7. World nuclear forces

Overview

At the start of 2023, nine states—the United States, the Russian Federation, the United Kingdom, France, China, India, Pakistan, the Democratic People's Republic of Korea (DPRK, or North Korea) and Israel—together possessed approximately 12 512 nuclear weapons, of which 9576 were considered to be potentially operationally available. An estimated 3844 of these warheads were deployed with operational forces (see table 7.1), including about 2000 that were kept in a state of high operational alert—the same number as the previous year.

Overall, the number of nuclear warheads in the world continues to decline. However, this is primarily due to the USA and Russia dismantling retired warheads. Global reductions of operational warheads appear to have stalled, and their numbers are rising again. At the same time, both the USA and Russia have extensive and expensive programmes under way to replace and modernize their nuclear warheads, their missile, aircraft and submarine delivery systems, and their nuclear weapon production facilities (see sections I and II).

China is in the middle of a significant modernization and expansion of its nuclear arsenal (see section V). Its nuclear stockpile is expected to continue growing over the coming decade and some projections suggest that it will deploy at least as many intercontinental ballistic missiles (ICBMs) as either Russia or the USA in that period. However, China's overall nuclear warhead stockpile is still expected to remain smaller than that of either of those states.

The nuclear arsenals of the other nuclear-armed states are even smaller (see sections III–IV, VI–IX), but all are either developing or deploying new weapon systems or have announced their intention to do so. India and Pakistan also appear to be increasing the size of their nuclear weapon inventories, and the UK has announced plans to increase its stockpile. North Korea's military nuclear programme remains central to its national security strategy and it may have assembled up to 30 nuclear weapons and could produce more. Israel continues to maintain its long-standing policy of nuclear ambiguity, leaving significant uncertainty about the number and characteristics of its nuclear weapons.

The availability of reliable information on the status of the nuclear arsenals and capabilities of the nuclear-armed states varies considerably. In some cases, estimates can be based on the amount of fissile material—plutonium and highly enriched uranium (HEU)—that a country is believed to have produced (see section X) and on observations of missile forces.

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Table 7.1. World nuclear forces, January 2023

All figures are approximate and are estimates based on assessments by the authors. The estimates presented here are based on public information and contain some uncertainties, as reflected in the notes to tables 7.1–7.10.

Country	Year of first nuclear test	Warhead stockpile[a]			Retired warheads	Total inventory
		Deployed[b]	Stored[c]	Total		
United States	1945	1 770[d]	1 938[e]	3 708	1 536[f]	5 244
Russia	1949	1 674[g]	2 815[h]	4 489	1 400[f]	5 889
United Kingdom	1952	120	105	225	–[i]	225[j]
France	1960	280	10	290	. .	290
China	1964	–	410	410	–	410
India	1974	–	164	164	. .	164
Pakistan	1998	–	170	170	. .	170
North Korea	2006	–	30	30	. .	30[k]
Israel	. .	–	90	90	. .	90
Total		**3 844**	**5 732**	**9 576**	**2 936**	**12 512**

. . = not applicable or not available; – = nil or a negligible value.

Notes: SIPRI revises its world nuclear forces data each year based on new information and updates to earlier assessments. The data for Jan. 2023 replaces all previously published SIPRI data on world nuclear forces.

[a] Some states, such as the USA, use the official term 'stockpile' to refer to this subset of warheads, while others, such as the UK, often use 'stockpile' to describe the entire nuclear inventory. SIPRI uses the term 'stockpile' to refer to all deployed warheads as well as warheads in central storage that could potentially be deployed after some preparation.

[b] These are warheads placed on missiles or located on bases with operational forces.

[c] These are warheads in central storage that would require some preparation (e.g. transport and loading on to launchers) before they could be deployed.

[d] This figure includes *c.* 1370 warheads deployed on ballistic missiles and *c.* 300 stored at bomber bases in the USA, as well as *c.* 100 non-strategic (tactical) nuclear bombs thought to be deployed across 6 airbases in 5 North Atlantic Treaty Organization member states (Belgium, Germany, Italy, the Netherlands and Turkey). These non-strategic bombs remain in the custody of the USA.

[e] This figure includes *c.* 100 non-strategic nuclear bombs stored in the USA. The remainder are strategic nuclear warheads.

[f] This figure refers to retired warheads that have not yet been dismantled.

[g] This figure includes *c.* 1474 strategic warheads deployed on ballistic missiles and c. 200 deployed at heavy bomber bases.

[h] This figure includes *c.* 999 strategic and *c.* 1816 non-strategic warheads in central storage.

[i] SIPRI previously estimated that the UK had *c.* 45 retired warheads awaiting dismantlement; however, SIPRI's assessment as of Jan. 2023 is that these warheads are likely to be reconstituted to become part of the UK's growing stockpile over the coming years (see note j).

[j] The British government declared in 2010 that its nuclear weapon inventory would not exceed 225 warheads. It is estimated here that the inventory remained at that number in Jan. 2023. A planned reduction to an inventory of 180 warheads by the mid 2020s was ended by a government review published in 2021. The review introduced a new ceiling of 260 warheads.

[k] Information about the status and capability of North Korea's nuclear arsenal comes with significant uncertainty. North Korea might have produced enough fissile material to build 50–70 nuclear warheads; however, it is likely that it has assembled fewer warheads, perhaps *c.* 30.

I. United States nuclear forces

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As of January 2023 the United States maintained a military stockpile of approximately 3708 nuclear warheads, the same number as the previous year. Approximately 1770 of these—consisting of about 1670 strategic and roughly 100 non-strategic (tactical) warheads—were deployed on ballistic missiles and at bomber bases. In addition, about 1938 warheads were held in reserve and around 1536 retired warheads were awaiting dismantlement (184 fewer than the previous year's estimate), giving a total inventory of approximately 5244 nuclear warheads (see table 7.2).

The US stockpile is expected to continue to decline slightly over the next decade as nuclear modernization programmes consolidate some nuclear weapon types. Although the US Department of Energy indicated in early 2022 that the USA was currently 'on pace to completely dismantle the weapons that were retired at the end of [fiscal year (FY)] 2008 by the end of FY 2022', that schedule appears to have slipped.[1]

The estimates presented here are based on publicly available information regarding the US nuclear arsenal and assessments by the authors.[2] While in 2021 the USA briefly restored a policy of declassifying the size of its nuclear stockpile and the annual number of dismantled warheads, this practice was not repeated in 2022.[3]

In 2022 the USA remained in compliance with the final warhead limits prescribed by the 2010 Russian–US Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START), which places a cap on the numbers of US and Russian deployed strategic nuclear forces.[4] The most recent exchange of treaty data, from September 2022, lists the USA as having 1420 warheads attributed to 659 deployed ballistic missiles and heavy bombers.[5] Just as with Russia, many of the USA's strategic delivery systems carry fewer warheads than their maximum capacity in order to meet the limits of New START. If the USA chose to no longer comply with the treaty, or if the treaty were to expire without a follow-on agreement, the

[1] US Department of Energy (DOE), National Nuclear Security Administration (NNSA), *Fiscal Year 2022 Stockpile Stewardship and Management Plan*, Report to Congress (DOE: Washington, DC, Mar. 2022), pp. 2-15–2-16. US fiscal years end on 30 Sep. of the named year.

[2] Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Commentary, 14 June 2021.

[3] US Department of State, 'Transparency in the US nuclear weapons stockpile', Fact sheet, 5 Oct. 2021.

[4] For a summary and other details of New START see annex A, section III, in this volume. On related developments in 2022 see chapter 8, section I, in this volume.

[5] US Department of State, Bureau of Arms Control, Verification and Compliance, 'New START Treaty aggregate numbers of strategic offensive arms', Fact sheet, 1 Sep. 2022. See also table 8.1 in chapter 8, section I, in this volume.

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Table 7.2. United States nuclear forces, January 2023

All figures are approximate and some are based on assessments by the authors.

Type	Designation	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield	No. of warheads[b]
Strategic nuclear forces		**746**				**3 508**[c]
Aircraft (bombers)		*107/66*[d]				*788*[e]
B-52H	Stratofortress	87/46	1961	16 000	20 x AGM-86B ALCMs 5–150 kt[f]	500[g]
B-2A	Spirit	20/20	1994	11 000	16 x B61-7, -11, B83-1 bombs[h]	288
Land-based missiles (ICBMs)		*400*				*800*[i]
LGM-30G Minuteman III						
	Mk12A	200	1979	13 000	1–3 x W78 335 kt	600[j]
	Mk21 SERV	200	2006	13 000	1 x W87-0 300 kt	200[k]
Sea-based missiles (SLBMs)		*14/280*[l]				*1 920*[m]
UGM-133A Trident II D5LE						
	Mk4	. .	1992	>12 000	1–8 x W76-0 100 kt	–[n]
	Mk4A	. .	2008	>12 000	1–8 x W76-1 90 kt	1 511
	Mk4A	. .	2019	>12 000	1 x W76-2[o] 8 kt	25
	Mk5	. .	1990	>12 000	1–8 x W88 455 kt	384
Non-strategic nuclear forces						**200**[p]
F-15E	Strike Eagle	. .	1988	3 840	5 x B61-3, -4	80
F-16C/D	Falcon	. .	1987	3 200[q]	2 x B61-3, -4	60
F-16MLU	Falcon[r]	. .	1985	3 200	2 x B61-3, -4	30
PA-200	Tornado[r]	. .	1983	2 400	2 x B61-3, -4	30
Total stockpile						**3 708**
Deployed warheads						1 770
Reserve warheads						1 938
Retired warheads awaiting dismantlement						**1 536**[s]
Total inventory						**5 244**[t]

. . = not available or not applicable; – = nil or a negligible value; ALCM = air-launched cruise missile; ICBM = intercontinental ballistic missile; kt = kiloton; SERV = security-enhanced re-entry vehicle; SLBM = submarine-launched ballistic missile.

[a] For aircraft, the listed range is for illustrative purposes only; actual mission range will vary according to flight profile, weapon payload and in-flight refuelling.

[b] These figures show the total number of warheads estimated to be assigned to nuclear-capable delivery systems. Only some of these warheads have been deployed on missiles and at airbases, as described in the notes below.

[c] Of these strategic warheads, *c.* 1670 were deployed on land- and sea-based ballistic missiles and at bomber bases. The remaining warheads were in central storage. This number differs from the number of deployed strategic warheads counted by the 2010 Russian–US Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START) because the treaty attributes 1 weapon to each deployed bomber, even though bombers do not carry weapons under normal circumstances. Additionally, the treaty does not count weapons stored at bomber bases and, at any given time, some nuclear-powered ballistic missile submarines (SSBNs) are not fully loaded with warheads and are thus not counted under the treaty.

[d] The first figure is the total number of bombers in the inventory; the second is the number of bombers that are counted as nuclear-capable under New START. The USA has declared that it will deploy no more than 60 nuclear bombers at any given time but normally only *c.* 50 are deployed, with the remaining aircraft in overhaul.

[e] Of the *c.* 788 bomber weapons, *c.* 300 (200 ALCMs and 100 bombs) were deployed at the bomber bases; all the rest were in central storage. Many of the gravity bombs are no longer fully active and are slated for retirement after deployment of the B61-12 is completed in the mid 2020s.

[f] The B-52H is no longer configured to carry nuclear gravity bombs.

[g] In 2006 the US Department of Defense decided to reduce the number of ALCMs to 528 missiles. Burg, R., Director of Strategic Security in the Air, Space and Information Operations, 'ICBMs, helicopters, cruise missiles, bombers and warheads', Statement before the US Senate, Armed Services Committee, Subcommittee on Strategic Forces, 28. Mar. 2007, p. 7. Since then, the number has probably decreased gradually to *c.* 500 as some missiles and warheads have probably been expended in destructive tests.

[h] Strategic gravity bombs are assigned to B-2A bombers only. The maximum yield of strategic bombs is 360 kt for the B61-7, 400 kt for the B61-11 and 1200 kt for the B83-1. However, all these bombs, except the B-11, have lower-yield options. Most B83-1s have been moved to the inactive stockpile and B-2As rarely exercise with the bomb.

[i] Of the 800 ICBM warheads, only 400 were deployed on the missiles. The remaining warheads were in central storage.

[j] Only 200 of these W78 warheads were deployed, as each ICBM has had its warhead load reduced to carry a single warhead; all of the remaining warheads were in central storage.

[k] SIPRI estimates that another 340 W87 warheads might be in long-term storage outside the stockpile for use in the W87-1 warhead programme to replace the W78.

[l] The first figure is the total number of SSBNs in the US fleet; the second is the maximum number of missiles that they can carry. However, although the 14 SSBNs can carry up to 280 missiles, 2 vessels are normally undergoing refuelling overhaul at any given time and are not assigned missiles. The remaining 12 SSBNs can carry up to 240 missiles, but 1–2 of these vessels are usually undergoing maintenance at any given time and may not be carrying missiles.

[m] Of the 1920 SLBM warheads, *c.* 970 were deployed on submarines as of Jan. 2023; all the rest were in central storage. Although each D5 missile was counted under the 1991 Strategic Arms Reduction Treaty (START I) as carrying 8 warheads and the missile was initially flight-tested with 14, the US Navy has reduced the warhead load of each missile to an average of 4–5 warheads. D5 missiles equipped with the new low-yield W76-2 are estimated to carry only 1 warhead each.

[n] It is assumed here that all W76-0 warheads have been replaced by the W76-1.

[o] According to US military officials, the new low-yield W76-2 warhead will normally be deployed on at least 2 of the SSBNs on patrol in the Atlantic and Pacific oceans.

[p] Of the 200 non-strategic bombs, *c.* 100 are thought to be deployed across 6 airbases in 5 North Atlantic Treaty Organization (NATO) member states (Belgium, Germany, Italy, the Netherlands and Turkey), although the weapons remain in the custody of the US Air Force. The other *c.* 100 bombs were in central storage in the USA. Older B61 versions will be dismantled once the B61-12 is deployed. The maximum yields of non-strategic bombs are 170 kt for the B61-3 and 50 kt for the B61-4. All have selective lower yields. The B61-10 was retired in 2016.

[q] Most sources list an unrefuelled ferry range of 2400 kilometres, but Lockheed Martin, which produces the F-16, lists 3200 km.

[r] These dual-capable aircraft are operated at airbases outside the USA by other members of NATO.

[s] Up until 2018, the US government published the number of warheads dismantled each year, but the administration of President Donald J. Trump ended this practice. The administration of President Joe Biden temporarily restored transparency, but publication of the 2018, 2019 and 2020 data showed that far fewer warheads had been dismantled than assumed (e.g. only 184 in 2020). Nonetheless, dismantlement of the warheads has continued, leaving an estimated 1536 warheads in the dismantlement queue as of Jan. 2023.

[t] In addition to these intact warheads, more than 20 000 plutonium pits were stored at the Pantex Plant, Texas, and perhaps 4000 uranium secondaries were stored at the Y-12 facility at Oak Ridge, Tennessee.

Sources: US Department of Defense, various budget reports and plans, press releases and documents obtained under the Freedom of Information Act; US Department of Energy, various budget reports and plans; US Air Force, US Navy and US Department of Energy, personal communication with officials; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

USA (like Russia) could add reserve warheads to missiles and bombers and potentially double its number of deployed strategic nuclear weapons.

This section enumerates the USA's holdings of nuclear weapons, both strategic (including those delivered by air, land and sea) and non-strategic. Before doing so, it first outlines the role played by nuclear weapons in US military doctrine and describes the USA's warhead-production capacity.

The role of nuclear weapons in US military doctrine

In 2022 the administration of US President Joe Biden released its long-awaited Nuclear Posture Review (NPR), the principal document outlining US nuclear policy. The 2022 NPR affirmed three roles for US nuclear weapons: 'Deter strategic attacks; Assure Allies and partners; and Achieve US objectives if deterrence fails.'[6] The review states that 'The United States would only consider the use of nuclear weapons in extreme circumstances to defend the vital interests of the United States or its Allies and partners'; however, it does not elaborate on what specifically constitutes 'vital interests', nor does it define the phrase 'Allies and partners'.[7] In contrast to the language about expanding nuclear options against non-nuclear attacks in the 2018 NPR issued by the administration of President Donald J. Trump, the 2022 NPR appears to reduce the emphasis on this role.[8] Even so, the NPR acknowledges 'the range of non-nuclear capabilities being developed and fielded by competitors that could inflict strategic-level damage', and the USA retains a wide range of options against nuclear and non-nuclear attacks.[9]

The USA under the Biden administration continued to implement the large-scale nuclear weapon programmes initiated under the 2009–17 administration of President Barack Obama and accelerated and expanded by the 2017–21 Trump administration. These modernization programmes cover all three legs of the nuclear triad (see below). However, the 2022 NPR

[6] US Department of Defense (DOD), *2022 National Defense Strategy of the United States of America* (DOD: Washington, DC, Oct. 2022), p. 7.

[7] US Department of Defense (note 6), p. 9.

[8] US Department of Defense (note 6), p. 7; and US Department of Defense (DOD), *Nuclear Posture Review 2018* (DOD: Washington, DC, Feb. 2018). On the 2018 NPR see Kristensen, H. M., 'US nuclear forces', *SIPRI Yearbook 2019*.

[9] US Department of Defense (note 6), p. 9.

includes two major changes from the previous review: cancelling the sea-launched cruise missile (SLCM-N) proposed by the Trump administration and retiring the B83-1 gravity bomb.

The 2022 NPR concludes that the SLCM-N is no longer necessary given existing capabilities, uncertainty as to whether it would provide leverage to negotiate arms control limits on Russia's non-strategic nuclear weapons, and the estimated cost in the light of other nuclear modernization programmes and defence priorities.[10] At the end of 2022, however, the US Congress continued funding of limited research for the SLCM-N: the FY 2023 National Defense Authorization Act allocated $25 million for this, in contradiction to the findings of the 2022 NPR.[11] If a new administration after 2024 decides to fully fund the programme, then the new missile could be deployed on attack submarines by the early 2030s. This would go against the US pledge from 1992 not to develop a nuclear sea-launched cruise missile and could potentially result in the first significant increase in the size of the US nuclear weapon stockpile since 1996.[12]

The Biden administration chose to continue the retirement of the B83-1 gravity bomb—the last nuclear weapon with a megaton-level yield in the US nuclear arsenal—which the Trump administration had put on hold. The 2022 NPR states that the B83-1 would be retired 'due to increasing limitations on its capabilities and rising maintenance costs'.[13] It also alludes to an eventual replacement weapon 'for improved defeat' of hard and deeply buried targets.[14]

Warhead production

Since the end of the cold war, the US nuclear weapon-production complex has relied on refurbishment of existing warhead types to maintain the nuclear arsenal. In 2018, however, the USA shifted to a much more ambitious plan focused on new warhead production, which depends heavily on the ability to produce new plutonium pits—the core of a nuclear weapon. Whereas production capacity in 2021 and 2022 was limited to around 10 plutonium pits per year, the National Nuclear Security Administration (NNSA) plans to produce

[10] US Department of Defense (note 6), p. 20. On the SLCM-N see US Office of the Under Secretary of Defense for Policy, *Strengthening Deterrence and Reducing Nuclear Risks*, part II, *The Sea-Launched Cruise Missile-Nuclear (SLCM-N)* (US Department of State, Office of the Under Secretary of State for Arms Control and International Security: Washington, DC, 23 July 2020), p. 3.

[11] US Senate, Committee on Armed Services, 'National Defense Authorization Act for Fiscal Year 2023: Report', 18 July 2022; and US House of Representatives, Committee on Armed Services, 'National Defense Authorization Act for Fiscal Year 2023: Report', 1 July 2022.

[12] Bush, G. W., US president, 'Address before a joint session of the Congress on the state of the union', 28 Jan. 1992.

[13] US Department of Defense (note 6), p. 20.

[14] US Department of Defense (note 6), p. 20.

up to 30 pits in 2026 and set an initial target of at least 80 pits per year by 2030 to meet the demands of the US nuclear modernization programmes.[15] In order to fulfil these objectives, the NNSA is modernizing its plutonium-processing facility (PF-4) at Los Alamos National Laboratory in New Mexico and creating a new plutonium-processing facility at the Savannah River Site in South Carolina.[16]

In February 2022 the NNSA confirmed what outside experts had long predicted—that the goal of producing up to 80 pits per year by 2030 would not be possible.[17] Hence, some of the nuclear weapon programmes described below will probably face delays or new delivery systems could be initially deployed with existing warheads.[18]

Strategic nuclear forces

US offensive strategic nuclear forces include heavy bombers, land-based intercontinental ballistic missiles (ICBMs) and nuclear-powered ballistic missile submarines (SSBNs). These forces, together known as the triad, changed little during 2022. SIPRI estimates that a total of 3508 nuclear warheads were assigned to the triad, of which an estimated 1670 warheads were deployed on ballistic missiles and at heavy bomber bases.

Aircraft and air-delivered weapons

As of January 2023 the US Air Force (USAF) operated a fleet of 152 heavy bombers: 45 B-1Bs, 20 B-2As and 87 B-52Hs. Of these, 66 (20 B-2As and 46 B-52Hs) were nuclear-capable and approximately 60 (18 B-2As and 42 B-52Hs) are assigned nuclear missions under US nuclear war plans. The B-2A can deliver gravity bombs (B61-7, B61-11 and B83-1) and the B-52H can deliver the AGM-86B/W80-1 nuclear air-launched cruise missile (ALCM). SIPRI estimates that approximately 788 warheads were assigned to strategic bombers, of which about 300 are deployed at bomber bases and ready for delivery on relatively short notice.[19] The USA is modernizing its nuclear

[15] US National Nuclear Security Administration (NNSA), 'Plutonium pit production', Fact sheet, Apr. 2019; and US Government Accountability Office (GAO), *Nuclear Weapons: NNSA Should Further Develop Cost, Schedule, and Risk Information for the W87-1 Warhead Program*, Report no. GAO-20-73 (GAO: Washington, DC, Sep. 2020), pp. 14–15.

[16] US Department of Energy (note 1), p. 8-7.

[17] Demarest, C., '80 pits by 2030 won't happen, NNSA boss reaffirms. But "acceleration" is in the works', *Aiken Standard*, 8 Feb. 2022. See also e.g. US Government Accountability Office (note 15), p. 5; Hunter, D. E. et al., 'Independent assessment of the two-site pit production decision: Executive summary', Institute for Defense Analyses (IDA) document no. NS D-10711, May 2019, p. 4; and Demarest, C., 'Plutonium pit production in SC might happen in 2035. The target was 2030', *Aiken Standard*, 12 June 2021.

