. IISS, p. 126.
37. Explanation of vote by Israel on the Comprehensive Nuclear-Test-Ban Treaty (L.29), UN General Assembly First Committee on Disarmament and International Security, New York, 4 November 2013, http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/1com/1com13/eov/L29_Israel.pdf.
38. IAEA Office of Legal Affairs, *Country Factsheet: Israel*, http://ola.iaea.org/factSheets/CountryDetails.asp?country=IL.
39. Alan Dowty, "The Enigma of Opacity: Israel's Nuclear Weapons as a Field of Study," *Israel Studies Forum*, Vol. 20, No. 2, Winter 2005, pp. 3-21.
40. Emily B. Landau and Tamar Malz-Ginzburg, eds., *The Obama Vision and Nuclear Disarmament*, Tel Aviv, 2011, http://www.inss.org.il/upload/(FILE)1300013686.pdf.
41. IISS, p. 128.
42. Cohen, Op. Cit., p. 9.
43. A relatively elite mainstream newspaper, comparable to the reputation of the *New York Times* within the US
44. Admittedly, an example is not proof. Without speculating as to the source or reason for the different headlines, they are offered here as illustrations of a difference in approach to nuclear issues at the domestic and international levels, whether by design or unintentionally.
45. Yossi Melman, "Israel is clinging dearly to its policy of nuclear ambiguity," *Ha'aretz*, 24 November 2011, http://www.haaretz.com/print-edition/features/israel-is-clinging-dearly-to-its-policy-of-nuclear-ambiguity-1.397389.
46. http://www.haaretz.co.il/news/politics/1.1574564.
47. Explanation of Vote by Israel on UNGA Draft Resolution A/C.1/69/L.1, "Establishment of a NWFZ in the region of the Middle East," 29 October 2014. http://reachingcriticalwill.org/images/documents/Disarmament-fora/1com/1com14/eov/L1_Israel.pdf
48. Explanation of Vote by Israel on UNGA Draft Resolution A/C.1/66/L.1, "Establishment of a NWFZ in the region of the Middle East," 26 October 2011. http://www.reachingcriticalwill.org/political/1com/1com11/eov/L1_Israel.pdf..
49. *Developments regarding the MEWMDFZ*, R. Acheson (Ed.), The NPT Action Plan Monitoring Report –March 2015, Reaching Critical Will, pp. 78-81.

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Pakistan

Zia Mian

Pakistan has been rapidly developing and expanding its nuclear arsenal since its nuclear weapon tests in May 1998. It is moving from an arsenal initially based on simple highly enriched uranium (HEU) fission weapons to greater reliance on lighter and more compact plutonium weapons. This has been made possible by the construction over the past fifteen years of three additional plutonium production reactors, all of which appear to be operational as of early 2015. To support this build-up, Pakistan has been blocking the start of talks at the United Nations Conference on Disarmament on an international treaty that would ban the production for weapons of HEU and plutonium – the key ingredients in nuclear weapons.

Pakistan is moving from aircraft-delivered nuclear bombs to ballistic missiles and also to ground-launched, air-launched, and possibly sea-based cruise missiles that can carry nuclear warheads. It is testing a battlefield missile system that is claimed to be nuclear-capable. Pakistan's arsenal is expected to continue to grow in size, with warheads moving to greater states of readiness as command and control systems are seen as more reliable.

The lack of official information makes estimates of Pakistan's spending on its nuclear weapons programme highly uncertain, but this cost is likely not a large share of its overall military spending. Pakistan's military spending is subsidized by large amounts of military aid from the United States and subsidized arms sales from China. To help it meet basic social and economic development needs, Pakistan receives large amounts of international aid and loans for budgetary support.

Status of Pakistan's nuclear forces

As of the end of 2014, Pakistan was believed to have on the order of 130 nuclear weapons, an almost ten-fold increase from the year 2000. The US government estimated in 2011 that Pakistan's stockpile may have been in the range of 90 to over 110 weapons.[1] The growth of the arsenal appears to have been steady for most of the past decade (see Table 1) but it may begin to increase at a faster rate in coming years as additional plutonium becomes available from the production reactors that came online in 2013 and 2014 and new delivery systems move from development to deployment.

There is little reliable information on the yields of Pakistan's nuclear weapons. The number and yields of the nuclear weapon tests carried out on 28 and 30 May 1998 are disputed, with Pakistan initially claiming six tests with some having explosive yields of tens of kilotons, while independent seismologists found evidence supporting a smaller number of tests and total yields of about 10 kt and 5 kt for the tests on 28 May and 30 May respectively.[2] A semi-official account claims that in 1998 "only two bombs were selected for tests" and another four designs were tested without fissile material.[3]

There is little known about Pakistan's weapon designs, although Pakistan is believed to have received in the early 1980s a first generation Chinese weapon design that used HEU.[4] If two weapons were tested in 1998, one may have used HEU and the other plutonium for the shell of fissile material (known as a 'pit') that undergoes the explosive nuclear chain reaction, or possibly a combination of both in a 'composite' pit.[5] Pakistan may also have developed 'boosted' weapons, in which tritium gas is injected into the pit just before it explodes to increase the fraction of the fissile material that undergoes fission and so significantly increase the explosive yield of the nuclear weapon.[6]

Pakistan is not believed to have thermonuclear weapons, although Pakistani nuclear weapon scientists claim they could develop such weapons if tasked and funded to do so.[7] This would most likely require additional nuclear weapon tests. After its tests in 1998, Pakistan declared a moratorium on nuclear testing, following a similar declaration by India.

Table 1: Estimated number of weapons in Pakistan's nuclear arsenal, 2000-2014

Year	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Weapons	14	20	26	32	38	44	50	60	70	80	90	100	110	120	130

Source: Adapted and updated from Robert S. Norris and Hans Kristensen, "Global Nuclear Weapons Inventories, 1945–2013," Bulletin of the Atomic Scientists, September/October 2013 vol. 69 no. 5, pp. 75-81.

Delivery systems

Pakistan is developing various road-mobile ballistic missile systems and ground-launched, air-launched and possibly sea-based cruise missiles to carry its nuclear weapons.

These missiles are at various stages in their development and it unclear which systems will eventually be deployed (Table 2).

Table 2: Pakistan's nuclear weapon delivery systems, 2014

DELIVERY SYSTEM	RANGE (KM)	DEPLOYMENT
AIRCRAFT		
Aircraft F-16A/B	1,600	1998
Mirage V	2,100	1998
AIRCRAFT		
Abdali (Hatf-2)	180	(R&D)
Ghaznavi (Hatf-3)	400	2004
Shaheen-1 (Hatf-4)	750	2003
Shaheen-1A (Hatf-4)	900	(R&D)
Ghauri (Hatf-5)	1200	2003
Shaheen-2 (Hatf-6)	2000	(R&D)
Nasr (Hatf-9)	60	(2014)
CRUISE MISSILES		
Babur (Hatf-7)	350-750	(R&D)
Ra'ad (Hatf-8)	350	(R&D)

Source: Adapted and updated from Hans Kristensen and Robert S. Norris, "Pakistan Nuclear Forces 2011," *Bulletin of the Atomic Scientists*, Volume 67, No. 4 pp. 91-99, and Phillip Schell and Hans Kristensen, "PArkistani nuclear forces" in *SIPRI Yearbook 2014: Armaments, Disarmament and International Security*, Oxford University Press, 2014 Pakistani pp. 328-332, and press release by Parkistan Inter-Services Public Relations Directorate.

Pakistan is believed to rely on US supplied F-16 fighter jets to deliver nuclear bombs and French supplied Mirage jets to deliver both bombs and the Ra'ad air-launched nuclear-armed cruise missile. It is unclear if the JF-17 jets that Pakistan recently acquired from China also will carry the Ra'ad cruise missile.[8] Pakistan has received assistance from the Democratic People's Republic of Korea (DPRK) and especially from China with its missile programme.

The reliability of Pakistan's missiles is uncertain. In January 2003, the liquid-fueled Ghauri missile (sometimes called Hatf V) was formally inducted into the army. It is believed to be derived from the DPRK's No-Dong missile. Work on the Ghauri missile started in the early 1990s and the first test was carried out in 1998. The reliability of the missile came into question after debris fell to earth from a Ghauri test in 2012.[9] The test, initially reported as being successful, was described as a "field training exercise" by the Strategic Missile Group of the Pakistan Army Strategic Force Command.[10]

Pakistan's most frequently tested missile system as of the end of 2014 is the 750 km-range solid-fueled Shaheen-I, which was handed over to the military in March 2003.[11] It is believed to be derived from the Chinese M-11 missile and US officials have suggested China may have provided Pakistan with M-11 missile components, 34 intact M-11 missiles, and "blueprints and equipment … to build a plant for making missiles," as well as technical assistance with further development of this missile.[12] A variant of this missile, dubbed Shaheen-1A, with longer range (about 900 km) has been tested.[13]

An even longer-range ballistic missile system, the Shaheen-II, with 1500–2500 km-range, is under development. It was first tested in 2004 and may be nearing deployment. In 2014, a Shaheen-II test was described as an Army Strategic Forces Command "field training exercise" that was "aimed at ensuring operational readiness of a Strategic Missile Group."[14] However, this test also aimed at "re-validating different design and technical parameters of the weapon system," suggesting this missile system may not be ready for deployment. In March 2015, Pakistan tested for the time a Shaheen-III missile, described as having a maximum range of 2750km.[15] With a missile of 2000 km range or longer, Pakistan can target anywhere in India.

The 2005 India-Pakistan Agreement on Pre-Notification of Flight Testing of Ballistic Missiles commits the two states to give 72 hours' notice before a ballistic missile flight test and to not test missiles close to their borders. It does not cover cruise missiles.

Pakistan is developing a nuclear-capable ground-launched cruise missile (Babur) and the Ra'ad air-launched cruise missile with ranges of about 600 km and 350 km respectively. Pakistan began testing these missiles in 2005 and 2007 respectively. The most recent test, conducted in early 2015, involved firing Ra'ad from a Mirage fighter jet, and was the sixth test of this missile system.[16] Pakistan may seek to put nuclear-armed cruise missiles on some of its submarines, or modify existing naval missiles to be nuclear capable.[17]

The most recent system to begin development is the 60 km-range Nasr missile. First tested in 2011, Nasr is described as a battlefield system able to carry "nuclear warheads of appropriate yield" and as "consolidating Pakistan's deterrence capability at all levels of the threat spectrum."[18] In a test in 2014, a salvo of four Nasr missiles was fired from a multi-tube launcher on the back of a truck.[19] Reports suggest that Nasr is presumably intended for use as a short-range battlefield nuclear weapon system against Indian conventional armoured forces during the early stages of a conflict. Analysis of such a scenario suggests Pakistan would need to deploy and use many tens of Nasr missiles to be able to destroy a significant fraction of the 1000 or so Indian tanks that may be involved in such an action.[20]

There is little public information about the storage and deployment status of Pakistan's nuclear weapons. It was believed in the late 2000s that "missiles are not mated with warheads and the physics packages (the fissile cores) are not inserted into the warheads themselves."[21] Reports suggested that while warheads are kept in component form, possibly by "isolating the fissile 'core' or trigger from the weapon and storing it elsewhere … all the components are stored at military bases."[22]

In the years since then, however, Pakistan has moved to developing cruise missiles and a potential battlefield nuclear weapon system. These systems may need nuclear warheads that are lighter and more compact than those that could be carried by the ballistic missiles. These new missiles also may not be as amenable as large, long-range ballistic missiles to having their warheads stored in component form ready to be integrated at short notice.

Seven possible locations for Pakistan's nuclear weapons storage have been suggested (Table 3). Some of these sites are associated with airbases that are home to nuclear weapon capable aircraft, which may carry either nuclear bombs or air-launched cruise missiles. Other sites are associated with warhead and missile development and assembly facilities, while some sites seem to be secure underground storage for weapons. No site has yet been identified for possible naval nuclear weapons.

Table 3: Pakistan nuclear weapon storage sites, 2014

FACILITY NAME/LOCATION	PROVINCE	FUNCTION
Sargodha Depot	Punjab	Potential storage site for bombs for F-16s at nearby Sargodha Air Base, and warheads for missiles
Shanka Dara Missile Complex	Punjab	Missile development and potential warhead storage capability
Fatejhang National Defense Complex	Punjab	Missile development and potential warhead storage
Wah Ordnance Facility	Punjab	Possible warhead production, disassembly and dismantlement facility
Masroor Weapons Depot	Sindh	Potential storage of bombs for Mirage Vs at Masroor Air Base, and warheads for missiles
Khuzdar Depot	Balochistan	Potential underground weapons storage
Tarbela Underground Complex	Khyber Pakhtunkhwa	Potential weapons storage

Source: Hans Kristensen and Robert Norris, "Worldwide Deployments of Nuclear Weapons, 2014," *Bulletin of the Atomic Scientists,* August 2014.

Fissile materials

Pakistan has developed an extensive nuclear infrastructure that allows it to produce both HEU and plutonium for weapons. This includes capacity for uranium mining, uranium enrichment, nuclear reactor fuel fabrication, nuclear reactor construction, and spent fuel reprocessing for plutonium recovery. There is no official information on Pakistan's fissile material production sites – although Pakistan and India each year exchange lists of nuclear facilities as part of their 1988 Agreement on the Prohibition of Attack against Nuclear Installations and Facilities.[23] These lists may include both military and civilian nuclear facilities, but are not made public.

Table 4 presents a list of Pakistan's fissile material production-related sites compiled from open sources as of 2014. While the histories and operating capacities of these facilities are not clear, it is well known that Pakistan has been producing HEU for nuclear weapons since the early 1980s and producing plutonium for weapons since the late 1990s.

Table 4: Pakistan's fissile material related facilities, 2014

LOCATION	FACILITY TYPE	MATERIAL
Dera Ghazi Khan	Uranium mine, ore concentration plant, conversion plant	Uranium
Issa Khel	Uranium mine	Uranium
Qabul Khel	Uranium mine	Uranium
Kahuta	Uranium enrichment (Khan Research Laboratories)	HEU
Gadwal (Wah)	Uranium enrichment (secondary plant)	HEU
Chaklala	Uranium enrichment (pilot plant)	HEU
Sihala	Uranium enrichment (pilot plant)	HEU
Golra	Uranium enrichment (pilot plant)	HEU
Khushab–I	Heavy-water plutonium production reactor	Plutonium
Khushab–II	Heavy-water plutonium production reactor	Plutonium
Khushab–III	Heavy-water plutonium production reactor	Plutonium
Khushab–IV	Heavy-water plutonium production reactor	Plutonium
Chashma (Khushab)	Reprocessing facility (being commissioned)	Plutonium
Rawalpindi	Reprocessing facility–I	Plutonium
Rawalpindi	Reprocessing facility–II	Plutonium
Khushab–I-IV	Tritium production	Tritium
Chashma (Kundian)	Reactor fuel-fabrication plant	
Multan	Heavy-water production facility	
Khushab	Heavy-water production facility	

Source: Adapted and updated from *Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks,* International Institute of Strategic Studies, London, 2007, and Feroz Hassan Khan, *Eating Grass: The Making of the Pakistani Bomb,* Stanford University Press, 2012.

Accurate estimates about Pakistan's production of HEU for its nuclear weapon programme are limited by uncertainty about Pakistan's enrichment capacity and the operating history of its centrifuge plants at Kahuta and Gadwal.[24] It is estimated that, as of the end of 2014, Pakistan could have a stockpile of about 3 tonnes of weapon-grade (90%-enriched) HEU.[25]

As of the end of 2014, Pakistan operates four weapons plutonium production reactors. A semi-official account states these reactors have a capacity of about 50 MW-thermal, with Khushab-IV possibly being larger, with a capacity of 50-100 MW-thermal.[26] The Khushab-I plutonium production reactor, a heavy-water-moderated, light-water-cooled, natural-uranium-fueled reactor has been operating since 1997-1998. The Khushab-II reactor started operation in late 2009 or early 2010. Khushab-III began operating early in 2013.[27] Khushab-IV began operation in 2014.[28]

Pakistan has been reprocessing spent fuel from the Khushab reactors at the Rawalpindi New Labs facility, which has two reprocessing plants, each with an estimated capacity of 10–20 tons per year of spent fuel.[29] These plants may not have the capacity to handle all the fuel from the four Khushab reactors, however. The spent fuel from Khushab-III and Khushab-IV may become available for reprocessing in 2015 and 2016 respectively, after the spent fuel has been cooled. As a result, Pakistan is estimated to have produced a total of almost 200 kg of plutonium as of the end of 2014.[30]

Satellite imagery from January 2015 suggests construction of the large reprocessing plant at Chashma may have been completed, and the facility may be being commissioned or even be operational.[31] The Chashma reprocessing plant was originally intended to handle 100 tons of spent fuel per year. This capacity would be sufficient in principle to treat all the spent fuel from the four Khushab reactors.

Infrastructure

Pakistan's nuclear weapons research, development, and production infrastructure are managed by the military-run Strategic Plans Division (SPD) and overseen by a National Command Authority (NCA) set up in February 2000 by General Pervez Musharraf. The NCA has responsibility for policy concerning the development and use of Pakistan's nuclear weapons. The NCA is chaired by the Prime Minister, and includes the ministers of foreign affairs, defence, and interior, the chairman of the Joint Chiefs of Staff committee, the military service chiefs, and the director-general of SPD. The founding director-general of SPD, Lt. General Khalid Kidwai, retired after fourteen years of service in December 2013, and was replaced by General Zubair Mahmood Hayat.

The SPD has responsibility for strategic weapons development and nuclear weapons planning and operations, as well as security of the nuclear complex. It also has an arms control group. The total number of staff of the SPD and the various programmes it is responsible for is uncertain. The former head of SPD has suggested that only about 2000 people hold "critical knowledge" of Pakistan's nuclear weapons complex.[32] A 2011 report suggested a total of about 70,000 professional staff in the entire strategic weapons complex.[33] A former SPD official has indicated that as of 2013 the security division alone had 20,000 personnel and the force would grow to a total of 28,000 within a few years.[34]

The nuclear weapons development and production infrastructure managed by SPD has three broad divisions: the A.Q. Khan Research Laboratory (Kahuta) produces enriched uranium; the Pakistan Atomic Energy Commission is responsible for uranium mining, fuel fabrication, reactor construction and operation, and spent fuel reprocessing to produce plutonium; and the National Development Complex is responsible for weapons and delivery system research and production.[35] These three bodies are managed by the National Engineering and Scientific Commission.

Pakistan's nuclear weapons currently are assigned to its Army Strategic Force Command, which has responsibility for ballistic and cruise missiles, and the Air Force Strategic Command, which deals with nuclear armed aircraft. Pakistan's Naval Strategic Force Command was established in 2012 and charged with "development and employment of … the nation's 2nd strike capability" but it is not known if this command has yet been issued any nuclear weapons.[36] Analysts believe Pakistan may be seeking naval nuclear armed cruise missiles that could be fired from ships or submarines.[37] Following India's launch in 2009 of its first nuclear-powered ballistic missile submarine, which began sea-trials in 2014, there are suggestions that Pakistan may be seeking a matching capability.[38]

Economics

Secrecy about the history and scale of the nuclear weapon and missile programmes, the extent of external technical and material support, and the effect of indirect support through military and economic aid means the full cost of Pakistan nuclear weapons programme cannot be estimated with any reliability. This is part of the larger historical pattern in which military spending largely has been unaccountable, even to Parliament. The annual military budget was debated in parliament in 2008, for the first time since 1965.[39]

In 2001, retired Major-General Mahmud Ali Durrani (who later served as National Security Advisor to the President of Pakistan) estimated that Pakistan's annual expenditure on "nuclear weapons and allied programs" was about $300–400 million (USD) and that Pakistan "will now need to spend enormous amounts of money for the following activities: a) a second strike capability; b) a reliable early warning system; c) refinement and development of delivery systems; d) command and control systems."[40] Citing an earlier estimate by Rammanohar Reddy for the cost of nuclear weapons development by India, Durrani suggested that Pakistan might need to spend about 0.5% of gross domestic product (GDP) for a period of at least 10 years on such nuclear weapons activities.[41]

General Pervez Musharraf, who seized power in 1999 and ruled until 2008, and held the positions of Chief of Army Staff and President, affirmed in 2004 that there had been a significant increase in nuclear weapon spending after 2000 (when SPD had been established) as part of a 15 year plan. General Musharraf claimed in particular that during the previous three to four years the government had spent more on the nuclear weapons programme than in the previous 30 years.[42] This increase in spending would be consistent with the large expansion in fissile material production capabilities and new missile system development that occurred after the year 2000.

An independent estimate in 2011 suggested Pakistan's nuclear spending could be about $800 million per year and possibly as much as $2 billion per year if health and environmental costs are included – and this spending was projected to rise significantly because of Pakistan's expanding nuclear programme.[43] This estimate relies on an unsubstantiated 2009 Pakistani newspaper report that annual spending on "core classified development programs" was not more than Rs. 10 billion and that overall the "strategic organisations of the country… got less than 0.5 per cent of the GDP."[44]

Pakistan's GDP was about $840 billion in purchasing power parity terms, and $232 billion in nominal terms in 2013 – the latest year for which World Bank data is available.[45] Assuming that Pakistan spends on the order of 0.5% of GDP on its nuclear weapons, and using purchasing power parity rather than market exchange rates to convert Pakistani rupees to US dollar equivalents, since most of the spending is for goods and services provided from within the country rather than imports, suggests that in 2013 nuclear weapon programme spending may have been up to about $4 billion a year.

For Pakistan to spend on the order of $4 billion per year on its nuclear weapons is feasible. The annual official military spending for 2014–2015 was budgeted at Rs700 billion, a 10% increase from the previous year.[46] Reports suggest this military budget does not include military pensions and various other direct and indirect costs associated with the armed forces and that including these costs would increase Pakistan's total military budget for 2014–2015 to around Rs. 1113 billion (about $38 billion, using current purchasing power parity exchange rates). This would suggest that, in purchasing power terms, as of 2013, Pakistan spent the equivalent of about 10% of its conventional military budget on nuclear weapons.

Pakistan is not reliant only on its own resources to support its military spending, including on nuclear weapons, or to meet its development needs. Since 2001, Pakistan has received an estimated $31 billion in military and economic assistance from the United States, of which about $10 billion was economic aid of various kinds.[47] The Congressional Research Service reported that in 2006, the United States signed arms deals with Pakistan for over $3.5 billion, including for 36 new F-16 jet fighters ($1.4 billion) and associated missiles and bombs (over $640 million) and upgrades for Pakistan's existing, older F-16 fighters ($890 million).[48]

Reflecting its concerns after September 2001 about the vulnerability of Pakistan's nuclear weapon and fissile materials to seizure by Islamist militants, the United States has provided Pakistan on the order of $100 million worth of assistance to secure its nuclear weapons, facilities, and materials.[49] This has included "training of Pakistani personnel in the United States and the construction of a nuclear security training center… [and] a raft of equipment from helicopters to night-vision goggles to … fencing and surveillance systems, and equipment for tracking nuclear material if it left secure areas."[50]

Pakistan has also received extensive military assistance from China for its nuclear weapons, missile, and conventional weapons programmes.[51] According to A.Q. Khan, in the early years of Pakistan's uranium enrichment programme, China supplied 15 tons of uranium hexafluoride (the gas used in centrifuges), 50 kg of weapon-grade HEU (enough for two weapons), the design details for a nuclear weapon, and technical help with the nuclear weapons programme.[52] Khan claims he provided China with the details of the European uranium enrichment gas centrifuges that Khan had acquired and provided training for Chinese technicians.[53]

China's conventional military assistance to Pakistan is beginning to rival the scale of support provided by the United States. In 2011, China agreed to fully fund the sale of 50 JF-17 jet fighters with advanced avionics to Pakistan.[54] According to Pakistan's Defence Minister Ahmad Mukhtar, these jets cost about $20–25 million each, which suggests that the total cost of the 50 JF-17 deal with China is about $1 billion or more.[55] Pakistan was also reported in 2014 to be close to buying six new submarines from China.[56] Pakistan dependence on military assistance from China is likely to grow as Pakistan's poor relations with the United States worsen.

Given its high levels of military spending and poor government finances because of governance failures, Pakistan is dependent on economic aid to meet even basic development needs. In December 2011, the World Bank announced a $5.5 billion aid package to support "poverty reduction and development" in Pakistan for the three-year period 2012–2014.[57] For comparison, between 1952 and 2003, the World Bank committed $18.2 billion of aid to Pakistan.[58] A comparison of a different sort is offered by the estimated damage of $10 billion caused by the 2010 floods in Pakistan that displaced some 20 million people and flooded over 50,000 square km area of land, and is described by the government of Pakistan as an "unprecedented calamity".[59]

International law and doctrine

Pakistan is not a signatory to the nuclear Non-Proliferation Treaty (NPT), nor has it signed the Comprehensive Test Ban Treaty (CTBT), and it appears to recognize no international legal obligation to restrain or end its nuclear weapons and missile programme.[60] Pakistan has said, however, that it supports "negotiation of a nuclear weapons convention along with a phased programme for the complete elimination of nuclear weapons within a specified time frame."[61]

Pakistan is the subject, along with India, of a unanimous UN Security Council resolution calling for restraint of its nuclear weapon and ballistic missile programmes. Resolution 1172 (June 1998) calls upon India and Pakistan immediately to stop their nuclear weapon development programmes, to refrain from weaponization or from the deployment of nuclear weapons, to cease development of ballistic missiles capable of delivering nuclear weapons and any further production of fissile material for nuclear weapons, to confirm their policies not to export equipment, materials or technology that could contribute to weapons of mass destruction or missiles capable of delivering them and to undertake appropriate commitments in that regard.[62] As of the end of 2014, Pakistan is clearly in violation of this Security Council resolution, as is India and possibly those countries that have exported nuclear and missile related technologies and materials to Pakistan and India.

Pakistan has continued to block talks at the United Nations Conference on Disarmament (CD) on a possible international treaty banning the production of fissile materials for nuclear weapons (commonly known as a fissile material cut-off treaty or FMCT). Most recently, in January 2015, Pakistan's objection prevented the consensus required by the CD rules of procedure to agree the annual programme of work and so ensuring there will be no formal FMCT talks this year.[63]

Pakistan explained at the CD in June 2014 that its concerns about a possible FMCT stem from India having accumulated a larger total fissile material stockpile than Pakistan, and the decision by the United States and other key countries, including those of the 48-nation Nuclear Suppliers Group (NSG), to waive three-decade old nuclear trade sanctions on India but to leave them in place for Pakistan.[64] NSG guidelines had forbidden members from selling uranium, nuclear reactors, and fuel cycle technologies to countries that were outside the NPT because such sales could allow the target countries to expand their nuclear weapons programme. In late 2011, Zamir Akram, Pakistan's ambassador to the UN Conference on Disarmament, proposed that if Pakistan received a waiver from the NSG similar to the one granted to India, Pakistan would be willing to join talks on an FMCT.