[18] US Air Force (USAF), *Report on Development of Ground-Based Strategic Deterrent Weapon*, Report to eight congressional committees (USAF: [Washington, DC,] May 2020), p. 4.

[19] The reduction in bomber weapons compared with *SIPRI Yearbook 2022* is not the result of new cuts but of new stockpile numbers causing a reassessment of the estimate.

bomber force by upgrading nuclear command-and-control capabilities on existing bombers, developing improved nuclear weapons (the B61-12 gravity bomb and the new AGM-181 Long-Range Standoff Weapon, LRSO) and building a new heavy bomber (the B-21 Raider).

The first six B-21s are expected to enter service in 2027; the aircraft will gradually replace the B-1B and B-2 bombers.[20] It is expected that the USAF will procure at least 100 (possibly as many as 145) of the new bombers, with the latest service costs estimated at approximately $203 billion for the entire 30-year operational programme, at an estimated production cost of $550 million per aircraft.[21] As a result of these developments, the number of US bomber bases with nuclear capability is expected to increase from two in 2022 to five by the early 2030s.[22]

The B-21 appears to have a slightly reduced weapons load than the B-2. It will be capable of delivering two types of nuclear weapon: the B61-12 guided nuclear gravity bomb, which is also designed to be deliverable from shorter-range non-strategic aircraft (see below); and the AGM-181 LRSO ALCM, which is in development. The AGM-181 LRSO will replace the AGM-86B ALCM in the early 2030s and will carry the W80-4 nuclear warhead, a modified version of the W80-1 warhead that is used on the AGM-86B. In mid 2022 the NNSA announced that the schedule for the first production unit of the W80-4 had slipped to the end of FY 2027, instead of FY 2025 as originally planned. Production is scheduled to be completed in FY 2031.[23]

Land-based missiles

As of January 2023 the USA deployed 400 LGM-30G Minuteman III ICBMs in 400 silos across three missile wings.[24] Another 50 empty silos are kept in a state of readiness for reloading with stored missiles if necessary. SIPRI estimates that 800 warheads were assigned to the ICBM force, of which 400 were deployed on the missiles. Each Minuteman III ICBM is armed with either a 335-kiloton W78/Mk12A or a 300-kt W87-0/Mk21 warhead. Missiles carrying the W78 can be uploaded with up to two more warheads

[20] Tirpak, J. A., 'B-21 Raider first flight now postponed to 2023', *Air Force Magazine*, 20 May 2022; and US Air Force, 'B-21 bomber to be unveiled Dec. 2', 20 Oct. 2022.

[21] Capaccio, A., 'Under-wraps B-21 bomber is seen costing $203 billion into 2050s', Bloomberg, 17 Nov. 2021; and Tirpak, J. A., 'A new bomber vision', *Air Force Magazine*, 1 June 2020.

[22] Dawkins, J. C., Commander, 8th Air Force and Joint-Global Strike Operations Center, Barksdale Air Force Base, 'B21 General Dawkins intro', YouTube, 19 Mar. 2020, 01:35; and Kristensen, H. M., 'USAF plans to expand nuclear bomber bases', FAS Strategic Security Blog, Federation of American Scientists, 17 Nov. 2020.

[23] Leone, D., 'Two-year delay for first LRSO warhead, but NNSA says will still deliver on-time to Air Force', Defense Daily, 4 Aug. 2022.

[24] Willett, E., 'AF meets New START requirements', US Air Force Global Strike Command, Press release, 28 June 2017.

for a maximum of three multiple independently targetable re-entry vehicles (MIRVs). ICBMs with the W87-0 can only be loaded with one warhead.[25]

The USAF has scheduled its next-generation ICBM to begin replacing the Minuteman III in 2028, with full replacement by 2036, although delays to this schedule are expected.[26] Flight-testing of this new ICBM—the LGM-35A Sentinel—is expected to begin in 2023.[27] Each Sentinel will be able to carry up to two warheads, with the USAF planning to produce a significantly modified warhead based on the same design as the W87-0, known as the W87-1. The cost of the W87-1 warhead-modernization programme has been estimated at between $12.2 billion and $14.2 billion, but this excludes the considerable costs of producing the plutonium pits for the warhead.[28] After the NNSA completed a review of the W87-1 in 2021, the programme entered the development engineering phase in 2022, with anticipated completion of the first production unit in FY 2030.[29] However, production of the W87-1 in time to meet the Sentinel's planned deployment schedule depended on the NNSA's projected production rate of at least 80 plutonium pits per year by 2030 (see above). The NNSA's acknowledgement that this objective is unrealistic probably means that the Sentinel will initially be deployed with the existing W87-0 warheads.[30]

Sea-based missiles

The US Navy operates a fleet of 14 Ohio-class SSBNs, of which 12 are normally considered to be operational with the remaining 2 typically undergoing refuelling and overhaul at any given time. Eight of the SSBNs are based at Naval Base Kitsap in Washington state, on the Pacific Ocean, and six at Naval Submarine Base Kings Bay in Georgia, on the Atlantic. The most recent refuelling was completed in 2022, meaning that all 14 boats are now potentially deployable until 2027, when the first Ohio-class submarine is expected to retire.[31]

Each Ohio-class SSBN can carry up to 20 Trident II D5 submarine-launched ballistic missiles (SLBMs). To meet the New START limit on deployed launchers, 4 of the 24 initial missile tubes on each submarine were deactivated so that the 12 SSBNs that are usually operational can carry no

[25] On the warheads and yields see also Kristensen, H. M. and Korda, M., 'United States nuclear forces', *SIPRI Yearbook 2021*, p. 341.

[26] Richard, C. A., Commander, US Strategic Command, Statement before the US Senate, Armed Services Committee, 13 Feb. 2020, p. 9. On the Sentinel see also Kristensen and Korda (note 25), p. 341.

[27] 'LGM-35A Sentinel intercontinental ballistic missile, USA', Airforce Technology, 29 July 2022.

[28] US Department of Energy (note 1), p. 8-32.

[29] Sirota, S., 'NNSA completes requirements review of GBSD's W87-1 warhead', Inside Defense, 22 Apr. 2021; and US National Nuclear Security Administration (NNSA), 'W87-1 modification program', Jan. 2022.

[30] Demarest, '80 pits by 2030 won't happen' (note 17); and US Air Force (note 18).

[31] US Navy, Office of the Chief of Naval Operations, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2020* (US Navy: Washington, DC, Mar. 2019).

more than 240 missiles.[32] At any given time 8–10 SSBNs are normally at sea, of which 4–5 are on alert in their designated patrol areas and ready to fire their missiles within 15 minutes of receiving the launch order. The US SSBN fleet conducts about 30 deterrence patrols per year.[33]

The Trident II D5 SLBMs carry two basic warhead types: the 455-kt W88 and the W76. The latter exists in two versions: the 90-kt W76-1 and the low-yield W76-2.[34] The NNSA has begun modernizing the ageing W88 warhead, and the first production unit of the W88 Alt 370 was completed on 1 July 2021.[35] Mass production was expected to be authorized by the end of 2022, but appears to have been delayed.[36] Each SLBM can carry up to eight warheads but normally carries an average of four or five. SIPRI estimates that around 1920 warheads were assigned to the SSBN fleet as of January 2023, of which nearly 1000 were deployed on SLBMs.[37]

The newest warhead, the low-yield W76-2, was first deployed in late 2019 and has now been deployed on SSBNs in both the Atlantic and the Pacific.[38] It is a modification of the W76-1 and is estimated to have an explosive yield of 8 kt.[39] The 2022 NPR left open the possibility that the W76-2 warhead might be retired in the medium term as the F-35A combat aircraft and the LRSO are fielded over the coming decade.[40]

Since 2017 the US Navy has been replacing its Trident II D5 SLBMs with an enhanced version, known as the D5LE (LE for 'life extension'), which is equipped with the new Mk6 guidance system. The upgrade is scheduled for completion in 2024.[41] In 2022 the US Navy conducted four flight tests of the D5LE. It will arm Ohio-class SSBNs for the remainder of their service lives (up to 2042) and will also be deployed on the United Kingdom's Trident submarines (see section III). A new class of SSBN, the Columbia class, will initially be armed with D5LE SLBMs, but from 2039 these will

[32] US Navy Office of Information, 'Fleet ballistic missile submarines—SSBN', Fact file, 25 May 2021.

[33] See e.g. Kristensen, H., 'US SSBN patrols steady, but mysterious reduction in Pacific in 2017', FAS Strategic Security Blog, Federation of American Scientists, 24 May 2018.

[34] The older W76-0 version has been, or remains in the process of being, retired. On these warheads see also Kristensen and Korda (note 25), pp. 342–43.

[35] US National Nuclear Security Administration (NNSA), 'NNSA completes first production unit of W88 Alteration 370', 13 July 2021.

[36] Leone, D., 'Mass production of refurbished nuclear weapons could begin soon, NNSA says', Exchange Monitor, 15 Sep. 2022.

[37] US Department of State (note 5).

[38] Arkin, W. M. and Kristensen, H. M., 'US deploys new low-yield nuclear submarine warhead', FAS Strategic Security Blog, Federation of American Scientists, 29 Jan. 2020; and US Department of Defense, 'Statement on the fielding of the W76-2 low-yield submarine launched ballistic missile warhead', Press release, 4 Feb. 2020.

[39] US military officials, Private communication with authors, 2019–20.

[40] US Department of Defense (note 6), p. 20.

[41] Wolfe, J., Director of US Strategic Systems Programs, 'US nuclear weapons policy, programs, and strategy in review of the defense authorization request for fiscal year 2020 and the Future Years Defense Program', Statement before the US Senate, Armed Services Committee, Subcommittee on Strategic Forces, 1 May 2019, p. 4.

be replaced with an upgraded SLBM, the D5LE2.[42] The US Navy's FY 2022 budget submission estimated the procurement cost of the first Columbia-class SSBN—the USS *District of Columbia* (SSBN-826)—at approximately $15 billion, followed by a cost of $9.3 billion for the second boat.[43] The USS *District of Columbia* is scheduled to start patrols in 2031.[44]

To arm the D5LE2, the NNSA has begun early design development of a new nuclear warhead, known as the W93. This would be the first new warhead design developed by the USA since the end of the cold war. The W93 warhead will be housed in a new Mk7 re-entry body (aeroshell) that will also be deployed on the UK's new Dreadnought-class submarines (see section III). The W93 appears intended to initially supplement, rather than replace, the W76-1 and the W88. Another new warhead is planned to replace those warheads. The completion of the first production unit of the W93 is tentatively scheduled for 2034–36.[45]

Non-strategic nuclear forces

As of January 2023 the USA had one basic type of air-delivered non-strategic weapon in its stockpile—the B61 gravity bomb, which exists in two versions: the B61-3 and the B61-4.[46] There were an estimated 200 of these bombs in the stockpile.

SIPRI estimates that the USAF has deployed approximately 100 of the B61 bombs outside the USA for potential use by combat aircraft operated by members of the North Atlantic Treaty Organization (NATO), although the weapons remain in USAF custody. They are at six airbases in five NATO member states: Kleine Brogel in Belgium; Büchel in Germany; Aviano and Ghedi in Italy; Volkel in the Netherlands; and İncirlik in Turkey.[47] The remaining (*c.* 100) B61 bombs are thought to be stored at Kirtland Air Force Base in New Mexico for potential use by US aircraft, possibly including

[42] Wolfe, J., Director of US Strategic Systems Programs, 'FY2021 budget request for nuclear forces and atomic energy defense activities', Statement before the US House of Representatives, Armed Services Committee, Subcommittee on Strategic Forces, 3 Mar. 2020, p. 5.

[43] O'Rourke, R., *Navy Columbia (SSBN-826) Class Ballistic Missile Submarine Program: Background and Issues for Congress*, Congressional Research Service (CRS) Report for Congress R41129 (US Congress, CRS: Washington, DC, 22 Feb. 2022), p. 9.

[44] Wolfe (note 41), p. 8.

[45] US Department of Energy (note 1), p. 2-10.

[46] A third version, the B61-10, was retired in Sep. 2016. US Department of Energy (DOE), National Nuclear Security Administration (NNSA), *Fiscal Year 2018 Stockpile Stewardship and Management Plan*, Report to Congress (DOE: Washington, DC, Nov. 2017), figures 1.1–1.7, p. 1-13.

[47] For detailed overviews of the dual-capable aircraft programmes of the USA and its NATO allies see Kristensen (note 8), pp. 299–300; and Andreasen, S. et al., *Building a Safe, Secure, and Credible NATO Nuclear Posture* (Nuclear Threat Initiative: Washington, DC, Jan. 2018).

in East Asia.[48] USA-based fighter wings for this mission include the 366th Fighter Wing at Mountain Home Air Force Base in Idaho.[49]

To replace all current versions of the B61 (including the non-strategic B61-3 and B61-4), the USA is producing the new B61-12 guided nuclear bomb. A guided tail-kit enables the B61-12 to hit targets more accurately, meaning that it can use lower yields and thus generate less radioactive fallout.[50] Full-scale production of the B61-12 began in late 2022 and is expected to be completed by 2026.[51] Once deployment to the bases outside the USA begins, the B61-3 and B61-4 bombs currently deployed at those bases will be returned to the USA and dismantled.

Operations to integrate the incoming B61-12 on seven types of aircraft operated by the USA or its NATO allies continued in 2022: the B-2A, the new B-21, the F-15E, the F-16C/D, the F-16MLU, the F-35A and the PA-200 (Tornado).[52] The F-35A will replace all Belgian, Dutch and US F-16s and German and Italian Tornado aircraft in the nuclear strike role.

[48] US Department of Defense, *Nuclear Posture Review 2018* (note 8), p. 48.

[49] Heflin, L., '53rd Wing WSEP incorporates NucWSEP, enhances readiness for real world operations', Press release, Air Combat Command, 9 Sep. 2021.

[50] Kristensen, H. M. and McKinzie, M., 'Video shows earth-penetrating capability of B61-12 nuclear bomb', FAS Strategic Security Blog, Federation of American Scientists, 14 Jan. 2016.

[51] Meub, K., 'B61-12 production begins', *Sandia LabNews*, Sandia National Laboratories, 11 Feb. 2022; and Defense Visual Information Distribution Service, 'F-35 dual-capable aircraft team meets goals ahead of schedule, earns prestigious award', F-35 Joint Program Office Public Affairs, 17 Feb. 2022.

[52] US Air Force (USAF), *Acquisition Annual Report Fiscal Year 2018: Cost-effective Modernization* (USAF: Washington, DC, [n.d.]), p. 24.

II. Russian nuclear forces

HANS M. KRISTENSEN AND MATT KORDA*

As of January 2023 the Russian Federation maintained a military stockpile of approximately 4489 nuclear warheads, a slight increase of around 12 warheads compared with the estimate for January 2022. About 2673 of these were strategic warheads, of which roughly 1674 were deployed on land- and sea-based ballistic missiles and at bomber bases. Russia also possessed approximately 1816 non-strategic (tactical) nuclear warheads. All of the non-strategic warheads are assessed to be at central storage sites. An additional 1400 retired warheads were awaiting dismantlement (100 fewer than the previous year's estimate), giving a total estimated inventory of approximately 5889 warheads (see table 7.3).

These estimates are based on publicly available information about the Russian nuclear arsenal and assessments by the authors. Because of a lack of transparency, estimates and analysis of Russia's nuclear weapon developments come with considerable uncertainty, particularly regarding the country's sizable stockpile of non-strategic nuclear weapons. However, it is possible to formulate a reasonable assessment of the progress of Russia's nuclear modernization by reviewing satellite imagery and other forms of open-source intelligence, official statements, industry publications and state media interviews with Russian government officials.[1]

This section enumerates Russia's holdings of strategic and non-strategic air-delivered, land-based and sea-based nuclear weapons. Before doing so, it first considers Russia's compliance with its bilateral arms control obligations and describes the role played by nuclear weapons in Russian military doctrine.

Russian compliance with New START

It was a tumultuous and discouraging year for the last remaining bilateral strategic arms control treaty between Russia and the United States, the 2010 Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START). This treaty places a cap on the numbers of Russian and US deployed strategic nuclear forces and allows for on-site inspections to verify compliance.[2]

At the end of 2022, the USA concluded that it was unable to determine whether or not Russia remained in compliance throughout the year with its

[1] Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Commentary, 14 June 2021.

[2] For a summary and other details of New START see annex A, section III, in this volume. On related developments in 2022 see chapter 8, section I, in this volume.

* The authors wish to thank Eliana Johns for contributing invaluable research to this publication.

obligation under the treaty to deploy no more than 1550 strategic warheads.[3] This was due to Russia's decision to indefinitely suspend treaty inspections.[4] The US report was careful to note, however, that 'While this is a serious concern, it is not a determination of noncompliance' and also assessed that Russia's deployed warheads were likely to have been under the New START limit at the end of 2022.[5]

In September 2022 Russia declared that it had 1549 deployed warheads attributed to 540 strategic launchers, thus remaining under the final warhead limits of New START.[6] Just as with the USA, many of Russia's strategic delivery systems carry fewer warheads than their maximum capacity in order to meet the New START limits. If Russia chose to no longer comply with the treaty limits, or if the treaty were to expire without a follow-on agreement, Russia (like the USA) could add reserve warheads to missiles and bombers and potentially double its number of deployed strategic nuclear weapons.[7]

The role of nuclear weapons in Russian military doctrine

Russia's official deterrence policy (last updated in 2020) lays out explicit conditions under which it could launch nuclear weapons: to retaliate against an ongoing attack 'against critical governmental or military sites' by ballistic missiles, nuclear weapons or other weapons of mass destruction (WMD), and to retaliate against 'the use of conventional weapons when the very existence of the state is in jeopardy'.[8] This formulation is largely consistent with previous public iterations of Russian nuclear policy.

In January 2022 Russia joined the four other permanent members of the United Nations Security Council in stating that 'a nuclear war cannot be won and must never be fought'.[9] This statement was reiterated by a member of Russia's delegation to the UN General Assembly in November 2022. He specifically noted how Russia's nuclear doctrine remained unchanged after its invasion of Ukraine in 2022: 'In response to today's absolutely ungrounded accusation that Russia allegedly threat[ened] to use nuclear weapons during

[3] US Department of State, 'New START treaty annual implementation report', Report to Congress, 31 Jan. 2023, p. 6.

[4] 'Russia suspends START arms inspections over US travel curbs', Reuters, 8 Aug. 2022; Atwood, K. and Hansler, J., 'Russia postpones nuclear arms control talks with US, State Department says', CNN, 28 Nov. 2022; and US Department of State (note 3), pp. 8–15.

[5] US Department of State (note 3), pp. 5–6.

[6] US Department of State, Bureau of Arms Control, Verification and Compliance, 'New START Treaty aggregate numbers of strategic offensive arms', Fact sheet, 1 Sep. 2022.

[7] Korda, M. and Kristensen, H., 'If arms control collapses, US and Russian strategic nuclear arsenals could double in size', FAS Strategic Security Blog, Federation of American Scientists, 7 Feb. 2023. On the negotiation of the renewal of New START see chapter 8, section I, in this volume.

[8] Russian Ministry of Foreign Affairs, 'Basic principles of state policy of the Russian Federation on nuclear deterrence', Approved by Russian Presidential Executive Order no. 355, 2 June 2020.

[9] 'Joint statement of the leaders of the five nuclear-weapon states on preventing nuclear war and avoiding arms races', 3 Jan. 2022. See also chapter 8, section I, in this volume.

Table 7.3. Russian nuclear forces, January 2023

All figures are approximate and some are based on assessments by the authors.

Type/ Russian designation (NATO designation)	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield	No. of warheads[b]
Strategic nuclear forces	**567**				**2 673**[c]
Aircraft (bombers)	*70*[d]				*580*[e]
Tu-95MS/M (Bear-H)[f]	55	1984/ 2015	6 500– 10 500	6–16 x 200 kt Kh-55 (AS-15A) or Kh-102 (AS-23B) ALCMs	448
Tu-160M1/M2 (Blackjack)	15	1987/ 2021	10 500– 13 200	12 x 200 kt Kh-55 or Kh-102 ALCMs, bombs	132
Land-based missiles (ICBMs)	*321*				*1 197*[g]
RS-20V Voevoda (SS-18 Satan)	34	1988	11 000– 15 000	10 x 500–800 kt[h]	340
RS-18 (SS-19 Stiletto)	–	1980	10 000	6 x 400 kt	–[i]
Avangard (SS-19 Mod 4)[j]	7	2019	10 000	1 x HGV	7
RS-12M Topol (SS-25 Sickle)	–[k]	1988	10 500	1 x 800 kt	–
RS-12M1 Topol-M (SS-27 Mod 1/mobile)	18	2006	10 500	1 x [800 kt]	18
RS-12M2 Topol-M (SS-27 Mod 1/silo)	60	1997	10 500	1 x [800 kt]	60
RS-24 Yars (SS-27 Mod 2/mobile)	171	2010	10 500	[4 x 250 kt][l]	684
RS-24 Yars (SS-27 Mod 2/silo)	22	2014	10 500	4 x [250 kt]	88
RS-28 Sarmat (SS-X-29)	. .	[2024]	>10 000	[10 x 500 kt]	–
Sirena-M[m]	9	2022	–	Command and control module	–
Sea-based missiles (SLBMs)	*11/176*[n]				*896*[o]
RSM-54 Sineva/Layner (SS-N-23 M2/3)[p]	5/80	2007/ 2014	9 000	4 x 100 kt[q]	320[r]
RSM-56 Bulava (SS-N-32)	6/96	2012	>8 050	[6 x 100 kt][s]	576
Non-strategic nuclear forces					**1 816**[t]
Navy weapons	. .				*835*
Submarines/surface ships/naval aircraft	. .	Land-attack cruise missiles, sea-launched cruise missiles, anti-submarine weapons, surface-to-air missiles, depth bombs, torpedoes[u]			835
Air force weapons	*266*				*506*
Tu-22M3M (Backfire-C)	60	1974	. .	3 x ASMs, bombs	300
Su-24M/M2 (Fencer-D)	70	1974	. .	2 x bombs	70[v]
Su-34 (Fullback)	124	2006	. .	2 x bombs	124[v]
Su-57 (Felon)	–	[2024]	. .	[bombs, ASMs]	. .
MiG-31K (Foxhound)	12	2018	. .	1 x ALBM	12

Type/ Russian designation (NATO designation)	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield	No. of warheads[b]
Air, coastal and missile defence	*882*				*385*
53T6 (SH-08 Gazelle)	68	1986	30	1 x 10 kt	68
S-300/400 (SA-20/21)	750[w]	1992/ 2007	. .	1 x low kt	290
3M55/P-800 Oniks (SS-N-26 Strobile), 3K55/K300-P Bastion (SSC-5 Stooge)	56	2015	>400	1 x [10–100 kt]	23
SPU-35V Redut (SSC-1B Sepal)	8[x]	1973	500	1 x 350 kt	4
Army weapons	*170*				*90*
9K720 Iskander-M (SS-26 Stone), 9M728 Iskander-K (SSC-7 Southpaw)	150	2005	350	1 x [10–100 kt]	70[y]
9M729 (SSC-8 Screwdriver)	20	2016	2 350	1 x [10–100 kt]	20[z]
Total stockpile					**4 489**
Deployed strategic warheads					1 674
Reserve warheads					2 815
Strategic					999
Non-strategic					1 816
Retired warheads awaiting dismantlement					**1 400**
Total inventory					**5 889**

. . = not available or not applicable; – = nil or a negligible value; [ ] = uncertain SIPRI estimate; ALBM = air-launched ballistic missile; ALCM = air-launched cruise missile; ASM = air-to-surface missile; HGV = hypersonic glide vehicle; kt = kiloton; ICBM = intercontinental ballistic missile; NATO = North Atlantic Treaty Organization; SLBM = submarine-launched ballistic missile.

[a] For aircraft, the listed range is for illustrative purposes only; actual mission range will vary according to flight profile, weapon payload and in-flight refuelling.

[b] These figures show the total number of warheads estimated to be assigned to nuclear-capable delivery systems. Only some of these warheads have been deployed on missiles and at airbases, as described in the notes below.

[c] Of these strategic warheads, *c.* 1674 were deployed on land- and sea-based ballistic missiles and at bomber bases. The remaining warheads were in central storage. This number is different from the number of deployed strategic warheads counted by the 2010 Russian–United States Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START) because the treaty attributes 1 weapon to each deployed bomber, even though bombers do not carry weapons under normal circumstances. Additionally, the treaty does not count weapons stored at bomber bases and, at any given time, some nuclear-powered ballistic missile submarines (SSBNs) are not fully loaded with warheads and are thus not counted under the treaty.

[d] All of Russia's long-range strategic bombers are nuclear-capable. Of these, only *c.* 55 are thought to be counted as deployed under New START. Because of ongoing bomber modernization, there is considerable uncertainty about how many bombers are operational.

[e] The maximum possible payload on the bombers is estimated to be *c.* 800 nuclear weapons but, given that only some of the bombers are fully operational, SIPRI estimates that only *c.* 580 weapons have been assigned to the long-range bomber force. Of these, *c.* 200 might be deployed and stored at the 2 strategic bomber bases. The remaining weapons are thought to be in central storage facilities.

[f] Two types of Tu-95MS aircraft were produced: the Tu-95MS6 (Bear-H6), which can carry 6 Kh-55 (AS-15A) missiles internally; and the Tu-95MS16 (Bear-H16), which can carry a total of 16 missiles, including 10 Kh-55 missiles externally. Both types were being modernized in 2022. The modernized aircraft, the Tu-95MSM, can carry 8 Kh-102 (AS-23B) missiles externally and possibly 6 internally, for a total of 14 missiles.

[g] These ICBMs can carry a total of 1197 warheads, but SIPRI estimates that they have had their warhead load reduced to *c.* 834 warheads, with the remaining warheads in storage.

[h] It is possible that, as of Jan. 2023, the RS-20Vs carried only 5 warheads each to meet the New START limit for deployed strategic warheads.

[i] It is believed that the remaining RS-18s have been retired, although activities continued at some regiments.

[j] The missile uses a modified RS-18 ICBM booster with an HGV payload.

[k] Although the final division at Vypolzovo had not yet completed its upgrade to the RS-24 by the end of 2022, it is believed that its legacy RS-12M missiles had been removed in preparation for the upgrade.

[l] It is possible that, as of Jan. 2023, the RS-24s carried only 3 warheads each to meet the New START limit on deployed strategic warheads.

[m] The division at Yurya is equipped with the new Sirena-M nuclear command and control missile, which is based on the RS-24 ICBM. The missiles are not nuclear-armed, but rather serve as an emergency launch communication module. They are included in this table because their launchers are counted against the limits permitted under New START.

[n] The first figure is the total number of nuclear-powered ballistic missile submarines (SSBNs) in the Russian fleet; the second is the maximum number of missiles that they can carry. Of Russia's 11 operational SSBNs (as of Jan. 2023), 1–2 are in overhaul at any given time and do not carry their assigned nuclear missiles and warheads (see note o).

[o] The warhead load on SLBMs is thought to have been reduced for Russia to stay below the New START warhead limit. Additionally, at any given time, 1–2 SSBNs are in overhaul and do not carry nuclear weapons. Therefore, it is estimated here that only *c.* 640 of the 896 SLBM warheads have been deployed.

[p] The current version of the RSM-54 SLBM might be the Layner (SS-N-23 M3), a modification of the previous version—the Sineva (SS-N-23 M2). However, the US Air Force's National Air and Space Intelligence Center (NASIC) did not include the Layner in its 2020 report on ballistic and cruise missile threats, and there is some uncertainty regarding its status and capability.

[q] In 2006 US intelligence estimated that the RSM-54 missile could carry up to 10 warheads, but it lowered the estimate to 4 in 2009. The average number of warheads carried on each missile has probably been limited to 4 multiple independently targetable re-entry vehicles (MIRVs) to meet the New START limits.

[r] SIPRI estimates that, at any given time, only 256 of these warheads are deployed on 4 operational Delta IV submarines, with the fifth boat in overhaul. The actual number may even be lower as 2 boats often undergo maintenance at the same time.

[s] It is possible that, as of Jan. 2023, RSM-56 Bulava (SS-N-32) SLBMs carried only 4 warheads each for Russia to meet the New START limit on deployed strategic warheads.

[t] According to the Russian government, non-strategic nuclear warheads are not deployed with their delivery systems but are kept in storage facilities. Some storage facilities are near operational bases. It is possible that there are more unreported nuclear-capable non-strategic systems.

[u] Only submarines are assumed to be assigned nuclear torpedoes.

[v] These estimates assume that half of the aircraft have a nuclear role.

[w] As of Jan. 2023 there were at least 80 S-300/400 sites across Russia, each with an average of 12 launchers, each with 2–4 interceptors. Each launcher has several reloads, which are assumed likely to be conventional.

[x] It is assumed that all SPU-35V Redut units, except for a single silo-based version in Crimea, had been replaced by the K-300P Bastion by Jan. 2023.

[y] This estimate assumes that around half of the dual-capable launchers have a secondary nuclear role. In its 2020 report, NASIC listed the 9M728 as 'Conventional, Nuclear Possible'.

[z] This figure assumes that there are 5 9M729 battalions, each with 4 launchers, for a total of 80 missiles. Each launcher is assumed to have at least 1 reload, for a total of at least 160 missiles. Most missiles are thought to be conventional, with 4–5 nuclear warheads per battalion, for a total of *c.* 20.

Sources: Russian Ministry of Defence, various press releases; US Department of State, START Treaty Memoranda of Understanding, 1990–July 2009; New START aggregate data releases, various years; US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat 2020* (NASIC: Wright-Patterson Air Force Base, OH, July 2020); US Department of Defense (DOD), *2022 National Defense Strategy of the United States of America* (DOD: Washington, DC, Oct. 2022); US Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020* (DOD: Washington, DC, Mar. 2020); DOD, various Congressional testimonies; BBC Monitoring; Russian news media; Russian Strategic Nuclear Forces website; International Institute for Strategic Studies, *The Military Balance*, various years; Cochran, T. B. et al., *Nuclear Weapons Databook*, vol. 4, *Soviet Nuclear Weapons* (Harper & Row: New York, 1989); *IHS Jane's Strategic Weapon Systems*, various issues; US Naval Institute, *Proceedings*, various issues; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

the special military operation in Ukraine, we would like to stress once again that Russia's doctrine in this sphere is purely defensive and does not allow any broad interpretation'.[10]

Nonetheless, the invasion of Ukraine has raised questions about Russia's nuclear doctrine, and about where, when and how Russia might use nuclear weapons. Several speeches made by Russian President Vladimir Putin and senior Russian officials and commentators alluding to the potential use of nuclear weapons in the conflict have added to the uncertainty.[11]

A few days after the invasion, Putin placed Russia's nuclear arsenal on 'high combat alert', saying that 'aggressive statements' from the North Atlantic Treaty Organization (NATO) had caused him to increase Russia's nuclear readiness.[12] However, it appears that this order did not involve deployment of additional nuclear systems; it was primarily related to enhancing staffing levels and nuclear command and control. By the end of 2022 none of Russia's nuclear forces had conducted any unusual deployment patterns in the context of the war in Ukraine.

[10] 'Russia's nuclear doctrine is purely defensive, says Russian diplomat', TASS, 9 Nov. 2022.

[11] See e.g. President of Russia, 'Address by the President of the Russian Federation', 24 Feb. 2022; President of Russia, 'Address by the President of the Russian Federation', 21 Sep. 2022; and 'Russia can defend new regions with nuclear weapons: Medvedev', Al Jazeera, 22 Sep. 2022.

[12] President of Russia, 'Meeting with Sergei Shoigu and Valery Gerasimov', 27 Feb. 2022.

Strategic nuclear forces

As of January 2023 Russia had an estimated 2673 warheads assigned for potential use by strategic launchers: heavy bombers, land-based intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs). This is an increase of approximately 108 warheads compared with January 2022 due to fluctuations in the arsenal caused by the deployment of newer ICBMs with multiple independently targetable re-entry vehicles (MIRVs) as well as the introduction of a new nuclear-powered ballistic missile submarine (SSBN).

Aircraft and air-delivered weapons

As of January 2023 the Long-Range Aviation command of the Russian Air Force operated a fleet of approximately 70 operational heavy bombers, comprising 15 Tu-160 (Blackjack) and 55 Tu-95MS (Bear) bombers.[13] Not all of these counted as deployed under New START and some were undergoing various upgrades. The maximum possible payload on the bombers is approximately 800 nuclear weapons. However, since not all of the bombers were fully operational, it is estimated here that the number of assigned weapons was lower—around 580. SIPRI estimates that approximately 200 of these weapons were probably stored at the two strategic bomber bases: Engels in Saratov oblast and Ukrainka in Amur oblast.[14]

Modernization of the bombers—which includes upgrades to their avionics suites, engines and long-range nuclear and conventional cruise missiles—continued throughout 2022 but remained subject to delays.[15] It seems likely that all of the Tu-160s (including at least 10 brand-new Tu-160M2 bombers) and most of the Tu-95s will eventually be upgraded to maintain a bomber force of perhaps 50–60 operational aircraft. These modernized bombers are intended to be a temporary bridge to Russia's next-generation bomber: the PAK-DA, serial production of which is planned to begin in 2028–29.[16] The

[13] For the missiles, aircraft and submarines discussed in this section, a designation in parentheses (e.g. Blackjack) following the Russian designation (e.g. Tu-160) is that assigned by the North Atlantic Treaty Organization (NATO). The Tu-95MS exists in two versions: the Tu-95MS16 (Bear-H16) and the Tu-95MS6 (Bear-H6).

[14] Podvig, P., 'Strategic aviation', Russian Strategic Nuclear Forces, 7 Aug. 2021.

[15] President of Russia, 'Meeting with workers of Gorbunov Kazan aviation factory and Tu-160M pilots', 25 Jan. 2018; Ignatyeva, L., 'New Kazan strategic bombardier hits the sky', Realnoe Vremya, 11 Jan. 2023; and President of Russia, 'Заседание коллегии Министерства обороны' [Ministry of Defence Board meeting], 21 Dec. 2022.

[16] 'PAK DA demonstrational model to be ready by 2023—Source', TASS, 2 Aug. 2021; 'Russia begins construction of the first PAK DA strategic bomber—Sources', TASS, 26 May 2020; Lavrov, A., Kretsul, R. and Ramm, A., 'ПАКетное соглашение: новейшему бомбардировщику назначили сроки выхода в серию' [PAKage agreement: The latest bomber assigned a deadline for production], *Izvestia*, 14 Jan. 2020; and 'Russia tests engine for next-generation strategic missile-carrying bomber', TASS, 31 Oct. 2022.

PAK-DA will also eventually replace all bombers deployed with non-strategic forces (see below).[17]

Both the Tu-160 and the Tu-95 strategic bombers currently carry the Kh-55 (AS-15) air-launched cruise missile (ALCM), but this is being replaced on the upgraded bombers by the new Kh-102 (AS-23B) ALCM. In November 2022 the British Ministry of Defence assessed that Russia was 'likely removing the nuclear warheads from ageing [Kh-55] nuclear cruise missiles and firing the unarmed munitions at Ukraine'.[18] Russia has used both types of bomber to conduct attacks on Ukraine. Some of Russia's strategic bombers have thus been damaged; at least two Tu-95 bombers were visibly damaged from a probable Ukrainian strike on Engels Airbase in December 2022.[19]

Land-based missiles

As of January 2023 the Strategic Rocket Forces (SRF)—the branch of the Russian armed forces that controls land-based ICBMs—consisted of 12 missile divisions grouped into 3 armies, deploying an estimated 321 ICBMs of different types and variations (see table 7.3).[20] These ICBMs can carry a maximum of about 1197 warheads, but SIPRI estimates that they have had their warhead load reduced to around 834 warheads to keep Russia below the New START limit for deployed strategic warheads. These ICBMs carry approximately half of Russia's estimated 1674 deployed strategic warheads.

Russia is close to completing the replacement of Soviet-era ICBMs with new types, although this process has taken much longer than expected. In December 2022 Colonel General Sergei Karakaev, commander of the SRF, stated that around 85 per cent of the ICBM force had been modernized.[21] The bulk of the modernization programme has focused on the RS-24 Yars (SS-27 Mod 2), a MIRVed version of the RS-12M1/2 Topol-M (SS-27 Mod 1). SIPRI estimates that, as of January 2023, the number of deployed RS-24s had grown to approximately 193 mobile- and silo-based RS-24 missiles, including five completed mobile divisions (at Barnaul, Irkutsk, Nizhniy Tagil, Novosibirsk and Yoshkar-Ola), with one more in progress (at Vypolzovo—sometimes referred to as Bologovsky).[22] Karakaev

[17] 'Russia to test next-generation stealth strategic bomber', TASS, 2 Aug. 2019.

[18] British Ministry of Defence (@DefenceHQ), Twitter, 26 Nov. 2022, <https://twitter.com/DefenceHQ/status/1596389927733927937>.

[19] Cenciotti, D., 'Explosion hits Engels-2 Airbase, Russia, reportedly damaging at least two Tu-95 bombers', The Aviationist, 5 Dec. 2022.

[20] One of these ICBM divisions, the 8th Missile Division at Yurya, Kirov oblast, was being modernized alongside the rest of the ICBM force; however, the division's Sirena-M ICBMs are believed to serve as back-up launch code transmitters and therefore have not been armed with nuclear weapons.

[21] Karakaev, S. V. (Col. Gen.), interviewed in Biryulin, R., Andreev, D. and Reznik, A., 'Ядерный щит России по-прежнему надёжен' [Russia's nuclear shield is still reliable], *Krasnaya Zvezda*, 16 Dec. 2022; and 'Russian TV show announces new ICBM to enter service soon', TRK Petersburg Channel 5, 21 Apr. 2014, Translation from Russian, BBC Monitoring.

[22] Karakaev (note 21); and authors' estimates.

stated that one regiment of the Vypolzovo division had begun combat duty by the end of 2022, and the entire division's upgrade to the RS-24 would be completed in 2023.[23] SIPRI estimates that this division has already been fully disarmed of its older RS-12M Topol (SS-25) ICBMs in preparation for receiving the new RS-24, indicating that the Topol ICBM is now fully out of service across the SRF.[24]

Deployment of the silo-based RS-24s continues at Kozelsk, Kaluga oblast, with one regiment of 10 silos completed in 2018 and the second completed in 2020.[25] The third regiment began combat duty in December 2021 and the regiment's first two missiles were placed into their silos in 2022.[26] However, commercial satellite imagery indicates that the necessary infrastructure upgrades are unlikely to be completed by the 2024 target date.[27] It is likely that the 60 RS-12M2 Topol-M (SS-27 Mod 1) silos at Tatishchevo, Saratov oblast, will eventually also be upgraded to the RS-24.

In December 2021 Russia completed the rearmament of the first of the former RS-20V regiments at Dombarovsky, Orenburg oblast, with six RS-18 (SS-19 Mod 4) missiles equipped with the Avangard hypersonic glide vehicle (HGV) system.[28] Russia has been installing Avangard-equipped missiles at a rate of two per year in upgraded complexes. In 2022 it installed the first missile in the second Avangard regiment at Dombarovsky. The entire regiment's rearmament is scheduled for completion by the end of 2027 with a total of 12 Avangard-equipped missiles.[29]

Russia has also been developing a new 'heavy' liquid-fuelled, silo-based ICBM, known as the RS-28 Sarmat (SS-X-29), as an additional replacement for the RS-20V. After many years of delay, Russia flight-tested its first RS-28 ICBM in April 2022.[30] However, no other RS-28 tests occurred in 2022, further delaying operational deployment of the missile.[31] Despite the lack of tests, in November 2022 the general director of the Makeyeva State

[23] Karakaev (note 21).

[24] Karakaev (note 21); and authors' estimates.

[25] 'Два полка РВСН в 2021 году будут перевооружены на ракетные комплексы "Ярс"' [Two regiments of the Strategic Rocket Forces will be re-equipped with 'Yars' missile systems in 2021], TASS, 21 Dec. 2020; Karakaev (note 21); and authors' assessment based on analysis of satellite imagery.

[26] Karakaev, S. V. (Col. Gen.), interviewed in Biryulin, R. and Andreev, D., 'Бесспорный аргумент России' [Russia's indisputable argument], *Krasnaya Zvezda*, 17 Dec. 2021; and Karakaev (note 21).

[27] Authors' assessment based on analysis of satellite imagery.

[28] President of Russia, 'Expanded meeting of the Defence Ministry Board', 21 Dec. 2021.

[29] President of Russia, [Ministry of Defence Board meeting] (note 15); and Karakaev (note 21).

[30] President of Russia, 'Test launch of Sarmat ICBM', 20 Apr. 2022.

[31] 'Russia re-adjusts Sarmat intercontinental ballistic missiles' test-launch program—source', TASS, 8 Nov. 2021; 'Часть районов Камчатки закроют на время испытания межконтинентальной баллистической ракеты' [Some areas of Kamchatka will be closed for the duration of the test of an intercontinental ballistic missile], Kamchatka-Info, 2 June 2022; and 'Путин: системы ПВО С-500 начали поступать в войска, МБР "Сармат" встанет на боевое дежурство до конца года' [Putin: S-500 air defence systems began to arrive with the troops, the Sarmat ICBM will be on combat duty before the end of the year], Interfax, 21 June 2022.

Rocket Centre stated that the RS-28 had already entered serial production.[32] The first division to receive RS-28 ICBMs will be the ICBM division at Uzhur, Krasnoyarsk krai.[33] Satellite imagery indicates that one regiment's older RS-20Vs have already been removed to prepare for the incoming RS-28 ICBMs, although it is unlikely that any had been loaded into these silos by the end of 2022.

Other reported development programmes for future ICBMs include the Osina-RV (derived from the RS-24) and the Kedr project, which purportedly includes research and development on next-generation missile systems.[34]

Russia reportedly conducted more than 200 small- and larger-scale exercises with road-mobile and silo-based ICBMs during 2022. These included combat patrols for road-mobile regiments, simulated launch exercises for silo-based regiments and participation in command staff exercises.[35] In December 2022 Karakaev noted that Russia plans to conduct eight ICBM flight tests in 2023, double the number of such tests in 2022.[36]

Sea-based missiles

As of January 2023 the Russian Navy had a fleet of 11 operational nuclear-armed SSBNs. The fleet included five Soviet-era Delfin-class or Project 667BDRM (Delta IV) SSBNs and six Borei-class or Project 955 (Dolgorukiy) SSBNs. One new Borei-class SSBN entered service in 2022.[37]

Russia plans to have a total of 10 Borei-class SSBNs, 5 assigned to the Northern Fleet (in the Arctic Ocean) and 5 to the Pacific Fleet, replacing all remaining Delfin-class SSBNs.[38] The three newest are of an improved design, known as Borei-A or Project 955A. After delays due to technical issues during sea trials, the first Borei-A was accepted into the navy in June 2020, the second in December 2021 and the third—the *Generalissimus Suvorov*—in December 2022.[39] A fourth Borei-A was launched in December 2022 and is

[32] Emelyanenkov, A., 'Генеральный конструктор Владимир Дегтярь: "Сармат" запущен в серийное производство' [General designer Vladimir Degtyar: 'Sarmat' has entered mass production], *Rossiskaya Gazeta*, 23 Nov. 2022.

[33] Karakaev (note 21).

[34] Karakaev (note 26); Военно-болтовой (@warbolts), Telegram, 15 June 2021, <https://t.me/warbolts/439>; 'Russia develops new-generation Kedr strategic missiles system', TASS, 1 Mar. 2021; and 'Источник сообщил, что работа по созданию ракеты "Кедр" начнется в 2023–2024 годах' [Source says work on 'Kedr' rocket will begin in 2023–2024], TASS, 2 Apr. 2021.

[35] Karakaev (note 21).

[36] Karakaev (note 21).

[37] President of Russia, 'Церемония подъёма флага на поступающих в состав ВМФ кораблях и спуска на воду атомной подлодки «Император Александр III»' [The ceremony of raising the flag on ships entering the Navy and launching the nuclear submarine 'Emperor Alexander III'], 29 Dec. 2022; and 'Russia's nuclear sub successfully tests Bulava missile', TASS, 3 Nov. 2022.

[38] 'Источник: еще две стратегические подлодки "Борей-А" построят на "Севмаше" к 2028 году' [Source: Two more 'Borei-A' strategic submarines to be built at 'Sevmash' by 2028], TASS, 30 Nov. 2020.