To address its concerns about India's larger stockpile, in 2014 Pakistan proposed that an FMCT should include the obligation to put under international monitoring:[65]

- fissile material that has not been weaponized as yet, but set aside either for new warheads or for the re placement and refurbishment of existing warheads;
- irradiated fuel and reactor-grade separated plutonium produced from any unsafeguarded reactor, military or otherwise;
- fissile material from retired warheads or those in the dismantlement queue, including such material already in waste disposal sites;
- fissile material declared excess for military purposes;
- fissile material for non-proscribed military activities like naval propulsion etc.; and
- fissile material designated for civil purposes.

This proposal would serve to freeze the size of nuclear weapon arsenals and suggests Pakistan may intend to keep its entire fissile material stockpile in the form of components in deployed warheads or as stored warhead components. Safeguards on the second category of material are clearly intended to capture India's large stockpile of unsafeguarded spent fuel and separated plutonium for its nuclear power reactors and prevent its possible use in weapons. This would serve to give Pakistan the parity that it seeks with India in fissile material stockpiles potentially available for weapons.

Pakistan's long-running search for strategic parity with India informs almost all its nuclear diplomacy.[66] It is debatable whether Pakistan's FMCT proposal is intended as a serious constructive suggestion or a diplomatic move to lessen the perception of Pakistan as being stubbornly uncooperative on this issue. Regardless, it is unlikely that the other nuclear-armed weapon would accept such broad constraints as part of an FMCT. Progress towards an FMCT at the CD may have to wait until Pakistan's SPD believes it has a big enough plutonium stockpile or the international community decides to make achieving an FMCT a much higher priority in its relationships with Pakistan.

Public discourse

Nuclear weapons have played a major role in Pakistan's domestic political discourse for over 40 years. Prime Minister Zulfikar Ali Bhutto, who launched the nuclear weapons programme in 1972, famously declared that Pakistan would get the bomb even if its people had to eat grass. Since then, Pakistani governments have sought to create a positive image of the nuclear weapons programme, often by linking it to national pride and national identity.

After the nuclear tests of May 1998, Pakistan's military and political leaders saw the bomb as a panacea for solving many long-standing national political, social and economic problems. One assessment observes that at the time Pakistan's leaders "told themselves and their people that the bomb would bring national security, allow Pakistan to liberate Kashmir from India, bind the nation together, make its people proud of their country and its leaders, free the country from reliance on aid and loans, and lay the base for the long-frustrated goal of economic development."[67] None of these hopes have come to pass in the nearly two decades since then.

Pakistan's major political parties nonetheless remain determined in their support for the nuclear weapons programme. The Pakistan Muslim League (PML), which came to power after the elections in 2013 and is led by Prime Minister Nawaz Sharif, claims credit for the bomb; the previous PML government, also led by Nawaz Sharif, ordered the 1998 nuclear tests. Pakistan's other national political party, the Pakistan People's Party (PPP) also claims credit for the nuclear programme because the PPP and the nuclear weapons programme were both founded by Zulfikar Ali Bhutto. Bhutto's daughter Benazir led the PPP and served two terms as Prime Minister, and after her assassination in 2007 her widower Asif Zardari took control of the PPP and became President of Pakistan. It is common place for Prime Ministers to inaugurate nuclear facilities and they are often photographed at nuclear missile tests and send public messages of commendation and congratulations after such tests.

The central thrust of most public debate about Pakistan's nuclear weapons is the struggle with India that has shaped Pakistan's history and politics since the two countries were formed by the partition of British India into independent states. Pakistan's nuclear weapons are widely seen as a response to India's nuclear weapons and its larger conventional military forces, and the experience of wars in 1947, 1965, 1971, and 1999, and many crises that threatened to lead to war. Pakistani fears of Indian hegemony have increased in recent years as India's economy has started to grow at a much faster rate than Pakistan's and as India has increased its already much larger military budget at a much faster rate.

The domestic nuclear debate in Pakistan was from time to time sensitive to international pressure on Pakistan to restrain its nuclear weapons programme. Ever since the attacks on the United States in September 2001, the United States and most of the outside world has not given high priority to confronting Pakistan's nuclear buildup and the nuclear arms race with India. The focus has been on maintaining a good relationship with Pakistan's army seen as a vital ally in the war against the Taliban in Afghanistan and a check on radical Islamist militancy. Given the situation in Afghanistan, and the continued concern about Islamist militant groups, this focus is unlikely to change for the foreseeable future.

The underlying dynamics of the Pakistan-India relationship may be shifting, however. A longer-term concern now driving Pakistan's nuclear programme is the United States' policy of cultivating a much stronger US strategic relationship with India to counter the rise of China as a potential great power competitor.[68] India's relationship with China is marked by both growing economic cooperation and increasing military competition, while China is becoming a closer military, political, and economic partner for Pakistan. This four-way relationship will tie the future of Pakistan's nuclear weapons, and those of India, to the emerging contest between the United States and China for long-term global hegemony, making nuclear restraint and disarmament increasing unlikely in South Asia.

Photo: Flickr / Gladys Martínez

Notes:

1. David E. Sanger and Eric Schmitt, "Pakistani Nuclear Arms Pose Challenge to U.S. Policy," *New York Times*, 31 January 2011.
2. Gregory van der Vink, Jeffrey Park, Richard Allen, Terry Wallace and Christel Hennet, "False Accusations, Undetected Tests And Implications for the CTB Treaty," *Arms Control Today*, May 1998, http://www.armscontrol.org/act/1998_05/vimy98.
3. Feroz Hassan Khan, *Eating Grass: The Making of the Pakistani Bomb*, Stanford University Press, 2012, pp.279.
4. See e.g., Hans M. Kristensen and Robert S. Norris, "Pakistan's Nuclear Forces, 2011," *op. cit.*
5. *Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks*, International Institute of Strategic Studies, London, 2007, p. 33.
6. Feroz Hassan Khan, *Eating Grass: The Making of the Pakistani Bomb*, Stanford University Press, 2012, pp.278-283.
7. Sohail Iqbal, "Hydrogen Bomb Test Awaits Govt Signal," *The News*, 1 June 1998.
8. Usman Ansari, "Despite Missile Integration, Nuke Role Unlikely for Pakistan's JF-17," *Defense News*, 7 February 2013.
9. "'Mysterious metal objects' in Dadu fell from Hatf V missile: ISPR," *Dawn*, 30 November 2012.
10. Press Release No PR260/2012-ISPR, Pakistan Inter-Services Public Relations Directorate, Rawalpindi, 28 November 2012.
11. "Pakistan Delivers Shaheen-I Ballistic Missile to Military," *Voice of America*, 6 March 2003.
12. Shirley A. Kan, "China and Proliferation of Weapons of Mass Destruction and Missiles: Policy Issues," Congressional Research Service, Report RL31555, 13 December 2007.
13. Press Release No PR98/2012-ISPR, Pakistan Inter Services Public Relations Directorate, Rawalpindi, 25 April 2012.
14. Press Release No PR248/2014-ISPR, Pakistan Inter Services Public Relations Directorate, Rawalpindi, 13 November 13.
15. Press Release No PR61/2015-ISPR, Pakistan Inter Services Public Relations Directorate, Rawalpindi, 9 March 2015.
16. Press Release No PR29/2015-ISPR, Pakistan Inter Services Public Relations Directorate, Rawalpindi, 2 February 2015. "Pakistan Carries Out Test Flight of Raad Missile." *Dawn*, 3 February 2015.
17. Eric Schmitt and David E. Sanger, "U.S. Says Pakistan Made Changes to Missiles Sold for Defense," *New York Times*, 30 August 2009.
18. Press Release No. PR94/2011-ISPR, Pakistan Inter Services Public Relations Directorate, Rawalpindi, 19 April 2011.
19. Press Release No PR210/2014-ISPR, Pakistan Inter Services Public Relations Directorate, Rawalpindi, 26 September 2014.
20. A.H. Nayyar and Zia Mian, "The limited military utility of Pakistan's battle-field use of nuclear weapons in response to large-scale Indian conventional attack," Briefing #61, Pakistan Security Research Unit, Peace Studies Department, Bradford University, November 2010. http://www.princeton.edu/sgs/faculty-staff/zia-mian/Limited-Military-Utility-of-Pakistans.pdf
21. *Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks*, International Institute of Strategic Studies, London, 2007, p. 33.
22. Joby Warrick, "Lack of Knowledge about Arsenal may Limit U.S. Options," *Washington Post*, 11 November 2007.
23. Agreement on the Prohibition of Attack against Nuclear Installations and Facilities, 31 December 19881. Under this agreement, India and Pakistan are to "refrain from undertaking, encouraging or participating in, directly or indirectly, any action aimed at causing the destruction of, or damage to, any nuclear installation or facility in the other country." The term "nuclear installation or facility" includes "nuclear power and research reactors, fuel fabrication, uranium enrichment, isotopes separation and reprocessing facilities as well as any other installations with fresh or irradiated nuclear fuel and materials in any form and establishments storing significant quantities of radio-active materials." Each year on 1 January the two countries exchange a list giving the latitude and longitude of its nuclear installations and facilities and changes. For the full text, see http://www.stimson.org/research-pages/agreement-on-the-prohibition-of-attack-against-nuclear-installations-and-facilities-/.
24. For an assessment, see *Global Fissile Material Report 2010: Balancing the Books*, International Panel on Fissile Materials, December 2010.
25. International Panel on Fissile Materials, www.fissilematerials.org.
26. Feroz Hassan Khan, *Eating Grass: The Making of the Pakistani Bomb*, Stanford University Press, 2012, page 203.
27. Pakistan begins operating third Khushab plutonium production reactor, IPFM, 30 June 2014, http://fissilematerials.org/blog/2014/06/pakistan_begins_operating.html.
28. David Albright and Serena Kelleher-Vergantini, "Pakistan's Fourth Reactor at Khushab Now Appears Operational," Institute for Science and International Security, 16 January 2015.
29. *Global Fissile Material Report 2010: Balancing the Books*, *op. cit.*
30. International Panel on Fissile Materials, www.fissilematerials.org.
31. David Albright and Serena Kelleher-Vergantini, "Pakistan's Chashma Plutonium Separation Plant: Possibly Operational", Institute for Science and International Security, 20 February 2015.
32. David E. Sanger, "Obama's Worst Pakistan Nightmare," *New York Times*, 8 January 2009.
33. Syed Irfan Raza, "Staff of Strategic Organisations Lack Forum for Grievances' Redressal," *Dawn*, 9 March 2011. The staff are listed as scientists, engineers, doctors, law officers, human resource officers and other technical personnel working for the Pakistan Atomic Energy Commission, National Engineering and Scientific Commission, Pakistan Space and Upper Atmosphere Research Commission, Maritime Technologies Complex, Khan Research Laboratories, Air Weapons Complex, Project Management Organisation, National Development Complex, and Defence Science and Technology Organisation.
34. Naeem Salik and Kenneth N. Luongo, Challenges for Pakistan's Nuclear Security," *Arms Control Today*, March 2013.
35. Key facilities in Pakistan's nuclear weapons program infrastructure are described in *Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks*, *op.cit.*
36. Press Release No PR122/2012-ISPR, Pakistan Inter Services Public Relations Directorate, 19 May 2012.
37. Tim Craig and Karen DeYoung, "Pakistan is Eyeing Sea-based and Short-range Nuclear Weapons, Analysts Say," *Washington Post*, 21 September 2014.
38. Usman Ansari, "Pakistani Navy to Develop Nuclear-Powered Submarines: Reports,' *Defense News*, 11 February, 2012.
39. Haroon Rashid, "Pakistan Reveals Defence Spending," *BBC*, 11 June 2008.
40. Mahmud Ali Durrani, *India and Pakistan: The Cost of Conflict and the Benefits of Peace*, Oxford University Press, 2001, p.32.
41. C. Rammanohar Reddy, "Nuclear Weapons versus Schools for Children: An Estimate of the Cost of the Indian Nuclear Weapons Programme," in M.V. Ramana and C. Rammanohar Reddy, eds., *Prisoners of the Nuclear Dream*, Orient Longman, 2003, pp.360-410.
42. Saleem Shahid, "Musharraf rules out rollback of N-plan," *Dawn*, 12 September 2004.
43. Bruce G. Blair & Matthew A. Brown, "World Spending on Nuclear Weapons Surpasses $1 Trillion Per Decade," Global Zero Nuclear Weapons Cost Study, June 2011, http://www.globalzero.org/files/scott/Global%20Zero%20Cost%20Study,%20June%202011.pdf.
44. Ansar Abbasi, "Pak Nuclear Programme Faces 35 pc Cut,"*The News*, 1 May 2009.
45. For Pakistan's GDP in recent years in purchasing power parity and nominal terms, see for example World Bank assessment at http://data.worldbank.org/country/pakistan.
46. Ismail Sheikh and Kamran Yousaf, "Budget 2014: Govt Announces 700bn Defence Budget," *Express Tribune*, 3 June 2014.
47. Congressional Research Service, "Direct Overt U.S. Aid Appropriations for and Military Reimbursements to Pakistan, FY2002-FY2016," 10 February 2015.
48. Richard F. Grimmett, "U.S. Arms Sales to Pakistan," Congressional Research Service, Report RS22757, 8 November 2007.
49. David E. Sanger and William J. Broad, "U.S. Secretly Aids Pakistan in Guarding Nuclear Arms," *New York Times*, 18 November 2007.
50. *Ibid.*
51. For declassified US government documents detailing China's support for the early stages of Pakistan's nuclear weapons programme, see William Burr, ed., *China, Pakistan, and the Bomb: The Declassified File on U.S. Policy, 1977-1997*, National Security Archive Electronic Briefing Book No. 114, March 5, 2004, http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB114/index.htm.
52. R. Jeffrey Smith and Joby Warrick, "A Nuclear Powers Act of Proliferation," *Washington Past*, 13 November 2009.
53. *Ibid.*
54. "Fifty Thunder Jets for Pakistan," *Dawn*, 19 May 2011.
55. "JF-17 Thunders: Pakistan to get 50 Chinese Jets in Six months," *Express Tribune*, 21 May 2011.
56. Farhan Bokhari, "China, Pakistan Set for Submarine Deal by End of Year, Say Officials," *Jane's Defence Weekly*, 5 February 2014.
57. "World Bank Group to Provide up to $5.5 billion to Pakistan for Next Three Years," Press Release No:2012/229/SAR, World Bank, 22 December 2011.
58. *Pakistan: An Evaluation of the World Bank's Assistance*, World Bank, Washington DC, 2006.

59. "Overview," *Pakistan Economic Survey 2010-2011,* Finance Division, Government of Pakistan, Islamabad, http://www.finance.gov.pk/survey/chapter_11/Overview%20of%20the%20Economy.pdf.
60. For Pakistan's views on nuclear disarmament, see e.g., Zia Mian and A.H. Nayyar, "Pakistan," in *Reducing and Eliminating Nuclear Weapons: Country Perspectives on the Challenges to Nuclear Disarmament*, International Panel on Fissile Materials, May 2010, http://www.fissilematerials.org/ipfm/site_down/gfmr09cv.pdf.
61. Statement by Ambassador Masood Khan, Pakistan's Permanent Representative, at the Informal Meeting on Nuclear Disarmament, Geneva, 5 February 2008, http://missions.itu.int/~pakistan/2005_Statements/CD/cd/stcdinf_5feb08.htm.
62. UN Security Council Resolution S/RES/1172 (1998), 6 June 1998.
63. Ambassador Zamir Akram, Statement at the Conference on Disarmament, 13 February 2015, www.reachingcriticalwill.org/images/documents/Disarmament-fora/cd/2015/statements/part1/13Feb_Pakistan.pdf
64. Ambassador Zamir Akram, Statement at the Conference on Disarmament, 4 June 2014, http://fissilematerials.org/library/pk14a.pdf
65. Ambassador Zamir Akram, Statement at the Conference on Disarmament, 5 June 2014, http://fissilematerials.org/library/pk14b.pdf
66. Zia Mian and A.H. Nayyar, "Pakistan," in *Banning the Production of Fissile Materials for Nuclear Weapons: Country Perspectives on the Challenges to a Fissile Material (Cutoff) Treaty*, International Panel on Fissile Materials, September 2008. See also Zia Mian and A.H. Nayyar, "Playing the Nuclear Game: Pakistan and the Fissile Material Cutoff Treaty," *Arms Control Today*, April 2010, www.armscontrol.org/act/2010_04/Mian
67. Pervez Hoodbhoy and Zia Mian, "Nuclear Fears, Hopes and Realities in Pakistan," *International Affairs*, volume 90, number 5, 2014.
68. Zia Mian and M.V. Ramana, "Asian War Machines," *Critical Asian Studies*, Volume 46, number 2, 2014.

Russia
Pavel Podvig

The structure and composition of Russia's nuclear forces largely reflect the evolution of the force that was created by the Soviet Union during the cold war. Russia continues to maintain the strategic triad of land-based intercontinental missiles, submarines with sea-launched ballistic missiles, and long-range bombers. In addition, Russia has kept its arsenal of tactical nuclear weapons, which is believed to include weapons that could be deployed on submarines, short- and intermediate-range aircraft, and air-defence missiles.

Russia also maintains the infrastructure that was build to support operations of nuclear forces – an early-warning system that includes satellites and radars, and a command and control system that could allow the strategic forces to operate in the extreme conditions of a nuclear attack.

Status of Russia's nuclear forces

According to the most recent New START data exchange, in September 2014 Russia had 528 operationally deployed strategic launchers that carried 1,643 nuclear warheads.[1] The actual number of delivery systems and warheads in the strategic arsenal is somewhat higher, mostly because New START does not accurately account for warheads associated with strategic bombers. Overall, as of January 2015, Russia was estimated to have about 1,900 deployed warheads in its strategic arsenal. The total number of warheads associated with strategic launchers is estimated to be 2,300.[2]

The number of warheads associated with non-strategic delivery systems is somewhat harder to estimate, for Russia never disclosed information about its tactical nuclear forces. It is believed to have about 2,000 non-strategic warheads that could be considered operational.[3] According to Russia's official statements, all these warheads are consolidated at centralised storage facilities.[4]

In addition to warheads that are associated with operationally deployed strategic and non-strategic systems, Russia has a substantial number of warheads that are awaiting dismantlement. This category is estimated to include about 3,500 tactical warheads.[5]

These estimates suggest that Russia has a total arsenal of about 8,000 nuclear warheads. Non-deployed nuclear warheads and the warheads that are awaiting dismantlement are stored at centralized facilities managed by the 12th Main Directorate of the Ministry of Defence.[6]

Russia does not maintain a large stock of reserve inactive warheads that could be operationally deployed at a relatively short notice. Instead, it has traditionally relied on its capability to remanufacture warheads as necessary. It is estimated that Russia remanufactures about 200 warheads each year.[7]

The number of warheads associated with operationally deployed strategic and non-strategic systems is unlikely to change significantly, since the deployment of new systems in the course of strategic modernisation will be balanced by withdrawal of old warheads. The total number of warheads will probably decline in the coming years as Russia will continue its warhead dismantlement programme. The current dismantlement rate is believed to be about 400-500 warheads a year (this number includes warheads that are being remanufactured).[8]

Russia's warhead manufacturing capacity is sometimes quoted as giving it a capability to quickly increase the number of deployed nuclear warheads. While theoretically some of this capability does exist, in practice the number of warheads that Russia could deploy is determined by the availability of delivery vehicles rather than warheads. This is particularly true for strategic weapons – the number of warheads that Russia declared as operationally deployed (1,643 in September 2014) – which is very close to the maximum number of warheads that Russia's deployed missiles can carry, so any "surge capacity" that Russia may have is quite insignificant.

Delivery systems

Russia maintains the strategic nuclear triad that that was build during the Soviet years – land-based intercontinental ballistic missiles (ICBMs), strategic nuclear submarines with submarine-launched ballistic missiles (SLBMs), and long-range bombers.

Land-based intercontinental missiles

The Strategic Rocket Forces that operate the ICBM leg of the strategic triad historically has been the largest component of the Soviet and Russian strategic forces. It currently includes 305 operationally deployed ballistic missiles of five different types that carry about 1166 warheads.[9]

The oldest ICBMs in the force are liquid-fuel silo based missiles that carry multiple independently-targeted reentry vehicles (MIRV) – R-36M2 (Western designation SS-18) with ten warheads and UR-100NUTTH (SS-19) with six warheads. As of the early 2015, the Strategic Rocket Forces were estimated to have 46 R-36M2 missiles and about 60 missiles of the UR-100NUTTH type. These missiles carry about 820 warheads, about a half of all Russia's operationally deployed strategic nuclear warheads. In addition, Russia has two types of single-warhead missiles – 72 road-mobile Topol (SS-25) missiles and 78 missiles of the Topol-M (SS-27) type, which are deployed both as road-mobile and as silo-based missiles. In 2010 Russia also began deployment of a MIRVed version of the Topol-M missile. Known as RS-24 Yars, the missile is believed to carry up to four independently targeted warheads. By 2015, the Strategic Rocket Forces deployed 49 missiles of this type – 45 road-mobile missiles and 4 missiles in silos.

Russia appears to be determined to preserve the leading role of land-based ICBMs in its strategic triad. In order to do so, it has undertaken a programme to replace the older ICBMs that are reaching the end of their service lives – SS-18, SS-19, and SS-25 – with missiles of new types, mostly Topol-M and RS-24 Yars. Deployment of SS-19 and SS-25 missiles began in the 1980s, so even though their service lives are regularly extended, these ICBMs are expected to be withdrawn from service by 2020. The currently deployed modification of the SS-18 missile, known as R-36M2 or RS-20V, was produced and deployed in the late 1980s-early 1990s. It could probably stay in service as long as until 2026, provided its service life is extended to 33 years, which seems likely.

To replace the SS-18 missile, Russia began development of a new "heavy" ICBM, which is known as Sarmat. This project is still on the early development stage, although the flight tests of the missile are expected to take place in 2017. Provided the development work is successful, the missile should be ready for deployment after 2020.[10] Like the ICBM it is intended to replace, SS-18, Sarmat will probably carry ten warheads and will be deployed in the same silos.

As a result of this process, by 2020 Russia's ICBM force will consist of about 46 R-36M2/SS-18 MIRVed silo-based missiles (which will be gradually replaced by Sarmat) and some 180 Topol-M and RS-24 Yars ICBM, deployed in silos and on road-mobile launchers. Some of the RS-24 missiles might be deployed on rail-mobile launchers – in 2014 Russia announced that it will begin development of the rail-mobile system, Barguzin.[11]

This composition of the force will allow Russia to maintain the size of the ICBM leg of the strategic triad at the level of about 1000 warheads through at least the mid-2020s.[12] The Rocket Forces would therefore preserve their status as the key component of the strategic triad.

Strategic submarines

As of the beginning of 2015, Russia's strategic submarine force included six Project 667BDRM (Delta IV) submarines, two submarines of the older Project 667BDR (Delta III) class, and three new Project 955 Borey submarines. Each submarine carries 16 SLBMs. Delta IV carries R-29RM missiles with four warheads each and Delta III carries R-29R missiles with three warheads. Borey submarines are built to carry new Bulava solid-propellant SLBMs with six warheads per missile. As of 2015, of the three new boats of this class, only one had a full complement of the missiles – because of the problems encountered by the Bulava missile in test flights the production schedule has slipped.

Overall, in the early 2015, Russia had an estimated 128 deployed SLBMs that were capable of carrying 512 nuclear warheads.

Submarines of the Delta III/Project 667BDR class are currently based at the Pacific fleet base Vilyuchinsk at the Kamchatka peninsula. In 2015 they will be joined by two new Project 955 Borey submarines.

Most of the Delta IV/Project 667BDRM submarines underwent an overhaul in the last decade or so and would probably be able to stay in service for additional 10-15 years. As part of the overhaul the submarines are receiving newly manufactured missiles of the R-29RM/SS-N-23 type. These missiles, known as Sineva, are essentially a moderate modification of the original liquid-fuel R-29RM missiles that submarines of this class were carrying before the overhaul. Russia has also tested a modification of the R-29RM Sineva SLBM that can carry up to ten warheads.[13] This version of the missile, known as Liner, could be deployed on submarines alongside with the regular R-29RM Sineva missiles, increasing the number of SLBM warheads if necessary.

By 2015, Russia has accepted for service three Project 955 Borey submarines that will be equipped with the new Bulava SLBM. This is a significant milestone for the programme, which has experienced serious delays from the very beginning. The lead submarine of this class, Yuri Dolgorukiy, has joined the Northern Fleet. Two submarines that followed, Alexander Nevskiy and Vladimir Monomakh, will be based in the Pacific. Three more Borey submarines are currently under construction – Knyaz Vladimir (laid down in July 2012), Knyaz Oleg (July 2014), and Generalissimus Suvorov (December 2014). According to the original plan, the total of eight submarines of this class will be built by 2020. Each submarine will be equipped with 16 Bulava missiles that are projected to carry up to six warheads each.

Development of the Bulava missile encountered some technical problems – it failed in eight out of 12 flight tests conducted in 2005–2009. After a series of successful tests carried out in 2010–2011, the missile was being prepared for deployment when it failed again in a test conducted in September 2013, raising questions about the reliability of the missile.[14] Despite these problems, the missile was eventually accepted for service and by the end of 2014 enough missiles had been produced to equip one submarine. Two submarines are expected to receive missiles in 2015.

The strategic fleet rearmament programme is unlikely to significantly increase the size of the SLBM leg of the strategic triad. Taking into account the submarines in overhaul, the number of operationally deployed SLBM warheads will remain on the level of 400–500 warheads

Strategic bombers

Strategic bombers traditionally played a secondary role in Soviet and then Russian nuclear postures. That role is unlikely to change in the future – there are no plans to do so. The modernisation programme that is currently underway is aimed primarily at maintaining the strategic bomber force in its current configuration and giving the bombers the capability to carry out conventional missions.

In 2015, Russia is estimated to have 66 heavy bombers – 11 Tu-160 aircraft and 55 turboprop Tu-95MS. Together, these bombers are capable of carrying more than 800 air-launched cruise missiles, although the actual number of cruise missiles that are available for deployment is probably somewhat smaller. Most open estimates assume that Russia allocates about 200 nuclear warheads to its bombers.[15]

Most of the currently operational bombers were built in the late 1980s, so they are currently undergoing overhaul to extend their service life. As part of this process, which is expected to take up to 15 years, Tu-160 aircraft receive an upgrade of their avionics, which is supposed to equip them for missions with conventional high-precision munitions. Tu-95MS bombers also receive a moderate upgrade, but it appears that they will continue to be assigned nuclear missions.[16]

Early warning and command and control

In addition to maintaining the full strategic triad, Russia has preserved key elements of the infrastructure that supports operations of strategic nuclear forces – the early-warning and command and control systems. It also operates a missile "defence" system deployed around Moscow that is supposed to protect the capital from a limited missile attack.

The early-warning system is designed to include two tiers – a network of radars that could detect incoming missiles and a constellation of satellites that could provide early detection of missile launches.