[39] Sevmash, 'На Севмаше состоялась церемония вывода из эллинга атомной подводной лодки «Генералиссимус Суворов»' [The commissioning ceremony of the nuclear submarine 'Generalissimus Suvorov' took place at Sevmash], 25 Dec. 2021; and President of Russia (note 37).

likely to be delivered to the navy no earlier than December 2023.[40] The next three Borei-A SSBNs are scheduled for delivery in the mid to late 2020s.[41]

Each of the 11 operational SSBNs can be equipped with 16 ballistic missiles and the Russian SSBN fleet can carry a total of 896 warheads.[42] However, one or two SSBNs is normally undergoing repairs and maintenance at any given time and is not armed. It is also possible that the warhead load on some missiles has been reduced to meet the total warhead limit under New START. As a result, SIPRI estimates that only about 640 of the 896 warheads have been deployed. The Delfin SSBNs are thought to carry RSM-54 SLBMs, either the Sineva (SS-N-23 M2) or a modified version, known as Layner (SS-N-23 M3), while the Borei and Borei-A SSBNs carry newer RSM-56 Bulava (SS-N-32) SLBMs.

In 2022 the Russian Navy continued to develop the Poseidon or Status-6 (Kanyon), a long-range, strategic nuclear-powered torpedo intended for deployment on two new types of special-purpose submarine: the K-329 *Belgorod* or Project 09852—a converted Antei-class or Project 949A (Oscar II) nuclear-powered guided-missile submarine (SSGN); and the Khabarovsk class or Project 09851.[43] Despite an apparent aborted test of the torpedo in November 2022, Russian defence sources indicated that 'the first batch' of Poseidon torpedoes had been produced and would soon be delivered to the *Belgorod*.[44] The official handover of the *Belgorod* to the Russian fleet took place in July 2022.[45] Following its delivery, the submarine was spotted operating in the Barents Sea throughout September 2022.[46] The *Belgorod* and the Khabarovsk submarines will each be capable of carrying up to six Poseidon torpedoes.[47]

[40] President of Russia (note 37).

[41] Sevmash, 'На Севмаше заложили атомные подводные крейсеры «Дмитрий Донской» и «Князь Потемкин»' [Nuclear-powered submarine cruisers 'Dmitry Donskoy' and 'Prince Potemkin' laid down at Sevmash], 23 Aug. 2021.

[42] The Delfin-class SSBNs carry RSM-54 Sineva/Layner (SS-N-23 M2/3) SLBMs, while the Borei and Borei-A SSBNs carry RSM-56 Bulava (SS-N-32) SLBMs. Each RSM-54 can carry up to 4 warheads, while each RSM-56 can carry up to 6 warheads. It is assumed that each RSM-56 has had its warhead load reduced to 4 warheads, to meet New START limits.

[43] Sutton, H. I., 'Khabarovsk-class-submarine', Covert Shores, 20 Nov. 2020; and Sutton, H. I., 'Poseidon torpedo', Covert Shores, 22 Feb. 2019.

[44] Sciutto, J., 'US observed Russian navy preparing for possible test of nuclear-powered torpedo', CNN, 10 Nov. 2022; and 'First batch of nuclear-armed drones Poseidon manufactured for special-purpose sub Belgorod', TASS, 15 Jan. 2023.

[45] 'Shipbuilders deliver special-purpose sub with nuclear-powered drones to Russian Navy', TASS, 8 July 2022.

[46] Sutton, H. I., 'New images reveal Russia's "missing" submarine Belgorod in Arctic', Naval News, 5 Oct. 2022.

[47] 'Вторую подлодку-носитель "Посейдонов" планируют спустить на воду весной–летом 2021 года' [Second 'Poseidon' carrier submarine to be launched in spring–summer 2021], TASS, 6 Nov. 2020.

Non-strategic nuclear forces

There is no universally accepted definition of 'tactical', 'non-strategic' or 'theatre' nuclear weapons. These terms generally refer to shorter-range weapons that are not covered by arms control agreements regulating long-range strategic forces. Russia's non-strategic nuclear weapons chiefly serve to compensate for perceived conventional inferiority relative to NATO forces; to provide regional (as opposed to intercontinental) deterrence options; and to maintain overall parity with the total US nuclear force level. There has been considerable debate among Western officials and experts about the role that non-strategic nuclear weapons have in Russian nuclear strategy, including potential first use.[48]

The US Defense Intelligence Agency estimated in 2021 that Russia had 1000–2000 non-strategic warheads.[49] SIPRI estimates that, as of January 2023, Russia had approximately 1816 warheads assigned for potential use by non-strategic forces—around 96 fewer than the previous year due to a reduction in the number of older launchers; however, these estimates come with a high degree of uncertainty. Most Russian delivery systems for non-strategic nuclear weapons are dual-capable, meaning that they can also deliver conventional warheads. They are intended for use by ships and submarines, aircraft, air- and missile-defence systems, and in army missiles.

Navy weapons

The Russian navy is estimated to have 835 warheads assigned for use by land-attack cruise missiles, anti-ship cruise missiles, anti-submarine rockets, depth bombs, and torpedoes delivered by surface ships, submarines and naval aviation.

The nuclear version of the long-range, land-attack Kalibr sea-launched cruise missile (SLCM), also known as the 3M-14 (SS-N-30A), is a significant

[48] On this debate see e.g. US Department of Defense, *Nuclear Posture Review 2018* (DOD: Washington, DC, Feb. 2018), p. 30; Kofman, M. and Fink, A. L., 'Escalation management and nuclear employment in Russian military strategy', War on the Rocks, 23 June 2020; Oliker, O., 'Moscow's nuclear enigma: What is Russia's arsenal really for?', *Foreign Affairs*, Nov./Dec. 2018; Stowe-Thurston, A., Korda, M. and Kristensen, H. M., 'Putin deepens confusion about Russian nuclear policy', Russia Matters, Harvard Kennedy School, 25 Oct. 2018; Tertrais, B., 'Russia's nuclear policy: Worrying for the wrong reasons', *Survival*, vol. 60, no. 2 (Apr. 2018); Ven Bruusgaard, K., 'The myth of Russia's lowered nuclear threshold', War on the Rocks, 22 Sep. 2017; and Kaushal, S. and Cranny-Evans, S., 'Russia's nonstrategic nuclear weapons and its views on limited nuclear war', Royal United Services Institute, 21 June 2022.

[49] Berrier, S., Director, US Defense Intelligence Agency, 'Worldwide threat assessment', Statement for the record, US Senate, Armed Services Committee, 26 Apr. 2021.

new addition to the navy's stock of weapons.[50] It has been integrated on numerous types of surface ship and attack submarine, including the new Yasen/Yasen-M or Project 885/885M (Severodvinsk) SSGN.[51] The third boat of this class was delivered to the Pacific Fleet in December 2021 and became operational in 2022.[52] Three additional Project 885M SSGNs are currently being built.

In addition to the 3M-14, the Project 855M SSGNs will be armed with the 3M-55 (SS-N-26) SLCM and the future 3M-22 Tsirkon (SS-NX-33) hypersonic anti-ship missile. Test launches of the latter missile were conducted in October 2022, and it is scheduled to enter service in 2026.[53]

Air force weapons

Approximately 506 non-strategic nuclear weapons are assigned to the Russian Air Force for use by Tu-22M3M (Backfire-C) intermediate-range bombers, Su-24M (Fencer-D) fighter-bombers, Su-34 (Fullback) fighter-bombers and MiG-31K (Foxhound) attack aircraft.[54] The new Su-57 (Felon) combat aircraft is also dual-capable. Deliveries began in 2020 and continued in 2022.[55]

The MiG-31K is equipped with the new 9A-7760 Kinzhal air-launched ballistic missile (ALBM). In 2022 it was operational with the Southern Military District and Northern Fleet and will eventually be integrated into the Western and Central Military Districts by 2024.[56] The first combat use of a conventional Kinzhal took place in March 2022 during the invasion of

[50] There is considerable confusion about the designation of what is commonly referred to as the Kalibr missile. The Kalibr designation actually refers not to a specific missile but to a launcher for a family of weapons that, in addition to the 3M-14 (SS-N-30/A) land-attack versions, includes the 3M-54 (SS-N-27) anti-ship cruise missile and the 91R anti-submarine missile. For further detail see US Navy, Office of Naval Intelligence (ONI), *The Russian Navy: A Historic Transition* (ONI: Washington, DC, Dec. 2015), pp. 34–35.

[51] It is important to caution that, although a growing number of vessels are capable of launching the dual-capable 3M-14, it is uncertain how many of them have been assigned a nuclear role.

[52] Manaranche, M., 'Yasen-M class SSGN "Novosibirsk" begins its sea trials', Naval News, 2 July 2021; Sevmash, 'На Севмаше состоялась церемония передачи Военно-морскому флоту двух атомных подводных лодок—"Князь Олег" и "Новосибирск"' [Sevmash held a hand-over to the Navy ceremony of two nuclear submarines—'Prince Oleg' and 'Novosibirsk'], 21 Dec. 2021; and 'Perm sub with Tsirkon hypersonic missiles to enter service with Russian Navy in 2026', TASS, 5 Jan. 2023.

[53] 'Perm sub with Tsirkon hypersonic missiles to enter service' (note 52).

[54] US Department of Defense, 'US nuclear deterrence policy', 1 Apr. 2019, p. 3; International Institute for Strategic Studies, *The Military Balance 2021* (Routledge: London, 2021); and authors' estimates. It is possible that the Su-30SM is also capable of delivering nuclear weapons.

[55] D'Urso, S., 'First serial production Su-57 Felon delivered to the Russian Aerospace Forces', The Aviationist, 30 Dec. 2020; Rob Lee (@RALee85), Twitter, 3 Feb. 2022, <https://twitter.com/RALee85/status/1489302156729593869>; and United Aircraft Corporation (UAC), 'ОАК передала Минобороны очередную партию серийных самолётов пятого поколения Су-57' [UAC handed over another batch fifth-generation Su-57s to the Defence Ministry], 28 Dec. 2022.

[56] President of Russia (note 28); 'Russia's upgraded MiG-31 fighters to provide security for Northern Sea Route', TASS, 26 Nov. 2021; and Kretsul, R. and Cherepanova, A., 'Прибавить гиперзвук: еще один военный округ вооружат «Кинжалами»' [Hypersonic boost: Another military district to be armed with 'Daggers'], *Izvestia*, 7 June 2021.

Ukraine: according to Sergei Shoigu, the Russian minister of defence, it had been used at least three times as of August 2022.[57]

Russia has also begun introducing the nuclear-capable Kh-32 (AS-4A) air-to-surface missile. This is an upgrade of the Kh-22N (AS-4) used on the Tu-22M3.[58]

Air-, coastal- and missile-defence weapons

Russian air-, coastal- and missile-defence forces are estimated to have around 385 nuclear warheads. Most have been assigned for use by dual-capable S-300 and S-400 air-defence forces and the Moscow A-135 missile-defence system. Russian coastal-defence units are believed to have been assigned a small number of nuclear weapons for anti-ship missions.

It is likely that the stock of warheads associated with Russia's air-, coastal- and missile-defence forces will eventually decrease as conventional air-defences improve—including the Nudol and Aerostat systems under development in 2022—and as legacy warheads are retired.

Army weapons

The Russian Army has an estimated 90 warheads to arm 9K720 Iskander-M (SS-26) short-range ballistic missiles (SRBMs) and 9M729 (SSC-8) ground-launched cruise missiles (GLCMs). As of January 2023 the dual-capable Iskander-M had completely replaced the Tochka (SS-21) SRBM in 12 missile brigades.[59] Unconfirmed rumours suggest that the 9M728 (SSC-7) may also have a nuclear capability.

The dual-capable 9M729 GLCM was cited by the USA as its main reason for withdrawing from the 1987 Treaty on the Elimination of Intermediate-range and Shorter-range Missiles (INF Treaty) in 2019.[60] SIPRI estimates that four or five 9M729 battalions have so far been co-deployed with four or five of the Iskander-M brigades. In 2020 and 2021 Russia indicated a willingness to impose a moratorium or a ban on future 9M729 deployments in European territory, subject to conditions.[61]

[57] 'Shoigu reveals Kinzhal hypersonic missile was used three times during special operation', TASS, 21 Aug. 2022.

[58] US Department of Defense (note 48), p. 8.

[59] Authors' assessment based on analysis of satellite imagery.

[60] US Department of State, Bureau of Arms Control, Verification and Compliance, 'INF Treaty at a glance', Fact sheet, 8 Dec. 2017. For a summary and other details of the INF Treaty see annex A, section III, in this volume. See also Topychkanov, P. and Davis, I., 'Russian–US nuclear arms control and disarmament', *SIPRI Yearbook 2020*; and Kile, S. N., 'Russian–US nuclear arms control and disarmament', *SIPRI Yearbook 2018*.

[61] President of Russia, 'Statement by Vladimir Putin on additional steps to de-escalate the situation in Europe after the termination of the Intermediate-Range Nuclear Forces Treaty (INF Treaty)', 26 Oct. 2020; and Russian Ministry of Foreign Affairs, 'Agreement on Measures to Ensure the Security of the Russian Federation and Member States of the North Atlantic Treaty Organization: Draft', Unofficial translation, 17 Dec. 2021. See also Kristensen, H. M. and Korda, M., 'Russian nuclear forces', *SIPRI Yearbook 2020*, p. 356.

III. British nuclear forces

HANS M. KRISTENSEN AND MATT KORDA*

As of January 2023 the United Kingdom's nuclear weapon stockpile consisted of approximately 225 warheads (see table 7.4)—an unchanged estimate from the previous year. SIPRI assesses that around 120 of these are operationally available for delivery by Trident II D5 submarine-launched ballistic missiles (SLBMs), with about 40 being carried on a nuclear-powered ballistic missile submarine (SSBN) that is on patrol at all times. The UK is expected to increase the number of warheads it possesses in the coming years.

These estimates are based on open-source information on the British nuclear arsenal and conversations with British officials. The UK has generally been more transparent about its nuclear activities than many other nuclear-armed states. However, it has never declassified the history of its stockpile or the actual number of warheads it possesses, and in 2021 it declared that it will no longer publicly disclose figures for the country's operational stockpile, deployed warheads or deployed missiles.[1]

This section briefly outlines the role played by nuclear weapons in the UK's military doctrine and then describes its sea-based missiles and its nuclear weapon modernization programme.

The role of nuclear weapons in British military doctrine

The British government has stated that it remains 'deliberately ambiguous about precisely when, how and at what scale [it] would contemplate the use of nuclear weapons'.[2] However, British policy also states that the UK 'would consider using . . . nuclear weapons only in extreme circumstances of self-defence, including the defence of [North Atlantic Treaty Organization (NATO)] Allies'.[3]

Like the United States, the UK operates its submarines with detargeted missiles, although it would take only moments to load the targeting coordinates. Unlike US SSBNs, which can launch in minutes, the UK says that its submarines 'are at several days' notice to fire'.[4]

[1] British Government, *Global Britain in a Competitive Age: The Integrated Review of Security, Defence, Development and Foreign Policy*, CP403 (Her Majesty's Stationery Office: London, Mar. 2021), pp. 76–77. On the challenges of collecting information on world nuclear forces more generally see Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Commentary, 14 June 2021.

[2] 10th Non-Proliferation Treaty Review Conference, National report of the United Kingdom, NPT/CONF.2020/33, 5 Nov. 2021, para. 13. On the review conference see also 'The 10th review conference of the Non-Proliferation Treaty', chapter 8, section II, in this volume.

[3] British Government (note 1), p. 76.

[4] British Ministry of Defence, 'The UK's nuclear deterrent: What you need to know', 17 Feb. 2022.

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Sea-based missiles

The UK is the only nuclear-armed state that operates a single type of nuclear weapon: the country's nuclear deterrent is entirely sea-based. The UK possesses four Vanguard-class SSBNs, based at Faslane on the west coast of Scotland, each of which can carry up to 16 Trident II D5 submarine-launched ballistic missiles.[5] In a posture known as continuous at-sea deterrence (CASD), which began in 1969, one British SSBN carrying approximately 40 warheads is on patrol at all times.[6] The second and third SSBNs remain in port but could be put to sea in a crisis. The fourth is in overhaul at any given time and is unable to deploy.

In its Integrated Review of Security, Defence, Development and Foreign Policy, published in March 2021, the British government announced a significant increase to the upper limit of its nuclear weapon stockpile, to a maximum of 260 warheads.[7] Until then, it was assumed that the UK's nuclear weapon stockpile had been gradually decreasing towards a goal of 180 warheads by the mid 2020s, as described in the UK's strategic defence and security reviews (SDSRs) of 2010 and 2015.[8] British officials clarified in 2021 that the target of 180 warheads stated in the SDSRs 'was indeed a goal, but it was never reached'.[9] Instead, in its statement submitted to the 10th review conference of the 1968 Treaty on the Non-Proliferation of Nuclear Weapons, held in 2022, the British government stated that the new and higher number of 260 warheads 'is a ceiling, not a target, and it is not our current stockpile number'.[10]

Replacement of the submarines

The UK's four Vanguard-class SSBNs entered service between December 1994 and February 2001, each with an expected service life of 25 years.[11] The

[5] Mills, C., *Replacing the UK's Strategic Nuclear Deterrent: Progress of the Dreadnought Class*, Research Briefing no. 8010 (House of Commons Library: London, 28 Sep. 2022), p. 9.

[6] British Ministry of Defence, 'UK's nuclear deterrent (CASD)', 17 Mar. 2021.

[7] British Government (note 1), p. 76. For further detail see Kristensen, H. M. and Korda, M., 'British nuclear forces', *SIPRI Yearbook 2022*, pp. 371–72.

[8] British Government, *Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review*, Cm 7948 (Her Majesty's Stationery Office: London, Oct. 2010), p. 38; and British Government, *National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom*, Cm 9161 (Her Majesty's Stationery Office: London, 2015), p. 34. See also Kristensen, H. M. and Korda, M., 'United Kingdom nuclear weapons, 2021', Nuclear notebook, *Bulletin of the Atomic Scientists*, vol. 77, no. 3 (May 2021).

[9] Liddle, A. (@AidanLiddle), British permanent representative to the Conference on Disarmament, Twitter, 16 Mar. 2021, <https://twitter.com/aidanliddle/status/1371912132141445120>. This information was also later confirmed by other officials. British officials, Interviews with the authors, May 2021.

[10] 10th Non-Proliferation Treaty Review Conference, NPT/CONF.2020/33 (note 2), para. 22.

[11] Mills (note 5), p. 10.

Table 7.4. British nuclear forces, January 2023

All figures are approximate and some are based on assessments by the authors.

Type/designation	No. of launchers	Year first deployed	Range (km)	Warheads x yield	No. of warheads
Sea-based missiles (SLBMs)	*4/64*[a]				*120*
Trident II D5	48[b]	1994	>10 000[c]	1–8 x 100 kt[d]	120
Total operationally available warheads					120[e]
Other stored warheads					105[f]
Total stockpile					**225**[g]

kt = kiloton; SLBM = submarine-launched ballistic missile.

[a] The first figure is the total number of nuclear-powered ballistic missile submarines (SSBNs) in the British fleet; the second is the maximum number of missiles that they can carry. However, the total number of missiles carried is lower (see note b). Of the 4 SSBNs, 1 is in overhaul at any given time.

[b] The 3 operational SSBNs can carry a total of 48 Trident SLBMs. The United Kingdom has purchased the right to 58 missiles from a pool shared with the United States Navy.

[c] The Trident II D5 missiles on British SSBNs are identical to the Trident II D5 missiles on US Navy SSBNs, which have demonstrated a range of more than 10 000 km in test flights.

[d] The British warhead is called the Holbrook, a modified version of the USA's W76 warhead, with a potential lower-yield option.

[e] Of the 120 operationally available warheads, c. 40 are deployed on the single SSBN that is at sea at any given time, with the remaining warheads assigned to the 2 other deployable SSBNs.

[f] This figure includes retired warheads that have not yet been dismantled. It seems likely that they will be reconstituted to become part of the UK's total stockpile over the coming years (see note g). Many of the stored warheads that have not been retired are thought to be undergoing upgrade from the Mk4 re-entry body to the Mk4A.

[g] The British government declared in 2010 that its inventory would not exceed 225 warheads, and that the UK would reduce the number of warheads in its overall nuclear stockpile to no more than 180. Despite these stated intentions, the UK's nuclear stockpile appears to have remained at *c*. 225 warheads. The UK's Integrated Review of Security, Defence, Development and Foreign Policy, published in 2021, introduced a new ceiling of 260 warheads.

Sources: British Ministry of Defence, white papers, press releases and website; British House of Commons, *Hansard*, various issues; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

2015 SDSR stated the government's intention to replace the Vanguard-class submarines with four new SSBNs, known as the Dreadnought class.[12]

The new submarines were originally expected to begin entering service by 2028, but this has been delayed until the early 2030s. The service life of the Vanguard-class SSBNs has been commensurately extended to an overall lifespan of about 37–38 years.[13] The work to upgrade the ageing SSBNs has been subject to delays and budget overruns. For example, the UK's lead SSBN, HMS *Vanguard*, completed its refit and rejoined the fleet in July 2022,

[12] British Government, Cm 9161 (note 8), para. 4.73.
[13] Mills (note 5), p. 10.

about three years later than expected. The cost of the *Vanguard* upgrade rose from an initial projection of about £200 million ($307 million) in 2015 to more than £500 million ($688 million) in 2021.[14]

The delay meant that the UK's three other SSBNs had to extend their deterrence patrols. The length of time at sea for British nuclear submarines has reportedly increased from about 60–70 days in the 1970s to over 140 days in recent years, with some reports suggesting that a new record for the Royal Navy of 157 days was set in 2022.[15] These extended patrols were potentially factors contributing to several operating errors, accidents and personnel issues (including low morale and allegations of drug and sexual abuse) that have dogged the UK's nuclear forces over the past five years.[16] Furthermore, a January 2023 inspection revealed that the work on the HMS *Vanguard* was of a poor standard—contractors apparently used superglue to repair critical parts surrounding the nuclear reactor's cooling pipes—and nuclear safety issues prevented the SSBN from going out on deterrence patrol.[17]

The missiles and warhead

Given that the UK draws its SLBMs from a common pool shared with the USA, the UK is benefiting from the US Navy's programme to extend the service life of the Trident II D5 missile. The first and second life-extended versions are known as the D5LE and the D5LE2, respectively; the D5LE will function until the early 2060s and the D5LE2 until the mid 2080s (see section I).[18]

The warhead carried on the Trident II D5 is called the Holbrook, which is produced by the UK but based closely on the USA's W76 warhead design. It is being incorporated into the more effective USA-produced Mk4A re-entry body (aeroshell).[19] It is possible that sufficient Mk4A-upgraded warheads had been produced by the end of 2021 to arm the UK's Vanguard-class SSBNs.[20]

[14] British Ministry of Defence, 'British jobs secured through upgrade to nuclear deterrent', 4 Dec. 2015; and Nutt, K., 'Trident submarine refit delay may cost taxpayers £500 million', *The National*, 10 Oct. 2021.