In the last decade Russia has initiated an extensive programme to build a network of new early-warning radars. The new radars are replacing old ones that were built during the Soviet time. Most of them were located outside of Russia, complicating the operations of the early-warning system. By 2015, Russia discontinued the use of all but two early-warning radars that are not located in Russia. The last two radars – in Belarus and Kazakhstan – will eventually be replaced as well.

There are two types of new early warning radars that Russia has been deploying since the mid-2000s – Voronezh-M and Voronezh-DM. The first Voronezh-M radar was deployed in Lekhtusi (near St.-Petersburg) in 2006. Two radars of this type have been built in Mishelevka and three more are under construction – in Orsk, Vorkuta, and Olenegorsk.[17] Two Voronezh-DM radars have been built in Armavir at the south of Russia and three more in Barnaul, Yeniseysk, and Kaliningrad.

While the modernisation of the radar network has been a largely successful programme, replacement of old early-warning satellites has encountered significant delay. Until recently, Russia has managed to maintain limited operations of the old early-warning satellite systems, known as US-KS and US-KMO. The US-KS system had a capability to detect missile launches form the territory of the United States, US-KMO also provided some capability to see launches originated elsewhere.[18] However, by 2015 Russia was left with no operational satellites in orbit.[19]

Russia has been working on a new space-based system, known as EKS, which will provide more reliable coverage of all areas of possible missile launches. The new system is expected to enter the flight test stage in 2015.[20]

The command and control system that provides communication between the central command authority and individual launchers has been undergoing almost continuous modernisation. The currently deployed system has been described as a "fifth-generation" system. According to the Russian military, this system provides the Strategic Rocket Forces not only with the capability to control individual launchers, but also with the flexible targeting capability.[21]

The missile "defence" system deployed around Moscow, known as A-135, includes the Don-2N battle-management radar in Pushkino and 68 short-range interceptors of the 53T6 (Gazelle) type, deployed in silos at five sites near Moscow. In the past, the system also included 32 long-range interceptors, but they have been withdrawn from the system. The interceptors are believed to be equipped with nuclear warheads. The system has only a limited capability against a ballistic missile attack. According to Soviet estimates made at the time the system was being built, A-135 is able to intercept one or two "modern ICBMs".[22]

Fissile materials

Russia's stock of weapon-grade materials is far larger than it would be necessary to support the current nuclear force. At the end of 2014 Russia was estimated to have about 128±8 tonnes of weapon-grade plutonium, of which 88 tonnes is either in weapons or available for military purposes. Russia's stock of highly enriched uranium (HEU) was estimated to include about 670±120 tonnes of HEU. Of this amount, about 655 tonnes are available for weapons and for fueling naval, research, and civilian reactors.[23]

The total amount of weapon-grade plutonium produced in Russia is estimated to be 145±8 tonnes. About 17 tonnes have been used in nuclear tests or lost in waste or lost nuclear warheads.[24] Russia shut down most of its plutonium production reactors in the early 1990s. Three reactors, however, continued to operate until 2008-2010, since they provided heat for nearby cities. About 15 tonnes of plutonium that have been produced by these reactors after September 1994 are covered by Russia's pledge not to use it for military purposes. Also, Russia declared 25 tonnes of plutonium from its pre-1994 stock as excess to national security needs. This material is not available for military purposes as well, leaving the potential military stock of 88 tonnes.

The 25 tonnes of excess military plutonium and 9 tonnes of the plutonium produced after 1994 will be eliminated as part of Russia's obligations under the US-Russian Plutonium Management and Disposition Agreement that was finalized in April 2010.[25]

The plutonium disposition programme in Russia will include elimination of the weapon-grade plutonium in fast reactors. Only one of these reactors, BN-600, is currently operational. The second one, BN-800, began initial operations in 2014. In order to begin the plutonium elimination activities, Russia is developing the technology to produce plutonium-containing fuel assemblies for the BN reactors and to build a facility that will manufacture the fuel.

In addition to the weapon-grade plutonium, as of the end of 2013 Russia had 51.9 tonnes of unirradiated separated civilian plutonium.[26] Virtually all this material is stored at a dedicated storage facility at the RT-1 reprocessing plant at the Mayak Combine.

The Soviet Union stopped production of highly enriched uranium (HEU) in 1988. Before that it had produced about 1470±120 tonnes of 90% HEU equivalent. About 287 tonnes of HEU have been used in various applications, military as well as civilian.[27] In addition to the weapons complex, among the largest users of HEU in Russia are the submarine fleet, civilian nuclear-powered ships, and the two tritium production reactors. Also, Russia operates more than 80 research reactors, critical and subcritical assemblies that use highly-enriched uranium.[28]

There were two major HEU elimination programmes in Russia – the US-Russian HEU-LEU deal, also known as the Megatons to Megawatts programme, and the Material Conversion and Consolidation project. The HEU-LEU programme blended down military-origin HEU to produce low-enriched uranium that is then used to fuel US nuclear reactors. The programme, which began in 1996, eliminated 500 tonnes of HEU by the end of 2013, when it was successfully completed. The Material Conversion and Consolidation project is also a joint US-Russian effort. It provides Russian research facilities with US financial assistance in order to eliminate their stocks of HEU by blending it down. It is estimated that as of 2015 the programme eliminated about 17 tonnes of HEU.

Most of the military nuclear material that is not in use is stored at one of the large storage facilities managed by the Rosatom State Corporation. These facilities are located in so-called closed cities – Ozersk, Seversk, Zheleznogorsk, Sarov, and Snezhinsk.[29] The weapon-origin plutonium that Russia declared excess to its national security needs has been moved to the Fissile Material Storage Facility at Mayak, which Russia built with US assistance.

Infrastructure

The work on nuclear weapons development is the responsibility of nuclear weapon laboratories that are subordinated to the State Corporation Rosatom – the All-Russian Scientific Research Institute of Experimental Physics (VNIIEF) in Sarov (formerly Arzamas-16) and the All-Russian Institute of Technical Physics (VNIITF) in Snezhinsk (Chelyabinsk-70). The third laboratory, the All-Russian Institute of Automatics (VNIIA) in Moscow, is involved in weapon research that does not deal with fissile material components. The laboratories also take part in civilian research programs.

The weapon laboratories conduct research that allows them to maintain the current nuclear arsenal and develop new nuclear warheads. In particular, they developed warheads for new ballistic missiles that are introduced to active service – Sineva, Bulava, RS-24, and Liner. The new warheads are reportedly based on the designs that were tested before the end of nuclear testing in Russia. To support the weapon development process Russia conducts subcritical experiments at the nuclear test site at Novaya Zemlya and relies on computer models.

In addition to weapon development, Rosatom is responsible for all aspects of fissile material production and for storage of military-related nuclear material that is not used in weapons or in other military applications (e.g. fuel of naval reactors).

In the past, Rosatom operated plutonium production reactors at the Mayak Plant in Ozersk (Chelyabink-65), Siberian Chemical Combine in Seversk (Tomsk-7), and the Mining and Chemical Combine in Zheleznogorsk (Krasnoyarsk-26). All these reactors have been shut down. The chemical reprocessing plants that were extracting weapon-grade plutonium from spent fuel of production reactors have been either shut down or converted for non-military applications.

The Mayak Plant continues to operate two production reactors, Ruslan and Lyudmila, that were built to provide tritium for the weapon program. Since Russia has plenty of tritium from dismantled weapons, these reactors have been converted to the production of isotopes for civilian purposes. However, they maintain the capability to produce tritium if necessary.[30]

Russia's uranium enrichment complex includes the Urals Electrochemical Plant in Novouralsk (Sverdlovsk-44), Siberian Chemical Combine in Seversk (Tomsk-7), Electrochemical Plant in Zelenogorsk (Krasnoyarsk-45), and Electrolyzing Chemical Combine in Angarsk. All these facilities operate gaseous centrifuges to enrich uranium. With the exception of Angarsk, all of them were involved in production of HEU for the military programme, which was discontinued in 1988. Today, these enrichment plants produce low-enriched uranium for civilian purposes. The plant in Zelenogorsk is also producing some highly-enriched uranium for non-military applications.[31]

Russia operates two major warhead assembly and dismantlement facilities – the Electrochemical Instrument Combine in Lesnoy (Sverdlovsk-45) and the Instrument Building Plant in Trekhgorny (Zlatoust-36).[32] The plant in Lesnoy has the capability to produce and handle HEU components for nuclear weapons. Plutonium components of nuclear charges are handled at the metallurgical facilities of the Mayak Plant, which can also produce HEU components. The weapon laboratories, VNIIEF and VNIITF, also have small-scale material handling and warhead assembly and disassembly facilities. All these facilities provide Russia with the capability to maintain its current active nuclear arsenal by providing the necessary remanufacturing capability.

Development of land-based and sea-based ballistic missiles is mostly concentrated in two design bureaus that act as primary contractors for a strategic system. The Moscow Institute of Thermal Technology (MIT) is the lead design organization for solid-propellant ballistic missiles. It has developed Topol (SS-25), Topol-M (SS-27), and RS-24 Yars ICBMs and the Bulava SLBM. It is also working on a range of other projects. The second design bureau, the Makeyev State Missile Center in Miass, is the lead developer of submarine-launched ballistic missiles. The Center designed the R-29R and R-29RM SLBMs that are currently deployed on Project 667BDR and Project 667BDRM submarines. It also designed the new modifications of the R-29RM missile– Sineva and Liner. In 2011, the Makeyev design bureau was awarded a contract to develop a new liquid-fuel silo-based ICBM, known as Sarmat.

All solid-propellant ballistic missiles are produced at the Votkinsk Plant. There are three types of strategic missiles that are currently in production – Topol-M and its RS-24 Yars modification, and Bulava. Liquid-fuel missiles are produced at the Krasnoyarsk Machine-Building Plant. Today, the plant is manufacturing Sineva and Liner modifications of the R-29RM missile. It will be producing the Sarmat ICBM as well.

The lead design organisation responsible for development of strategic submarines is the Central Design Bureau for Marine Engineering "Rubin" in St.-Petersburg. This design bureau developed all ballistic missile submarines of the Russian Navy – Project 667BD, Project 667BDRM, and Project 955. The only class of ballistic missile submarines that is currently in production is Project 995 Borey (and its modifications). These submarines are built at the Sevmash ship-building plant in Severodvinsk.

Strategic bombers that are currently in service – Tu-95MS and Tu-160 – were developed by the Tupolev design bureau, which remains the leading developer of long-range bomber aircraft. As of 2011, no new aircraft are being produced. However, some planes are undergoing modernisation at the Kazan Aviation Plant (Tu-160) or at the Taganrog Aviation Plant (Tu-95MS).

Modernisation

The Russian government has not published a full account of specific strategic weapons modernisation programmes or their cost. Nevertheless, the publicly available information allows one to outline the key elements of the strategic modernisation effort.

Rearmament of the ICBM leg of the strategic triad concentrates on deployment of multiple-warhead RS-24 Yars missiles. These ICBMs will replace the currently deployed Topol (SS-25) and, to some extent, UR-100NUTTH (SS-19) missiles. Being a multiple-warhead missile, RS-24 allows Russia to keep the number of deployed warheads at the relatively high level without the need to produce a large number of missiles. At the same time, if future arms control agreements would require it, Russia could quickly reduce the number of deployed warheads without decommissioning its ICBMs.

In addition to the RS-24 deployment, Russia is working on a number of other ICBM projects. In 2011 the government made a decision to begin development of a new multiple-warhead liquid-fuel ICBM, Sarmat. The new missile is likely to be ready for deployment in 2018, although the scale of deployment will be limited – 46 missiles.[33] Another new ICBM, RS-26, is developed by the Moscow Institute of Thermal Technology. While this missile is an ICBM for the purposes of New START, it is believed to be an intermediate-range missile based on RS-24 Yars.[34] Another project related to the RS-24 Yars missile is the plan to build a rail-mobile system, Barguzin. This system is expected to include an RS-24 ICBM.[35]

At this point, there are no plans to extend modernisation of the strategic fleet beyond the planned construction of eight Project 955 submarines. Depending on the progress with construction of new submarines the six older ships of the Project 667BDRM class might stay in service longer than previously planned, probably until 2020. If so, they will likely to receive the Liner modification of the R-29RM SLBM, which could carry up to ten warheads, allowing the navy to maintain the number of warheads in the sea-based leg of the strategic triad at the level of 400–500 warheads in the event of delay with the construction of Project 955 submarines.

As far as the strategic aviation is concerned, in the next few years Russia will continue an overhaul of its current strategic bomber fleet. At the same time, it started development of a new-generation strategic bomber, known as a PAK DA (Advanced Aviation System for the Long-Range Aviation). It is expected that the new aircraft will conduct its first flight in 2013 and enter service in 2023.[36]

Russia's strategic modernisation plans demonstrate that it is determined to maintain its strategic nuclear forces and to preserve the parity with the United States in the number of warheads and delivery systems. Arms control and disarmament efforts could change these plans and result in a smaller force, but it is likely that most of the reductions would be done by reducing the number of deployed warheads rather than by eliminating strategic launchers.

Economics

Modernisation of the strategic forces is part of the broader rearmament programme that was expected to spend 19 trillion rubles (about $600 billion at the exchange rate at the time) on various military systems in 2011–2020. About 10 percent of the total funds allocated for rearmament, or 1.9 trillion rubles, is being spent on the modernisation of the strategic forces.

Military spending is one of the largest spending categories in Russia's federal budget. It has been largely protected from 10 percent across the board cuts that have affected other budget expenditures as a result of economic sanctions imposed on Russia in 2014 and the economic crisis caused by the fall of the oil price in 2014. Nevertheless, the military modernisation budget has come under pressure as well. In 2015 Russia was supposed to approve a new long-term rearmament programme. This programme, initially estimated to cost about 56 trillion rubles, was scaled down in 30 billion rubles. Then, as it was increasingly clear the budget may not support a program of this size, its approval was postponed until 2018.[37]

Financial constraints could affect the scale of strategic modernisation. Although Russia has managed to minimize the effects of the economic crisis of the 2008, its economy is heavily dependent on export of natural resources, so a fall in oil and gas prices has already forced the government to reconsider its spending priorities. The sanctions imposed on Russia in 2014 after the annexation of Crimea also have strong effect on the economic outlook. However, the rearmament effort appears to have strong support of the political leadership and the public, so significant cuts of the modernisation programme are unlikely. This situation may change if the political environment in Russia would allow an open discussion of government spending priorities and the role of nuclear weapons in the national security policy, but so far this discussion has been very limited.

International law and doctrine

The issues related to the legitimacy of nuclear weapons under international law are rarely discussed in Russia. The official National Security Doctrine, approved in 2009, calls for maintaining "strategic stability" and lists strengthening Russia's strategic nuclear forces as one of the priorities of the national defence policy. The military doctrine adopted in 2010 also emphasizes the role of Russia's nuclear forces in maintaining "strategic stability" in the world.[38] In 2014, Russia adopted a revised version of the doctrine, which left the key elements of the 2010 document in place.

Although the official documents do not question Russia's right to possess nuclear weapons, they also recognise its responsibilities as a nuclear-armed state party to the nuclear Non-Proliferation Treaty (NPT). The national security doctrine recognises the goal of building a world free of nuclear weapons as part of overall progress toward "strategic stability" with equal security for all. High priority is also given to nuclear disarmament and to nuclear non-proliferation.

In its military doctrine, Russia reserves the right to use nuclear weapons "in response to a use of nuclear or other weapons of mass destruction against her and (or) her allies, and in a case of an aggression against her with conventional weapons that would put in danger the very existence of the state." While this policy assumes the right to a first use of nuclear weapons, the range of scenarios in which Russia would consider using nuclear weapons is somewhat limited. It should be noted that early versions of the military doctrine apparently included an option of preventive use of nuclear weapons, which was later removed from the document.[39]

As part of the bilateral US-Russian nuclear arms reduction process, Russia has substantially reduced its strategic nuclear arsenal. Both countries consider these reductions to be their contribution toward the goals of article VI of the NPT. In addition, Russia periodically reiterates its commitment to the US-Russian Presidential Initiatives of 1992, in which the two countries declared their intent to substantially reduce their arsenals of non-strategic nuclear weapons. Russia concentrated all its non-strategic nuclear weapons at centralised storage facilities on its national territory.[40] However, Russia has been reluctant to discuss legally-binding measures related to its tactical nuclear weapons before the United States removes its nuclear weapons from Europe.

Public discourse

Public opinion in Russia tends to support the nuclear status of the country – according to a poll conducted in 2006, 76 percent of all the respondents believed that Russia "needs nuclear weapons." More than half of the population consider nuclear weapons to be the main guarantee of the security of the country and about 30 percent of respondents believe that nuclear weapons play an important, although not a decisive, role.[41] No similar research of public attitudes toward nuclear weapons has been conducted recently, but it is unlikely that they changed in a significant way.

The public discussion of issues related to nuclear weapons reflects these attitudes – their role in providing for the security of the country is almost never questioned. To a large extent, the lack of critical assessment of the role of nuclear weapons is a result of the lack of an open and informed discussion of national security priorities and policies that would involve independent voices. While there are non-governmental research organisations that are involved in the discussion of defence policies, there are no independent public organisations that have nuclear weapons related issues on the agenda. Accordingly, the public discussion is focused largely on technical issues of US-Russian arms control negotiations and nuclear non-proliferation.

The strategic modernisation programme described above is also rarely criticized, despite its very substantial cost. The government has presented the programme as an essential element of the strategy that would allow Russia to maintain its nuclear arsenal and to preserve approximate parity with the United States. This strategy, in turn, has been described as the only way to preserve the sovereignty of the country and its status in international affairs. In general, public opinion in Russia tends to view favourably the efforts to support the military industry and introduce modern equipment to the armed forces. Government policy and public attitudes combine to ensure that the strategic modernization efforts undertaken by the Russian government will continue as one of the high-priority programmes that are unlikely to be affected by budgetary pressures.

Notes:

1. "New START Treaty Aggregate Numbers of Strategic Offensive Arms," 1 October 2014, http://www.state.gov/t/avc/rls/232359.htm.
2. "Russian Strategic Nuclear Forces," http://russianforces.org/; H. M. Kristensen and R. S. Norris, "Russian Nuclear Forces, 2014," *Bulletin of the Atomic Scientists* 70, no. 2 (3 March 2014): 75–85, doi:10.1177/0096340214523565.
3. Kristensen and Norris, "Russian Nuclear Forces, 2014," *op. cit*.
4. "[A]ll Russian non-strategic nuclear weapons have been withdrawn from the territory of the former USSR to Russia and concentrated in the central storage facilities." "Statement by the Delegation of the Russian Federation on Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons at the Second Session of the Preparatory Committee for the 2010 Non-Proliferation Treaty Review Conference," 28 May 2008, http://ploughshares.ca/wp-content/uploads/2009/05/Russia08-2.pdf.
5. Kristensen and Norris, "Russian Nuclear Forces, 2014," *op. cit*.
6. *Global Fissile Material Report 2009: A Path to Nuclear Disarmament. Fourth Annual Report of the International Panel on Fissile Materials,* International Panel on Fissile Materials, 2009, pp. 135–137, http://ipfmlibrary.org/gfmr09.pdf.
7. *Global Fissile Material Report 2011: Nuclear Weapon and Fissile Material Stockpiles and Production,* International Panel on Fissile Materials, 2011, p. 5, http://ipfmlibrary.org/gfmr11.pdf.
8. *Ibid.*
9. Russia has not made public its part of the New START data exchange, so these numbers are estimates based on the publicly available information. This estimate assumes that the composition of the Strategic Rocket Forces is as follows: R-36M2 - 46 missiles, UR-100NUTTH - 60, Topol - 72, Topol-M (silo and road-mobile) - 78, RS-24 - 49. "Strategic Rocket Forces - Russian Strategic Nuclear Forces," accessed 25 February 2015, http://russianforces.org/missiles/.
10. "Sarmat Tests to Begin in 2015 - Blog - Russian Strategic Nuclear Forces," accessed 26 January 2015, http://russianforces.org/blog/2015/01/sarmat_tests_to_begin_in_2015.shtml.
11. "Rail-Mobile ICBM, Barguzin, Gets a Green Light - Blog - Russian Strategic Nuclear Forces,", 17 December 2014, http://russianforces.org/blog/2014/12/rail-mobile_icbm_barguzin_gets.shtml.
12. This assumes that 50 R-36M2 or Sarmat missiles will carry 500 warheads, 78 Topol-Ms - 78 warheads, and about 100 RS-24 - 400 warheads.
13. "Liner SLBM Explained - Blog - Russian Strategic Nuclear Forces," 4 October 2011, http://russianforces.org/blog/2011/10/liner_slbm_explained.shtml.
14. "Bulava Missile Test History," accessed 26 February 2015, http://russianforces.org/navy/slbms/bulava.shtml.
15. Kristensen and Norris, "Russian Nuclear Forces, 2014.," *op. cit.*
16. Alexander Stukalin, "Bears and Blackjacks Are Back. What Next?," *Moscow Defense Brief* 26, no. 4 (2011), http://mdb.cast.ru/mdb/4-2010/item4/article1/.
17. "Four Early-Warning Radars Began Combat Duty in 2014 - Blog - Russian Strategic Nuclear Forces," 19 December 2014, http://russianforces.org/blog/2014/12/four_early-warning_radars_bega.shtml.
18. Pavel Podvig, "History and the Current Status of the Russian Early-Warning System," *Science & Global Security* 10, no. 1 (2002): 21–60.
19. "Russia Lost All Its Early-Warning Satellites - Blog - Russian Strategic Nuclear Forces," accessed 11 February 2015, http://russianforces.org/blog/2015/02/russia_lost_all_its_early-warn.shtml.
20. Ibid.
21. "Rocket Forces to Deploy Fifth-Generation Command and Control System - Blog - Russian Strategic Nuclear Forces," 4 July 2013, http://russianforces.org/blog/2013/07/rocket_forces_to_deploy_fifth-.shtml.
22. "Very Modest Expectations: Performance of Moscow Missile Defense - Blog - Russian Strategic Nuclear Forces," 23 October 2013, http://russianforces.org/blog/2012/10/very_modest_expectations_sovie.shtml.
23. *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament,* International Panel on Fissile Materials, 2013, http://ipfmlibrary.org/gfmr13.pdf.
24. Anatoli Diakov, "The History of Plutonium Production in Russia," *Science & Global Security* 19, no. 1 (2011): 28–45.
25. Pavel Podvig, "U.S.-Russian Plutonium Management Disposition Agreement," IPFM Blog, 11 May 2010, http://fissilematerials.org/blog/2010/05/us-russian_plutonium_mana.html.
26. *INFCIRC/549/Add.9/16. Communication Received from the Russian Federation Concerning Its Policies Regarding the Management of Plutonium*, International Atomic Energy Agency, 6 October 2014).
27. Pavel Podvig, "History of Highly Enriched Uranium Production in Russia," *Science & Global Security* 19, no. 1 (2011): 46–67.
28. Pavel Podvig, "Approaches to Reducing the Use of Highly-Enriched Uranium for Research in Russia," Submitted for presentation at the 2013 Annual Meeting of the Institute of Nuclear Material Management.
29. Pavel Podvig, *Consolidating Fissile Materials in Russia's Nuclear Complex, IPFM Research Report #7,* International Panel on Fissile Materials, May 2009.
30. Ibid., p. 10.
31. "Russia Launches HEU Production Line - IPFM Blog," 29 October 2012, http://fissilematerials.org/blog/2012/10/russia_launches_heu_produ.html.
32. Two other major warhead assembly facilities - the Avangard Plant in Sarov/Arzamas-16 and the Start Production Association in Zarechny/Penza-19 - have been shut down. Pavel Podvig, *Consolidating Fissile Materials in Russia's Nuclear Complex, op. cit*.
33. "Sarmat Deployment Plans - Blog - Russian Strategic Nuclear Forces," 27 December 2014, http://russianforces.org/blog/2014/12/sarmat_deployment_plans.shtml.
34. 18 December 2013, http://russianforces.org/blog/2013/12/more_news_about_rs-26_missile.shtml.
35. "Rail-Mobile ICBM, Barguzin, Gets a Green Light - Blog - Russian Strategic Nuclear Forces," 17 December 2014, http://russianforces.org/blog/2014/12/rail-mobile_icbm_barguzin_gets.shtml.
36. "Plans for the New Strategic Bomber - Blog - Russian Strategic Nuclear Forces," 22 May 2014, http://russianforces.org/blog/2014/05/plans_for_the_new_strategic_bo.shtml.
37. Дмитрий Бутрин and Иван Сафронов, "Вооружения вступили в бой с возражениями," *Газета "Коммерсантъ,"* 19 February 2015.
38. "Военная Доктрина Российской Федерации 5 Февраля 2010 Года," 5 February 2010, http://news.kremlin.ru/ref_notes/461.
39. Pavel Podvig, "Instrumental Influences," *The Nonproliferation Review* 18, no. 1 (2011): 39–50, doi:10.1080/10736700.2011.549170.
40. "Statement by the Delegation of the Russian Federation on Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons at the Second Session of the Preparatory Committee for the 2010 Non-Proliferation Treaty Review Conference," 2013.
41. Ildar Akhtamzyan, *Opinion Poll "Attitudes in the Russsian Federation towards WMD Proliferation and Terrorism,"* PIR Center Report, Moscow: Human Rights Publishers, 2006, pp. 16–17.

United Kingdom

John Ainslie[1]

Status of the United Kingdom's nuclear forces

In September 2010, the UK government announced that it had "not more than 225" Trident nuclear warheads and that this would be reduced to "not more than 180" by the mid 2020s.[2] 120 of these warheads were "operationally available" as of January 2015.[3]

The UK Trident warhead contains a mixture of UK and US elements. The high explosive in the warhead is British.[4] Three key components are supplied from the US.[5] They are parts of the US W76 warhead. In 1978 and 1979 the UK conducted nuclear tests to develop a small high-yield warhead design.[6] The UK then received information on the W76 design from the US in August 1980.[7] The final design probably combines US and UK features. The yield is likely to be similar to the W76, i.e. around 100 kilotons. A lower-yield variant of this warhead has also been produced. [8] The number of lower-yield warheads is not known, but these are likely to constitute only a small proportion of the stockpile

Delivery systems

The UK's only delivery system is the US-built Trident D5 missile. There are four Vanguard class submarines. Normally three of these are armed with Trident missiles and the fourth is in refit.[9] Each armed submarine carries 40 nuclear warheads. [10] These are deployed on eight missiles.

Fissile materials

Calder Hall and Chapelcross power stations produced over 1 tonne of weapons grade plutonium for the Trident programme between 1985 and 1995.[11] When the UK ceased production in 1995, the stockpile of military plutonium was 3.5 tonnes. In 1999 the MoD placed 0.3 tonnes of weapons grade plutonium under international safeguards, leaving 3.2 tonnes not subject to these safeguards.[12]

In 2002 the UK had a stockpile of 21.64 tonnes of highly enriched uranium (HEU).[13] Some of this has come from the US. The UK produced between four and five tonnes of HEU at Capenhurst between 1954 and 1962.[14] This implies that the UK procured an additional 21–22 tonnes of HEU from the US between 1964 and 2002.[15] A large proportion of the HEU stock will be in the form of submarine reactor fuel.

Infrastructure

Nuclear warheads are developed and manufactured at the Atomic Weapons Establishment (AWE) sites of Aldermaston and Burghfield in Berkshire. The work at Aldermaston includes the production of plutonium, HEU, and Berylium components and research into warhead design. Warheads are assembled and disassembled at Burghfield.

Vanguard class submarines operate from HM Clyde Naval Base, 25 miles from Glasgow, Scotland's largest city. The base includes a submarine facility, Faslane, and a nuclear weapons depot, Coulport. Submarines are built at Barrow in Furness. The fuel cores for naval reactors are manufactured by Rolls Royce in Derby. There is normally one Vanguard class submarine in refit at Devonport dockyard.

Rolls Royce operates a prototype submarine reactor at HMS Vulcan, Dounreay. It is planning to close down this reactor in 2015.[16] In 2012 a fuel core problem was identified in the prototype reactor.
The nuclear firing chain is a substantial element of the infrastructure for Trident.[17] The key facilities are: (1) the Nuclear Operations and Targeting Centre, underneath the MoD Main Building in Whitehall, London; (2) Commander Task Force 345, at the Permanent Joint Headquarters, Northwood, Middlesex; and (3) Corsham Computer Centre, a deep underground bunker in Wiltshire that processes the UK's fire control and targeting software. The primary way to send launch instructions to submarines is through two Very Low Frequency transmitters at Skelton and Anthorn in Cumbria.

The Strategic Weapons System Integrated Project Team (SWS IPT) at Abbey Wood in Bristol manages the Trident programme and the projects to modernise UK nuclear forces.

Modernisation

In December 2006 President Bush wrote to Prime Minister Blair, agreeing to support the British nuclear weapon programme. Bush referred to "the steps outlined in your letter to maintain and modernize the U.K.'s capability in this area for the longer term."[18]

Warhead Modification Program (Mk4A)

A significant program is underway to modify the Trident warhead that is currently in service. In 2006 the UK Government said "the existing nuclear warhead design will last into the 2020s."[19] The December 2014 update to parliament on the future of the nuclear deterrent said "the current warhead ... is planned to remain in service into the 2040s."[20] This indicates that the UK has decided to extend the life of the current warhead by around 20 years. This will require a significant refurbishment project.

The government has been reticent about the existence of the warhead modification programme and has told Members of Parliament that it is not possible to identify how much it costs.[21] However, there are several references to the project in official documents. Annual reports from the Defence Nuclear Environmental and Safety Board in 2006–2008 referred to a "Warhead Modification" program.[22] In 2007 a lists of MOD projects included "Mk4A refurbishment programme". This was later renamed "Nuclear Weapons Mk4A".[23]

The work is being carried out under the wider "Nuclear Warhead Capability Sustainment Programme". The aims of this programme include delivering and sustaining "the capability to underwrite the UK stockpile now and in the future including *transition to Mk4A*" and developing and delivering "the UK stockpile to the Mk4A warhead (production, skills, science) approved design."[24]

The Safety Review of the Atomic Weapons Establishment for 2013 refers to "Mk4A assessment" and "Mk4A operations" as key future activities.[25] A 2014 report from the Office of Nuclear Regulation (ONR) said, "The United Kingdom (UK) Ministry of Defence (MoD) and AWE plc have decided to implement the *existing warhead service life modifications.*"[26] The first phase of this programme involves adapting warhead surveillance systems at the Burghfield assembly facility. Changes will be made to "procedures, tooling, equipment, commissioning and operator training".[27]

The UK warhead modification project is similar to the US Mk4A / W76-1 upgrade. A senior staff engineer at Lockheed Martin in California is responsible for planning, coordinating, and executing the development and production of "UK Trident Mk4A Reentry Systems as part of the UK Trident Weapon System Life Extension program."[28] A common component of the US and UK programmes is a new Mk4A Arming, Fuzing, and Firing (AF&F) system which is manufactured in the US.

The original US W76-0/Mk4 warhead was designed for deployment on the relatively inaccurate C4 missile against a limited range of types of targets.[29] The Mk4A AF&F was developed so that warheads on D5 missiles would be effective against hardened targets.[30] The draft military characteristics for Mk4A include "near surface burst," which was not an option for Mk4.[31] A 1994 report indicated that the proposed D5/Mk4A combination would be effective against a wide range of targets, including SS-11 missile silos.[32]

The UK Trident warhead includes a Gas Transfer System (GTS). The GTS stores tritium and injects it into the plutonium pit. The GTS in UK warheads are manufactured in the US. The UK modification programme will almost certainly include replacing the GTS with a new design, Acorn II, which is part of the US W76-1 upgrade. The new GTS is likely to improve the performance of the warhead.[33]

A significant component of the US W76-1 upgrade is the refurbishment of the fusion part of the nuclear warhead, the secondary. A declassified Sandia National Laboratory report, written in 2001, shows that there are several problems, including corrosion, with the W76 secondary.[34] Aldermaston has worked closely with the US laboratories on research into Uranium corrosion, the problem which lies behind the upgrade to the secondary. It is likely that the secondary and radiation case of the UK warhead will be refurbished in order to extend their life into the 2040s.

In March 2011 Sandia National Laboratory announced that it had conducted "the first W76-1 United Kingdom trials test" at their Weapons Evaluation and Test Laboratory (WETL) and that this had "provided qualification data critical to the UK implementation of the W76-1."[35] One of the centrifuges in WETL simulates the ballistic trajectory of the W76/Mk4 submarine-launched reentry-vehicle.[36]

New warhead

The modified warhead would only be in service for the initial part of the projected life of the new successor submarine. On 29 June 2007 David Gould, the senior official responsible for defence procurement, told an Industry Day meeting that their plan was "to replace the entire Vanguard Class submarine system. *Including the warhead and missile.*"[37]

The 2014 update to parliament on the future nuclear deterrent said "a decision on whether to replace the existing warhead will not be required until the next Parliament."[38] This places the decision between 2015 and 2020. A more precise date was given in 2010 by the Defence Minister Liam Fox, who said "We don't have to think about new warheads until 2019."[39] The 2014 update says that it would take 17 years to develop a new warhead. This suggests that a new warhead could be in service in 2036.

The Nuclear Warhead Capability Sustainment Programme provides the extensive range of facilities which would be required to design and build a new warhead. One of the aims of the programme is "to have the capability required for a future warhead if required."[40] It also sustains the expertise needed. In 2006 Clive Marsh, Chief Scientist at AWE, said that most of their research and development work at the establishment focused on design capabilities, including the potential to develop a successor, as distinct from supporting the current warhead.[41]

There are a number of signs which indicate that AWE is not just sustaining generic capabilities for warhead development, but that it is developing designs as options for a successor warhead. The MoD set up a Warhead Pre-Concepts Working Group.[42] AWE is the Coordinating Design Organisation for "potential successor warhead candidates".[43] There is a directorate within AWE responsible for work on the Successor, separate from other directorates which deal with Trident and Capability.[44]

Owen Price, a senior official at AWE, said the Establishment has been increasing the range of tasks that it can carry out, in order to improve its ability to design and build a new warhead.[45] He highlighted systems engineering and warhead integration as two critical capabilities AWE will need to develop for a successor warhead programme.[46]

Three areas where AWE is working on new designs are AF&F, Gas Transfer Systems, and Neutron Generators.

The UK is developing an AF&F for a successor warhead. This is a joint AWE, US Air Force, and US Navy initiative. The goal is "the development of a joint arming, fuzing, and firing system for application to the Air Force Mk12A, the Navy Mk5 and a UK re-entry system."[47] This is related to UK successor warhead designs of a specific size.[48] A joint working group of US Navy, US Air Force, and British engineers leads the work.[49] AWE is producing Demonstrators to test new AF&F concepts in laboratory conditions and in a relevant environment.[50] They are developing electronics,[51] circuit boards,[52] High Integrity Software and Hardware,[53] firing sets,[54] and capacitors[55] for AF&Fs. The engineers designing these components are expected to spend some of their time working in the US.[56] Likewise, their American counterparts at Sandia National Laboratory have been told they will be collaborating with AWE.[57]

AWE is developing new GTS for a successor warhead. They are working on "designs of hydrogen storage and delivery systems for possible future warheads".[58] The establishment has recruited staff to design new GTS and to test the new models in the UK and US.[59] Researchers are developing new pressure vessels and joining technologies.[60] AWE is working with two American laboratories, Sandia and Los Alamos, to design "long-life GTS".[61] The laboratories have shared their advanced designs for GTS valves.

AWE recruited engineers and scientists, between 2006 and 2011, to develop new neutron generators and their components.[62] In 2008 the Establishment was developing "novel neutron tube" designs for neutron generators in collaboration with the US.[63]

Missile system life extension

The US Strategic Systems Program (SSP) is extending the life of the D5 Trident weapon system. They are updating all the Trident subsystems: launcher, navigation, fire control, guidance, missile, and re-entry.[64] All of these modernization measures apply to the system deployed on British submarines. In December 2006, US President Bush wrote to Prime Minister Blair, saying, "We will work to ensure that the necessary components of the overall system are made available to the United Kingdom to support life-extended D5 missiles."[65] One US contract in November 2014 refers to the "UK VANGUARD Class SSBN Work Planning Document for Trident II SWS Modernization".[66]

The US Navy plans to carry out the first operational test of the Life Extended missile (D5 LE) in October 2018.[67] A graph in the 2006 report on the future of the UK nuclear deterrent suggests that the Trident D5 LE missile will enter service with the Royal Navy around 2020.

A key part of the D5LE program is the development, by Charles Stark Draper Laboratory, of a new guidance system, Mk6LE.[68] Draper is replacing the gyroscope, accelerometer, and stellar camera in the guidance module.[69] Mk6LE will be more flexible and easier to upgrade than the current Mk6 unit.[70] The new guidance system will be able to "support new missions".[71] It will "allow for mission adaptability".[72] Draper has, over several decades, improved the performance of missile guidance systems. The effect has been to make each new generation of ballistic missiles more accurate than the last. Its development of the Mk6LE is a continuation of this trend.[73] The combination of new hardware and software in this advanced guidance system will improve the capability of the D5 missile.

The Mk98 Fire Control System (FCS) controls the launch of Trident missiles. In 2002/03 the US supplied an upgraded Mod 5 FCS to the UK Trident fleet.[74] This meant that the missiles could be more rapidly retargeted.[75] The FCS was further modified to Mod 7 in 2011.[76] General Dynamics Advanced Information Systems (GDAIS) are now designing the next upgrade, Mod 9.[77] This will operate alongside the new Mk6LE missile guidance system.[78]

The navigation system provides information on the exact position of the submarine and is critical for the performance of Trident. The US Strategic Systems Program is upgrading the Electro Static Gyro Navigation (ESGN) system on British and American Trident submarines. [79]

The Reentry Bodies on a Trident missile are spun off the Post Boost Control Vehicle by a Release Assembly. Lockheed Martin has developed a new Alternate Release Assembly (ARA). Tests on the ARA were carried out in 2011 and 2012. A 2014 contract for components of the Trident missile system includes the provision of "hardware to support the United Kingdom's ARA system".[80] This indicates that the new ARA will be introduced onto Trident missiles in service with the Royal Navy over the next few years.

New missile

The intention is that the UK successor submarine will remain in service until the 2060s and the US Ohio replacement will be operational until the 2080s. The Life Extension programme for D5 will only sustain this missile until the early 2040s. D5 will not be available for most of the intended lives of the new submarines. The UK government has acknowledged that "investment in a replacement ballistic missile would eventually be needed."[81] Rear Admiral Benedict, head of the US Strategic Systems Program, has said "This is not a decision we can postpone through 2020-2030 – this is a near-term decision that will affect sustainment and recapitalization."[82]

Successor submarine

Approval for initial work on a new nuclear-armed submarine was given in 2007. The "Main Gate" decision, to proceed further with the project and to place the main construction contracts, is due to be made in early 2016.

£4,181 million is being spent on the new submarines prior to the Main Gate decision. This initial expenditure is on design work, development of a new reactor, and the purchase of "long lead" items for the first two submarines.

The successor submarine will be powered by a new reactor, PWR3. The design of the new plant is heavily dependent on "a high level of technology transfer from the US".[83] A review of the PWR3 design was due at the end of 2014. This was expected to mark the design freeze of the reactor plant.[84] The first PWR3 reactor is due to be built by Rolls Royce by 2023.[85] The design has a passive cooling system. This is the most significant change in reactor design that the MOD has ever made. The MOD failed to anticipate how difficult it would be to recruit a sufficient number of qualified engineers to design and produce the new reactor. As a result, the estimated cost of developing the new reactor increased by £151 million in 2014.[86] A contract has been placed for the design and production of a new fuel core, core J, for the reactor in the first successor submarine.

The US Navy was working with the Royal Navy in a joint research programme, from FY2010 to FY2014, to reduce the electromagnetic signatures of the UK Successor and US Ohio Replacement submarines.[87] This, along with the reduced noise-signature of the PWR3 reactor, will mean that the new submarines will be more difficult to detect than current vessels. This is an enhancement of capability.

In October 2014 General Dynamics Electric Boat was awarded a contract for $59 million to build 12 missile tubes for the first successor class submarine. Until then the UK government had stressed that its intention was to reduce the number of operational missiles carried on each submarine to eight. It had not always made it clear that the new submarines might have an additional four empty missile tubes. For example on 19 October 2010 John Duncan, the British ambassador for multilateral arms control and disarmament, told the UN General Assembly's First Committee that Britain would "configure the next generation of submarines with only eight operational missile tubes."[88]

By building the submarines with four extra missile tubes, the UK is leaving open the possibility that a future government could increase the firepower of the nuclear fleet by 50%. The approach taken today may echo that adopted in the 1980s, when the government decided that Trident submarines would only need to carry 12 missiles when they entered service but ordered that Vanguard class submarines should be built with 16 launch tubes in case a future government wanted to add more missiles later.[89]

The missile tubes are part of the Common Missile Compartment (CMC), which is being developed in the US for both US and UK submarines. Some of the work in the US on CMC is specifically for the UK successor submarine.[90]

The decision on whether three or four submarines will be built will be taken in 2016. The government's planning assumption is that there will be four.[91] This is reflected in the missile tube order. The US Navy issued a press release indicating that General Dynamics expect to build a total of 48 missile tubes for 4 UK submarines.[92] Tubes for the later submarines may be included as options in the contract.

The first successor submarine is due to enter service in 2028. The Audit Office report says that the new submarines are expected to have a 25 year life with the option of at least a five year extension. However this probably understates the projected life of the new vessels. One advantage of the PWR3 reactor is that it would enable the successor submarine to remain in service for longer than the current Vanguard class. A presentation from Babcock Marine says that the new submarines will be in service until 2067.[93]

Infrastructure

Atomic Weapons Establishment

The Atomic Weapons Establishment (AWE) designs and manufactures the UK's nuclear weapons at Aldermaston and Burghfield in Berkshire. The government has a large programme to rebuild or refurbish most of the facilities at these sites. This work is part of the Nuclear Warhead Capability Sustainment Program which began in 2005 and is due to continue until 2025. The budget for this program is £21,884 million.[94] Over 40 % of the expenditure is for capital projects.[95] In 2007 Nick Bennet, Director of Strategic Technologies in the MoD, said that the NWCSP included "some 100 facility schemes focused at AWE over the next 20 years."[96]

The UK government has tried to separate this project from the Trident replacement programme. For example, in November 2005 the MoD told the House of Commons Defence Committee, "This additional investment at AWE is required to sustain the existing warhead stockpile in-service irrespective of decisions on any successor warhead."[97]

Owen Price of AWE has questioned whether the rebuilding work can really be separated from the design and production of a new warhead. He noted that "in the absence of this funding, it might be reasonable to assume that intellectual and infrastructure capabilities future options would have been more limited or less credible."[98]

In 2002 AWE was considering whether to build a new warhead assembly/disassembly facility at Aldermaston rather than Burghfield. One reason it did not locate the building at Aldermaston was that "there might not be sufficient room at Aldermaston to accommodate facilities for a successor programme as well as Trident."[99] This suggests that at least some of the new facilities are specifically required for a new warhead.

The plutonium pits for warheads are manufactured in building A90 at Aldermaston. This is being refurbished at a cost of £272 million. A90 is a replica of facility PF-4 at Los Alamos Nuclear Laboratory in the United States. There is close liaison with the US site over manufacturing techniques and upgrading work.

Highly enriched uranium (HEU) components are currently produced in building A45. In 2011 AWE were planning to spend £32 million on an upgrade to this facility. In August 2012 corrosion was found in structural steelwork in the building and it was closed pending repairs which are due to be completed in May 2015.[100]

A new Enriched Uranium Facility (EUF) is under construction. The new complex, Project Pegasus, will manufacture, process, and store HEU components for warheads. It is critical for the UK's capacity to build new warheads. One of its aims is to "undertake the specialised chemical and metallurgical operations needed to manufacture enriched uranium components for successor warheads to Trident, should they be built."[101]

AWE has liaised with its US counterparts over the development of the equivalent American plant, the Uranium Processing Facility. The US plant will manufacture and assemble the fusion stage and the radiation case of warheads. The EUF will probably produce the same components. It will also carry out the initial fabrication of fuel rods for nuclear-powered submarines.[102]

The EUF was due to be completed in 2018. The start of the project was delayed due to concerns from the Office of Nuclear Regulation. In 2014 the MOD was reviewing the project after concerns that the cost, thought to be around £634 million, was spiralling out of control.[103]

Trident nuclear warheads are currently assembled and disassembled in a complex at AWE Burghfield which has four "Gravel Gertie" assembly bays. A new facility, with a similar production capacity, is under construction at a cost of around £700 million. This has four assembly chambers each of which is surrounded by double walls. The new building, Project Mensa, is due to be completed in 2015. A High Explosives Fabrication Facility (Circinus) and a substantial office complex (Gemini) have also been completed at Aldermaston. One new component manufacturing facility (Leo) at Burghfield became operational in 2011 and a second (Phoenix) was due to be been completed in 2014.

A new laser facility, Orion, became fully operational in April 2013. Although the Orion laser is available for academic research, 85% of the facilities' time is allocated to support for the nuclear weapons' programme.[104] The laser conducts high energy density physics experiments to support AWE's warhead certification programme.[105] High Energy Density Physics research at Aldermaston is "typically in support of secondary physics".[106] Orion will be able to simulate, for a fraction of a second, the intense heat and extreme pressures that are experienced during the fusion stage of a thermonuclear explosion.[107] Under an agreement signed in 2014 the UK and France will share use of Orion and the new French Megajoule laser which is under construction.[108]

A Technology Development Centre is under construction, adjacent to the existing hydrodynamic test facilities at Aldermaston. The new centre will provide "a capability for undertaking research and development into x-ray and other diagnostic techniques in support of future hydrodynamic experiments to be undertaken within the Epuré facility located in Valduc."[109] The key equipment in the centre will be an Inductive Voltage Adder (IVA) x-ray machine. Components of the IVA have been built in the US and will be assembled in the new centre at Aldermaston.[110] Epuré is due to be operational for British purposes in 2016, using a French x-ray machine. Aldermaston will develop a second x-ray machine for Epuré by 2019 and a third by 2022.

AWE operates several of the most powerful supercomputers in the UK. In 2010 AWE ordered Blackthorn and Willow computers which have a combined performance of 721 Teraflops (trillion calculations per second).[111] There was a further jump in AWE's computing power in January 2014 when three SGI ICE X computers were installed. These will have a combined performance of 1.8 Petaflops (thousand trillion calculations per second).[112] AWE's supercomputers are used to "simulate and understand the science of nuclear explosions."[113] The move to Petaflop computing will enhance the UK's ability to modernise existing warheads and to design new ones.

Other infrastructure

The 2006 White Paper said that the government expected to spend £2–3 billion, at 2006 prices, on infrastructure over the life of the successor submarine.[114] The 2010 defence review indicated that the government "agreed to defer and potentially to remove over £1 billion of future spending on infrastructure over the next 10 years."[115] The postponement was for a period of ten years.[116] The submarine infrastructure facilities at Faslane, Coulport, and Devonport each have a projected lifespan of 40 years. The MoD plans to extend the life of these facilities to keep them operational until 2040.[117] Its plans for the sustaining this infrastructure until the 2060s are not clear.

The construction of new facilities at Barrow, where the successor submarine will be built, was brought forward in 2014. This has increased by around £300 million, the amount which is due to be spent before the Main Gate decision.

The UK government is spending £1,255 million on the Core Production Capability project.[118] Rolls Royce is building a new facility to develop and build the fuel cores for submarine reactors at Raynesway in Derby. The project is to be completed by 2022. This project is critical for the successor submarine programme. Core J1, the fuel core for the first successor submarine, is also funded under this project.

There were initial proposals to modernize the Nuclear Command and Control system or "Nuclear Firing Chain". In November 2010 the Defence Minister announced that these plans had been postponed for ten years and might be cancelled.[119]

Timelines

Upgrade of nuclear warhead to Mk4A – 2015-2025
Decision on new warhead – 2019
New warhead in service – 2036
D5 LE missile in service with Royal Navy – 2020
New missile in service – 2040
Main gate decision on successor submarine – 2016
First successor submarine in service – 2028
End of life of successor submarine – 2067
Completion of Nuclear Warhead Capability Sustainment Program at AWE – 2025
Completion of Core Producion Capability – 2022
Faslane shiplift, Coulport Explosive Handling Jetty and Devonport Dry Dock – Life extended until 2040

Economics

Production of the successor submarine is estimated to cost around £25 billion.[120] In 2007 the running costs of the new system were projected to be £1.5 billion.[121] On this basis, the total operating costs for the planned 39-year lifespan would be £59 billion. A large part of the £21 billion Nuclear Warhead Capability Sustainment Program should also be considered as part of the true costs of Trident replacement. The total through-life costs of Trident replacement are likely to be in the region of £100 billion. Former Defence Minister, Nick Harvey, suggested that this was a minimum amount, saying, "I would have thought that £100 billion is the very least it would cost. I would take a private guess that the quantum would in fact be well in excess of that figure."[122]

There have been substantial reductions in some areas of the UK's defence budget, including army personnel. In December 2013 the Chief of Defence Staff, General Nick Houghton, argued that the MoD would have to live with future cuts. He said it should move away from spending huge amounts on "exquisite technology" for large-scale conflict and focus instead on maintaining adequate levels of personnel and developing new equipment that is appropriate to current and future threats.[123]

A further round of budget cuts is expected between 2015 and 2020. In December 2014 the Institute of Fiscal Studies (IFS) argued that cuts of 22% overall might be required. Some areas of funding (health, education, and overseas aid) are protected. As a result the IFS calculated that 41% cuts might be required in non-protected departments, such as defence.[124] There is serious concern within the UK military about the impact of further cuts in personnel, which may be introduced in order to pay for the equipment budget, including nuclear procurement.[125] Labour MP Roger Godsiff has argued against Trident replacement on these grounds. In January 2015 he told the House of Commons, "In a choice between spending money on conventional weapons and improving our internal security or committing £100 billion to a mythical so-called independent deterrent, I know which I would choose."[126]

The key UK-based companies in the Trident programme include BAE Systems, Babcock Marine, Rolls Royce, and Serco. BAE Systems operates the submarine construction yard at Barrow in Furness. Babcock Marine runs Devonport dockyard, which refits nuclear submarines, and support facilities at the Clyde Naval Base. Rolls Royce designs, manufactures, and supports the nuclear reactors on British submarines. Serco has a one-third share in AWE Management Limited (AWEML), which operates the UK nuclear warhead development and manufacturing facilities. BAE Systems, Babcock Marine, and Rolls Royce are the three main contractors for the successor submarine. They are also the three Tier 1 suppliers in the wider Submarine Enterprise Performance Program (SEPP).[127]

US arms giant Lockheed Martin plays a leading role in the UK nuclear weapons' programme. It is the lead contractor for the Trident missile system. The company also has a one-third share in AWEML. Lockheed Martin UK maintains components of the Trident missile system at the Clyde Naval Base. AWEML, Lockheed Martin UK, and Babcock Marine are partners in ABL Alliance, a joint venture that is responsible for nuclear warhead and Strategic Weapon System activities at the Clyde Naval Base. Lockheed Martin manages Sandia National Laboratory, the US facility which designs and produces non-nuclear components of the UK Trident warhead. The Managing Director and the Production Director at AWEML are both US citizens and former employees of Lockheed Martin.

Other US-based companies involved in the UK Trident programme include Jacob's Engineering, General Dynamics, and Electric Boat. Jacob's Engineering has a one-third share in AWEML. General Dynamics produces support systems for Trident, including the Fire Control System. Electric Boat is assisting BAE Systems with the successor submarine.

International law and doctrine

In his submission to the 2012 nuclear Non-Proliferation Treaty (NPT) Preparatory Committee Peter Duncan, the UK ambassador said that the UK did not support a treaty banning nuclear weapons. He said that the recent focus on the humanitarian impact of nuclear weapons stemmed from frustration with the pace of disarmament and he added "we share that frustration".[128] However, in setting out the case for Trident replacement, the previous UK government argued that the NPT does not set a timetable for nuclear disarmament and does not specifically prohibit the updating of nuclear capabilities.[129] By pursuing an extensive program of modernisation the UK is obstructing progress towards disarmament. It can hardly claim that it truly shares the exasperation of states which do not possess nuclear weapons.

The UK's modernisation plans are closely bound up with its special nuclear relationship with the US.[130] The transfer of nuclear weapon design information, warhead components, and fissile material from the US to the UK is contrary to the spirit of the NPT and sets an example that is inconsistent with the purpose of the Treaty.

In 2010 H.E. Judge Mohammed Bedjaoui, former President of the International Court of Justice, was asked for his view on the legality of a nuclear weapon system that deploys over 100 warheads, each with a yield of 100 kilotons (like the UK Trident force). He concluded:

> Even in an extreme circumstance of self-defence, in which the very survival of a State would be at stake, the use of a 100 kt nuclear warhead (regardless of whether it was targeted to land accurately on or above a military target) would always fail the tests of controllability, discrimination, civilian immunity, and neutral rights and would thus be unlawful....
> The modernization, updating or renewal of such a nuclear weapon system would also be a material breach of the NPT obligations, particularly the unequivocal undertaking by the nuclear-weapon states to 'accomplish the total elimination of their nuclear arsenals leading to nuclear disarmament' and the fundamental Article VI obligation to negotiate in good faith on cessation of the arms race and on nuclear disarmament, with the understanding that these negotiations must be pursued in good faith and brought to conclusion in a timely manner.[131]

In November 2006 Phillipe Sands QC and Helen Law gave advice on the legality of the maintenance and replacement of the UK Trident system. They said:

> If the position of the UK is that a nuclear deterrent remains necessary whilst there is the unascertainable risk of a future threat developing, this amounts to a de facto acceptance that the UK will never fully disarm. In our opinion, this can only negate the good faith with which the UK is required to negotiate [to achieve nuclear disarmament under Article VI of the NPT].[132]

The Mk4A warhead modification program and the upgrade of all elements of the Trident system are likely to enhance the targeting capability of Trident. Sands and Law argue that upgrades of this nature would be likely to increase the circumstances in which the UK's nuclear weapons would be used and that this would be contrary to the UK's obligation to pursue a diminishing role for nuclear weapons, as set out at the 2000 NPT Review Conference and reaffirmed at the 2010 NPT Review Conference. Lord Murray, formerly the senior government law officer in Scotland, has said that the deployment of Trident on continuous patrol, in the absence of an imminent danger to Britain, could be seen as "a continuing threat of unrestricted use against others" and therefore contrary to international law.[133] He also has questioned whether the upgrading of Trident can be reconciled with the UK's obligation to pursue negotiations on disarmament in good faith.