[15] Sabbagh, D. and Edwards, R., 'Safety fears as UK Trident submarines are put to sea for longest-ever patrols', *The Guardian*, 6 Dec. 2022.

[16] Edwards, R., 'Threat to nuclear safety from prolonged Trident patrols', The Ferret, 6 Dec. 2022; and Nicolls, D., 'Royal Navy nuclear-armed submarine forced to abort mission after catching fire', *Daily Telegraph*, 7 Nov. 2022. See also e.g. Lusher, A., 'Nuclear submarine sex and drugs scandal: Nine Trident crew expelled from Navy amid "cocaine" and affairs allegations', *The Independent*, 28 Oct. 2017.

[17] Starkey, J., 'Sub standard: Nuclear security alert after botched attempt to fix Trident submarine with super glue', *The Sun*, 30 Jan. 2023; and Middleton, J., 'Royal Navy orders investigation into nuclear submarine "repaired with glue"', *The Guardian*, 1 Feb. 2023.

[18] Mills (note 5), p. 11.

[19] For detail on how the upgrade improves the weapon's capability see Cullen, D., *Extreme Circumstances: The UK's New Nuclear Warhead in Context* (Nuclear Information Service: Reading, Aug. 2022).

[20] Nukewatch, 'Warhead convoy movements summary 2021', 2021.

In 2020 the British government announced its intention to replace the Holbrook with a new warhead that will use the Mk7 aeroshell being developed for the USA's new W93 warhead (see section I).[21] According to the British Ministry of Defence, the replacement warhead is 'not exactly the same warhead [as the W93] but . . . there is a very close connection, in design terms and production terms'.[22]

Although the future of the W93 programme is being debated in the USA, British officials stated in 2021 that the UK's warhead-replacement programme would move forward regardless of the status of the USA's W93 programme.[23] In both the UK and the USA, the decision to introduce new warheads is thought to stem from strong internal political pressure to enhance nuclear infrastructure and capabilities.[24] The UK has not issued an official cost estimate or timeline for its programme, but it is likely that the new warhead will come into service sometime in the late 2030s or early 2040s.[25]

[21] Wallace, B., British Secretary of State for Defence, 'Nuclear deterrent', Written Statement HCWS125, British House of Commons, 25 Feb. 2020; and Wolfe, J., Director of US Strategic Systems Programs, 'FY2022 budget request for nuclear forces and atomic energy defense activities', Statement before the US Senate, Armed Forces Committee, Subcommittee on Strategic Forces, 12 May 2021, pp. 6–7. For further detail see Kristensen, H. M. and Korda, M., 'British nuclear forces', *SIPRI Yearbook 2021*, pp. 360–61.

[22] Lovegrove, S., Permanent Secretary, Ministry of Defence, Statement, British House of Commons, Defence Committee, 'Oral evidence: MOD annual report and accounts 2019–20', HC 1051, 8 Dec. 2020, Q31.

[23] Mehta, A., 'UK official: American warhead decision won't impact British nuclear plans', *Defense News*, 13 Apr. 2021.

[24] Cullen (note 19), p. 6.

[25] Cullen (note 19), p. 4.

IV. French nuclear forces

HANS M. KRISTENSEN AND MATT KORDA*

As of January 2023 France's nuclear weapon stockpile consisted of about 290 warheads, the same number as in January 2022. The warheads are allocated for delivery by 48 submarine-launched ballistic missiles (SLBMs) and approximately 50 air-launched cruise missiles (ALCMs) produced for land- and carrier-based aircraft (see table 7.5). However, the 10 warheads assigned to France's carrier-based aircraft are thought to be kept in central storage and are not normally deployed.

The estimate of France's nuclear weapon stockpile is based on publicly available information.[1] France is relatively transparent about many of its nuclear weapon activities and has in the past publicly disclosed the size of its stockpile and details of its nuclear-related operations.[2]

This section begins by outlining the role played by nuclear weapons in France's military doctrine and its nuclear modernization programmes. It then describes its air-delivered and sea-based weapons.

The role of nuclear weapons in French military doctrine

France considers all of its nuclear weapons to be strategic and reserved for the defence of France's 'vital interests'.[3] While this concept has appeared in various governmental white papers and presidential speeches for several decades, what constitutes France's 'vital interests' remains unclear. In February 2020 President Emmanuel Macron announced that 'France's vital interests now have a European dimension';[4] however, in October 2022 he clarified that these interests 'would not be at stake if there was a nuclear ballistic attack in Ukraine or in the region', suggesting that the threshold for nuclear weapon use by France may be higher than previous comments had implied.[5]

In addition, France's report to the 10th review conference of the 1968 Treaty on the Non-Proliferation of Nuclear Weapons, held in 2022, states that 'For deterrence to work, the circumstances under which nuclear weapons would be used are not, and should not be, precisely defined, so as not to enable a

[1] Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Commentary, 14 June 2021.

[2] Macron, E., French President, Speech on defence and deterrence strategy, École de Guerre, Paris, 7 Feb. 2020 (in French, with English translation).

[3] Tertrais, B., *French Nuclear Deterrence Policy, Forces and Future: A Handbook*, Recherches & Documents no. 04/2020 (Fondation pour la Recherche Stratégique: Paris, Feb. 2020), pp. 25–29, 62–63.

[4] Macron (note 2). See also Kristensen, H. M. and Korda, M., 'French nuclear forces', *SIPRI Yearbook 2021*.

[5] 'Avec Emmanuel Macron' [With Emmanuel Macron], *L'événement*, France 2, 12 Oct. 2022 (author translation).

* The authors wish to thank Eliana Johns for contributing invaluable research to this publication.

Table 7.5. French nuclear forces, January 2023

All figures are approximate and some are based on assessments by the authors.

Type/designation	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield	No. of warheads
Land-based aircraft					
Rafale BF3[b]	40	2010–11	2 000	1 x [<300 kt] TNA[c]	40
Carrier-based aircraft					
Rafale MF3[b]	10	2010–11	2 000	1 x [<300 kt] TNA[c]	10[d]
Sea-based missiles (SLBMs)	*4/64*[e]				*240*
M51.1	16	2010	>6 000	4–6 x 100 kt TN 75	80
M51.2[f]	32[g]	2016	>9 000[h]	4–6 x 100 kt TNO	160
M51.3[i]	–	[2025]	>[9 000]	[up to 6] x 100 kt TNO	–
Total stockpile					**290**[j]

– = nil or a negligible value; [ ] = uncertain SIPRI estimate; kt = kiloton; SLBM = submarine-launched ballistic missile; TNA = *tête nucléaire aéroportée* (air-launched nuclear warhead); TNO = *tête nucléaire océanique* (sea-based nuclear warhead).

[a] For aircraft, the listed range is for illustrative purposes only; actual mission range will vary according to flight profile, weapon payload and in-flight refuelling.

[b] The BF3 and MF3 aircraft both carry the ASMPA (*air–sol moyenne portée–améliorée*) air-launched cruise missile (ALCM). Most sources report that the ASMPA has a range of 500–600 kilometres, although some suggest that it might be over 600 km.

[c] There is uncertainty as to the yield of the new TNA warhead. Some non-official sources continue to attribute a yield of 300 kt to the TNA, the same yield as the previous TN81 warhead carried by the original ASMP missile. However, MBDA, the manufacturer of the ASMPA missile that carries the TNA, has stated that the warhead has a 'medium energy' yield, which is thought to be less than 100 kt. The TNA also appears to be based on the same design as the TNO, which is believed to have a yield of 100 kt. In the absence of official or consistent authoritative sources, these numbers should be treated as uncertain estimates.

[d] The 10 warheads assigned to France's carrier-based aircraft are thought to be kept in central storage and are not normally deployed.

[e] The first figure is the total number of nuclear-powered ballistic missile submarines (SSBNs) in the French fleet; the second is the maximum number of missiles that they can carry. However, the total number of missiles carried is lower (see note g). Of the 4 SSBNs, 1 is in overhaul at any given time.

[f] SIPRI estimates that 1 SSBN—*Le Vigilant*—has yet to be upgraded to carry the M51.2 SLBM and its accompanying TNO warhead.

[g] France has 48 SLBMs in service—enough to equip the 3 operational SSBNs.

[h] The M51.2 has a 'much greater range' than the 6000-km range of the M51.1 according to the French Ministry of the Armed Forces.

[i] The M51.3 is under development and has not yet been deployed.

[j] In Feb. 2020 President Emmanuel Macron reaffirmed that the arsenal 'is currently under 300 nuclear weapons'. A few of the warheads are thought to be undergoing maintenance and inspection at any given time.

Sources: Speeches (in French) of French presidents and defence ministers: Macron, E., Speech on defence and deterrence strategy, École de Guerre, Paris, 7 Feb. 2020; Parly, F., French Minister of the Armed Forces, Speech, ArianeGroup, Les Mureaux, 14 Dec. 2017; Hollande, F., Speech on nuclear deterrence, Istres Airbase, 19 Feb. 2015; Sarkozy, N., Speech on the new defence policy, Porte de Versailles, 17 June 2008; Sarkozy, N., Speech on the white paper on national defence and security, nuclear deterrence and the non-proliferation of nuclear weapons, Cherbourg, 21 Mar. 2008; and Chirac, J., Speech on France's defence policy, Île Longue, Brest, 19 Jan. 2006. Other sources: French Ministry of Defence/Ministry of the Armed Forces, various publications; French National Assembly, various defence bills; *Air Actualités*, various issues; *Aviation Week & Space Technology*, various issues; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; Tertrais, B., *French Nuclear Deterrence Policy, Forces and Future: A Handbook*, Recherches & Documents no. 04/2020 (Fondation pour la Recherche Stratégique: Paris, Feb. 2020); and authors' estimates.

potential aggressor to calculate the risk inherent in a potential attack.'[6] France reserves the right to issue 'a sole, one-time-only nuclear warning', suggesting that it could use a nuclear weapon against a military, political or symbolic target as a signal to a potential adversary.[7]

The Macron administration has strongly reaffirmed a commitment to the long-term modernization and strengthening of France's air- and sea-based nuclear forces.[8] Current plans include the modernization of aircraft and ALCMs and of nuclear-powered ballistic missile submarines (SSBNs, or *sous-marins nucléaires lanceurs d'engins*, SNLEs) and SLBMs (see below). By 2040 France is expected to have fielded a next-generation combat aircraft equipped with a new cruise missile and four new SSBNs equipped with an upgraded ballistic missile.

Aircraft and air-delivered weapons

The airborne component of the French nuclear forces consists of land- and carrier-based aircraft. The French Air and Space Force has 40 deployed nuclear-capable Rafale BF3 aircraft based at Saint-Dizier Airbase in north-east France. The French Naval Nuclear Air Force (*Force aéronavale nucléaire*, FANu) consists of a squadron of 10 Rafale MF3 aircraft for deployment on the aircraft carrier *Charles de Gaulle*. The FANu and its nuclear-armed missiles are not permanently deployed but can be rapidly deployed by the French president in support of nuclear operations.[9]

The Rafale aircraft are equipped with medium-range air-to-surface cruise missiles (*air–sol moyenne portée–améliorée*, ASMPA), which are currently

[6] 10th Non-Proliferation Treaty Review Conference, National report of France, NPT/CONF.2020/42/Rev.1, 1 Aug. 2022, p. 3. On the review conference see also 'The 10th review conference of the Non-Proliferation Treaty', chapter 8, section II, in this volume.

[7] 10th Non-Proliferation Treaty Review Conference, NPT/CONF.2020/42/Rev.1 (note 6), p. 4.

[8] Macron, E., French President, Speech on the challenges and priorities of defence policy (in French), Toulon, 19 Jan. 2018; and Élysée, 'Transformer nos armées : le Président de la République présente le nouveau projet de loi de programmation militaire' [Transforming our armed forces: The President of the Republic presents the new military programming bill], 20 Jan. 2023.

[9] Pintat, X. et al., 'Rapport d'information fait au nom de la commission des affaires étrangères, de la défense et des forces armées par le groupe de travail "La modernisation de la dissuasion nucléaire"' [Information report made on behalf of the Committee on Foreign Affairs, Defense and the Armed Forces by the working group 'Modernization of nuclear deterrence'], Report no. 560, French Senate, 23 May 2017.

being refurbished.[10] In March 2022 France conducted a second successful flight test of the new version, the *air–sol moyenne portée–amélioré rénové* (ASMPA-R). It subsequently approved the start of serial production of the missiles and midlife refurbishment of the upgraded missile inventory, which will keep the ASMPA in service until 2035.[11] The ASMPA-R missiles are equipped with the same warhead as the ASMPA, the *tête nucléaire aéroportée* (TNA, air-launched nuclear warhead), which the missile's producer (MBDA) says has a 'medium energy' yield.[12]

The Ministry of the Armed Forces has begun developing a successor: a fourth-generation air-to-surface nuclear missile (*air–sol nucléaire de 4e génération*, ASN4G) with enhanced stealth and manoeuvrability to counter potential technological improvements in air defences.[13] The ASN4G is scheduled to reach initial operational capability in 2035 to replace the ASMPA-R.[14] France is also modernizing and expanding its fleet of Rafale aircraft. The French military budget for 2023 includes plans for the delivery of 13 new Rafale aircraft to the armed forces.[15]

Sea-based missiles

The main component of France's nuclear forces is the Strategic Oceanic Force (*Force océanique stratégique*, FOST). It consists of four Le Triomphant-class SSBNs based on the Île Longue peninsula near Brest, north-west France. Each can carry 16 SLBMs; however, at any given time one SSBN is out of service for overhaul and maintenance work and is therefore not armed. France has 48 SLBMs in service—enough to equip the three operational SSBNs.

The French Navy maintains a continuous at-sea deterrence posture with one SSBN on patrol at all times. In March 2022 there were reports that the French Navy had deployed more than one SSBN for the first time since the 1980s, possibly in response to Russia's invasion of Ukraine.[16] It is unclear

[10] For further detail see Kristensen and Korda (note 4), p. 366.

[11] Mills, C., *Nuclear Weapons at a Glance: France*, Research Briefing no. 9074 (House of Commons Library: London, 28 July 2022), p. 10; and Scott, R., 'Successful flight test of upgraded ASMPA missile paves way for refurbishment', Janes, 30 Mar. 2022.

[12] MBDA, 'ASMPA: Air-to-ground missile, medium range, enhanced'.

[13] French Ministry of the Armed Forces, 'La dissuasion nucléaire' [Nuclear deterrence], *Actu Défense*, 14 June 2018, p. 1; and Tran, P., 'France studies nuclear missile replacement', *Defense News*, 29 Nov. 2014.

[14] Medeiros, J., '"Faire FAS" : 55 ans de dissuasion nucléaire aéroportée' ['Go FAS': 55 years of airborne nuclear deterrence], *Air Actualités*, Oct. 2019, p. 36.

[15] Jennings, G., 'France begins Rafale F4 flight trials', Janes, 21 May 2021; and French Ministry of the Armed Forces (MAF), *Projet de loi de finances: 2023—LPM 2019–2025 Année 5* [Finance bill: 2023—Miliary Programming Law 2019–2025 year 5] (MAF: Paris, Sep. 2022), p. 41.

[16] Jézéquel, S., 'Pourquoi la France a-t-elle fait appareiller trois sous-marins nucléaires au départ de l'Ile-Longue ?' [Why did France sail three nuclear submarines from Île-Longue?], *Le Télégramme*, 21 Mar. 2022.

whether this practice will continue or whether it was a one-off test of the capability.

France's SLBM, the M51, is undergoing a series of upgrades. The missile is equipped with multiple independently targetable re-entry vehicles (MIRVs) and the first version, the M51.1, can carry up to six 100-kiloton TN 75 warheads. The second version, the M51.2, is armed with a new warhead, the *tête nucléaire océanique* (TNO, sea-based nuclear warhead), which is assumed to have a yield of 100 kt.[17] SIPRI estimates that one of France's four SSBNs, *Le Vigilant*, has yet to be upgraded to carry the M51.2 SLBM and its accompanying TNO warhead. To allow for targeting flexibility, some of the SLBMs carried by France's SSBNs carry fewer warheads than others.[18] France has also commenced design work on another upgrade, the M51.3, which will have improved accuracy. It is due to be operational in 2025.[19]

A production programme for a third-generation SSBN, designated the SNLE 3G, was officially launched in early 2021.[20] The SNLE 3G will eventually be equipped with a further modification of the M51 SLBM, the M51.4.[21] The construction of the first of four submarines in the class is scheduled to begin in 2023 and is expected to be completed by 2035. The other three submarines will be delivered on a schedule of one boat every five years.[22]

[17] Groizeleau, V., 'Dissuasion : 25 milliards en cinq ans pour le renouvellement des deux composantes' [Deterrence: 25 billion in five years for the renewal of the two components], Mer et Marine, 2 Oct. 2019; and Groizeleau, V., 'Dissuasion : F. Hollande détaille sa vision et l'arsenal français' [Deterrence: F. Hollande outlines his vision and the French arsenal], Mer et Marine, 20 Feb. 2015.

[18] Tertrais (note 3), p. 57.

[19] French Ministry of the Armed Forces, 'Missiles balistiques stratégiques (MSBS)' [Strategic ballistic missiles], 28 Jan. 2020; and Parly, F., French Minister of the Armed Forces, Speech (in French), ArianeGroup, Les Mureaux, 14 Dec. 2017.

[20] French Ministry of the Armed Forces, 'Florence Parly, ministre des armées, annonce le lancement en réalisation des sous-marins nucléaires lanceurs d'engins de 3e génération (SNLE 3G)' [Florence Parly, minister of the armed forces, announces the launch of the 3rd-generation nuclear-powered ballistic missile submarines (SNLE 3G)], 19 Feb. 2021; and Mackenzie, C., 'France to begin building new ballistic missile subs', *Defense News*, 22 Feb. 2021.

[21] Tertrais (note 3), pp. 56, 60, 65.

[22] French Ministry of the Armed Forces (note 20); Groizeleau, 'Dissuasion : 25 milliards en cinq ans' (note 17); and Mackenzie (note 20).

V. Chinese nuclear forces

HANS M. KRISTENSEN AND MATT KORDA*

As of January 2023 China maintained an estimated total stockpile of about 410 nuclear warheads—around 60 more than SIPRI's estimate for the previous year. China's warheads are assigned to its operational land- and sea-based ballistic missiles and to nuclear-configured aircraft (see table 7.6). Although the Chinese nuclear stockpile is projected to continue growing over the coming decade and the number of Chinese intercontinental ballistic missiles (ICBMs) is likely to reach or even exceed the numbers held by either Russia or the United States, China's overall nuclear warhead stockpile is still expected to remain smaller than that of either of those states.

SIPRI's estimate of 410 warheads relies on publicly available information on the Chinese nuclear arsenal.[1] Since China has never declared the size of its nuclear arsenal, many of the assessments here rely on data from the US Department of Defense (DOD) and must therefore be treated with caution. For example, in its 2022 report to the US Congress on Chinese military and security developments, the US DOD projected that China might field a stockpile of roughly 1500 warheads by 2035.[2] This projection relies, however, on several assumptions about China's future force posture and plutonium production. It remains to be seen how accurate these assumptions are.

This section continues by summarizing the role played by nuclear weapons in China's military doctrine. It then describes the air-delivered, land-based and sea-based nuclear weapons that constitute the three legs of China's nascent nuclear triad.

The role of nuclear weapons in Chinese military doctrine

The Chinese government's declared aim is to maintain China's nuclear capabilities at the minimum level required to safeguard national security, with the goal of 'deterring other countries from using or threatening to use nuclear weapons against China'.[3] The posture is changing significantly, with hundreds of missile silos being built, additional submarines under construction and new nuclear bombers being added to the force.

[1] Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Commentary, 14 June 2021.

[2] US Department of Defense, *Military and Security Developments Involving the People's Republic of China 2022*, Annual Report to Congress (Office of the Secretary of Defense: Washington, DC, 29 Nov. 2022), p. 98; and Sokolski, H. D. (ed.), *China's Civil Nuclear Sector: Plowshares to Swords?*, Nonproliferation Policy Education Center (NPEC) Occasional Paper no. 2102 (NPEC: Arlington, VA, Mar. 2021).

[3] Chinese State Council, *China's National Defense in the New Era* (Information Office of the State Council: Beijing, July 2019), chapter 2.

* The authors wish to thank Eliana Johns for contributing invaluable research to this publication.

This development has triggered widespread discussions about long-standing elements of Chinese nuclear doctrine, including its stated nuclear 'no-first-use' (NFU) policy.[4] In its 2022 report the US DOD assessed that China is implementing an 'early warning counterstrike' strategy—akin to a 'launch-on-warning' (LOW) posture—using ground- and space-based sensors to enable rapid launch of missiles before an adversary can destroy them.[5] The US DOD noted that, as of 2022, China had deployed at least three early-warning satellites to facilitate this posture.[6]

Despite the continuing increase in the sophistication and size of China's nuclear arsenal, there is no official public evidence that the Chinese government has deviated from its long-standing core nuclear policies, including its NFU policy.[7] Additionally, in its 2022 report the US DOD stated that China 'probably believes a LOW posture is consistent with its no first use policy'.[8]

The Chinese nuclear posture has traditionally involved procedures for loading warheads on to launchers in a crisis, but with warheads, missiles and launchers kept separate during peacetime.[9] A transition to a LOW posture, where space-based sensors could detect an incoming attack before impact, does not necessarily require China to keep warheads on delivery vehicles under normal circumstances; doing so would constitute a significant change to the country's long-held nuclear custodial practices. Nevertheless, missile brigades do still need training to load warheads. According to the US DOD's 2022 report, the brigades of the People's Liberation Army (PLA) Rocket Force (PLARF) conduct 'combat readiness duty' and 'high alert duty' drills, which 'apparently includes assigning a missile battalion to be ready to launch and rotating to standby positions as much as monthly for unspecified periods of time'.[10] Since at least 2020, the PLARF has also begun to conduct nuclear attack survival exercises that are designed to test troops' readiness to launch nuclear counterattacks in the event of an imminent detonation.[11] This suggests that China is practising launching missiles in a LOW scenario.