Dependence on American support is a significant driver for Britain's modernisation efforts. The Royal Navy is determined to buy the latest American equipment, so it is not left with the costs and problems of sustaining an obsolete system. One of the main goals of AWE's research programme is to retain Britain's unique access to the closely guarded secrets of the US nuclear laboratories. In return for this assistance, the United States expects that the UK would join any nuclear coalition of the willing.[134] The US-UK nuclear exchange is based on the Mutual Defence Agreement, which was renewed for a further ten years in 2014.

The UK's nuclear targeting policy during the Cold War was designed to destroy 50% of the buildings in Moscow and other Soviet cities. The decision to acquire Trident, in 1980, enabled targeting to be more precise, but the focus remained on facilities in and around Moscow.[135] In 2012 the Deputy Prime Minister Nick Clegg implied that UK targeting policy was still focused on the Russian capital.[136] A study by Scottish CND, published for the 2013 Oslo Conference on the Humanitarian Impact of Nuclear Weapons, found that an attack with 40 Trident nuclear warheads on targets in and around Moscow would result in 5.4 million short-term fatalities.[137]

Public discourse

The Conservative Party supports replacing Trident with a new fleet of nuclear submarines armed with ballistic missiles. It argues that Trident and its replacement should be kept on continuous patrol. While the decision on three or four submarines will not be taken until 2016, the planning assumption is that four vessels will be built. Some Conservative MPs argue that the UK should keep nuclear weapons in order to retain its status in the world. Oliver Colville MP said, "I can confirm my commitment to our retaining our nuclear arsenal because, in my opinion, it is the cornerstone of our membership of NATO and of our seat on the UN Security Council."[138] The senior Conservative MP Michael Heseltine gave a further reason for keeping Trident, saying in a BBC debate, "to leave France as the only nuclear power in Europe would be a reckless piece of irresponsibility."[139]

The Labour Party conducted an extensive review of policies in 2014. Several submissions to the review argued that Trident should be scrapped, but this option was rejected. Others proposed that Trident replacement should be considered in the 2015 Defence Review and this has become party policy. Apart from this, the Labour party position is the same as that of the Conservative party. When the idea of taking Trident off patrol was raised in 2013 it was rejected by Labour's defence spokesperson. The party's position is that it supports continuous patrols unless there is convincing new evidence for abandoning this posture. Vernon Coaker, Labour Defence spokesperson, told the House of Commons on 20 January 2015, "We want a minimum independent credible deterrent, based on continuous-at-sea deterrence."[140]

As part of the Coalition government, the Liberal Democrats initiated a review of alternatives to a Trident-type system.[141] The study was conducted by the Cabinet Office. It reviewed a range of alternative nuclear weapon systems, including submarine-launched cruise missiles and air-launched missiles. It presented a complex range of alternative levels of alert. The review argued that developing anything other than a Trident-type system would take longer and cost more. The report was flawed in a number of ways: it did not consider nuclear disarmament as an option; it assumed that any future force must be armed with weapons with a similar yield to Trident; and in its unclassified form the report failed to define the level of damage that a UK nuclear force would be required to inflict.

Liberal Democrats have changed their policy as a result of this study. The party has joined the Conservatives and Labour in recommending a replacement similar to Trident. The Liberal Democrat MP Alan Reid told the House of Commons, "A submarine system with ballistic missiles remains the most effective and least vulnerable form of deterrent."[142]

In February 2015, Centre Forum, a Liberal Democrat think tank, suggested that the UK could acquire 100 UK versions of the US B61-12 bomb and deploy them both on land-based aircraft and on the UK's new aircraft carriers.[143] However, in the light of the Cabinet Office report, this proposal is unlikely to receive much support.

The Liberal Democrats depart from their Conservative and Labour colleagues in arguing that the submarines do not need to maintain a continuous patrol. They also say that fewer than four submarines should be built. Liberal Democrat minister Danny Alexander said that these changes would save £4 billion in the through-life costs of the system. This implies a total cost of £96 billion rather than £100 billion.

The Liberal Democrat policy of opposing continuous patrols has been attacked by their political opponents. For example, Bob Stewart MP said, "We cannot have a part-time deterrent."[144] All UK operational nuclear weapons are based in Scotland. The Scottish National Party (SNP), which has formed the Scottish Government since May 2007, is strongly opposed to Trident. On 6 August 2014 the Scottish Parliament passed a resolution calling for the "speediest safe withdrawal of nuclear weapons from Scotland" and supporting a global ban on nuclear weapons.

Photo: Pond5/Pzaxe

A referendum on Scottish independence was held in September 2014. The future of Trident was a key issue in the referendum campaign. Prior to the vote the Scottish Government said that an independent Scotland would demand that all nuclear weapons were removed within four years and it would introduce a constitutional ban on nuclear weapons. Removing Trident from Scotland would be likely to leave the UK without any nuclear weapons, because of the severe difficulties of relocating Trident.[145] In 2012 a report by the Scottish Campaign for Nuclear

Disarmament argued that it would be practically possible to remove all nuclear warheads from Scotland in two years and to dismantled them all within four years.[146] 45% of the population voted for independence. While this means that Scotland remains within the United Kingdom, the issue is likely to re-emerge in future years.

In December 2014 the SNP joined with Plaid Cymru (the National Party of Wales) and the Green Party in a joint statement which said that, if there was a hung parliament after the May 2015 election, they would only support a UK government that is committed to abandoning the plans for Trident replacement.

UK government's decisions to build or upgrade nuclear weapons have, since the 1960s, have been based on the argument that "now is not the time to disarm". Sir Michael Quinlan, former permanent secretary at the MoD, said that each set of decision-makers, over several decades, produced "a set of rationales to clothe that gut decision."[147] Former Prime Minister Tony Blair wrote in his biography, "Imagine standing up in the House of Commons and saying I've decided to scrap it. We're not going to say that, are we?"[148]

Supporters of the UK nuclear force argue that even if the UK abandoned nuclear weapons, this would have no effect on other nuclear armed states.[149] Professor Michael Clarke, Director General of the Royal United Services Institute, disagrees. He argues that if Britain were to scrap Trident this would be the most significant nuclear decision the world has ever seen.[150] Professor William Walker points out that such a move would be unique because of Britain's role in the early development of nuclear weapons and its position as one of the three custodians of the NPT.[151] Walker adds that if Britain disarmed this would be far more dramatic than the examples of disarmament we have seen so far. These have been in the peculiar situations of the disintegration of the Soviet Union and the end of apartheid in South Africa. Clarke adds that, even if others don't follow and we end up in an unstable scenario with more nuclear-armed states, Britain would still be better off by not being one of them.

Notes:

1. Thanks are noted to Peter Burt of the Nuclear Information Service (http://www.nuclearinfo.org/) and Veronika Tudhope of Scottish CND for their assistance with research.
2. Strategic Defence and Security Review 2010, para 3.11, http://www.direct.gov.uk/prod_consum_dg/groups/dg_digitalassets/@dg/@en/documents/digitalasset/dg_191634.pdf.
3. Statement by Defence Minister Michael Fallon, Hansard, 20 January 2015, http://www.publications.parliament.uk/pa/cm201415/cmhansrd/cm150120/debtext/150120-0002.htm.
4. The UK Trident warhead contains EDC37, a British explosive, rather than the American equivalent, PBX9501.
5. The UK has purchased three W76 components—the Arming, Fuzing and Firing System, Gas Transfer System and Neutron Generator—from the US. Hansard, 4 December 2009.
6. John Ainslie, "UK nuclear tests 1974-1991," November 2011, http://banthebomb.org/ne/images/stories/pdfs/uktests.pdf
7. "Minutes of the MoD Trident Group," The National Archives (TNA) DEFE 24-2125 e79, 7 August 1980.
8. The White Paper on Trident replacement in December 2006 referred to "the continuing availability of a lower yield from our warhead". The Future of the United Kingdom's Nuclear Deterrent, December 2006, Cm 6994, paras 4-9.
9. There are periods, following the end of a long refit, when only two submarines are armed.
10. Statement by Defence Minister Michael Fallon, Hansard, 20 January 2015, http://www.publications.parliament.uk/pa/cm201415/cmhansrd/cm150120/debtext/150120-0002.htm.
11. John Ainslie, "Special Nuclear Materials for the UK Trident Programme," http://banthebomb.org/ne/images/stories/pdfs/tridentsnm.pdf. This includes an analysis of the figures published in "Plutonium and Aldermaston: a historical account," MoD, 2000.
12. "Plutonium and Aldermaston: a historical account," MoD, 2000.
13. "Historical accounting for UK defence Highly Enriched Uranium," MoD, March 2006.
14. In February 1957 the plan was to produce 4910 kg of HEU at Capenhurst between 1958/9 and 1961/2, Cost estimates for plutonium and uranium 235 for the years 1958-63—see "Note by the Technical Policy Branch," Risley, February 1957, TNA AB16-3878 e12. There was a requirement for 3463 kg of HEU for Green Grass and Red Snow warheads between 1957/8 and 1961/2, TNA AB43-92 e46, 4 May 1964. In 1996 the Stockholm International Peace Research Institute (SIPRI) estimated that Capenhurst had produced 3.8–4.9 tonnes of HEU, almost all of this between 1959 and 1961. Available at http://nuclearweaponarchive.org/Uk/UKFacility.html.
15. The official account of the HEU stockpile says that the two sources of HEU for the UK military programme were the Capenhurst plant (until 1962) and the United States. Historical accounting for UK defence Highly Enriched Uranium, MOD, March 2006. 7.5 tonnes were obtained from the US between 1964 and 1969 in exchange for plutonium. See "Plutonium and Aldermaston: a historical account," MoD, 2000. This implies that the UK procured the remaining 14-15 tonnes of HEU from the US between 1970 and 2002.
16. The MoD said that Vulcan would be scaled down or closed after 2015. See BBC, 2 November 2011. Rolls Royce told John Thurso MP that it would retain a workforce of around the current size beyond 2030. See- John O'Groat Journal, 16 November 2011.
17. Trident Value for Money – C4 Infrastructure, obtained under the Freedom of Information Act by Greenpeace.
18. Letter from George W Bush to Tony Blair, 7 December 2006.
19. 2006 White Paper on Trident replacement.
20. 2014 update to parliament.
21. Hansard House of Commons, 26 October 2011, Column 203W,
22. Defence Nuclear Environment and Safety Board Assurance reports for 2006, 2007, and 2008.
23. MoD project P00221E. Excel spreadsheet accessed on the MOD website in 2007 but no longer online.
24. Government Major Projects Portfolio data MoD, 2013, https://www.gov.uk/government/collections/major-projects-data#2014-data.
25. Environment, safety, health and quality function, Annual review on safety to the regulatory community (CY 13), AWE, 31 July 2013.
26. Government Major Projects Portfolio data, MoD, 2013, https://www.gov.uk/government/collections/major-projects-data#2014-data.
27. Ibid.
28. https://www.linkedin.com/pub/paul-tom/b/b09/672
29. A key Measure of Effectiveness for C4/Mk4, when it was originally developed, was a target with a vulnerability number (VNTK) of 27P0. A target of this type would be destroyed by blast overpressure of around 150 psi, which is far less than required to destroy a hardened target. C4 achieved sufficient accuracy to be effective against 27P0. This Measure of Effectiveness for C4/Mk4 was used again in 1994. Joint DoD/DoE Trident Mk4/Mk5 Reentry Body Alternate Warhead Phase 2 Feasibility Study Report, January 1994, p9-14.
30. Joint DoD/DoE Trident Mk4/Mk5 Reentry Body Alternate Warhead Phase 2 Feasibility Study Report, January 1994; Sharpening Trident, John Ainslie, 2009, http://www.swordofdamocles.org/pdf/sharpeningtrident.doc
31. Joint DoD/DoE Trident Mk4/Mk5 Reentry Body Alternate Warhead Phase 2 Feasibility Study Report, January 1994, Appendix B p 8. A near-surface burst detonates the warhead before it reaches the ground, but at a height where the fireball will touch the surface.
32. A redacted chart shows the effectiveness of D5/Mk4A against a range of targets up to VNTK 46L8 (SS-11) with a comment "This represents a set of targets likely to be eligible for the Mk4A", Alternate Warhead Study pp. 9–17.
33. "The tritium GTS can be the easiest way to improve the performance margin of an existing weapon without extensive rebuilding of the weapon or its nuclear components. Changes to the tritium GTS can sometimes compensate for the potential loss of performance margin due to aging or other phenomena" Independent Analysis Tritium R&D Facility Consolidation, October 2008, available at http://www.complextransformationspeis.com/RM_508%20-%20TechSource%202008g.pdf.
34. http://www.trivalleycares.org/new/govdocs/SecondaryLifetimeAssessment01-part1.pdf
35. Sandia Lab Accomplishments, March 2011, http://www.sandia.gov/LabNews/labs-accomplish/2011/lab_accomp-2011.pdf; reported by Hans Kristensen in the Federation of American Scientist Blog on 1 April, http://www.fas.org/blog/ssp/2011/04/britishw76-1.php.
36. Justification for Critical Decision 1, SNL Weapons Evaluation Test Laboratory at Pantex, Amarillo, Texas, http://www.arcplanning.com/projects/archive/screen-pdf/19712.801_wetl.pdf.
37. Speech by David Gould, Chief Operating Officer, Defence Equipment and Support, to the Future Deterrent Industry Day at Abbey Wood, Bristol on 29 June 2007.
38. December 2014 update
39. http://www.unian.info/world/420345-uk-and-france-agree-to-joint-nuclear-testing-treaty.html
40. Government Major Projects Portfolio data MOD 2013 https://www.gov.uk/government/collections/major-projects-data#2014-data
41. "Our research and development work splits into two main but inter-related areas. The first is the requirement to maintain the current Trident stockpile. The second is to develop our overall warhead design and assurance capabilities, including the ability to provide a new warhead lest our government should ever need it as a successor to Trident. Most of our research is conducted into this capability area". Clive Marsh, Chief Scientist AWE, http://www.youtube.com/watch?v=gT8qCFkbIv4.
42. Future Nuclear Deterrent Industry Day, Nuclear Warhead Context, Nick Bennet – DG Strat Tech, 29 June 2007. Reply by Des Browne to question from Nick Harvey, Hansard, 28 November 2007.
43. How Much Science Is Enough? Nicola S Cox and Duncan R Farr, A collection of papers from the 2009 PONI Conference Series, Center for Strategic and International Studies, 2010, p. 52.
44. "At AWE, this portfolio of experience is spread across the Trident, Capability and Successor Directorates". How Much Science Is Enough? p. 53.
45. AWE's capacity to carry out certain tasks was at a low ebb in the late 1990s. In some areas they retained the ability to specify work, but not to carry it out themselves - Must Life Extension Compromise Responsiveness? Owen Price, AWE, A collection of papers from the 2005 PONI conference series, Center for Strategic and International Studies, 2006, p. 113f.
46. Must Life Extension Compromise Responsiveness? p. 120. A key aim of the Technology Division at AWE is to improve systems engineering and warhead integration skills—How Much Science is Enough? p. 51.
47. US Air Force Research, Development Test and Evaluation FY2012 BA 5, PE 060422F Nuclear Weapon Support
48. One task in the AF&F project, to be carried out in FY2011, was to "document enveloping requirements to support Navy, Air Force and UK applications", US Navy Research, Development, Test & Evaluation budget FY2012, BA7 PE 0101221N Strategic Sub & Wpn Supt, February 2011. The UK successor warhead will probably be designed to fit into the US Mk5 Re-entry Vehicle.
49. US Navy Research Development Test and Evaluation budget FY2010, BA-7, PE 0101221N Strategic Sub & Weapons System Support, May 2009.
50. "Development of the Integrated AF&F demonstrators … to TRL4 and TRL5" Vacancy for Arms Fusing and Firing (AF&F) Mechanical Design Engineer, accessed 25 April 2011. Technical Readiness Level 4 (TRL 4) is testing in a laboratory and TRL 5 is testing in a relevant environment.

Notes:

51. Vacancy for Electrical/Electronic Design Engineer, accessed 25 April 2011.
52. Vacancy for Senior Digital Electronics Research and Development Engineer, accessed 25 April 2011.
53. Vacancy for Formal Methods and Software Engineer, accessed 15 May 2008.
54. Vacancies for Firing Unit Mechanical Designer and Electronics Engineer, accessed 25 April 2011.
55. Vacancy for Pulsed Energy Component Scientist, accessed 31 October 2010.
56. "Liaise with overseas colleagues … longer-term secondment overseas may be required to support collaborative activities" Vacancy for Senior Digital Electronics Research and Development Engineer, accessed 25 April 2011.
57. SNL vacancy for Weapons Systems Engineer, accessed 10 July 2011. The scope of this post includes "support arming, fusing, and firing (AF&F) architecture development". The employee is expected to "participate in advanced architecture studies in collaboration with the Department of Defence and the United Kingdom Atomic Weapons Establishment".
58. AWE vacancy for Design Engineer - Gas Transfer, accessed 12 November 2007.
59. AWE vacancy for Hydrogen Storage Engineer - Gas Transfer, accessed 11 July 2008.
60. AWE vacancies for Pressure Vessel Engineer – Gas Transfer (12 November 2007), Joining Engineer—Gas Transfer (12 November 2007), Senior Pressure Vessel Engineer—Gas Transfer (12 November 2007).
61. Fiscal Year 2009 Program Implementation Plan, Directed Stockpile Work, Research and Development Program, National Nuclear Security Administration (NNSA), Revision 3, 26 August 2009, p. 26.
62. AWE vacancies for Mechanical – Design Engineer (25 April 2011), High Voltage Test Equipment Engineer (13 June 2006), Electro-Explosives Specialist (21 October 2006), Neutron Tube Design Team Leader (22 July 2006), Thin Film Specialist (22 July 2006).
63. AWE vacancy for vacuum tube materials scientist, accessed 8 May 2008.
64. Statement of Rear Admiral Terry Benedict, Director Strategic Systems Programs, Subcommittee on Strategic Forces of the Senate Armed Services Committee, 6 April 2011, available at http://armed-services.senate.gov/statemnt/2011/04%20April/Benedict%2004-06-11.pdf.
65. Letter from George W Bush to Tony Blair, 7 December 2006.
66. https://www.fbo.gov/?s=opportunity&mode=form&id=-171065ca74b831af3215017edbbeefdc&tab=core&_cview=0
67. http://www.dod.mil/pubs/foi/logistics_material_readiness/acq_bud_fin/SARs/14-F-0402_DOC_73_Trident_II_MissileDecember2013SAR.PDF
68. http://www.draper.com/profile_boost_guidance.html.
69. A solid-state Interferometric Fiber Optic Gyroscope (IFOG) will replace the current mechanical gyro, an Alternate Pendulous Integrating Gyroscopic Assembly (Alt PIGA) that will replace the current PIGA accelerometer. Charles Stark Draper Laboratory and the E2V Corporation have designed a new stellar camera. http://www.akama.com/company/The_Charles_Stark_Draper_Laboratory_Inc_a27463334185.html; A simulation-based Integration Approach for the First Trident Mk6 Life Extension Guidance System, presentation to the AIAA Missile Sciences Conference, Monterey, 18-20 November 2008.
70. Explorations, Spring 2006, Draper Laboratory,
71. Explorations, Spring 2006, Draper Laboratory,
72. A simulation-based Integration Approach for the First Trident Mk6 Life Extension Guidance System, presentation to the AIAA Missile Sciences Conference, Monterey, 18-20 November 2008,
73. "Since the development of MK1, Draper has significantly improved the reliability and accuracy of the follow-on systems, continuing today with the development of the MARK 6 MOD 1 system" Mk6 Mod 1 is an alternative name for Mk6LE, available at http://www.draper.com/Documents/Flier_Strategic.pdf.
74. Written answer by Adam Ingram to question from Angus Robertson, Hansard, 18 June 2004.
75. Admiral JT Mitchell, SSPO, testimony to Senate Committee on Armed Services, 11 May 1993, quoted in Proliferation of WMD and US Nuclear Strategy, Hans Kristensen, BASIC, 1998.
76. Statement of Rear Admiral Terry Benedict, Director Strategic Systems Programs, Subcommittee on Strategic Forces of the Senate Armed Services Committee, 6 April 2011, available at http://armed-services.senate.gov/statemnt/2011/04%20April/Benedict%2004-06-11.pdf.
77. Solicitation N0003005G0068NJ09 Mk98 Mod 8/9 Concept Exploration, 26 July 2006, www.fbodaily.com.
78. Solicitation N00030-07-G-0044X793, Mk6 LE 344 update 26 August 2009, www.fbodaily.com; Mk98 Mod 9 is part of the SSP Shipboard Integration (SSI) increment 4.
79. Draft request for proposal (DRFP) N00030-10-R-0018, SSP, 24 June 2009, www.fbodaily.com; The first navigation upgrade is SSI increment 4.
80. https://www.fbo.gov/index?s=opportunity&mode=-form&tab=core&id=2c06b9957b49029b70e2cfbe4cc3f137
81. The United Kingdom's Future Nuclear Deterrent: The Submarine Initial Gate Parliamentary Report, May 2011.
82. A joint Navy-Air Force ballistic missile. DoDBuzz, 21 October 2011, available at http://www.dodbuzz.com/2011/10/21/a-joint-navy-air-force-ballistic-missile/.
83. Major Projects Report, MOD, National Audit Office, January 2015 http://www.nao.org.uk/wp-content/uploads/2015/01/Major-projects-report-2014-appendices-and-project-summary-sheets.pdf
84. 2014 update to parliament
85. 'Nuclear submarines' Parliamentary written answer by Peter Luff. Official Report (Hansard), 2 July 2012, Column 470W: http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm120702/text/120702w0003.htm#12070253000285
86. Major Projects Report, MOD, National Audit Office, January 2015 http://www.nao.org.uk/wp-content/uploads/2015/01/Major-projects-report-2014-appendices-and-project-summary-sheets.pdf
87. FY2012 budget, Navy RDT&E, BA 4 Advanced Component Development and Prototypes, PE 0603561N, Advanced Submarine System Development.
88. http://www.nti.org/media/pdfs/60_3.pdf?_=1316627912
89. United Kingdom Strategic Deterrent. Note by the Secretary of State for Defence for MISC 7 cabinet subcommittee, 2 November 1981. The National Archives, AIR 8-2846 e70i
90. Part of one order requires the contractor to "perform systems engineering Analysis and modelling efforts related to launch Probability of Success (POS), model development, shock analysis, on/offload analysis, stowage vibration, etc. In support of the UK Unique CMC and UK Successor Programs" between April 2015 and March 2017. https://www.fbo.gov/index?s=opportunity&mode=form&id=5cfe9616f97f74f2c193c2c4a9a3e027&tab=core&_cview=1
91. 2014 update
92. http://www.navy.mil/submit/display.asp?story_id=84166
93. http://www.thecqi.org/Documents/community/NUCSIG/Public%20downloads/Bootle%202011/5%20CQINucSIG%20presentation%20Jan%2011%20at%20Bootle%20Website%20version.ppt
94. Government Major Projects Portfolio data MOD 2013 https://www.gov.uk/government/collections/major-projects-data#2014-data
95. MOD response to Freedom of Information request from Nuclear Information Service.
96. Future Nuclear Deterrent Industry Day, Nuclear Warhead Context, Nick Bennet –DG Strat Tech, 29 June 2007.
97. The future of the UK's Strategic Nuclear Deterrent: Written evidence from the Ministry of Defence, HC 835 2005/06 Ev 5.
98. Must Life Extension Compromise Responsiveness? Owen Price, AWE, A collection of papers from the 2005 PONI conference series, Center for Strategic and International Studies, 2005, p. 116. http://csis.org/images/stories/poni/090108_2005_conference_series_text.pdf
99. Recommendation for the AWE Burghfield Site, AWE, 3 December 2002. This also said, "There is insufficient space at Aldermaston alone to accommodate the new operational facilities in the Company's Major Investment Schemes and those that would be required for any Successor Programme." A list of requirements for the Aldermaston site in this report included "future facilities for a successor system".
100. http://news.onr.org.uk/2013/12/onr-extend-terms-of-awe-improvement-notice/
101. Enriched Uranium Facility Initial Gate Business Case', paragraph 1. Reference DES/NW/PSO/555/35. Ministry of Defence, 3 April 2007, quoted in Project Pegasus—AWE Aldermaston's proposed Enriched Uranium Facility, Nuclear Information Service, 2010.
102. Enriched Uranium Facility Initial Gate Business Case', paragraph 1. Reference DES/NW/PSO/555/35. Ministry of Defence, 3 April 2007, quoted in Project Pegasus—AWE Aldermaston's proposed Enriched Uranium Facility, Nuclear Information Service, 2010.
103. http://www.independent.co.uk/news/uk/politics/mod-orders-review-in-to-spiralling-cost-of-project-pegasus-nuclear-plant-9893206.html
104. http://www.awe.co.uk/app/uploads/2014/10/Treadwell-et-al-Orion-a-commissioned-user-facility-2013.pdf
105. http://www.awe.co.uk/app/uploads/2014/09/Discovery24September2013.pdf
106. High Energy Density Physics, NNSA, April 2001, Appendix G – UK Statement on High Energy Density Physics.