[4] Chinese Ministry of National Defense, 'China resolutely opposes 2022 Pentagon report on Chinese military: Defense spokesperson', 6 Dec. 2022.

[5] US Department of Defense (note 2), pp. 99–100.

[6] US Department of Defense (note 2), pp. 99–100.

[7] Santoro, D. and Gromoll, R., 'On the value of nuclear dialogue with China', Pacific Forum, *Issues & Insights* (special report), vol. 20, no. 1 (Nov. 2020); and Kulacki, G., 'Would China use nuclear weapons first in a war with the United States?', The Diplomat, 27 Apr. 2020.

[8] US Department of Defense (note 2), p. 99.

[9] Stokes, M. A., *China's Nuclear Warhead Storage and Handling System* (Project 2049 Institute: Arlington, VA, 12 Mar. 2010), p. 8; Li, B., 'China's potential to contribute to multilateral nuclear disarmament', *Arms Control Today*, vol. 41, no. 2 (Mar. 2011); and US Department of Defense (note 2), p. 95.

[10] US Department of Defense (note 2), p. 95.

[11] Baughman, J., 'An assessment of People's Liberation Army Rocket Force survivability training', China Aerospace Studies Institute, 15 Aug. 2022; and Lu, Z., Liu, X. and Yue, X., [The missile was successfully launched, but all the personnel were 'killed'. Is it a victory?], *PLA Daily*, 7 Dec. 2021 (in Chinese).

Table 7.6. Chinese nuclear forces, January 2023

All figures are approximate and some are based on assessments by the authors.

Type/Chinese designation (US designation)	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield[b]	No. of warheads[c]
Aircraft	*20*[d]				*20*
H-6K (B-6)	10	2009	3 100	1 x bomb	10
H-6N (B-6N)	10	2020	3 100	1 x ALBM	10
H-20 (B-20)	–	[2028]	. .	. .	–
Land-based missiles	*382*				*318*
DF-4 (CSS-3)	6[e]	1980	5 500	1 x 3.3 Mt	–
DF-5A (CSS-4 Mod 2)	6	1981	12 000	1 x 4–5 Mt	6
DF-5B (CSS-4 Mod 3)	12	2015	13 000	5 x 200–300 kt	60
DF-5C (CSS-4 Mod 4)	. .	[2024]	13 000	[MIRV]	. .
DF-15 (CSS-6)	. .	1990	600	1 x . .[f]	. .
DF-17 (CSS-22)	54[g]	2020	>1 800	1 x HGV[h]	. .
DF-21A/E (CSS-5 Mod 2/6)	24[i]	2000/2016	>2 100[j]	1 x 200–300 kt	24[k]
DF-26 (CSS-18)	162	2016	>3 000	1 x 200–300 kt	54[l]
DF-27 (. .)	–	[2026]	5 000–8 000	1 x 200–300 kt	–
DF-31 (CSS-10 Mod 1)	6	2006	7 200	1 x 200–300 kt	6
DF-31A/AG (CSS-10 Mod 2)[m]	84	2007/2018	11 200	1 x 200–300 kt	84
DF-41 (mobile version) (CSS-20)	28[n]	2020	12 000	3 x 200–300 kt	84
Sea-based missiles (SLBMs)	*6/72*[o]				*72*
JL-2 (CSS-N-14)	–	2016	>7 000	1 x 200–300 kt	–
JL-3 (CSS-N-20)	72[p]	2022	>10 000	[Multiple]	72
Total stockpile	**474**				**410**

. . = not available or not applicable; – = nil or a negligible value; [ ] = uncertain SIPRI estimate; ALBM = air-launched ballistic missile; HGV = hypersonic glide vehicle; kt = kiloton; MIRV = multiple independently targetable re-entry vehicle; Mt = megaton; SLBM = submarine-launched ballistic missile.

[a] For aircraft, the listed range is for illustrative purposes only; actual mission range will vary according to flight profile, weapon payload and in-flight refuelling.

[b] Warhead yields are listed for illustrative purposes. Actual yields are not known, except that older and less accurate missiles were equipped with megaton-yield warheads. Newer long-range missile warheads probably have yields of a few hundred kilotons, and it is possible that some warheads have even lower yield options.

[c] Figures are based on estimates of 1 warhead per nuclear-capable launcher, except for the MIRV-capable DF-5B, which can carry up to 5 warheads, and the MIRV-capable DF-41, which is estimated to carry up to 3 warheads. China's warheads are not thought to be deployed on launchers under normal circumstances but kept in storage facilities. All estimates are approximate.

[d] The number of bombers only counts those estimated to be assigned a nuclear role. H-6 bombers were used to deliver nuclear weapons during China's nuclear weapon testing programme (1 test used a fighter–bomber) and models of nuclear bombs are exhibited in military museums. It is thought (but not certain) that a small number of H-6 bombers previously had a secondary contingency mission with nuclear bombs. The United States Department of Defense (DOD) reported in 2018 that the People's Liberation Army Air Force has been reassigned a nuclear mission, which is expected to revolve primarily around China's new dual-capable ALBM.

[e] The US DOD's 2022 report still listed the old liquid-fuelled DF-4 as an element of China's fixed intercontinental ballistic missile (ICBM) force, but as of Jan. 2023 SIPRI assesses that the DF-4 is in the process of being retired and most likely no longer has an operational nuclear strike role.

[f] The US Central Intelligence Agency concluded in 1993 that China 'almost certainly' had developed a warhead for the DF-15, but it is unclear whether the capability was fielded. As of Jan. 2023 SIPRI assesses that the DF-15 serves an entirely conventional role.

[g] This number is based on the assumption that at least 3 DF-17 brigades were operational as of Jan. 2023.

[h] The DF-17 carries an HGV with an unknown payload. The US DOD's 2021 and 2022 reports to the US Congress noted that the DF-17 is 'primarily a conventional platform' but that it could 'be equipped with nuclear warheads'.

[i] In 2017 the National Air and Space Intelligence Center of the US Air Force (USAF) reported that China had 'fewer than 50' DF-21A launchers. The DF-21E is thought to be a replacement for the DF-21A.

[j] The range of the nuclear-armed DF-21 variants, the DF-21A (CSS-5 Mod 2) and the DF-21E (Mod 6), is thought to be greater than the 1750 km reported for the original DF-21 (CSS-5 Mod 1), which has been retired. The USAF has reported the range as 2150 km.

[k] It is assumed that nuclear launchers do not have any reloads, unlike conventional versions (DF-21C and DF-21D) that are assumed to have 1 reload.

[l] The DF-26 is a dual-capable launcher. It is thought that its mission is primarily conventional and that only some of the launchers (perhaps up to one third) are assigned nuclear warheads. Only 1 nuclear warhead is assumed for each of the DF-26's missiles that have been assigned a nuclear mission, with any reloads assumed to be conventional.

[m] The DF-31AG is thought to carry the same missile as the DF-31A.

[n] This number assumes that at least 2 brigades were operational as of Jan. 2023.

[o] The first figure is the total number of operational nuclear-powered ballistic missile submarines (SSBNs) in the Chinese fleet; the second is the maximum number of missiles that they can carry.

[p] In Nov. 2022 the commander of the US Pacific Fleet stated that China was replacing its deployed JL-2 SLBMs with JL-3 SLBMs, although it is unknown how many have been replaced. Capaccio, A., 'China has put longer-range ICBMs on its nuclear subs, US says', Bloomberg, 19 Nov. 2022. It is thought that the system is also intended to arm the future Type 096 SSBN, which will not be ready for several years.

Sources: US Air Force (USAF), National Air and Space Intelligence Center, *Ballistic and Cruise Missile Threat*, various years; USAF Global Strike Command, various documents; US Central Intelligence Agency, various documents; US Defense Intelligence Agency, various documents; US Department of Defense, *Military and Security Developments Involving the People's Republic of China*, Annual Report to Congress, various years; Kristensen, H. M., Norris, R. S. and McKinzie, M. G., *Chinese Nuclear Forces and US Nuclear War Planning* (Federation of American Scientists/Natural Resources Defense Council: Washington, DC, Nov. 2006); *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; Google Earth satellite imagery; and authors' estimates.

Aircraft and air-delivered weapons

Chinese medium-range bombers were used to conduct more than 12 atmospheric nuclear tests in the 1960s and 1970s.[12] Until 2018 this capability to deliver nuclear weapons using Hong-6 or H-6 (B-6) bombers was not fully operational and was probably a back-up contingency mission.[13] In 2018, however, the US DOD reported that the PLA Air Force (PLAAF) was 'newly re-assigned a nuclear mission'.[14] The H-6N (B-6N) is apparently China's 'first nuclear-capable air-to-air refuelable bomber', and it had been operationally fielded by 2020.[15] In addition, the PLAAF has been developing its first long-range strategic bomber, the H-20 (B-20), with an anticipated range of more than 10 000 kilometres, a stealthy design and dual-capability—that is, able to deliver both conventional and nuclear weapons.[16]

To arm the H-6N, China has been developing two new air-launched ballistic missiles (ALBMs), one of which is assessed by the USA to be potentially nuclear-capable.[17] The US DOD stated in its 2022 report that the PLAAF's operational airborne nuclear capability was still 'developing tactics and procedures' to conduct the nuclear mission and noted that this capability gave China a 'nascent nuclear triad'.[18]

Land-based missiles

China's nuclear-capable land-based ballistic missile arsenal has been undergoing significant modernization as China replaces its ageing silo-based,

[12] De Geer, L.-E., 'Detection by Sweden of Chinese nuclear tests in the atmosphere', ed. V. Fedchenko, SIPRI, *The New Nuclear Forensics: Analysis of Nuclear Materials for Security Purposes* (Oxford University Press: Oxford, 2015), table 8A.1.

[13] For the aircraft, missiles and submarines discussed here, a designation in parentheses (in this case B-6) following the Chinese designation (in this case H-6) is that assigned by the USA.

[14] US Department of Defense, *Military and Security Developments Involving the People's Republic of China 2018*, Annual Report to Congress (Office of the Secretary of Defense: Washington, DC, 16 May 2018), p. 75.

[15] US Department of Defense (note 2), pp. 59–60.

[16] US Department of Defense (note 2), p. 83; and US Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020* (US Department of Defense: Washington, DC, Mar. 2020), figure 1.1, p. 3.

[17] US Department of Defense (note 2), pp. 55–56; Ashley, R., Director, US Defense Intelligence Agency, 'Worldwide threat assessment', Statement for the record, US Senate, Armed Services Committee, 6 Mar. 2018, p. 8; US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat 2020* (NASIC: Wright-Patterson Air Force Base, OH, July 2020), p. 7; and Stewart, V. R., Director, US Defense Intelligence Agency, 'Worldwide threat assessment', Statement for the record, US Senate, Armed Services Committee, 9 Feb. 2016. See also Kristensen, H. M. and Korda, M., 'Chinese nuclear forces', *SIPRI Yearbook 2022*, pp. 384–85.

[18] US Department of Defense (note 2), p. 60.

liquid-fuelled missiles with large numbers of new mobile and silo-based, solid-fuelled models.[19]

Intercontinental ballistic missiles

In 2021 commercial satellite imagery revealed that China had started construction of hundreds of new missile silos across northern China.[20] By January 2023 the number of new silos under construction was approximately 350, spread out among three large fields in northern China and three mountainous areas in east-central China. The northern silo fields are thought to be intended for solid-fuelled Dongfeng (DF) ICBMs—most likely the DF-31A (CSS-10 Mod 2) or the DF-41 (CSS-20)—while the more mountainous sites are expected to be filled with liquid-fuelled DF-5B (CSS-4 Mod 3) ICBMs.[21] By January 2023 silo construction at the northern fields had been largely completed, along with perimeter fences, electrical and radio towers, and air defence systems.[22] Notably, China's new northern silo fields are located deeper inside China than any other known ICBM base, including the new silos in east-central China, making them less vulnerable to long-range conventional strikes.[23]

SIPRI assesses that, as of January 2023, the total number of Chinese ICBM launchers—including training launchers, new launchers under construction and operational launchers—exceeded 450, with approximately 142 of those thought to be operational. It appears that the USA made a similar assessment in December 2022. The US DOD had previously estimated that, as of the end of 2021, China had 300 ICBM launchers with as many missiles in its inventory.[24] This estimate probably included launchers still under construction and missiles in production for them. The jump between the US DOD's assessments of 2021 and 2022 triggered a congressional notification from US Strategic Command that China had surpassed the USA in total ICBM launchers (but not in deployed ICBMs or warheads assigned to ICBMs).[25]

If China eventually fills each of the silos under construction with a single-warhead missile, it would have the capacity to deploy approximately

[19] Missile ranges specified here refer to Western definitions. China defines missile ranges differently: short, <1000 kilometres; medium, 1000–3000 km; long, 3000–8000 km; and intercontinental, >8000 km.

[20] Lewis, J. and Eveleth, D., 'Chinese ICBM silos', Arms Control Wonk, 2 July 2021; Korda, M. and Kristensen, H. M., 'China is building a second nuclear missile silo field', FAS Strategic Security Blog, Federation of American Scientists, 26 July 2021; and Lee, R., 'PLA likely begins construction of an intercontinental ballistic missile silo site near Hanggin Banner', China Aerospace Studies Institute, 12 Aug. 2021.

[21] US Department of Defense (note 2), p. 94; and authors' estimates.

[22] Authors' assessment based on analysis of satellite imagery.

[23] Korda and Kristensen (note 20).

[24] US Department of Defense (note 2), p. 167.

[25] Inhofe, J. (@JimInhofe), Twitter, 5 Dec. 2022, <https://twitter.com/JimInhofe/status/1599877030299901952>.

560 warheads on its ICBMs. If each silo were filled with a missile equipped with three multiple independently targetable re-entry vehicles (MIRVs), this number could rise to approximately 1200 warheads. However, as of January 2023 it remained unclear how China ultimately plans to operate the new silos: whether they will all be filled, how many warheads each missile would carry, and whether a portion of them could potentially have conventional strike roles.[26]

China has four basic types of ICBM: the DF-4, the DF-5, the DF-31 and the DF-41, with variants of each type. Most have a single warhead, while a smaller but growing number can deliver multiple warheads.

As of January 2023 SIPRI assesses that China's oldest ICBM system, the DF-4 (CSS-3), is nearing the completion of its gradual retirement from service and probably no longer has an operational nuclear strike role. SIPRI estimates that the number of deployed missiles in the DF-5 (CSS-4) family of ICBMs, the Chinese missiles assumed to have the longest range, has increased slightly as China has probably begun to deploy upgraded versions in the new silos currently under construction in east-central China.

In its 2022 report the US DOD noted that China appeared to be doubling the number of launchers in some mobile ICBM brigades from 6 to 12, although some new bases appear to have only 8 launchers.[27] China is believed to have deployed at least two mobile DF-41 brigades, with a third base nearing completion—totalling around 28 launchers—and appears to be preparing for the integration of additional DF-41 brigades.[28] The US DOD assessed in 2022 that China might ultimately plan to deploy the DF-41 in both road-mobile and silo-based modes, in some or all of China's new missile silo fields, and potentially in a rail-based mode as well.[29]

The US DOD's 2022 report states that China has also begun developing a new missile called the DF-27, which could have a range of 5000–8000 km.[30] However, public information about this new missile is scarce and its purported range can already be covered by China's other ICBMs. This suggests that the DF-27 could eventually be used in a conventional strike role.

After many years of research and development, China has equipped a small number of ICBMs with nuclear MIRVs. The DF-5B can reportedly carry up to five warheads per missile, while the DF-41 can probably carry no more

[26] The conventional strike role is based on circumstantial evidence in Lee, R., 'A case for China's pursuit of conventionally armed ICBMs', The Diplomat, 17 Nov. 2021.

[27] US Department of Defense (note 2), p. 65; and Eveleth, D. (@dex_eve), Twitter, 3 Nov. 2021, <https://twitter.com/dex_eve/status/1456009540982374404>.

[28] US Department of Defense (note 2), p. 65; and Lee, R. (@roderick_s_lee), Twitter, 28 Dec. 2021, <https://twitter.com/roderick_s_lee/status/1475885536254599172>.

[29] US Department of Defense (note 2), p. 65.

[30] US Department of Defense (note 2), p. 65.

than three.[31] The DF-5C (CSS-4 Mod 4) that is believed to be in development might also be able to deliver MIRVs.

In 2021 China reportedly conducted a test of what appeared to be a fractional orbital bombardment system (FOBS) equipped with a hypersonic boost-glide system.[32] In its 2022 report the US DOD assessed that the tested system came close to striking its target after flying completely around the world for approximately 40 000 km and over 100 minutes.[33] While details about this new system are scarce, if the initial reporting is accurate, then it may be intended to counter advances in US missile defences.

Intermediate- and medium-range ballistic missiles

In 2016 the PLARF began deploying the dual-capable DF-26 (CSS-18) intermediate-range ballistic missile (IRBM) with an estimated maximum range exceeding 3000 km. The missile can reach targets in India, the South China Sea and the western Pacific Ocean, probably including US bases on Guam.[34] The missile is equipped with a manoeuvrable re-entry vehicle (MaRV) that can be rapidly swapped with another warhead. This theoretically allows the PLARF to switch the missile's mission between precision conventional strikes and nuclear strikes against ground targets—and even conventional strikes against naval targets—relatively quickly.[35] The majority of the DF-26s are thought to serve a conventional mission, with a smaller number (perhaps up to one third) assigned a nuclear role. In its 2022 report the US DOD noted that, among China's nuclear forces, the DF-26 is the weapon system that is most likely to be fielded with a lower-yield warhead 'in the near-term', although it remains unclear whether very low-yield options have been produced for China's nuclear forces.[36]

The US DOD estimated in its 2022 report that China might have up to 250 DF-26 launchers and 250 or more DF-26 missiles in its inventory.[37] However, this is significantly more than is indicated by the apparent operational base infrastructure; the US DOD's estimate may thus include launchers that are in production or otherwise not yet fully operational. There were sightings of the missile at several PLARF brigade bases during 2022, and SIPRI assesses that five or six DF-26 brigades appear to be operational, with around

[31] US Department of Defense (note 2), pp. 65, 94; and Lewis, J. G., 'China's belated embrace of MIRVs', eds M. Krepon, T. Wheeler and S. Mason, *The Lure and Pitfalls of MIRVs: From the First to the Second Nuclear Age* (Stimson Center: Washington, DC, May 2016), pp. 95–99.

[32] Sevastopulo, D., 'China conducted two hypersonic weapons tests this summer', *Financial Times*, 20 Oct. 2021. See also Raju, N., 'Developments in space security', *SIPRI Yearbook 2022*, pp. 573–74.

[33] US Department of Defense (note 2), p. 65.

[34] US Department of Defense (note 2), p. 64.

[35] Pollack, J. H. and LaFoy, S., 'China's DF-26: A hot-swappable missile?', Arms Control Wonk, 17 May 2020; Deng, X., 'China deploys Dongfeng-26 ballistic missile with PLA Rocket Force', *Global Times*, 26 Apr. 2018; and US Department of Defense (note 2), p. 65.

[36] US Department of Defense (note 2), p. 98.

[37] US Department of Defense (note 2), p. 167.

162 launchers in total, although only about one third of those are assumed to have a nuclear mission.

The US DOD's 2022 report indicates a sizable increase in China's force of medium-range ballistic missiles (MRBMs), from 150 launchers and 150 or more missiles in 2020 to 250 launchers and 500 or more missiles at the end of 2021.[38] These numbers are probably on the higher end of an estimated range and, as with the above IRBM estimate, could also include launchers and missiles in production. The increase in MRBMs—coupled with the corresponding decrease in China's short-range ballistic missiles (SRBMs)—is most likely due to the replacement of many SRBMs with the new DF-17 (CSS-22) MRBM equipped with a hypersonic glide vehicle (HGV). While China's MRBMs are generally dual-capable, most of them are probably assigned conventional payloads.[39] SIPRI estimates that, as of January 2023, around 24 of the PLARF's MRBMs—the DF-21A/E (CSS-5 Mods 2 and 6)—were assigned nuclear weapons.

Sea-based missiles

In 2022 China continued to pursue its strategic goal from the early 1980s of developing and deploying sea-based nuclear weapons. The PLA Navy (PLAN) currently fields six Type 094 (Jin class) nuclear-powered ballistic missile submarines (SSBNs), two of which are Type 094As—upgraded variants of the original design.[40] The US DOD's 2022 report assesses that these six operational SSBNs constitute China's 'first credible, sea-based nuclear deterrent'.[41] China's SSBN fleet is based at Hainan Island in the South China Sea.

Each of China's Type 094 submarines can carry up to 12 three-stage, solid-fuelled Julang (JL) submarine-launched ballistic missiles (SLBMs), which exist in two types: the JL-2 (CSS-N-14) and the JL-3 (CSS-N-20). US reports in late 2022 suggested that China had replaced or was in the process of replacing the JL-2 SLBMs with the longer-range JL-3.[42] The JL-3 is capable of carrying multiple warheads and has an estimated range of more than 10 000 km.[43] Unless the range is significantly more than 10 000 km, the JL-3 would not be able to strike continental USA if fired from the South China Sea.

[38] US Department of Defense (note 2), p. 167; and US Department of Defense, *Military and Security Developments Involving the People's Republic of China 2020*, Annual Report to Congress (Office of the Secretary of Defense: Washington, DC, 1 Sep. 2020), p. 166.

[39] US Department of Defense (note 2), p. 65.

[40] Chan, M., 'China's new nuclear submarine missiles expand range in US: Analysts', *South China Morning Post*, 2 May 2021.

[41] US Department of Defense (note 2), p. 53.

[42] Capaccio, A., 'China has put longer-range ICBMs on its nuclear subs, US says', Bloomberg, 19 Nov. 2022.

[43] US Air Force (note 17), p. 33.

There has been considerable speculation about whether the missiles on China's SSBNs are routinely fitted with nuclear warheads. The US DOD stated in its 2022 report that China 'likely began near-continuous at-sea deterrence patrols' in 2021.[44] This wording implies that China may have begun intermittent patrols with nuclear weapons onboard, although it is not definitive and would constitute a significant change to the country's long-held practice of keeping nuclear warheads in central storage in peacetime.