107. Warhead assurance under CTBT constraints, Dr Daryl Lanberg, Chief Scientist AWE, PONI Fall Conference, 21 September 2010.
108. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277167/France-UK_Summit-Declaration_on_Security_and_Defence.pdf
109. http://planning.westberks.gov.uk/rpp/index.asp?caseref=11/02557/COMIND
110. "Initial Tests of the AWE Hydrus IVA Marx" and "Status of the AWE Hydrus Fabrication". 18th IEEE Pulsed Power Conference 2011, p 96 & 113. http://ppc.missouri.edu/abstract.pdf
111. http://www.top500.org/site/47363
112. http://www.sgi.com/company_info/newsroom/press_releases/2013/november/awe.html
113. http://www.awe.co.uk/app/uploads/2014/07/AWE-OVERVIEW-FINAL.pdf
114. The Future of the United Kingdom's Nuclear Deterrent, December 2006, Cm 6994.
115. Strategic Defence and Security Review, 2010, para 3.15.
116. Reply by Liam Fox Hansard 3 November 2010 Col 855W.
117. Nuclear submarine infrastructure – scope to minimise future costs, DES-SM LoD-Infra-01/03, 7 July 2010, obtained under the Freedom of Information Act by Greenpeace.
118. Major Projects Report, MOD, National Audit Office, January 2015 http://www.nao.org.uk/wp-content/uploads/2015/01/Major-projects-report-2014-appendices-and-project-summary-sheets.pdf
119. Reply by Liam Fox Hansard 3 November 2010 Col 855W.
120. Reply by Defence Minister Dr Murrison, Hansard, 13 February 2014, Colunm 846W
121. Memorandum from the MOD, 19 February 2007, published in The Future of the UK's Strategic Nuclear Deterrent, the White Paper, 9th report from the House of Commons Defence Committee 2006/07, 27 February 2007.
122. Hansard 20 January 2015 Col 119
123. https://www.rusi.org/publications/newsbrief/ref:A52D66D2E8A623/#.VKZ0F9KsWuI
124. http://www.ifs.org.uk/uploads/publications/budgets/as2014/as2014_crawford.pdf
125. https://www.rusi.org/analysis/videos/ref:V549164E7D47F2/#.VKZwBNKsWuJ
126. Hansard 20 January 2015 Col 117
127. The United Kingdom's Future Nuclear Deterrent: The Submarine Initial Gate Parliamentary Report, May 2011, para 4.2
128. http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/npt/prepcom14/statements/29April_UK.pdf
129. The Future of the United Kingdom's Nuclear Deterrent, December 2006, Cm 6994, para 2-9
130. US-UK Nuclear Sharing – Deterring Disarmament, John Ainslie, 2011. Published by Reaching Critical Will for the 2011 NPT Prep Com.
131. Postscript by HS Judge Mohammed Bedjaoui in Trident and International Law: Scotland's Obligations, Rebecca Johnson and Angie Zelter (Eds), Luath Press, 2011, pp. 90-91.
132. Phillipe Sands QC and Helen Law, 'The United Kingdom's Nuclear Deterrent: Current and Future Issues of Legality," in Rebecca Johnson and Angie Zelter (Eds.) *Trident and International Law: Scotland's Obligations*, Luath Press, 2011, p. 146.
133. Note by Lord Murray for a Scottish Government Summit on a Future Without Nuclear Weapons, 22 October 2007. Lord Murray is a former Lord Advocate, the senior Government law officer in Scotland, and also a former Judge on the High Court of Justiciary and Court of Session.
134. In 1992 Nick Witney, Director of Nuclear Policy at the MOD, discussed this issue with Michael Quinlan. Witney wrote that he had been told by a US official that if America was going to threaten nuclear action against Saddam Hussein then this official would urge the President to make sure that other Western nuclear powers (ie Britain and France) were involved. On Nuclear Deterrence, The Correspondence of Sir Michael Quinlan, Tanya Ogilvie-White, IISS, 2011, p. 255.
135. Unacceptable Damage, John Ainslie, 2013. http://www.swordofdamocles.org/pdf/UnacceptableDamage.pdf
136. "The idea of a like-for-like entirely unchanged replacement for Trident is basically saying we will spend billions and billions of pounds on a nuclear missile system designed with the sole strategic purpose of flattening Moscow at the press of a button". http://guardian.co.uk/uk/2012/sep/26/trident-nuclear-missiles-review-downgrading
137. If Britain Fired Trident, The humanitarian consequences of a nuclear attack by a Trident submarine on Moscow, John Ainslie, Scottish CND, 2013. http://www.swordofdamocles.org/pdf/ifbritainfiredtrident.pdf
138. Hansard 20 January 2015 Col 111
139. Question Time, BBC, 19 February 2015.
140. Hansard 20 January 2015 Col 104
141. Trident Alternatives Review, July 2013, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/212745/20130716_Trident_Alternatives_Study.pdf
142. Hansard 20 January 2015 Col 170
143. http://www.centreforum.org/assets/pubs/retiring-trident.pdf
144. Hansard 20 January 2015 Col 112
145. No Place For Trident, Scottish Independence and Nuclear Disarmament, John Ainslie, Scottish CND, 2014. http://www.swordofdamocles.org/pdf/noplacefortrident.pdf
146. Disarming Trident, Scottish CND, 2012, http://www.swordofdamocles.org/pdf/disarmingtrident.pdf
147. Lord Hennessy, Inaugural Michael Quinlan lecture, House of Lords, 2 February 2011, quoting a statement by Quinlan to himself, http://www.parliament.uk/documents/lords-information-office/2011%20Lord%20Hennessy%20Robing%20Room%20Lecture%20.pdf.
148. Tony Blair, *A Journey*, September 2010.
149. "There is no evidence or likelihood that others would follow the UK down a unilateralist route." The Future of the United Kingdom's Nuclear Deterrent, December 2006, Cm 6994, p. 20.
150. Presentation by Professor Michael Clarke, Director of the Royal United Services Institute, in the Trident: Should we keep it? Debate, Edinburgh, 23 June 2011.
151. Presentation by Professor William Walker at Trident and International Law: Scotland's Obligations conference, Scottish Parliament, 12 February 2011.

United States

Greg Mello and
Trish Williams-Mello

The United States is conducting a complete overhaul of all components of its nuclear triad, requiring three full decades of investment. This will cost, including current operations, at least $1 trillion. The new weapons and factories placed into service will last, i.e. generate nuclear threats (their purpose), until late in this century. US nuclear modernisation is already producing significant new nuclear capabilities with unknowable consequences, and significant additional new capabilities are planned and budgeted. No warhead retirements are occurring under New START and none are committed. Future dismantlements have been made contingent on construction of new factories and deployment of new weapons.

The modernisation programme-of-record has been dogged by delays, cancellations, downscaling, and cost overruns; its completion in an era of budgetary uncertainty and constraint is widely questioned. Modernisation competes with warhead dismantlement for scarce physical and financial resources in the production complex. There are deep concerns in government (including the military) and in civil society about nuclear weapons cost and relevance, but so far not one member of Congress publicly opposes maintaining a policy of "mutual assured destruction" (MAD) based on a triad of delivery systems with thousands of nuclear warheads.

Status of US nuclear forces

Warheads

As of 1 April 2015 the United States deployed 1,597 strategic warheads on 785 strategic delivery vehicles on or in 898 deployed and non-deployed launchers.[1] In all the United States possesses at least 7,100 warheads including deployed strategic warheads, non-strategic warheads, operational warheads not deployed, and including a minimum of 2,340 intact but "retired" warheads. An unknown number of retired warheads are in "managed retirement" or "war reserve" status.[2]

In addition the US stores more than 15,000 plutonium pits from dismantled nuclear weapons, thousands of which could be reused, as well as thousands of thermonuclear secondaries and millions of other parts.[3] Warheads removed from deployed strategic stockpile to comply with New START are not being retired but rather transitioned to the maintained "hedge" stockpile, with the result that New START will not result in any significant change in the size of the active US stockpile until the late 2020s at the earliest. Current policy makes retirements contingent on successful completion of planned warhead modernisation and construction of new warhead production capacity.[4]

Delivery systems

The US strategic "triad" consists of: 447 Minuteman III intercontinental ballistic missiles (ICBMs) carrying 447 warheads with the capacity for additional warheads to be uploaded; 14 Ohio-class submarines each with 24 launch tubes for Trident D5 submarine-launched ballistic missiles (SLBMs) carrying about 1,152 warheads with an upload capacity of more than that many warheads again; and 96 nuclear capable strategic bombers, 20 B2As and 76 B-52Hs. Of these heavy bombers, 60 (44 B-52Hs and 16 B-2As) have been assigned nuclear roles.[5] Each heavy bomber is counted as one warhead under New START, although up to 20 warheads on cruise missiles can be deployed on a single B-52H and up to 16 nuclear gravity bombs can be carried on each B-2.[6] The active US stockpile also includes about 500 non-strategic weapons, with about 180 deployed at NATO air bases in Europe for delivery by US F-15Es, F-16s, and host country F-16s and Tornado aircraft.[7]

Fissile materials

The US has produced or acquired approximately 850 metric tons (MT) of highly-enriched uranium (HEU) and 112 MT of weapon-grade plutonium, of which 609 MT and 95 MT remain, respectively (current HEU stock is exclusive of HEU in spent naval reactor fuel).[8]

Modernisation

The US government is officially committed to modernising or replacing all its nuclear bombs and warheads; all the submarines, missiles, and aircraft that carry them; its nuclear targeting, command, and control systems; and its laboratories and production plants that design, maintain, and manufacture warheads. US policy and budget documents all manifest an intent to keep thousands of nuclear weapons in service for most of this century, together with the capability to bring stored warheads back into service and to design and manufacture new warheads and delivery systems.[9]

A nuclear weapon system consists of a nuclear explosive, a delivery system, a launch platform or air base, and the surveillance, intelligence, targeting, command, and control systems that enable nuclear use. All system components work together to produce the nuclear threat. Using this definition, the US is replacing and modernising all of its nuclear weapon systems. The result will be, in all US cases, new or renewed nuclear weapon systems with new military capabilities – even if some components, such as the nuclear explosive components in a warhead, change only a little.

Modernisation is continuous, underway, and is already incorporating new capabilities that expand potential nuclear target sets, increasing or making new threats. One example is the upgraded submarine-launched warhead, the W76-1, now a little more than halfway through production. The W76-1 is being equipped with an advanced fuze that enables, together with the increases in missile accuracy and range available from the D5 missile over the original C4 missile, targeting of Russian missile silos and other "hard" targets from ocean launches, a capability not present in the original W76-0.[10]

Another example is the proposed B61-12 gravity bomb now in advanced design and testing, which will have a precision-guidance tail fin system enabling 30-meter accuracy (down from the original 110-170 meters),[11] allowing much lower nuclear yields, again expanding possible nuclear targets and increasing the "credibility" of the associated nuclear threats. In January 2014, US Air Force Chief of Staff, General Norton Schwartz, confirmed that the modernised B61 will have improved military capabilities to attack targets with greater accuracy and less radioactive fallout.[12] Yet the 2010 US Nuclear Posture Review (NPR) pledged that nuclear weapon life extension programs "will not support new military missions or provide for new military capabilities."[13] The B61-12 violates the NPR pledge – as does the W76-1/Trident D5 combination and as would the W80-4 warhead on the proposed Long-Range Stand-Off (LRSO) stealth cruise missile as well.

The military characteristics of nuclear weapon systems are, in general, secret. Seemingly modest "improvements" in one aspect of a weapon (e.g. a new fuze with more accurate detonation placement) can combine with other "improvements" (increased stealth, forward basing, nearby-ocean launches, greater accuracy, or increased range) to create – intentionally or unintentionally – an entirely more threatening nuclear posture. Also, new and potentially destabilising threats cannot be analysed one weapon system at a time but must consider the entire military-political threat spectrum, including the capabilities of ballistic missile defenses, early warning systems, command and control, cyberwar, financial war, and conventional military offenses and defenses, all of which are evolving and changing in ways impossible to understand and predict. A stable "balance of terror" therefore cannot be assumed, especially given new geopolitical realities, one feature of which is unpredictability.

One certainty is that nuclear modernisation programmes will elicit compensatory responses from others. In the US, nuclear modernisation programmes require from one to three decades to complete; weapon service lives are in the 30 to 40 year range, expressive of great sunk costs, a political reality whether rational or not. For all these reasons, nuclear modernisation decisions will generate very long-lasting threats to the US and the world.

However, there is a great difference between modernisation aspirations on the one hand and practical accomplishment on the other. Virtually all the warhead and infrastructure modernisation projects in the Department of Energy (DOE) have experienced serious cost overruns and schedule delays that have selectively eroded support by congressional appropriators and the military, causing DOE to downscale, defer, or cancel several projects. Nuclear weapons programmes as a whole, including both DOE and the (larger) Department of Defense (DoD) programmes, face an approximate $10 billion/year shortfall starting in the early 2020s, roughly the total cost of modernisation across both DOE and DoD during this period and almost one third of nuclear weapons costs in all.[14]

More than just being limited by money shortfalls, modernisation programmes are also affected by persistent management problems in both DoD and DOE. One industry executive, expressing a common industry view, complained about "parts obsolescence, supply chain, employee recruitment and retention, funding and national program visibility."[15] DOE's warhead programmes have been on the Government Accountability Office's (GAO's) "High Risk" list for waste, fraud, and abuse since the early 1980s.[16]

Production of upgraded warheads competes for space, staff, and budget with warhead dismantlement at the Pantex nuclear weapons factory in Texas. At one time, the applicable rule of thumb for planning was that one upgraded warhead consumes the Pantex resources necessary to dismantle approximately two warheads.[17] It is a concrete metaphor for the peace and security consumed by modernisation.

Delivery systems

Submarines and SLBMs

The oldest of the 14 Ohio-class SSBNs is scheduled for retirement in 2027, a supposedly-firm date driven by reactor age and hull fatigue,[18] with one retirement to follow in each subsequent year through 2039 as later-built SSBNs age out. The first of 12 SSBN(X)s is expected to be deployed in 2031, with one subsequent boat entering service each year until 2042. This will give a minimum fleet size of 10 SSBNs from 2031 through 2040.

The SSBN(X), like the Ohio-class submarines it would replace, will carry Trident D5 missiles – 16 missiles each instead of the 24 on Ohio-class boats.[19] The launch tubes are to be in Common Missile Compartments (CMCs), each with four missiles, which will also be used on the UK's planned Vanguard- replacement SSBNs, which if built will also use D5 missiles. The UK Ministry of Defence is collaborating on the design of the CMC and so far has paid for most of design work.[20]

The D5 missiles are currently being upgraded for service through 2042 at a current steady annual cost of $1.2 billion, which in FY16 will buy 12 solid rocket motors, 35

Life Extension Program (LEP) kits, and other hardware.[21] In round numbers, D5 missiles cost $30 million each.[22] The Navy is very concerned about preserving the industrial base for large solid propellant rocket motors and can reasonably be expected to continue purchasing D5s for a long time both for its own use and for lease to the UK – should the UK continue to deploy SSBNs. Wolfsthal, Lewis, and Quint therefore use today's annual cost as a reasonable estimate of future D5 and successor missile costs, a $36 billion total over 30 years.[23]

The total estimated cost for the full multi-decade SSBN(X) procurement programme is speculative at this point but thought to lie in the vicinity of $100 billion – exclusive of missiles, warheads, deployment and other operational costs, DOE propulsion reactor development, and decommissioning.[24] Of that ballpark $100 billion, more than half will be spent – and more than half the boats purchased – before the first SSBN(X) goes into service in 2031.[25] For this reason, submarine-based nuclear modernisation costs, including warheads, will comprise more than half of all nuclear modernisation costs over the coming decade – $46 billion out of $79 billion.[26]

Funding the SSBN(X) presents something of a crisis for the Navy's ambitious plans to modernise and increase its overall fleet size, from 281 ships today to 306 ships by 2022.[27] Annual shipbuilding budgets have been about $16 billion for the past three decades. In a recent study, the Congressional Budget Office (CBO) estimates that the Navy's current plans will cost an additional $5 billion annually, i.e. $21 billion each year; the $5 billion annual increment is about the expected cost of each SSBN(X) past the first one, not counting initial development.[28]

According to CBO, under level extensions of the present $16 billion budget the best way to fulfill the Navy's "forward deployment" goals (read: power projection) would be to purchase 25% fewer ships of all kinds than planned, including 2 fewer SSBN(X)s. The 30-year price tag with level funding would then be $483 billion, instead of the $621 billion that CBO estimates is really needed for all the new ships the Navy wants. Should shipbuilding budgets fall below present levels to $14 billion annually, only 8 SSBN(X)s would be affordable and the Navy would build 1/3 fewer ships than it wants over the next 30 years. CBO's projections assume "business as usual" industry conditions, which as we note below may not always prevail. They do not include inflation, i.e. they are expressed in constant 2015 dollars.

As a first step in solving these funding problems Congress last year created a new military account, called the "Sea-Based Deterrence Fund," which remains to be filled with money.

The Navy has made clear on several occasions that the SSBN(X), which is slated to go into advance procurement in 2017 and full procurement in 2021, is its top priority – the plain meaning of which is that in the event of budget shortfalls and cost overruns it will protect the SSBN(X) over all other priorities.[29] It may have to do so. Whether the Navy is able to expand its annual shipbuilding budget, or move the SSBN(X) into the new "Sea-Based Deterrence Fund," as well as how many SSBN(X)s are actually built, all remain to be seen.

Intercontinental ballistic missiles (ICBMs)

The US has 450 Minuteman III silos controlled by 45 launch centers in three Air Force bases spread across parts of Colorado, Wyoming, Nebraska, Montana, and North Dakota. Each base is the home of a missile wing of 150 silos with 15 launch centers, divided into three squadrons, each with 50 silos. The US plans to empty 50 of these silos and maintain them in "warm" standby while storing their missiles elsewhere to meet New START requirements by 2018.
Minuteman III missiles carry the 335 kt W78 and 300 kt W87 warheads, currently in a single warhead configuration. The US stores an estimated 490 W78 and W87 warheads, beyond the number deployed. There are more than enough of the more modern W87 warheads to arm all the Minuteman missiles, but not enough to do so while also providing a significant upload hedge.[30]

Over the decade or so ending in 2012, the Air Force spent $7 billion replacing and upgrading nearly all components of these missiles, from the flight controls to the propellant in all three stages, to the guidance systems. According the Air Force they are "basically new missiles except for the shell." The last of the life extension work, which extends the service life of these missiles to 2030, is slated for completion this year.[31] Fuzing systems for both the Mark 12A reentry vehicle (RV) (for the W78) and Mark 21 (for the W87) were part of this upgrade, with what implications for burst accuracy we do not know.[32] But by 2010, the upgraded missile already had "expanded targeting options, improved accuracy and survivability," that is, significant new military characteristics.[33] Upgrades to the missile's silo-based and above-ground launch infrastructure are now a very high Air Force priority. Further upgrades to the missile system itself are as well, in part to sustain the industrial base and in part to continuously upgrade the missile and prepare for what will follow it.[34]

Given the already-extensive upgrades to the Minuteman system and its resulting capabilities, the Air Force fiscal year 2012 budget request contained no funds to even study a future ICBM.[35] The lack of such a study was however seen by Republicans as backtracking from a commitment made in 2010 to enable New START ratification.[36] The analysis of alternatives was subsequently funded in 2013 and completed in June of 2014. It examined options for sustaining ICBMs through 2075 that included incremental modernisation of the Minuteman III, an all-new ICBM, a rail-mobile ICBM, super-hardened silos, and an underground mobile missile moved from one silo to another by a vast underground subway-like network of tunnels.[37]

No final ICBM modernisation strategy has yet been announced, but the Air Force recently said its Minuteman follow-on system, now called the "Ground-Based Strategic Deterrent" (GBSD), is expected to cost \$40-\$ 60 billion and will be initially fielded in 2027. The Air Force is asking for a \$75 million appropriation in FY 2016 for GBSD, rising to \$325 million by FY 2020.[38] Supposedly, still, "nothing is off the table" to build a "faster, better, smarter" ICBM system.[39]

Another \$287 million is included in the Air Force's FY 2016 budget request for modernising the nuclear command, control, and communications (NC3) architecture, part of an estimated \$52 billion tab for upgrading NC3 for all nuclear systems over the decade to come (see also below). The NC3 architecture includes a nationwide network of underground wiring dating back to the 1960s, outdated computer systems running in some cases on 5½" floppy disks, and other anachronisms. At times the Air Force describes the launch systems as antiquated and, it implies, dangerous. Despite whatever dangers there may be above and beyond the dangers of the system itself, the Air Force suggests that following existing budget law will prevent needed improvements to outdated US command and control systems.[40]

Unlike bombers which can be recalled, and submarines that cannot be found in the sea and so need not be given an immediate order to launch, ground-based missiles can be destroyed by incoming missiles within a few minutes, creating institutional pressures to launch a nuclear attack almost instantly in the event of a perceived incoming attack. On 26 January2015, retired General James Mattis, former commander of US Central Command, said during a hearing of the Senate Armed Services Committee that "the government should consider eliminating the land-based leg of the nuclear triad," in part because it might reduce the risk of mistaken threats.[41] As noted below, this is also the recommendation of General Cartwright, another former STRATCOM chief, Chuck Hagel, and other senior figures.

Heavy bombers

The Long-Range Strike Bomber (LRS-B) programme aims to augment and gradually replace the current US heavy bomber fleet, starting in the late 2020s, after first delivery in mid-decade and subsequent flight testing.[42] The unclassified program began in 2012, but the short development path and low apparent R&D budget imply a longer and far more expensive "black" program.[43] R&D costs for a new bomber are typically in the \$20-45 billion range.[44]

According to the Air Force, this bomber represents an essential component in its evolving joint portfolio of conventional and nuclear deep-strike capabilities.[45] It is the conventional power projection and bombing role which is primary for the LRS-B; nuclear certification will come later and may "take some time."[46]

The existing US heavy bomber fleet consists of 76 B-52Hs, 61 B-1s (which are not nuclear-capable), and 20 B-2As.[47] The B-52H first entered service in 1961, the first B-1 in 1986, and the first B-2A in 2003. Their average airframe ages are 50, 28, and 20 years, respectively. The Air Force has extended the operational life of the B-52 and B-1 to 2040 and that of the B-2 to 2058.[48] All three bombers have been and still are being continuously upgraded and meticulously maintained, although there are also longevity challenges for each.

Importantly, these challenges are not strictly technical but are intertwined with issues of each airplane's unique capabilities and vulnerabilities, its numbers (low, in the case of the B-2), its basing limitations, its operating cost (very high, in the case of the B-2), the evolution of munitions and defensive capabilities, its supplier base (limited, in every case), and the evolution of land and ship-born air defences.

Even at 50 or more years, the B-52 remains robust. "Every aspect of the aircraft – structurally, the capability to hold weapons and avionics, the power – has large margins in it," according to Boeing's B-52 manager.[49] The B-52H is the Air Force's only nuclear bomber capable of deploying long-range standoff weapons. The B-1, meanwhile, has the largest internal bomb capacity, but is not stealthy. The B-2 is the world's only long-range stealth bomber.

There is a great deal of uncertainty, vagueness, and debate about what the missions of Air Force bombers actually are and will be, and therefore about the expected future relevance and role of each of its existing bombers as well as the proposed LRS-B. A significant and demanding part of the bomber mission is directed at "the Asia-Pacific region," i.e. China, and requires "continuous bomber presence… [specifically] at Anderson Air Force Base, Guam – and corresponding displays of worldwide power projection missions by all three bombers."[50] But assuming it is possible, is it really necessary or even desirable, even from the most hawkish perspective, to attempt to overcome the most modern future air defences, e.g. those of nuclear-armed China, with bombers?

One of the questions raised about the LRS-B is whether a human crew is necessary for conventional bombing missions. While initially the LRS-B will be deployed as a "manned" aircraft, it could eventually be "optionally" manned, but never for nuclear missions.[51]

Other uncertainties delayed the LRS-B. Would it be better to focus on a less-expensive stand-off bomber capable of launching cruise missiles, which is a mission the B-52 can do today? If a bomber is too expensive to risk, as the B-2 is today and as the LRS-B will also be if it experiences cost overruns, will it be unusable against all but the most helpless enemies? How many bombers are "needed," and how many tons of bombs and stand-off munitions will "need" to be dropped on what targets, which will have what defences? And what will it really cost? These and other questions have been asked pointedly at the highest levels in the military – especially, up to 2011 at least, by the then-Vice Chairman of the Joint Chiefs Gen. James Cartwright, who strongly opposed the LRS-B in favor of an inexpensive "truck" for delivering large quantities, if desired, of precision munitions – which describes, to our eye, the B-1 and B-52, for a long time to come. LRS-B got the go-ahead only after Cartwright was no longer able to stop it.[52] The LRS-B under development is rumored to be about half as large as the B-2A, which has the smallest payload of the three existing heavy bombers, with two engines similar in size to the engine on the new F-35.[53]

Since the B-52 the Air Force has had a poor record in bomber acquisition, the details of which are beyond this sketch. Will the LRS-B be any different? Experience suggests that it will be difficult to remain within the $550 million cost cap (exclusive of development costs) that was imposed by Secretary Gates when he finally approved the programme. The Air Force has already begun to back-track on this: "No, of course it's not going to be $550 million a copy, once you add in everything," said Air Force deputy acquisition chief Lt. Gen. Charles Davis last year.[54] A not-inconsiderable aspect of the LRS-B program is maintenance of the industrial and supplier base for combat aircraft. But with a starting cost of at least $550 million each, will there really be enough money and airplanes to accomplish this? In an attempt to mitigate this risk and to stretch out the cost, the Air Force proposes to buy a large number of LRS-Bs (80-100) over a relatively long period of time.[55]

To deliver the first LRS-B by the mid-2020s, the Air Force is asking for $1.2 billion in FY 2016, rising to $3.79 billion by 2020.[56] The full brunt of LRS-B acquisition begins concurrently with the SSBN(X), the F-35 Joint Strike Fighter, and a host of other Navy and Air Force acquisition programs, leading analysts like Todd Harrison at the Center for Strategic and Budgetary Assessment to conclude that there will simply not be enough money to buy it all.[57]

The Congressional Budget Office estimates that in the 2020s nuclear modernisation, all in all, will cost more than nuclear operating and sustainment combined. The Air Force LRS-B is responsible for the second largest portion of this, behind the Navy's SSBN(X), with the Air Force projected to spend $21 billion on new bombers over the next 10 years (vs. $19.2 billion for bomber operations and sustainment).[58] A separate nuclear deterrence account for the Air Force, like that for the Navy, is under consideration, but a new account does not create new money.[59]

Assuming the LRS-B were "necessary," could it be delayed? The continued airworthiness of the three existing bombers, with their diverse capabilities and large combined numbers, is not in question. The nuclear mission of the B-2 and B-52 is not a significant factor in driving the new bomber at this time. The answer to whether the LRS-B can be delayed really depends on the urgency of the mission proposed for it – which has nothing to do with defence.[60]

Warheads

The programme-of-record for DOE warhead modernisation is described at length in the most recent DOE Stockpile Stewardship and Management Plan.[61] DOE calls it the "3+2" plan because it would produce a single new gravity bomb to replace all others (the B61-12, to be replaced later by the B61-13), a new cruise missile warhead (the W80-4), and, eventually, three successive "interoperable" ballistic missile warheads, in the meantime pursuing life extension programmes (LEPs) to produce the W76-1 SLBM warhead and replace the fuze and high explosives in the W88 SLBM warhead ("Alteration 370"). LEPs for the W87 warhead and the B61-7 and B61-11 bombs have already been completed. As noted above, the 3+2 plan is unlikely to be realized and was widely considered "dead on arrival" as written when first proposed.