China has probably begun construction of its next-generation SSBN, the Type 096.[45] A potential hull section was visible in commercial satellite imagery in February 2021.[46] Reports vary widely on the design parameters, but the new submarine is expected to be larger and quieter than the Type 094 and could potentially be equipped with more missile-launch tubes. Given the expected lifespans of the current Type 094 and the next-generation Type 096 SSBNs, the PLAN is expected to operate both types concurrently.[47] It remains unclear how many SSBNs the PLAN ultimately intends to operate. Satellite imagery from December 2022 shows that China was nearing completion of two new piers at the Longpo Naval Base. This would raise the total number of potential submarine berths at the base from 8 to 12, although some of these could be intended for attack submarines.

[44] US Department of Defense (note 2), p. 96.

[45] US Department of Defense (note 2), p. 96.

[46] Sutton, H. I., 'First image of China's new nuclear submarine under construction', Naval News, 1 Feb. 2021.

[47] US Department of Defense (note 2), p. 96.

VI. Indian nuclear forces

HANS M. KRISTENSEN AND MATT KORDA*

As of January 2023 India was estimated to have a growing stockpile of about 164 nuclear weapons—a small increase from the previous year (see table 7.7). These weapons were assigned to a maturing nuclear triad of aircraft, land-based missiles and nuclear-powered ballistic missile submarines (SSBNs).

The warhead estimate is based on calculations of India's inventory of weapon-grade plutonium (see section X), the estimated number of operational nuclear-capable delivery systems, India's nuclear doctrine, publicly available information on the Indian nuclear arsenal, and private conversations with defence officials.[1] The Indian government has provided little public information about the size of its nuclear forces, other than conducting occasional parade displays and announcing missile flight tests.

This section starts by outlining the role played by nuclear weapons in Indian military doctrine. It then enumerates India's holdings of nuclear weapons—its aircraft and air-delivered weapons and its land- and sea-based missiles—and assesses the nuclear capability of its cruise missiles.

The role of nuclear weapons in Indian military doctrine

The limited ranges of India's initial nuclear systems meant that, until the early 2010s, their only credible role was to deter Pakistan. However, with the development over the subsequent decade of longer-range missiles capable of targeting all of China, in recent years it appears that India has placed increased emphasis on deterring China.

While India has adhered to a nuclear no-first-use (NFU) policy since 1999, this pledge was qualified by a 2003 caveat (reaffirmed in 2018) that India could also use nuclear forces to retaliate against attacks by non-nuclear weapons of mass destruction (WMD).[2] Doubts about India's commitment to the NFU policy have increased with evidence that some parts of India's nuclear arsenal are being kept at a much higher state of readiness.[3] This has prompted a debate about whether India could be transitioning towards

[1] Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Commentary, 14 June 2021.

[2] Indian Ministry of External Affairs, 'The Cabinet Committee on Security reviews [o]perationalization of India's nuclear doctrine', Press release, 4 Jan. 2003; Indian Ministry of External Affairs, 'Draft report of National Security Advisory Board on Indian nuclear doctrine', 17 Aug. 1999; and Indian Prime Minister's Office, 'Prime Minister felicitates crew of INS Arihant on completion of nuclear triad', Press release, 5 Nov. 2018.

[3] For further detail see Kristensen, H. M. and Korda, M., 'Indian nuclear forces', *SIPRI Yearbook 2021*.

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a counterforce nuclear posture to target an adversary's nuclear weapons earlier in a crisis, even before they could be used.[4]

Aircraft and air-delivered weapons

India has several types of combat aircraft with performance characteristics that potentially make them suitable as nuclear-delivery platforms, including the Mirage 2000H, Jaguar IS and Rafale. However, there is no official source that confirms the nuclear-capable role of these aircraft, with one exception: a detailed source describes how the Mirage 2000H was converted for a nuclear strike role in the 1990s.[5] SIPRI estimates that approximately 48 nuclear gravity bombs were assigned to Indian aircraft as of January 2023.

Land-based missiles

The Indian Army's Strategic Forces Command operates five types of mobile nuclear-capable ballistic missile: the short-range Prithvi-II and Agni-I; the medium-range Agni-II; and the intermediate-range Agni-III and Agni-IV. SIPRI estimates that India had around 80 operational missiles as of January 2023. At least two new land-based ballistic missiles were in development: the medium-range Agni-P and the intermediate-range Agni-V; a variant with an intercontinental range, the Agni-VI, was in the design stage of development.[6]

Several of India's land-based ballistic missiles achieved significant milestones in 2022. The Agni-P completed its third test launch in October 2022, following two (one failed and one successful) in 2021. The Indian Army typically requires at least three consecutive successful tests before a missile can be inducted into military service.[7] The Agni-P is described by the Indian Ministry of Defence as a next-generation nuclear-capable ballistic missile. It reportedly incorporates technology developed specifically for the Agni-V programme, including an advanced navigation system and a new mobile canisterized launch system, which will reduce the time required to place the

[4] Clary, C. and Narang, V., 'India's counterforce temptations: Strategic dilemmas, doctrine, and capabilities', *International Security*, vol. 43, no. 3 (winter 2018/19); Kaushal, S. et al., 'India's nuclear doctrine: The Agni-P and the stability–instability paradox', Royal United Services Institute (RUSI), 8 July 2021; and Rajagopalan, R., *India and Counterforce: A Question of Evidence*, ORF Occasional Paper no. 247 (Observer Research Foundation: New Delhi, May 2020).

[5] Kampani, G., 'New Delhi's long nuclear journey: How secrecy and institutional roadblocks delayed India's weaponization', *International Security*, vol. 38, no. 4 (spring 2014), pp. 94, 97–98. For further detail see Kristensen, H. M. and Korda, M., 'Indian nuclear forces', *SIPRI Yearbook 2022*, pp. 393–94.

[6] Vikas, S. V., 'Why India may not test Agni 6 even if DRDO is ready with technology', OneIndia, 10 July 2019.

[7] Gupta, S., 'Agni-P missile moves towards induction after user trials', *Hindustan Times*, 23 Oct. 2022; and O'Donnell, F., 'Aim for higher testing standards', *The Pioneer* (Nioda), 27 July 2015.

Table 7.7. Indian nuclear forces, January 2023

All figures are approximate and some are based on assessments by the authors.

Type/designation	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield[b]	No. of warheads[c]
Aircraft[d]	*84*				*48*
Mirage 2000H	32	1985	1 850	1 x 12 kt bomb	32
Jaguar IS	16	1981	1 600	1 x 12 kt bomb	16
Rafale	36	2022	2 000	. .	–
Land-based missiles	*80*				*80*
Prithvi-II	24	2003	250[e]	1 x 12 kt	24
Agni-I	16	2007	>700	1 x 10–40 kt	16
Agni-II	16	2011	>2 000	1 x 10–40 kt	16
Agni-III	16	2018	>3 200	1 x 10–40 kt	16
Agni-IV	8	2022	>3 500	1 x 10–40 kt	8
Agni-V	. .	[2023]	>5 000	1 x 10–40 kt	. .
Agni-VI	–	[2027]	>6 000	1 x 10–40 kt [possible MIRV]	–
Agni-P	–	[2025]	1 000–2 000	[1 x 10–40 kt]	–
Sea-based missiles	*3/14*[f]				*16*
Dhanush	2	2013	400	1 x 12 kt	4[g]
K-15 (B-05)[h]	12[i]	2018	700	1 x 12 kt	12
K-4	–[j]	[2025]	3 500	1 x 10–40 kt	–
Other stored warheads[k]					[*20*]
Total stockpile	**178**				**164**[k]

. . = not available or not applicable; – = nil or a negligible value; [ ] = uncertain SIPRI estimate; kt = kiloton; MIRV = multiple independently targetable re-entry vehicle.

[a] For aircraft, the listed range is for illustrative purposes only; actual mission range will vary according to flight profile, weapon payload and in-flight refuelling.

[b] The yields of India's nuclear warheads are not known. The 1998 nuclear tests demonstrated yields of up to 12 kt. Since then, it is possible that boosted warheads have been introduced with a higher yield, perhaps up to 40 kt. There is no open-source evidence that India has developed 2-stage thermonuclear warheads.

[c] Aircraft and several missile types are dual-capable—that is, they can be armed with either conventional or nuclear warheads. This estimate counts an average of 1 nuclear warhead per launcher. All estimates are approximate.

[d] The Rafale is listed as a potential future nuclear delivery platform. It seems likely that it would probably initially replace the Jaguar in that role. However, in the absence of official or authoritative sources, SIPRI has not attributed nuclear weapons to Rafale aircraft in its estimate for Jan. 2023. Other aircraft that could potentially have a secondary nuclear role include the Su-30MKI.

[e] The Prithvi-II's range is often reported as 350 kilometres. However, the United States Air Force's National Air and Space Intelligence Center sets the range at 250 km.

[f] The first figure is the number of operational vessels—2 ships and 1 nuclear-powered ballistic missile submarine (SSBN); the second is the maximum number of missiles that they can carry. India has launched 3 SSBNs, but only 1—INS *Arihant*—was believed to be operational as of Jan. 2023, and it was believed to have only a limited operational capability. The second SSBN—INS *Arighat*—was conducting sea trials throughout 2022 and might become operational in 2023. The third, known as S4, was reportedly launched in Nov. 2021 but, as of Jan. 2023, its status remained unclear.

[g] Each Sukanya-class patrol ship equipped with Dhanush missiles was thought to have possibly 1 reload.

[h] The K-15 may have been renamed the B-05. Some sources have referred to the K-15 missile as 'Sagarika', which was the name of the missile-development project, rather than the missile itself.

[i] Each of India's first 2 SSBNs has 4 missile tubes, each of which can carry 3 K-15 submarine-launched ballistic missiles (SLBMs), for a total of 12 missiles per SSBN. Only 1 SSBN was believed to be operational as of Jan. 2023 (see note f).

[j] Each of the 8 missile tubes on India's third and fourth SSBNs will be able to carry 3 K-15 SLBMs or 1 K-4 SLBM once the latter missile becomes operational.

[k] In addition to the *c.* 144 warheads estimated to be assigned to operational forces, SIPRI estimates that *c.* 20 warheads might have been produced for missiles nearing operational status, including the Agni-V (*c.* 8 warheads) and the K-15 (*c.* 12 warheads for INS *Arighat*), for a total estimated stockpile of *c.* 164 warheads. India's warhead stockpile is expected to continue to increase.

Sources: Indian Ministry of Defence, annual reports and press releases; International Institute for Strategic Studies, *The Military Balance*, various years; US Air Force (USAF), National Air and Space Intelligence Center, *Ballistic and Cruise Missile Threat*, various years; Indian news media reports; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

missiles on alert in a crisis.[8] The solid-fuelled Agni-P can reportedly manoeuvre during re-entry, which could allow the missile to evade future missile defences of states in the region (e.g. China and Pakistan). An unidentified government source denied that the Agni-P was intended to replace older Agni missiles.[9]

In 2022 India also conducted test launches of the Prithvi-II, the Agni-III, the Agni-IV and the Agni-V. Notably, the Indian government, for the first time, described the Agni-IV test as 'part of routine user training launches', which is the language typically used to describe tests of Indian missiles already in service.[10] Given the missile's apparent induction in 2014 and subsequent serial production, SIPRI assesses that the Agni-IV became operational in 2022.[11] The three-stage, solid-fuelled Agni-V was test launched for the ninth time in December 2022.[12] Reports on the test suggest that the Indian Defence Research and Development Organisation (DRDO) may have been testing a new solid rocket motor made from lighter composite materials to increase the missile's range.[13]

[8] Indian Ministry of Defence (MOD), 'DRDO successfully flight tests new generation Agni P ballistic missile', Press release, 28 June 2021; and Rout, H. K., 'India test fires new generation nuclear capable Agni-Prime missile off Odisha coast', *New Indian Express*, 28 June 2021.

[9] Philip, S. A., 'Agni Prime is the new missile in India's nuclear arsenal. This is why it's special', ThePrint, 30 June 2021; and Zhen, L., 'India's latest Agni-P missile no great threat to China: Experts', *South China Morning Post*, 1 July 2021.

[10] Indian Ministry of Defence, 'Intermediate range ballistic missile, Agni-4, successfully tested', Press release, 6 June 2022; Indian Ministry of Defence, 'Year end review 2022', 17 Dec. 2022; and Wright, T., 'India's test of the Agni-IV', International Institute for Strategic Studies, 27 June 2022.

[11] Subramanian, T. S., 'Agni-IV missile successfully test fired', *The Hindu*, 20 Jan. 2014.

[12] Sharma, A., 'India tests long-range missile for nuclear deterrence', AP News, 15 Dec. 2022; and Gupta, S., 'Has the range of Agni V missile been increased?', *Hindustan Times*, 16 Dec. 2022.

[13] Gupta (note 12).

India is developing a land-based version of the short-range K-15 submarine-launched ballistic missile (SLBM), known as the Shaurya.[14] However, because of the high level of uncertainty about the status of the Shaurya, it is not included in SIPRI's estimate for January 2023.[15]

India is believed to be developing multiple independently targetable re-entry vehicles (MIRVs), but as of January 2023 the status of the programme remained unclear. The technology has reportedly been tested on the Agni-P and could potentially be used on the intercontinental Agni-VI currently in development.[16] The Agni-VI is controversial because its expected range may extend well beyond India's possible regional targets in Pakistan and China.

Sea-based missiles

With the aim of creating an assured second-strike capability, India has continued to develop the naval component of its nascent nuclear triad and to build a fleet of four to six SSBNs.[17] The first of these SSBNs, INS *Arihant*, completed what the Indian government described as its first 'deterrence patrol' in 2018—although it seems unlikely that the missiles were armed with nuclear warheads at the time.[18] A second SSBN, INS *Arighat*, was launched in November 2017 and underwent advanced sea trials in 2021–22 ahead of its expected commissioning into the Indian Navy in 2023.[19] Satellite imagery indicates that each submarine has been equipped with a four-tube vertical-launch system and each could carry up to 12 two-stage, short-range K-15 SLBMs (which may have been renamed the B-05).[20] SIPRI estimates that 12 nuclear warheads have been delivered for potential deployment by INS *Arihant* and another 12 have been produced for INS *Arighat*.

A third submarine, known as S4, was reportedly launched in November 2021, and a fourth is under construction for possible launch in 2023.[21] These

[14] See e.g. Press Trust of India, 'India successfully test-fires nuclear capable hypersonic missile Shaurya', *Hindustan Times*, 3 Oct. 2020; and Gupta, S., 'Govt okays induction of nuke-capable Shaurya missile amid Ladakh standoff', *Hindustan Times*, 6 Oct. 2020.

[15] For further detail see Kristensen and Korda (note 5), p. 395.

[16] Rout, H. K., 'India to conduct first user trial of Agni-V missile', *New Indian Express*, 13 Sep. 2021.

[17] Davenport, K., 'Indian submarine completes first patrol', *Arms Control Today*, vol. 48, no. 10 (Dec. 2018).

[18] Peri, D., 'Now, India has a nuclear triad', *The Hindu*, 18 Oct. 2016; Indian Prime Minister's Office (note 2); Davenport (note 17); and Joshi, Y., 'Angels and dangles: Arihant and the dilemma of India's undersea nuclear weapons', War on the Rocks, 14 Jan. 2019.

[19] 'Indian submarine fleet to get fresh impetus by early 2023', *Economic Times* (Mumbai), 21 Oct. 2022.

[20] Indian Defence Research and Development Organisation (DRDO), 'MSS—achievements', 6 Sep. 2019.

[21] Biggers, C. (@CSBiggers), Twitter, 28 Dec. 2021, <https://twitter.com/CSBiggers/status/1476048094580117509>; and Unnithan, S., 'A peek into India's top secret and costliest defence project, nuclear submarines', *India Today*, 10 Dec. 2017; and Bhattacharjee, S., 'Third Arihant class submarine quietly launched in November', *The Hindu*, 4 Jan. 2022.

submarines are believed to be significantly larger than the first two; satellite imagery indicates that they are approximately 20 metres longer.[22] They will reportedly have eight launch tubes able to hold up to 24 K-15 missiles or 8 K-4 missiles.[23] The K-4 is in development but probably remains several years away from operational capability. Two potential test launches of the K-4 in 2022 were apparently disrupted by the presence of Chinese spy ships.[24]

India's first naval nuclear weapon, the short-range Dhanush missile, is a version of the dual-capable Prithvi-II that can be launched from two Sukanya-class offshore patrol vessels.[25] Given the slow speed and high degree of vulnerability of the Sukanya-class vessels, the system will probably be retired when the SSBN programme with longer-range missiles matures.

Cruise missiles

There have been numerous media claims that some Indian cruise missiles are nuclear-capable. These claims concern the ground- and air-launched Nirbhay subsonic cruise missile and the supersonic air-, ground-, ship- and submarine-launched BrahMos cruise missile.[26] Notably, one of the latter was accidentally launched into Pakistani territory in March 2022 (see section VII).

Although a DRDO poster at an Indian defence exhibition in October 2022 listed the Nirbhay as capable of delivering 'conventional and strategic warheads', as of January 2023 no known official or authoritative source had explicitly attributed nuclear capability to India's cruise missiles.[27] In addition, United States sources list the BrahMos as 'conventional'.[28] The systems are therefore excluded from SIPRI's estimate for January 2023.

[22] Sutton, H. I., 'Indian Navy's third ballistic missile submarine doubles missile armament', Covert Shores, 29 Dec. 2021.

[23] Bhattacharjee (note 21). See also Kristensen and Korda (note 5), p. 397.

[24] 'Chinese spy ships may complicate India's missile test plans in Indian Ocean for the second month in a row', *Swarajya*, 7 Dec. 2022.

[25] 'Nuke-capable Dhanush and Prithvi-II launched', *New Indian Express*, 12 Mar. 2011; and Indian Ministry of Defence (MOD), *Annual Report 2018–19* (MOD: New Delhi, 2019), p. 100.

[26] See e.g. Pandit, R., 'India successfully tests its first nuclear-capable cruise missile', *Times of India*, 8 Nov. 2017; Gady, F.-S., 'India successfully test fires indigenous nuclear-capable cruise missile', The Diplomat, 8 Nov. 2017; and Mitra, J., 'Nuclear BrahMos: On the anvil?', South Asian Voices, 10 July 2018.

[27] A copy of the DRDO poster is available on Twitter. Alpha Defense (@alpha_defense), Twitter, 19 Oct. 2022, <https://twitter.com/alpha_defense/status/1582584800191590401>.

[28] US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat 2017* (NASIC: Wright-Patterson Air Force Base, OH, June 2017), p. 37.

VII. Pakistani nuclear forces

HANS M. KRISTENSEN AND MATT KORDA*

According to SIPRI estimates, Pakistan possessed approximately 170 nuclear warheads as of January 2023—a small increase compared with the previous year (see table 7.8). These weapons were assigned to Pakistan's nascent triad of aircraft, ground-launched ballistic and cruise missiles, and sea-launched cruise missiles. The development of several new delivery systems and Pakistan's growing accumulation of fissile material (see section X) suggest that its nuclear weapon arsenal and fissile material stockpile are likely to continue to expand over the next decade, although projections vary considerably.[1]

The Pakistani government has never publicly disclosed the size of its nuclear arsenal. Limited official public data and exaggerated news stories about Pakistan's nuclear weapons mean that analysing the number and types of Pakistani warheads and delivery vehicles is fraught with uncertainty.[2] The estimates in this section are based on the authors' analysis of Pakistan's nuclear posture, fissile material production, public statements by Western officials and private conversations with Pakistani officials.

This section starts by outlining the role played by nuclear weapons in Pakistan's military doctrine. It then describes Pakistan's air-delivered and land-based weapons and the nascent sea-based capability.

The role of nuclear weapons in Pakistani military doctrine

Pakistan has been pursuing the development and deployment of new nuclear weapons and delivery systems as part of its 'full spectrum deterrence posture' in relation to India.[3] This includes long-range missiles and aircraft as well as several short-range, lower-yield nuclear-capable weapon systems.[4]

[1] See e.g. Sundaresan, L. and Ashok, K., 'Uranium constraints in Pakistan: How many nuclear weapons does Pakistan have?', *Current Science*, vol. 115, no. 6 (25 Sep. 2018); Salik, N., 'Pakistan's nuclear force structure in 2025', Regional Insight, Carnegie Endowment for International Peace, 30 June 2016; and Jones, G. S., 'Pakistan's nuclear material production for nuclear weapons', Proliferation Matters, 16 Feb. 2021. See also Berrier, S., Director, US Defense Intelligence Agency, 'Worldwide threat assessment', Statement for the record, US Senate, Armed Services Committee, 26 Apr. 2021. On Pakistan's fissile material stockpile see Kile, S. N. and Kristensen, H. M., 'Pakistani nuclear forces', *SIPRI Yearbook 2019*; and International Panel on Fissile Materials, 'Pakistan', 31 Aug. 2021.

[2] Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Commentary, 14 June 2021.

[3] Kidwai, K., Keynote address and discussion session, 77th South Asian Strategic Stability workshop, 'Deterrence, nuclear weapons and arms control', International Institute for Strategic Studies (IISS) and Centre for International Strategic Studies (CISS), 6 Feb. 2020. For a detailed assessment of Pakistan's nuclear posture see Tasleem, S. and Dalton, T., 'Nuclear emulation: Pakistan's nuclear trajectory', *Washington Quarterly*, vol. 41, no. 4 (winter 2019).

[4] Pakistani Inter Services Public Relations (ISPR), Press release no. PR-94/2011-ISPR, 19 Apr. 2011.

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Pakistan has placed an emphasis on non-strategic (tactical) nuclear weapons specifically in response to India's 'Cold Start' doctrine.[5]

In March 2022 India accidentally launched a conventional BrahMos cruise missile into Pakistani territory during a 'routine maintenance and inspection' exercise.[6] India reportedly did not alert Pakistan during the crisis and only issued a public statement two days after the incident. Pakistan may not have tracked the missile correctly while it was in flight.[7] During the incident, the Pakistan Air Force (PAF) Air Defence Operations Centre is reported to have suspended all military and civilian aircraft for nearly six hours and placed frontline bases and strike aircraft on high alert.[8] The two countries' initial responses to the incident suggest that regional crisis frameworks in South Asia may be far less stable than previously assumed.

In October 2022 United States President Joe Biden commented that Pakistan was 'one of the most dangerous nations in the world' due to the lack of 'cohesion' in its nuclear security and command and control procedures.[9] Pakistan forcefully rebutted this statement.