The 100 kt W76-1 provides significant and potentially destabilising new military capabilities to the ballistic missile submarine fleet, as noted above. About 3,030 W76 warheads were in the stockpile in 2007; an estimated 1,600 W76-1s will be produced from this inventory.[62]

The B61-12 LEP will consolidate the roles of the existing B61-3, B61-4, B61-7, and B61-10 bombs with one new bomb, the B61-12, using the B61-4 nuclear explosive with selectable yields from 0.3 to 50 kilotons (kt). When the B61-12 is deployed, the B61-7, B61-11, and B83 strategic bombs will be placed in the hedge arsenal or retired, leaving just one type of gravity bomb. About 480 B61-12s are planned, giving a unit cost of at least $22 million per bomb, including the DoD-funded precision guided tail kit but not including unspecified DoD and DOE programme costs.[63] The B61-12 is to be deliverable by the B-2, F-15E, F-16, and Tornado aircraft and later by the F-35A and Long Range Strike Bomber (LRSB).

Given the apparent failure of opposition to the B61-12 to date, it may be well to also focus on insuring the full retirement and dismantlement, and not just the storage, of the balance of the gravity bomb inventory.

The W88 Alt 370 programme, scheduled to begin as the W76-1 production run ends in 2020, will install a new arming, firing, and fuzing (AF&F) system to replace the original late-1980s AF&F and will also replace ("refresh") the warhead's conventional high explosive (CHE), allowing the upgraded 475 kt warhead to remain deployed through the late 2030s.[64]

A senior official has described the Long-Range Stand-Off (LRSO) warhead as a "no-kidding new warhead."[65] A W80 warhead variant, dubbed "W80-4," has been selected for this new delivery system.[66] No new plutonium warhead core ("pit") production is required for this warhead. W80 and W80-1 yields are selectable from 5 kt up to the 150-200 kt range.[67]

In 2014, the first of the three proposed "interoperable" warhead (IW) programs was delayed by five years, to 2030, reflecting the lack of any near-term need and poor military acceptance.[68] IW-1 is to be based on the 300 kt W87. IW-1 would not require a pit production campaign to arm existing ICBMs with new "W87-like" warheads but would if an upload hedge for ICBMs is also desired, or if W88 warheads are also replaced as is currently planned in the late 2030s.[69] Pit production costs (for operations, infrastructure upgrades, and waste management) are huge – in the $10+ billion range over the next two decades, and if attributed to IW-1 would roughly double its costs.

Meanwhile the future of the IW concept as a whole is now in doubt.[70] Current plans entail separate new fuzing systems for the ICBM and SLBM component of IW-1 as well as separate production schedules. "IW-2" and "IW-3," which are not slated to begin even as conceptual design programs until 2023 and 2030 respectively, are not fully described in any public documents and can be considered placeholders.[71]

Economics

Nuclear weapon costs occur in both the DOE and DoD budgets. The DOE budget request for fiscal year 2016 includes $8.847 billion for nuclear weapons activities, not including $283 million in related administrative costs. This is a proposed 10% increase from 2015, an annual growth rate exceeded only twice in US history (1962 and 1982).[72] It is higher in constant dollars than the last peak in

nuclear warhead spending for development, testing, and production under President Reagan in 1985.[73] Current budget projections entail continuous cost increases through 2040.[74]

Over the past years there have been many reports and studies on the cost of the US nuclear programme and possible options for savings.[75] In December 2013 the Congressional Budget Office (CBO) published an authoritative report assessing the projected costs of the US nuclear forces for the 2014–2023 timeframe, utilising long-term cost databases maintained by CBO and with full access to Department of Defense data.[76] This study was updated in January 2015.[77] According to CBO, maintaining and modernising the current US stockpile will cost $348 billion over the 2015–2024 decade, including about $79 billion for modernisation sensu stricta, exclusive of any abnormal cost overruns (which are in fact normal at DOE). Since most modernisation efforts are still in the initial phase, annual costs are expected to generally increase over the decade and continue to increase afterward.[78]

CBO's modernisation costs do not include all the weapon science programs and experimental facilities that underpin new warhead designs, or any portion of the operating costs of DOE warhead complex, little of which is needed for stockpile maintenance and surveillance exclusive of new production. CBO attributes only 25% of the estimated cost of the new strategic bomber to its nuclear mission, 10% of F-15E and F-16 costs, and no costs for the F-35, the most expensive weapon system in history, which will carry the B61-12 bomb.[79] CBO also does not include in its modernisation figure any of the $52 billion it estimates will be spent over coming decade on nuclear command, control, and communications (NC3).[80] CBO's estimates thus understate the modernisation portion of total nuclear weapon costs.

CBO's overall estimates are broadly consistent with a January 2014 independent study from the James Martin Center, which concluded that the total 30-year cost of the US stockpile (through 2042 in their study) would fall in the range of $1 trillion dollars, again assuming no unusual cost overruns.[81] Neither the CBO nor the James Martin Center totals include the ongoing cleanup of the large, contaminated DOE warhead complex, some portion of which is necessary for continued operations.

Modernisation costs can be somewhat artificially divided into those for warheads proper, the so-called "life extension programs" (LEPs), DOE costs for modernising and maintaining the warhead factories and labs which produce them, DoD costs for delivery systems, and other DoD costs. DOE reports the total estimated cost for currently-proposed LEPs, not including facility costs and other supporting programmes and overhead, as follows:[82]

DOE's programme costs usually exceed the agency's high-end estimates, often greatly. These are warhead and bomb costs only.

DOE's total estimated nuclear weapon cost through 2040 is in the ballpark of $250 billion in constant 2015 dollars assuming 2% inflation, or $300 billion if then-year dollars are simply summed. These totals include LEPs, operation and modernisation of production infrastructure, weapon science, and all other "Weapons Activities" costs but they do not include DOE administration.[83] DOE administration of its nuclear weapons contractors has been running about $300 million per year.[84]

The discussion and table below omit completed LEPs: the W87 (1999-2005) and the combined B61-7 and B61-11 LEP (2006-2009).[85]

One of the main obstacles to US nuclear weapons modernisation plans may be the erosion of the ability of the US military-industrial complex to complete ever-more complex manufacturing and industrial projects. Work on a major plutonium facility on which more than $600 million already had been appropriated was postponed for at least five years after litigation halted incipient construction and

Total Estimated Costs for DOE Life Extension Programs, Millions of 2015 dollars (high estimates)						
Warhead/ Bomb	DOE cost	DoD cost	Total	First production	Completion	Completion
W76-1	4,397	Not reported	>4,397	2008	2020	SLBM, 1600 units
B61-12	9,278	1,422	10,700	2020	2025	Bomb, 480 units
W88 Alt 370	2,690	1,176	3,866	2020	2025	SLBM, 400 units
W80-4	7,845	207	10,997	2025	2032	Cruise missile
IW-1	11,682	3,152	14,834	2030	2043	Replaces W78 & W88
IW-2	12,139	3,152	15,291	2034	2049	R. W87, W76, ICBM?
IW-3	11,047	3,152	11,254	~2041	2057	R. SLBM?
B61-13	11,323	207	11,530	2040s	2057	Replaces B61-12
Total	70,401	12,468	>83,076			

costs ballooned to more than ten times original estimates.[86] After 13 years of work, the project was finally canceled, only to be replaced with a new multibillion-dollar plan with crucial details still "to be determined."[87] Eight different plans to replace and modernise production of plutonium pits in the US have failed over the past 25 years.[88] Construction of a new Uranium Processing Facility (UPF) has been delayed more than a decade and its costs too have increased more than tenfold.[89] The project has now been significantly down-scoped; its new design is still mostly under wraps.[90] Robert Alvarez, a former senior DOE and now private analyst, describes the DOE warhead complex as being in a state of "incipient collapse."[91] Some current and former congressional and executive branch analysts and managers express similar concerns in private. Reasons cited typically include rampant mismanagement, runaway overhead and salaries, and other consequences of privatization, mal-investment, poor employee morale, unaccountable contract structures, internal and external deception, and loss of essential skills.

International law and doctrine

More than four decades after the United States signed and ratified the nuclear Non-Proliferation Treaty (NPT), it retains a nuclear arsenal large enough to end civilization, if not human life, in a few minutes.[92] None of its bilateral reduction agreements with Russia fundamentally change the character or posture of nuclear weapon deployments, or the consequences should deterrence fail. Stockpile reductions, which began in 1968, are not disarmament, and in any case no further reductions are currently planned or being negotiated. There are strong disagreements between Russia and the US concerning compliance with the Intermediate Range Nuclear Forces (INF) Treaty.

The US has signed but not ratified the Comprehensive nuclear Test Ban Treaty (CTBT); ratification was rejected by the US Senate in 1999 even after a bargain was made to modernise its nuclear weapons infrastructure in exchange for ratification. The Obama administration has stated that CTBT ratification "remains a top priority for the United States"[93] but there are no realistic near-term prospects for ratification. If the past is any guide, any attempt to obtain consent for ratification from the Senate, which has not occurred since 1999, is likely to be accompanied by new programmatic and funding commitments to the nuclear weapons establishment as was the case for New START, the ratification of which required a three-decade commitment to comprehensive force modernisation. There has been no technical need, or any expressed desire, for nuclear testing in or from the US warhead complex for almost 20 years. The negative consequences of nuclear testing for US security are very well-established throughout the foreign policy establishment. As a result there is no realistic prospect of resuming nuclear testing by the US. CTBT ratification by the US, or its continued absence, have no influence on US modernisation decisions or on US nuclear stockpile decisions generally.

At the conclusion of the 2000 NPT Review Conference, the US agreed that a no-backtracking "principle of irreversibility" applies to nuclear disarmament. Yet endless modernisation of the research laboratories and factories necessary to design and produce nuclear weapons is inherently incompatible with any "principle of irreversibility" in regard to disarmament. Doing so with the express intention of being able to re-arm, and to permanently hold open the potential to reconstitute large nuclear arsenals throughout the course of disarmament, also is inconsistent with an "unequivocal undertaking" to eliminate nuclear arsenals.

The US announced its withdrawal from the Anti-Ballistic Missile Treaty in 2001; continuing US development and deployment of ballistic missile "defence" systems is a serious impediment to further disarmament progress as well.

The US 2010 Nuclear Posture Review (NPR) states that the US will keep relying on its nuclear weapons as an important part of its national security and will also do this for the foreseeable future.[94] On 19 June 2013 President Obama announced in Berlin that his administration would, together with its NATO allies, seek "bold reductions in US and Russian tactical nuclear weapons in Europe."[95] On the same day, however, the US administration published a report on President Obama's new guidance on the employment of nuclear weapons.[96] Among other things, the report reaffirmed that "as long as nuclear weapons exist," the United States will maintain a "safe, secure and effective arsenal for its protection and that of its allies."[97] At the third conference on the humanitarian impact of nuclear weapons, hosted by Austria in December 2014, the US representative stated that his government "does not support efforts to move to a nuclear weapons convention, a ban, or a fixed timetable for elimination of all nuclear weapons."[98]

Public discourse

Recent scholarship confirms that US public opinion is not at all correlated with the outcome of congressional policy debates.[99] This is not a recent phenomenon, but recent trends in campaign finance law have certainly not improved the situation. Nuclear weapons policy, for example regarding modernisation, is among the most arcane topics in the national security field, itself the largely inaccessible "home turf" of what former congressional staffer Mike Lofgren has called the "Deep State".[100] For these reasons, among many others, it is no surprise that there is little public discussion or debate about US nuclear weapons policies.

What civil society discussion there is about US nuclear weapons policy is dominated by NGO specialists and skewed towards drumming up fear of nuclear weapons coming into the possession of non-nuclear weapon states or non-state actors, rather than pointing to the very real dangers posed by nuclear weapons held as central elements of national security policies in the hands of the world's most powerful states. Despite this, there is also an undercurrent of concern and at times anger expressed in editorial pages and at times in Congress, directed more often at DOE than DoD, about nuclear weapon costs, federal and contractor competence, worker and public safety, and the relevance of the entire enterprise at its present scale to national security.[101]

With minor exceptions, US NGO arms control and disarmament organisations, when presented in 2010 with the political necessity of a comprehensive commitment to modernising every part of the US nuclear stockpile, including delivery systems and supporting laboratories and production plants, in order to gain the 67 Senate votes necessary to ratify New START, chose to actively or passively support the full modernisation program.[102] Loyalty to Democratic allies and to New START – despite the absence of significant disarmament requirements in the latter – were deemed more important than any concerns about modernisation. Modernisation commitments were by contrast taken very seriously by Republicans and the nuclear weapons lobby. Subsequent deviations from those promises have elicited very strong congressional responses, often bipartisan in the Senate, centered in the armed services committees. Post-New START efforts by NGOs to trim or postpone them have so far been largely ineffective, with the exceptions of the new plutonium and uranium production facilities, the first of which was delayed by litigation and subsequently canceled and the second, downsized under budget pressure.[103]

US NGO critiques of modernisation are typically focused on degree. For example there is little objection to modernising the B61 tactical gravity bomb to some degree. The modernisation component that mainly has been considered objectionable in this case is the precision-guided tail kit, which very much changes the character and potential target set of the weapon. Simpler and cheaper upgrades would not however be as long-lived or offer the novel military characteristics desired, and at this point have been definitely rejected. There is almost no NGO objection to the scale and cost of the warhead complex as a whole, which in effect subsidizes each specific modernisation program with a much larger overhead that is tacitly accepted – again, with some exceptions –by US NGOs, blunting arguments raised about cost.

It is difficult to concisely summarize the chaotic currents of Congress, but those currents certainly do not run toward disarmament. Not one member of Congress publicly opposes a policy of nuclear "deterrence" and "mutual assured destruction" based on a triad of modernised or new delivery systems with thousands of nuclear warheads. In the United States, disarmament remains an abstract aspiration if not just a propaganda theme. The pursuit of global military dominance backed by constantly modernised nuclear weapons remains the concrete reality.

The proposed "Smarter Approach to Nuclear Expenditures (SANE) Act of 2015" (S.831), introduced by Senator Markey, two other liberal Democrats, and one independent liberal in the Senate on 23 March 2015, is illustrative of the state of the disarmament and modernisation debate in Congress.[104] This is the fourth year that Senator Markey (formerly Representative Markey) and his House colleague Rep. Blumenauer have introduced versions of this legislation in the House and now also the Senate. It is supported by many of the largest US arms control NGOs as well many others.[105]

Successive versions of the proposed SANE Act have attracted little serious legislative interest. The first version, in 2012 (H.R.3974, 112th Congress) had 48 (Democratic Party only) cosponsors (out of 435) but died in the House Armed Services Committee without a recorded vote. There was no companion senate bill. In 2013, the next version (H.R.1506, 113th Congress) had 41 (Democratic Party only) cosponsors, again with no companion senate bill and no recorded vote. In 2014 the SANE Act (S.2070 and H.R.4107, with the same text but called the "REIN-IN Act" in the House, 113th Congress) had 13 House cosponsors (Democratic Party only) and two Senate cosponsors, again with no recorded votes in either house.[106]

This year's SANE Act is similar to preceding years. It proposes to save $86 billion over 10 years from nuclear weapon modernisation programs by: immediately reducing the number of SSBNs operated by the Navy from 14 to 8 and delaying (but not canceling) the acquisition of the SSBN(X); delaying (but not canceling) development and purchase of a new Long Range Strike Bomber (LRSB); canceling the F-35's nuclear mission ($400 million only); reducing the scope of (but not canceling) the B61-12 LEP; delaying (but not canceling) development of a new ICBM; canceling the proposed new cruise missile (LRSO); and canceling the W78 LEP (meaning the warhead would be retired in about 2030) and the Uranium Processing Facility (UPF), without however providing for a safe uranium facility for dismantlement. None of the successive SANE acts have addressed the Cold-War-sized DOE laboratory complex, and none address stockpile size. The modernisation delays proposed would last until the end of the Act's 10-year accounting period, after which the delayed work and its costs would reappear in amplified form. The costs of interrupting work now in progress, e.g. on SSBN(X) procurement, would be very substantial in both dollar and management terms. Thus the SANE Act "savings" of $86 billion would be substantially, though not wholly, eventually forfeited in the absence of further legislation.

The SANE Act, which has no legislative prospects in this or any foreseeable session of Congress, does not lay the groundwork for potential future bipartisan support. Nor does it address the unresolved issues of DOE accountability, which already attract considerable bipartisan interest. These defects notwithstanding, the lack of legislative interest in this bill is indicative of the wider atmosphere in Congress in which neither party has any visible interest in nuclear disarmament and only a little interest in second-guessing the executive branch's modernisation decisions.

More broadly, the post-New-START search, on the part of US arms control NGOs and their congressional allies, for the elusive modernisation "sweet spot" has been unsuccessful, with the exception of plutonium and uranium facility plans. Rapidly rising tensions with Russia, consciously provoked by recent US actions, have all but doomed such efforts for the foreseeable future.[107] As one long-time government analyst put it, "[t]he fight against the B61-12 was lost on the streets of Kiev."[108]

Efforts to delay or rein in modernisation that remain within the mainstream nuclear "deterrence" paradigm of thousands of warheads of multiple types, delivered by a triad of delivery systems and including both extended deterrence and tactical nuclear weapons, all of which are supported by a large laboratory and production plant complex, can at best offer modest savings – so modest as to be hardly worth the candle. The budgetary savings available from a more modest B61 overhaul that would last only one decade instead of two and would not allow retirement of several other types of bombs, was not enough to motivate Congress to override military wishes. To save significant sums and to motivate new political allies, more fundamental questions must be raised about nuclear deterrence policies than those being raised in Washington today. Small proposed policy adjustments will garner little attention.

The main loci of government concerns about modernisation overreach and programme accountability more generally are the two appropriations committees, which must balance warhead budgets with others within a finite budget, the White House budget office, and finally the military itself, which as noted above has no identified source of funding for the increase in nuclear modernisation costs expected in the 2020s. The nuclear weapons share of overall military spending must double in the 2020s, from 2.6% to 5% or 6%, if all the planned nuclear modernisations are to proceed.[109] Either the overall size of the military budget must grow, other military accounts must shrink, or some of both, for nuclear modernisation to proceed.

Budget conflicts over modernisation are already intense. DOE Secretary Moniz recently testified that the LRSO in particular could be delayed as other programmes already have been delayed, if existing, bipartisan-enacted, military budget caps are not to be loosened this year.[110] Whether, and if so how, that budget law is changed, and not the merits of the LRSO, may well determine that program's fate, despite the fact that as a new strategic nuclear weapon suitable for a stealthy first strike, and not countable under New START, there is a lot about this weapon to discuss.

Current majority party proposals to raise caps on military spending involve massive cuts to social programs.[111] The future of US nuclear modernisation, and of US nuclear weapons generally, is likely to be decided by these and other budget tradeoffs as well as by the impact of unforeseen events arising outside and independent of the "ordinary" policy planning process.[112]

Deep cuts are possible and have been considered. By early 2013, DoD, senior military officers, and all other relevant agencies had signed off on a classified decision directive that would allow negotiated cuts to the deployed strategic US stockpile of about one-third. With cuts to the hedge arsenal, an overall stockpile of 2,500 to 3,500 warheads was possible. A negotiated cut to 500 deployed strategic warheads was considered but rejected.[113] For one reason or another that plan was not implemented, but its consensus logic very likely remains intact, classified though it be. Other recent proposals for still deeper cuts have been made, notably a detailed proposal by former Vice Chair of the Joint Chiefs and former STRATCOM Commander in Chief General James Cartwright, former Senator and now former Secretary of Defense Chuck Hagel, and other senior authors, which would in ten years lead to an arsenal of 900 total warheads, half of which would be deployed in a dyad of delivery systems, without ICBMs, and without tactical nuclear weapons.[114] Whether, when, and how these proposals will inform future stockpile decisions remain to be seen.

Those contemplating the modernisation programme must ask, does nuclear modernisation really, as some say, "challenge the entire disarmament regime"?[115] There is no disarmament regime. Modernisation challenges and hopefully dispels the myth that there is now, or will soon be, any "disarmament regime" in the US, or emerging from any US-led process. As former Obama White House nuclear czar Gary Samore recently put it, "Nuclear disarmament is not going to happen…It's a fantasy. We need our weapons for our safety, and we're not going to give them up."[116]

Notes:

1. "New START Treaty Aggregate Numbers of Strategic Offensive Arms," *U.S. Department of State*, 1 April 2015, http://www.state.gov/t/avc/rls/240062.htm.
2. "US nuclear forces, 2015," Hans M. Kristensen and Robert S. Norris Bulletin of the Atomic Scientists, March 2015, pp. 107-119. http://bos.sagepub.com/content/71/2/107.full.pdf+html. The Government Accountability Office (GAO), with access to classified stockpile data unavailable to Kristensen and Norris, says there are "several thousand" intact, retired warheads. "Nuclear Weapons: Actions Needed by NNSA to Clarify Dismantlement Performance Goal," GAO-14-449, 30 April, 2014. http://www.gao.gov/products/GAO-14-449. See "U.S. claims of nuclear weapons retirement, dismantlement "may be misleading" – GAO," Los Alamos Study Group, 1 May 2014, http://www.lasg.org/press/2014/press_release_1May2014.pdf.
3. In 2009 there were "more than 14,000" pits in storage at the Pantex plant. It was thought at the time Pantex might exceed its storage limit of 20,000 pits by 2014. See Jim McBride,"Pantex may hit storage limit in 2014," *Amarillo Globe-News*, 29 January 2009,http://amarillo.com/stories/012909/new_12389377.shtml. By 2013 dismantlement had added 1,560 pits. Only a few pits have left the site. For secondaries and other parts, see GAO, *op. cit.*
4. GAO, *op. cit.*
5. Kristensen and Norris, *op. cit.* Kristensen and Norris say there are 93 B-52H bombers, but the Air Force lists a total B52 inventory of only 76 planes. "FY 2016 Budget Overview, Appendix, A-37," United States Air Force, February 2015, http://www.saffm.hq.af.mil/shared/media/document/AFD-150210-042.pdf. The Congressional Research Service also says there are 76 B-52s. "CRS Insights, Budget Highlight: Air Force Long Range Strike Bomber," Gertler, Jeremiah, 2 July 2014, http://fas.org/sgp/crs/weapons/IN10095.html. All US ICBMs have been de-MIRVed as of 16 June 2014. "Last Malmstrom ICBM reconfigured under treaty," *Air Force Times* 19 June 2014, http://archive.airforcetimes.com/article/20140619/NEWS04/306190038/Last-Malmstrom-ICBM-reconfigured-under-treaty. US SLBMs could in theory deliver up to 2,688 W76-0, W76-1, and W88 warheads at 8 warheads per missile.
6. "Weapons Carriage Capability of the B-52H," B-52 Stratofortress Association [accessed 24 March 2015], http://www.stratofortress.org/current-operations.htm; Kristensen and Norris, op. cit.
7. Kristensen and Norris, *op. cit.*
8. *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament, Seventh annual report of the International Panel on Fissile Material, October 2013*, p. 11. http://ipfmlibrary.org/gfmr13.pdf; "The United States Plutonium Balance, 1944-2009," U.S. Department of Energy, 26 June 2012, http://www.lasg.org/technical/PU_rpt_rev_26Jun2012.pdf.
9. Department of Energy FY 2016 Congressional Budget Request, Vol. 1: National Nuclear Security Administration, February 2015, http://energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume1_1.pdf. "Fiscal Year 2016 Stockpile Stewardship and Management [SSMP] Plan: Report to Congress," March 2015, Department of Energy, http://nnsa.energy.gov/sites/default/files/FY16SSMP_FINAL%203_16_2015_reducedsize.pdf.
10. "That Old Designing Fever," Greg Mello, *Bulletin of the Atomic Scientists*, January 2000, pp. 51-57. Archived without paywall at http://lasg.org/DesigningFever.pdf. George Lewis and Theodore A. Postol, "The Capabilities of Trident against Russian Silo-Based Missiles: Implications for START III and Beyond," presentation at "The Future of Russian-US Strategic Arms Reductions: START III and Beyond" conference, Cambridge, MA, USA, 2 February 1998. Todd Jacobson, "Accelerated Return of W76-0 Warheads from Navy to NNSA on Track," *Nuclear Security and Deterrence Monitor*, 6 February 2015 (paywall).
11. Hans Kristensen, "B61 LEP: Increasing NATO Nuclear Capability and Precision Low-Yield Strikes," Federation of American Scientists, 15 June 2011, http://fas.org/blogs/security/2011/06/b61-12/.
12. Hans Kristensen, "General Confirms Enhanced Targeting Capabilities of B61-12 Nuclear Bomb," FAS Strategic Security Blog, 23 January 2014, http://fas.org/blogs/security/2014/01/b61capability/. Hans Kristensen, "B61-12: The New Guided Standoff Nuclear Bomb," presentation at the NPT Preparatory Committee meeting, 2 May 2014, http://fas.org/programs/ssp/nukes/publications1/Brief2014_PREPCOM2.pdf.
13. "Nuclear Posture Review," DoD, April 2010, http://www.defense.gov/npr/docs/2010%20Nuclear%20Posture%20Review%20Report.pdf.
14. Todd Jacobson, "As Admin. Makes Pitch for Modernization Support, 'Affordability Problems' Loom," *Nuclear Security and Deterrence Monitor*, 6 March 2015, http://www.lasg.org/press/2015/NSDM_6Mar2015.html.
15. Brian Bradley, "Industry Confronting Multiple Issues with Aging Triad," *Nuclear Security and Deterrence Monitor*, 6 March 2015.
16. "Department of Energy's Contract Management for the National Nuclear Security Administration and Office of Environmental Management," GAO, GAO-15-290, 11 February 2015, http://www.gao.gov/highrisk/doe_contract_management/why_did_study.
17. Philip Coyle, former senior nuclear laboratory and DoD weapons official, interview with Greg Mello, mid-2000s.
18. If policy allowed a minimum fleet of 8 SSBNs instead of 10, five could be decommissioned now, saving their operational costs and allowing postponement of SSBN(X) procurement by two years. If it were possible to conserve reactor fuel and hull life by taking some of the next oldest submarines off patrol, SSBN(X) procurement could also be delayed. Short of these measures, each year of further delay in SSBN(X) procurement lowers the minimum fleet size by one boat.
19. "Navy Ohio Replacement (SSBN[X]) Ballistic Missile Submarine Program: Background and Issues for Congress," O'Rourke, Ronald, Congressional Research Service (CRS), 24 March 2015. http://fas.org/sgp/crs/weapons/R41129.pdf.
20. Ibid.
21. "Program Acquisition Cost by Weapon System, Trident II Ballistic Missile Modification, United States Department of Defense Fiscal Year 2016 Budget Request, February 2015, Office of the Under Secretary of Defense. http://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2016/FY2016_Weapons.pdf.
22. "Navy Extends Trident II D5 Nuclear Missile Service Life," Osborn, Kris, 11 April 2014, defensetech.org, http://defensetech.org/2014/04/11/navy-extends-trident-ii-d5-nuclear-missile-service-life/.
23. Wolfsthal, J.B., Lewis, J., and M. Quint, "The One Trillion Triad – US Strategic Nuclear Modernization Over the Next Thirty Years," James Martin Center for Nonproliferation Studies, January 2014, http://cns.miis.edu/opapers/pdfs/140107_trillion_dollar_nuclear_triad.pdf.
24. See "The $100 Billion Boomer Bill" in "Stackley: Navy Needs to Develop Weapons Faster, Congress Should Rollback Restrictive Legislation," LaGrone, Sam, *USNI News*, 7 January 2015, http://news.usni.org/2015/01/07/stackley-navy-needs-develop-weapons-faster-congress-rollback-restrictive-legislation. CBO estimates the current cost as $92 billion. See "Preserving the Navy's Forward Presence with a Smaller Fleet," March 2015, CBO, https://www.cbo.gov/sites/default/files/cbofiles/attachments/49989-ForwardPresence-2.pdf. See also "Navy Official: Congress, Navy Need to Have 'Very Important Discussion' on Ohio Replacement Funding," Bradley, Brian, *Nuclear Security and Deterrence Monitor*, 9 January 2015 (paywall). For prior estimates ranging to $102 billion (in 2013 or 2014 dollars) see footnote 19 in Wolfsthal, J.B., Lewis, J., and M. Quint, *op. cit.* Recently a figure of $139 billion was used by Rear Adm. Breckenridge, Director, Navy Warfare Integration Division, for the total SSBN(X) program cost; see "Navy Might Have to Look Outside Itself to Fund Ohio-Class Replacement," Bradley, Brian, *Nuclear Security and Deterrence Monitor*, 20 March 2015 (paywall).
25. "Projected Costs of U.S. Nuclear Forces, 2015 to 2024," CBO, 22 January 2015 with supplementary tables, https://www.cbo.gov/sites/default/files/cbofiles/attachments/49870-NuclearForces.pdf (main report), https://www.cbo.gov/publication/49870 (includes links to tables). For procurement schedule see CRS, 2015, *op. cit.*
26. CBO, "Projected Costs…2015 to 2024," *op. cit.*
27. "Preserving the Navy's Forward Presence with a Smaller Fleet," March 2015, CBO, https://www.cbo.gov/sites/default/files/cbofiles/attachments/49989-ForwardPresence-2.pdf.
28. Ibid. and CRS, "Navy Ohio Replacement (SSBN[X])…" *op. cit.*
29. CRS, "Navy Ohio Replacement (SSBN[X])…" *op. cit.*
30. See chart, p. 21, in "U.S. Plutonium 'Pit' Production: Additional Facilities, Production Restart are Unnecessary, Costly, and Provocative," Los Alamos Study Group, January 2010, http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/066B_Pit%20management%20recommendations%20Mello%201-22-10.pdf.
31. "Life Extension Programs send missiles into the future," Pampe, Carla, 24 October 2012, Air Force Global Strike Command, http://www.afgsc.af.mil/news/story.asp?id=123323606.
32. "Sustainment efforts hitting their stride," Kleiman, Michael, 377th Air Base Wing Public Affairs, http://www.kirtland.af.mil/news/story_print.asp?id=123266882. Cited by Kristensen and Norris, 2015, op. cit. For implications of new fuzing for W76-1, see text and note 10.
33. "LGM-30G Minuteman III," US Air Force fact sheet, 26 July 2010, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104466/lgm-30g-minuteman-iii.aspx.

34. Re "the missile itself:" "USAF to Award ICBM Ground Subsystem Contract This Month Under New Contracting Structure," Bradley, Brian, 9 January 2015, *Nuclear Security and Deterrence Monitor* (paywall); "Lockheed and Boeing Teaming Up on GBSD Guidance System," Bradley, Brian, 16 January 2015, *Nuclear Security and Deterrence Monitor* (paywall).
35. "Pentagon Budget Omits Funds for Promised ICBM Modernization Study," 16 February 2011, Grossman, Elaine, *Global Security Newswire*, http://www.nationaljournal.com/nationalsecurity/pentagon-budget-may-omit-funds-for-promised-icbm-modernization-study-20110215.
36. "Update to the National Defense Authorization Act of FY2010 Section 1251 Report, 'New START Treaty Framework and Nuclear Force Structure Plans,'" 17 November 2010, DoD, http://www.lasg.org/budget/Sect1251_update_17Nov2010.pdf.
37. "Air Force Readies Contracts to Shape Minuteman III Modernization Plans," *Insidedefense.com*, 12 March 2013. "Air Force Set to Begin Briefing Leadership on Analysis of ICBM Alternatives," Jacobson, Todd, 27 June 2014, *Nuclear Security and Deterrence Monitor* (paywall). "Next-Gen ICBM Study Completed and Will Be Briefed to OSD This Month," *Inside the Air Force*, 19 June 2014, (paywall), https://defensenewsstand.com/topic/missiles-%26-munitions?page=9.
38. "New Ground-Based Strategic Deterrent Expected to Cost $40-$60 Billion, Official Says," Bradley, Brian, *Nuclear Security & Deterrence Monitor,* 6 March 2015 (paywall).
39. "Head of Air Force A10 Shares Details of GBSD, Takes on Modernization Critics," Bradley, Brian, 23 January 2015, *Nuclear Security and Deterrence Monitor* (paywall).
40. "B-2 DMS, Minuteman 3 NC3 Facilities Could See Cuts Under Sequestration," Bradley, Brian, *Nuclear Security & Deterrence Monitor,* 2 February 2015. (paywall)
41. Air Force and Navy Chiefs Make Case to SASC for Nuclear Enterprise Funding, *Nuclear Security & Deterrence Monitor,* 30 January 2015.
42. "U.S. Air Force Bomber Sustainment and Modernization: Background and Issues for Congress," Gertler, Jeremiah, Congressional Research Service (CRS), 4 June 2014, http://fas.org/sgp/crs/weapons/R43049.pdf.
43. "CRS Insights, Budget Highlight: Air Force Long Range Strike Bomber," Gertler, 2 July 2014, http://fas.org/sgp/crs/weapons/IN10095.html.
44. See Wolfsthal et. al. *op. cit.*
45. "FY 2016 Budget Overview," United States Air Force Appendix, CM-7, http://www.saffm.hq.af.mil/shared/media/document/AFD-150210-042.pdf
46. "Long-Range Strike Caucus Meets to Rally Support for Bombers," Bradley, Brian, *Nuclear Security & Deterrence Monitor,* 30 January 2015 (paywall).
47. United States Air Force FY 2016 Budget Overview, Appendix, A-37, http://www.saffm.hq.af.mil/shared/media/document/AFD-150210-042.pdf
48. "U.S. Air Force Bomber Sustainment and Modernization: Background and Issues for Congress," Gertler, Jeremiah, Congressional Research Service (CRS), 4 June 2014, http://fas.org/sgp/crs/weapons/R43049.pdf.
49. "Will the $55 billion bomber program fly?" Axe, David, 26 March, 2012, Center for Public Integrity, http://www.publicintegrity.org/2012/03/26/8498/will-55-billion-bomber-program-fly.
50. CRS, "U.S. Air Force Bomber Sustainment and Modernization," *op. cit.*
51. CRS Insights, *op. cit.*
52. Axe, *op. cit.*
53. "Shrouded in Mystery, New Bomber Makes Waves," Mehta, Aaron, *Defense News*, 19 January 2015, http://www.defensenews.com/story/defense/air-space/strike/2015/01/18/air-force-bomber-industry/21805275/.
54. "Air Force Brass: New Bomber to Exceed $550 Million Each," *Global Security Newswire*, 6 March 2014, http://www.nti.org/gsn/article/air-force-general-predicts-cost-new-bomber-will-exceed-550-million/.
55. See p. 29, CRS "U.S. Air Force Bomber Sustainment and Modernization" *op. cit.*
56. "Air Force, Riding Budget Boost, Warns On Sequester; U-2 is Back," Clark, Colin, *Breaking Defense*, 2 February 2015, http://breakingdefense.com/2015/02/air-force-riding-budget-boost-warns-on-sequester-u-2-is-back/
57. "LRS-B, Next Boomer May Force Weapons Cuts," *Breaking Defense*, 4 September 2014, http://breakingdefense.com/2014/09/lrs-b-next-boomer-may-force-weapons-cuts/.
58. "Projected Costs of U.S. Nuclear Forces, 2015 to 2024," CBO, 2015 *op. cit.*
59. Separate Air Force Nuclear Modernization Fund Gaining Traction, *Nuclear Security & Deterrence Monitor,* 30 January 2015.
60. CRS "U.S. Air Force Bomber Sustainment and Modernization" *op. cit.*
61. FY2016 SSMP, DOE, op. cit.
62. Stan Norris and Hans Kristensen, "The U.S. nuclear stockpile, today and tomorrow," and "U.S. Nuclear Forces, 2009," *Bulletin of the Atomic Scientists* Sept./Oct. 2007 and Mar./Apr. 2009. Kristensen 2015, *op. cit.*
63. Hans Kristensen, "B61-12: The New Guided Standoff Nuclear Bomb," presentation at the NPT Preparatory Committee meeting, 2 May 2014, http://fas.org/programs/ssp/nukes/publications1/Brief2014_PREPCOM2.pdf. Hans Kristensen, "B61-12: NNSA's Gold-Plated Nuclear Bomb Project", FAS Strategic Security Blog, 26 July 2012.
64. DOE FY2016 SSMP, *op. cit.*
65. Senior defence official to Greg Mello, circa 2010.
66. DOE FY2016 SSMP, *op. cit.*
67. In our experience, published warhead yields are usually ultimately sourced to the *Swords of Armageddon* research of Hansen, Chuck, http://www.uscoldwar.com/.
68. DOE FY2015 SSMP, Figure 2-2, http://nnsa.energy.gov/sites/default/files/nnsa/04-14-inlinefiles/2014-04-11%20FY15SSMP_FINAL_4-10-2014.pdf.
69. Los Alamos Study Group, January 2010, *op. cit.*, p. 20
70. Todd Jacobson, "Former LLNL Director: '3+2' Warhead Strategy Unlikely To Be Realized," *Nuclear Security and Deterrence Monitor*, 28 March 2014, http://www.lasg.org/press/2014/NSDM_28Mar2014.html.
71. DOE FY2016 SSMP, *op. cit.*
72. "Administration's nuclear warhead design, production budget larger than Reagan and Bush, again," Los Alamos Study Group, 2 February 2015, http://www.lasg.org/press/2015/press_release_2Feb2015.html.
73. [73] Ibid.
74. "FY2016 SSMP," DOE *op. cit.*
75. See for example: Rumbaugh, R. and Cohn, N., "Resolving Ambiguity: Costing Nuclear Weapons," June 2012: http://www.stimson.org/images/uploads/research-pdfs/RESOLVING_FP_4_no_crop_marks.pdf; Tom Collina,"U.S. Nuclear Modernization Programmes," Arms Control Association, August 2012, http://www.armscontrol.org/factsheets/USNuclearModernization;"What Nuclear Weapons Cost Us," Ploughshares Fund, September 2012, http://www.ploughshares.org/sites/default/files/resources/What%20Nuclear%20Weapons%20Cost%20Us%20Final%20(100212).pdf; Wolfsthal, J.B., Lewis, J., and M. Quint, *op. cit.*
76. "Projected Costs of U.S. Nuclear Forces, 2014 to 2023," CBO, 19 December 2013, http://www.cbo.gov/sites/default/files/cbofiles/attachments/12-19-2013-NuclearForces.pdf.
77. "Projected Costs of U.S. Nuclear Forces, 2015 to 2024," CBO, 22 January 2015 with supplementary tables, https://www.cbo.gov/sites/default/files/cbofiles/attachments/49870-NuclearForces.pdf (main report), https://www.cbo.gov/publication/49870 (includes links to tables).
78. CBO, 2013 and 2015. CBO's 2015 estimates show a slight peak in 2022 but DOE's more recent FY2016 SSMP does not. Full-scale DoD procurements for all the new delivery platforms come only after 2024.
79. CBO, 2013.
80. CBO, 2015.
81. Wolfsthal, Lewis, and Quint, *op.cit.*
82. "Fiscal Year 2016 SSMP," DOE, *op. cit.*
83. Ibid., Figure 8-12.
84. Department of Energy FY 2016 Congressional Budget Request, Vol. 1: National Nuclear Security Administration, February 2015, http://energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume1_1.pdf. Administrative costs for "Weapons Activities" can be computed pro-rata from overall Office of the Administrator costs.
85. See chart, p. 21, in "U.S. Plutonium 'Pit' Production: Additional Facilities, Production Restart are Unnecessary, Costly, and Provocative," Los Alamos Study Group, January 2010, http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/066B_Pit%20management%20recommendations%20Mello%201-22-10.pdf.
86. "CMRR cost history," Los Alamos Study Group, 8 August 2012, http://www.lasg.org/CMRR/CMRR_cost_history.pdf.
87. "$4.3 Billion in Additional Construction, Equipment Proposed for Los Alamos Plutonium Factory," Los Alamos Study Group, 28 August 2014, http://www.lasg.org/press/2014/press_release_28Aug2014.html.
88. Seven plans are mentioned in "U.S. Nuclear Weapon 'Pit' Production Options for Congress," Congressional Research Service, 21 February 2014, http://www.lasg.org/MPF2/CRS_Pit_Prod_21Feb2014.pdf, the eighth is the Chemistry and Metallurgy Research Upgrades project, 1992-2001.
89. Robert Alvarez, "Y-12: Poster child for a dysfunctional nuclear weapons complex," *Bulletin of Atomic Scientists*, 4 August 2014, http://thebulletin.org/y-12-poster-child-dysfunctional-nuclear-weapons-complex7361.
90. Todd Jacobson, "First Glimpse of Revamped UPF Provided by Contractor," *Nuclear Security and Deterrence Monitor,* 21 November 2014, http://www.lasg.org/press/2014/NSDM_21Nov2014.html.
91. Robert Alvarez to Greg Mello, February 2015.
92. See the archive by Steven Starr, http://www.nucleardarkness.org/.

Notes:

93. Rose Gottemoeller,"The Obama Administration's Second Term Priorities for Arms Control and Nonproliferation," Remarks at the Geneva Centre for Security Policy, 20 March 2013, http://www.state.gov/t/us/206454.htm.
94. "Nuclear Posture Review report", Department of Defense United States of America, April 2010, p. 1, http://www.defense.gov/npr/docs/2010%20Nuclear%20Posture%20Review%20Report.pdf.
95. Remarks by the President Obama at the Brandenburg Gate – Berlin, Germany, The White House Office of the Press Secretary, 19 June 2013, http://www.whitehouse.gov/the-press-office/2013/06/19/remarks-president-obama-brandenburg-gate-berlin-germany.
96. "Report on Nuclear Employment Strategy of the United States – Specified in Section 491 of 10 U.S.C.", US Department of Defense, 12 June 2013, http://www.defense.gov/pubs/ReporttoCongressonUSNuclearEmploymentStrategy_Section491.pdf.
97. Ibid.
98. Intervention during Session I, Vienna Humanitarian Impact of Nuclear Weapons Conference, "Impact of Nuclear Weapons Explosions" delivered by Ambassador Adam Scheinman, Special Representative of the President for Nuclear Nonproliferation, 8 December 2014, http://vienna.usmission.gov/141208nwe.html.
99. "The central point that emerges from our research is that economic elites and organized groups representing business interests have substantial independent impacts on U.S. government policy, while mass-based interest groups and average citizens have little or no independent influence." "Testing Theories of American Politics: Elites, Interest Groups, and Average Citizens," Gilens, Marten and Page, Benjamin I., *Perspectives on American Politics*, September 2014, Vol. 12/No. 3, pp. 564-581. http://scholar.princeton.edu/sites/default/files/mgilens/files/gilens_and_page_2014_-testing_theories_of_american_politics.doc.pdf.
100. "Anatomy of the Deep State," 21 February 2014, Lofgren, Mike. http://billmoyers.com/2014/02/21/anatomy-of-the-deep-state/.
101. Examples chosen somewhat at random from the *New York Times* include "Nuclear Time Warp," 10 June 2012, and "Throwing Money at Nukes," 26 May 2013, *New York Times* editorial board, http://www.nytimes.com/2012/06/11/opinion/nuclear-time-warp.html?_r=1&nl=todaysheadlines&emc=edit_th_20120611 and http://www.nytimes.com/2013/05/27/opinion/throwing-money-at-nukes.html?hp&_r=1 respectively. Even the generally-supportive *Albuquerque Journal* can be caustic regarding competence: "Bureaucratic ineptitude entrenched at LANL," *Albuquerque Journal* editorial board, 6 October 2013, archived at http://www.lasg.org/press/2013/ABQ_JRNL_6Oct2013.html. For more, see the running critical media archive at http://www.lasg.org.
102. "Update to the National Defense Authorization Act of FY2010 Section 1251 Report, 'New START Treaty Framework and Nuclear Force Structure Plans,'" 17 November 2010, DoD, http://www.lasg.org/budget/Sect1251_update_17Nov2010.pdf. This updated the May 2010 reports prepared pursuant to Section 1251 of the FY2010 National Defense Authorization Act in preparation for the December New START ratification vote. Further details are available for DOE's program in the May 2010 versions, archived at http://www.lasg.org/budget/NNSA_Planning_Budgeting.html.
103. Information regarding the canceled Chemistry and Metallurgy Research Replacement Nuclear Facility (CMRR-NF) can be found at http://www.lasg.org/CMRR/open_page.htm. The follow-on plutonium plan, not yet described, is discussed at http://www.lasg.org/MPF2/first_page.html. An overview of the Uranium Processing Facility (UPF) can be found at http://www.lasg.org/UPF/UPF_title_page.html.
104. Sen. Markey & Rep. Blumenauer Introduce Bicameral Legislation to Cut $100 Billion from Wasteful Nuclear Weapons Budget http://www.markey.senate.gov/news/press-releases/sen-markey-and-rep-blumenauer-introduce-bicameral-legislation-to-cut-100-billion-from-wasteful-nuclear-weapons-budget
105. Ibid.
106. Legislative history from the Library of Congress. Search by Congress (112th, 113th, or 114th) and bill number at http://thomas.loc.gov/home/LegislativeData.php?&n=BSS&c=114.
107. See for example, "Who's Telling the 'Big Lie' on Ukraine?", Parry, Robert, 2 September 2014, *Consortium News*, https://consortiumnews.com/2014/09/02/whos-telling-the-big-lie-on-ukraine/.
108. Anonymous congressional analyst to Greg Mello, 2014.
109. Todd Jacobson, "As Admin. Makes Pitch for Modernization Support, 'Affordability Problems' Loom," *Nuclear Security and Deterrence Monitor*, 6 March 2015.
110. Senator Udall: "Do you worry the threat of sequestration might hurt our modernization …?" Moniz: "Absolutely. In fact DoD & DOE, for our different but complimentary responsibilities for nuclear security, have both said that sequestration caps will make it very, very difficult. Frankly, if the budget that we have requested in concert with the DoD and the Nuclear Weapons Council is reduced substantially, I think that there is no doubt that we will have to work with DoD to push out [into the future] military capabilities that they very much want. In fact, in this budget, we were able – the B61, we would try to probably hold that, but then the cruise missile for example would almost certainly have to get pushed out substantially, as we have already pushed out other parts of the stockpile refurbishment." DOE Secretary Ernest Moniz, Senate Appropriations Energy and Water Development Subcommittee, webcast, begins at 1:10:50, http://www.appropriations.senate.gov/webcast/energy-water-development-subcommittee-hearing-fy16-department-energy-budget, accessed 31 March 2015.
111. See for example "Increased Military Spending Wins Out After Dueling Budget Votes in House," Weisman, Jonathan, 25 March 2015, *New York Times*, http://www.nytimes.com/2015/03/26/us/politics/increased-military-spending-wins-out-after-dueling-budget-votes-in-house.html?emc=edit_th_20150326&nl=todaysheadlines&nlid=21653813.
112. A short list of these "known unknowns" might include the risks of: additional costly accidents, fiascos, and shutdowns in the DOE warhead complex; financial and economic reversals that affect federal fiscal accounts; wars; environmental and public health calamities such as major droughts, epidemics, and earthquakes, as well as large-scale terrorist events with society-wide impacts, any or all of which could affect federal income and expense priorities (especially in the sensitive Energy and Water appropriations subcommittees); major cost overruns in military or nuclear weapons accounts; and a nuclear weapons ban that affects the perceived legitimacy, utility, and feasibility of contested nuclear weapons programs.
113. "Obama administration embraces major new nuclear weapons cut; Advisers reach consensus that current arsenals are larger than needed to target foes," Smith, R. Jeffrey Smith, 8 February 2013, http://www.publicintegrity.org/2013/02/08/12156/obama-administration-embraces-major-new-nuclear-weapons-cut.
114. "Modernizing U.S. Nuclear Strategy, Force Structure and Posture," James Cartwright et. al., May 2012, Global Zero, http://www.globalzero.org/files/gz_us_nuclear_policy_commission_report.pdf.
115. "Disarm and Modernize," Mecklin, John, *Foreign Policy*, 24 March 2015, https://foreignpolicy.com/2015/03/24/disarm-and-modernize-nuclear-weapons-warheads/.
116. "U.S. unease about nuclear-weapons fuel takes aim at a South African vault," Birch, Douglas, and Smith, R. Jeffrey, Center for Public Integrity, 14 March 2015, http://www.washingtonpost.com/world/africa/us-unease-about-nuclear-weapons-fuel-takes-aim-at-a-south-african-vault/2015/03/13/b17389f6-2bc1-4515-962d-03c655d0e62d_story.html.

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About the authors

Ray Acheson
is the Director of Reaching Critical Will. She monitors and analyses many international processes related to disarmament and arms control. Ray is the editor of RCW's reports and analyses of UN meetings and of several collaborative civil society publications. She represents WILPF on the International Steering Group of the International Campaign to Abolish Nuclear Weapons (ICAN) and is on the Board of Directors of the Los Alamos Study Group.

John Ainslie
is coordinator of the Scottish Campaign for Nuclear Disarmament. In addition to supporting the anti-nuclear weapons movement in Scotland he has carried out research into the history of the British nuclear weapons programme, the Polaris and Trident systems, and defence nuclear safety issues over the past 20 years.

Merav Datan
is an international lawyer and a former adjunct professor at Rutgers Law School. She is a board member of the Lawyers Committee on Nuclear Policy and former director of the Women's International League for Peace and Freedom's UN Office in New York. She has also worked as a consultant for the United Nations Department for Disarmament Affairs (WMD Branch) and as Middle East Political Advisor for Greenpeace International.

Hans M. Kristensen
is Director of the Nuclear Information Project at the Federation of American Scientists in Washington, D.C., where he researches and writes about the status and operations of nuclear forces of the nine nuclear weapon states. He is a frequent advisor to the news media on the status of nuclear forces and policy. Kristensen is co-author of the bi-monthly Nuclear Notebook column in the Bulletin of the Atomic Scientists and the World Nuclear Forces overview in the SIPRI Yearbook. Prior to his current position, Kristensen was a consultant to the Nuclear Program at the Natural Resources Defense Council in Washington, DC and Program Officer at the Nautilus Institute in Berkeley, CA.

Greg Mello
is the Executive Director and co-founder of the Los Alamos Study Group, where he works on policy research, environmental analysis, congressional education and lobbying, community organizing, litigation, and advertising. Greg led the first environmental enforcement at Los Alamos National Laboratory. He was a hydrogeologist for the New Mexico Environment Department and later a consultant to industry. In 2002 Greg was a Visiting Research Fellow at Princeton's Program on Science and Global Security. Greg's research, analysis, and opinions have been published in the New York Times, Washington Post, the Bulletin of the Atomic Scientists, Issues in Science and Technology, in the New Mexico press, and elsewhere.

Zia Mian
directs the Project on Peace and Security in South Asia at Princeton University's Program on Science and Global Security and teaches at Princeton's Woodrow Wilson School of Public and International Affairs. His research and teaching focus on nuclear weapons and nuclear energy policy, especially in Pakistan and India. He is co-editor of Science & Global Security, the international technical journal of arms control, nonproliferation, and disarmament and co-deputy chair of the International Panel on Fissile Materials (IPFM). He is the editor of several books, most recently Bridging Partition: People's Initiative for Peace between India and Pakistan, and has also worked on two documentary films for the Eqbal Ahmad Foundation, Crossing the Lines: Kashmir, Pakistan, India and Pakistan and India under the Nuclear Shadow.
In addition to his research and writing, he is active with a number of civil society groups working for nuclear disarmament, peace, and justice.

Pavel Podvig
is the director and principal investigator for the Russian Nuclear Forces Project (www.RussianForces.org). He is also a Senior Research Fellow at the United Nations Institute for Disarmament Research and a member of the International Panel on Fissile Materials. Pavel started his work on arms control at the Center for Arms Control Studies at the Moscow Institute of Physics and Technology. In recognition of his work in Russia, the American Physical Society awarded Podvig the Leo Szilard Lectureship Award of 2008 (with Anatoli Diakov). Podvig worked with the Program on Science and Global Security at Princeton University, the Security Studies Program at MIT, and the Center for International Security and Cooperation at Stanford University.

M. V. Ramana
a physicist by training, is currently appointed jointly with the Nuclear Futures Laboratory and the Program on Science and Global Security, both at Princeton University, and works on the future of nuclear energy in the context of climate change and nuclear disarmament. He is the author of The Power of Promise: Examining Nuclear Energy in India and Bombing Bombay? Effects of Nuclear Weapons and a Case Study of a Hypothetical Explosion. He is co-editor of Prisoners of the Nuclear Dream. He is on the National Coordinating Committee of the Coalition for Nuclear Disarmament and Peace (India), a member of the International Panel on Fissile Materials, and on the Science and Security Board of the Bulletin of the Atomic Scientists.

Trish Williams-Mello
is the Operations Director of the Los Alamos Study Group. Prior to moving to New Mexico in 2000, she was the Operations and Development Director for Serious Texans Against Nuclear Dumping (STAND) of Amarillo, TX for 10 years and served on their board after her move. Trish co-founded the Panhandle Area Neighbors And Landowners (PANAL), as well as the Pantex Plant Citizens Advisory Board.

Hui Zhang
is a Senior Research Associate at the Project on Managing the Atom in the Belfer Center for Science and International Affairs at Harvard University's John F. Kennedy School of Government. Dr. Zhang is leading a research initiative on China's nuclear policies for the Project on Managing the Atom in the Kennedy School of Government. His researches include verification techniques of nuclear arms control, the control of fissile material, nuclear terrorism, China's nuclear policy, nuclear safeguards and non-proliferation, and policies of nuclear fuel cycle and reprocessing.

Reaching Critical Will is the disarmament programme of the Women's International League for Peace and Freedom (WILPF), the oldest women's peace organisation in the world. Reaching Critical Will works on issues related to disarmament and arms control of many different weapon systems; militarism and military spending; and gendered aspects of the impact of weapons and of disarmament processes.

Reaching Critical Will

WILPF Geneva
1, Rue de Varembé,
1211 Geneva 20
Switzerland
T: +41 (22) 919 7080
E: disarm@wilpf.ch

WILPF New York
777 UN Plaza, 6th Floor
New York, NY 10017
USA
T: +1 212 682 1265
E: info@reachingcriticalwill.org

www.reachingcriticalwill.org