Aircraft and air-delivered weapons

As of January 2023 Pakistan was estimated to operate a small stockpile of nuclear gravity bombs.

Two versions of the Ra'ad (Hatf-8) air-launched cruise missile (ALCM) were being developed to supplement this stockpile by providing the PAF with a nuclear-capable stand-off capability at ranges of 350–600 kilometres.[10] Neither version had been operationally deployed as of January 2023.

Pakistan has several types of combat aircraft with performance characteristics that make them suitable as nuclear-delivery platforms, including the Mirage III, the Mirage V, the F-16 and the JF-17. However, no official sources have confirmed their nuclear-capable roles. Given this significant uncertainty, SIPRI assesses that the Mirage III and possibly the Mirage V are

[5] On the doctrine—under which India looks to maintain the capability to launch large-scale conventional strikes or incursions against Pakistani territory at a level below the threshold at which Pakistan would retaliate with nuclear weapons—see Kidwai (note 3); and Saalman, L. and Topychkanov, P., *South Asia's Nuclear Challenges: Interlocking Views from India, Pakistan, China, Russia and the United States* (SIPRI: Stockholm, Apr. 2021). For a US diplomatic assessment of India's 'Cold Start' strategy see Roemer, T., US Ambassador to India, 'Cold Start: A mixture of myth and reality', Cable New Delhi 000295, 16 Feb. 2010, via WikiLeaks. Although Indian officials had previously denied the existence of the Cold Start doctrine, India's chief of the army staff acknowledged its existence in an interview in 2017. Unnithan, S., '"We will cross again"', *India Today*, 4 Jan. 2017.

[6] Korda, M., 'Flying under the radar: A missile accident in South Asia', FAS Strategic Security Blog, Federation of American Scientists, 4 Apr. 2022.

[7] Korda (note 6).

[8] Bhatt, M., 'The curious case of a misfired missile', *DNA* (Mumbai), 14 Mar. 2022.

[9] Khan, Z., 'Pakistan hits back at Biden's "dangerous nation" comment', AP News, 15 Oct. 2022.

[10] For further detail on the Ra'ad ALCM see Kristensen, H. M. and Korda, M., 'Pakistani nuclear forces', *SIPRI Yearbook 2021*, p. 387.

Table 7.8. Pakistani nuclear forces, January 2023

All figures are approximate and some are based on assessments by the authors.

Type/designation	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield[b]	No. of warheads[c]
Aircraft[d]	*36*				*36*
Mirage III/V	36[e]	1998	2 100	1 x 5–12 kt bomb or Ra'ad ALCM (in development)[f]	36
Land-based missiles	*126*[g]				*126*
Abdali (Hatf-2)	10	2002	200	1 x 5–12 kt	10
Ghaznavi (Hatf-3)	16	2004	300	1 x 5–12 kt	16
Shaheen-I/IA (Hatf-4)[h]	16	2003/2022	750/900	1 x 5–12 kt	16
Shaheen-II (Hatf-6)	24	2014	2 000	1 x 10–40 kt	24
Shaheen-III[i]	–	[2023]	2 750	1 x 10–40 kt	–
Ghauri (Hatf-5)	24	2003	1 250	1 x 10–40 kt	24
Nasr (Hatf-9)	24	2013	70	1 x 5–12 kt	24
Ababeel	–	. .	2 200	[MRV or MIRV][j]	–
Babur/-1A GLCM (Hatf-7)[k]	12	2014/[early 2020s]	350/450	1 x 5–12 kt	12
Babur-2 GLCM[l]	–	. .	900	1 x 5–12 kt	–
Sea-based missiles					
Babur-3 SLCM	–	[2025]	450	1 x 5–12 kt	–
Other stored warheads[m]					[*8*]
Total stockpile	**162**				**170**[m]

. . = not available or not applicable; – = nil or a negligible value; [ ] = uncertain SIPRI estimate; ALCM = air-launched cruise missile; GLCM = ground-launched cruise missile; kt = kiloton; MIRV = multiple independently targetable re-entry vehicle; MRV = multiple re-entry vehicle; SLCM = sea-launched cruise missile.

[a] For aircraft, the listed range is for illustrative purposes only; actual mission range will vary according to flight profile, weapon payload and in-flight refuelling.

[b] The yields of Pakistan's nuclear warheads are not known. The 1998 nuclear tests demonstrated a yield of up to 12 kt. Since then, it is possible that boosted warheads have been introduced with a higher yield. There is no open-source evidence that Pakistan has developed 2-stage thermonuclear warheads.

[c] Aircraft and several missile types are dual-capable—that is, they can be armed with either conventional or nuclear warheads. Cruise missile launchers (aircraft and land- and sea-based missiles) can carry more than 1 missile. This estimate counts an average of 1 nuclear warhead per launcher. Pakistan does not deploy its warheads on launchers but keeps them in separate storage facilities.

[d] There are unconfirmed reports that Pakistan modified for a nuclear weapon-delivery role some of the 40 F-16 aircraft procured from the United States in the 1980s. However, it is assumed here that the nuclear weapons assigned to aircraft are for use by Mirage aircraft. When the Mirage IIIs and Vs are eventually phased out, it is possible that the JF-17 will take over their nuclear role in the Pakistan Air Force.

[e] Pakistan possesses many more than 36 Mirage aircraft, but this table only includes those that are assumed to have a nuclear weapon-delivery role.

[f] The Ra'ad (Hatf-8) ALCM has a claimed range of 350 km and an estimated yield of 5–12 kt. However, there is no available evidence to suggest that the Ra'ad has been deployed and it is therefore not included in the operational warhead count. In 2017 the Pakistani military displayed

a Ra'ad-II variant with a reported range of 600 km. It was test flown for the first time in 2020 and several additional flights will be needed before it becomes operational.

[g] Some launchers might have 1 or more missile reloads.

[h] It is unclear whether the Shaheen-IA has the same 'Hatf-4' designation as the Shaheen-I.

[i] The designation for the Shaheen-III is unknown.

[j] The Pakistani military claimed in 2017 that the Ababeel can deliver multiple warheads using MIRV technology, but does not appear to have provided any further information since then.

[k] Pakistan has been upgrading its original Babur GLCMs to Babur-1As by improving their avionics and target-engagement systems to hit both land and sea targets. The range of the original Babur is listed as 350 km by the US Air Force's National Air and Space Intelligence Center, while Pakistan claims that the range of the improved Babur-1A is 450 km.

[l] The Babur-2 GLCM is sometimes referred to as the Babur-1B.

[m] In addition to the *c.* 162 warheads estimated to be assigned to operational forces, SIPRI estimates that *c.* 8 warheads have been produced to arm future Shaheen-III missiles, for a total estimated stockpile of *c.* 170 warheads. Pakistan's warhead stockpile is expected to continue to increase.

Sources: Pakistani Ministry of Defence, various documents; US Air Force (USAF), National Air and Space Intelligence Center, *Ballistic and Cruise Missile Threat*, various years; International Institute for Strategic Studies, *The Military Balance*, various years; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

the most likely to have a nuclear-delivery role. The Mirage III has been used for developmental test flights of the nuclear-capable Ra'ad ALCM, while the Mirage V is believed to have been given a strike role with Pakistan's small arsenal of nuclear gravity bombs.[11]

At the end of 2022 Pakistan had more than 100 operational JF-17 aircraft and had plans in place to acquire around another 188 JF-17s to replace the ageing Mirage III and Mirage V aircraft.[12] When the Mirage aircraft are eventually phased out, it is possible that the JF-17 will take over their nuclear role in the PAF and that the Ra'ad ALCM will be integrated on to the JF-17.[13]

Land-based missiles

As of January 2023 Pakistan's nuclear-capable ballistic missile arsenal comprised an estimated 126 short- and medium-range systems.

Pakistan has deployed four types of solid-fuelled, road-mobile short-range ballistic missile: the Abdali (also designated Hatf-2), the Ghaznavi (Hatf-3), the Shaheen-I/IA (Hatf-4) and the Nasr (Hatf-9). The dual-capable Ghaznavi was test launched twice in 2021, after which the PAF listed its range

[11] International Institute for Strategic Studies (IISS), *The Military Balance 2022* (Routledge: London, 2022), p. 297; and Dominguez, G., 'Pakistan test-launches longer-range variant of Ra'ad II ALCM', Janes, 19 Feb. 2020. For further detail on the nuclear capability of the F-16s see Kristensen, H. M. and Kile, S. N., 'Pakistani nuclear forces', *SIPRI Yearbook 2020*, p. 370.

[12] Aamir, A., 'Pakistan to boost air strike power with 50 enhanced fighter jets', Nikkei, 6 Feb. 2022.

[13] 'Ra'ad ALCM: The custodian of Pakistan's airborne nuclear deterrence', PakDefense, 6 Dec. 2020; and Pakistan Strategic Forum, 'Update on Pakistan: "JF-17 Thunder's integration with RA'AD II ALCM"', 8 July 2020.

as 290 km.[14] The Shaheen-IA, an extended-range version of the Shaheen-I, was test launched twice in 2021—once to a range of 900 km.[15] While the Shaheen-I was displayed at the 2021 Pakistan Day Parade, it was replaced by the Shaheen-IA at the 2022 parade, potentially indicating the latter system's deployment.[16] Notably, the Abdali—Pakistan's oldest ballistic missile type—was not displayed at the Pakistan Day Parade in either 2021 or 2022 and has not been tested since 2013, perhaps indicating that the missile is being superseded by newer systems.

The arsenal also included two types of operational medium-range ballistic missile: the liquid-fuelled, road-mobile Ghauri (Hatf-5); and the two-stage, solid-fuelled, road-mobile Shaheen-II (Hatf-6).[17] A longer-range variant in development, the Shaheen-III, has been test launched at least three times—in 2015, 2021 and April 2022—but was probably not yet deployed as of January 2023.[18] This missile has a claimed range of 2750 km, making it the longest-range system that Pakistan has tested to date. The Ghauri, Shaheen-II and Shaheen-III were all displayed at the Pakistan Day Parade in 2022. The Pakistani government has claimed that the Ababeel (a variant of the Shaheen-III under development) could deliver multiple warheads, using multiple independently targetable re-entry vehicle (MIRV) technology, but its last test launch was in 2017 and its status remained unclear as of January 2023.[19]

[14] Pakistani Inter Services Public Relations (ISPR), 'Pakistan conducted a training launch of surface to surface ballistic missile Ghaznavi', Press release no. PR-141/2021-ISPR, 12 Aug. 2021; and Pakistani Inter Services Public Relations (ISPR), 'Pakistan today conducted a successful training launch of surface to surface ballistic missile Ghaznavi, capable of delivering nuclear and conventional warheads up to a range of 290 kilometers', Press release no. PR-19/2021-ISPR, 3 Feb. 2021.

[15] Pakistani Inter Services Public Relations (ISPR), 'Pakistan conducted successful flight test of Shaheen-1A surface to surface ballistic missile', Press release no. PR-199/2021-ISPR, 25 Nov. 2021; and Pakistani Inter Services Public Relations (ISPR), 'Pakistan conducted successful flight test of Shaheen-1A surface to surface ballistic missile, having a range of 900 kilometers', Press release no. PR-59/2021-ISPR, 26 Mar. 2021.

[16] Pakistani Inter Services Public Relations (ISPR), 'Pakistan Day Parade: 23 March 2022', ISPR Official, YouTube, 24 Mar. 2022; and Pakistani Inter Services Public Relations (ISPR), 'Pakistan Day Parade: March 2021', ISPR Official, YouTube, 25 Mar. 2021.

[17] United States Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat 2020* (NASIC: Wright-Patterson Air Force Base, OH, July 2020), p. 25; and Pakistani Inter Services Public Relations (ISPR), 'Pakistan conducted successful training launch of surface to surface ballistic missile Shaheen-II', Press release no. PR-104/2019-ISPR, 23 May 2019.

[18] Pakistani Inter Services Public Relations (ISPR), 'Shaheen 3 missile test', Press release no. PR-61/2015-ISPR, 9 Mar. 2015; Jamal, S., 'Pakistan tests nuclear-capable Shaheen-III ballistic missile', *Gulf News*, 20 Jan. 2021; and ISPR spokesperson (@OfficialDGISPR), Twitter, 9 Apr. 2022, <https://twitter.com/OfficialDGISPR/status/1512710884518359042>.

[19] Pakistani Inter Services Public Relations (ISPR), Press release no. PR-34/2017-ISPR, 24 Jan. 2017. The US Air Force's National Air and Space Intelligence Center also describes the 2017 test as involving 'the MIRV version of the Ababeel'. US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat 2017* (NASIC: Wright-Patterson Air Force Base, OH, June 2017), p. 25. On the Ababeel see also Kile and Kristensen (note 1), p. 335.

In addition to expanding its arsenal of land-based ballistic missiles, Pakistan has continued to develop the nuclear-capable Babur (Hatf-7) ground-launched cruise missile, with an estimated range of 350 km.[20] The Babur has been test launched about 12 times since 2005 and it has been used in army field training since 2011, indicating that the system is probably operational. An upgraded version, with a claimed range of 450 km, is known as the Babur-1A and was featured in the 2022 Pakistan Day Parade.[21] A version known as the Babur-2 (sometimes referred to as the Babur-1B) has a claimed range of 900 km and was tested most recently in December 2021.[22]

Sea-based missiles

As part of its efforts to achieve a secure second-strike capability, Pakistan has sought to create a nuclear triad by developing a sea-based nuclear force. The Babur-3 submarine-launched cruise missile (SLCM) is intended to establish a nuclear capability for the Pakistan Navy's three Agosta-90B diesel–electric submarines.[23] Pakistan test launched the Babur-3 in 2017 and 2018.[24]

[20] US Air Force (note 19), p. 37.

[21] Pakistani Inter Services Public Relations, 'Pakistan Day Parade: 23 March 2022' (note 16); and Pakistani Inter Services Public Relations (ISPR), 'Press release no. PR24/2021, Pak conducted successful launch of Babur cruise missile—11 Feb 2021(ISPR)', ISPR Official, YouTube, 11 Feb. 2021.

[22] Pakistani Inter Services Public Relations (ISPR), 'Pakistan conducted a successful test of an enhanced range version of the indigenously developed Babur cruise missile', Press release no. PR-142/2018-ISPR, 14 Apr. 2018; Gupta, S., 'Pakistan's effort to launch 750km range missile crashes', *Hindustan Times*, 23 Mar. 2020; and Pakistani Inter Services Public Relations (ISPR), 'Pakistan conducted a successful test of an enhanced range version of the indigenously developed Babur cruise missile 1B', Press release no. PR-222/2021-ISPR, 21 Dec. 2021.

[23] Pakistani Inter Services Public Relations (ISPR), Press release no. PR-10/2017-ISPR, 9 Jan. 2017; and Panda, A. and Narang, V., 'Pakistan tests new sub-launched nuclear-capable cruise missile. What now?', The Diplomat, 10 Jan. 2017.

[24] Pakistani Inter Services Public Relations (ISPR), 'Pakistan conducted another successful test fire of indigenously developed submarine launched cruise missile Babur having a range of 450 kms', Press release no. PR-125/2018-ISPR, 29 Mar. 2018. Reports of a ship-launched cruise missile test in 2019 might have been for a different missile. Gady, F.-S., 'Pakistan's Navy test fires indigenous anti-ship/land-attack cruise missile', The Diplomat, 24 Apr. 2019.

VIII. North Korean nuclear forces

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The Democratic People's Republic of Korea (DPRK, or North Korea) maintains an active but highly opaque nuclear weapon programme. SIPRI estimates that, as of January 2023, North Korea possessed around 30 nuclear weapons (see table 7.9, end of section), but that it probably possessed sufficient fissile material for an approximate total of 50–70 nuclear devices, depending on warhead design.

These estimates are based on calculations of the amount of fissile material—plutonium and highly enriched uranium (HEU)—that North Korea is believed to have produced for use in nuclear weapons (see section X), its nuclear weapon testing history and its observable missile forces. Analysing the numbers and types of North Korean warheads and delivery vehicles is fraught with uncertainty due to limited and untrustworthy public sources. Most of the data presented here is derived from sources outside North Korea, including satellite imagery, United States government reports and statements (which may also be biased), and expert analyses.[1]

North Korea has conducted a total of six nuclear explosive tests: in 2006, 2009, 2013, twice in 2016, and most recently 2017.[2] In January 2020 the North Korean government announced that it would no longer observe the moratorium on conducting nuclear explosive tests or flight tests of intermediate-range and intercontinental ballistic missiles that it imposed upon itself in 2018.[3] It actually ended the moratorium in 2022 by launching a Hwasong-12 (KN17) intermediate-range ballistic missile (IRBM).[4] This publicly acknowledged long-range ballistic missile launch was part of an unprecedentedly busy year of missile testing for North Korea: it conducted more than 90 tests of short-range ballistic missiles (SRBMs), medium-range ballistic missiles (MRBMs), land-attack cruise missiles, hypersonic glide vehicles (HGVs), submarine-launched ballistic missiles (SLBMs), IRBMs and intercontinental ballistic missiles (ICBMs).

In addition, in January 2021 the North Korean leader, Kim Jong Un, announced that North Korea had been able to develop tactical (i.e. non-

[1] Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Commentary, 14 June 2021.

[2] Fedchencko, V., 'Nuclear explosions, 1945–2017', *SIPRI Yearbook 2018*.

[3] Nebehay, S., 'North Korea abandons nuclear freeze pledge, blames "brutal" US sanctions', Reuters, 21 Jan. 2020.

[4] For the missiles and submarines discussed in this section, a designation in parentheses (e.g. KN17 in this case) following the North Korean designation (e.g. Hwasong-12) is the designation assigned by the US Department of Defense.

* The authors wish to thank Eliana Johns for contributing invaluable research to this publication.

strategic) nuclear weapons and 'a super-large hydrogen bomb'.[5] The latter claim might refer to a weaponized design of the nuclear device that was tested in 2017 and is suspected to have had a thermonuclear yield.[6] Kim also emphasized the need to 'make nuclear weapons smaller and lighter for more tactical uses', possibly for deployment on some of the new shorter-range missiles that were test launched in 2021–22.[7]

This section continues by summarizing the role played by nuclear weapons in North Korea's military doctrine. It then outlines the country's capabilities for production of fissile material and nuclear warheads before describing its missiles and missile programmes.

The role of nuclear weapons in North Korean military doctrine

North Korea has repeatedly signalled through doctrinal commitments and the testing of new capabilities that it will continue to develop its long- and short-range nuclear capabilities to serve as both a deterrent and potentially a response to any perceived threat.

According to North Korea's 2013 Law on Consolidating the Position of a Self-defence Nuclear Power, the country's nuclear arsenal would only be used 'to repel invasion or attack from a hostile nuclear weapons state and make retaliatory strikes', and nuclear weapons would not be used against non-nuclear states 'unless they join a hostile nuclear weapons state in its invasion and attack on the DPRK'.[8] In a speech in October 2020, Kim Jong Un reiterated North Korea's pledge not to use nuclear weapons 'preemptively'.[9] This does not constitute a no-first-use policy, however, since Kim made it clear that he could turn to nuclear weapons if 'any forces infringe upon the security of our state'.[10]

The development of tactical weapons with lower yields could indicate plans to have the capability to respond on a more limited scale to threats that do not meet the threshold for a full-scale nuclear attack. In 2022 North Korea tested several short-range missiles that state media claimed were meant for deploying tactical nuclear weapons, and it even launched a barrage of missiles that simulated use of its tactical battlefield nuclear weapons to 'hit and

[5] Korean Central News Agency, 'On report made by Supreme Leader Kim Jong Un at eighth Party Congress of WPK', KCNA Watch, 9 Jan. 2021.

[6] Fedchencko (note 2), p. 299.

[7] Korean Central News Agency (note 5); and 'Respected comrade Kim Jong Un guides military drills of KPA units for operation of tactical nukes', *Rodong Sinmun*, 10 Oct. 2022.

[8] [Law on Consolidating the Position of a Self-defence Nuclear Power], adopted by the Supreme People's Assembly 1 Apr. 2013, articles 4 and 5 (in Korean). For an English translation see Korean Central News Agency, 'Law on consolidating position of nuclear weapons state adopted', Korea News Service, 1 Apr. 2013.

[9] 'Kim Jong Un's October speech: More than missiles', 38 North, 13 Oct. 2020.

[10] 'Kim Jong Un's October speech' (note 9). On North Korea's nuclear doctrine and likely targets see also Kristensen, H. M. and Korda, M., 'North Korean nuclear forces', *SIPRI Yearbook 2022*, pp. 411–15.

wipe out the set objects'.[11] The eventual deployment of tactical weapons also raises questions about North Korea's nuclear command and control, particularly surrounding whether Kim has pre-delegated nuclear launch authority to his battlefield commanders.

Notably, on 8 September 2022 the North Korean Parliament, the Supreme People's Assembly, passed a law promulgating a new doctrine that specified updated principles and conditions for the use of nuclear weapons.[12] The law, which updated and repealed the 2013 law, requires that North Korea's nuclear forces are 'regularly ready for action'.[13] It also clarifies that nuclear weapons could be used pre-emptively—contradicting the pledge from October 2020—in response to a perceived nuclear or non-nuclear attack on North Korea's leadership or the command structure of its nuclear forces, or other significant attack against a strategic target.[14] It also suggests that North Korea could use nuclear weapons to 'seize the initiative' during wartime.[15] In a speech to the assembly, Kim Jong Un declared that the law codified North Korea's 'irreversible' status as a nuclear-armed state and that it would 'never give up' its nuclear weapons.[16]

Further, in December 2022 the plenary meeting of the Central Committee of the Worker's Party of Korea (WPK) highlighted the importance of 'mass-producing of tactical nuclear weapons' for use against regional targets, in Japan and the Republic of Korea (South Korea).[17] It also noted that the first mission of North Korea's nuclear force is to 'deter war and safeguard peace and stability', but that, if deterrence fails, it will 'carry out the second mission, which will not be for defense'. North Korea's strategy also includes the development of another ICBM system 'whose main mission is quick nuclear counterstrike'.[18] This probably refers to North Korea's planned development of a solid-fuelled ICBM, which would allow launch crews to maintain a higher state of readiness and execute a quicker launch process than a liquid-fuelled ICBM.

[11] 'Respected comrade Kim Jong Un guides military drills' (note 7).

[12] [Law on the Nuclear Weapons Policy of the Democratic People's Republic of Korea], adopted by the Supreme People's Assembly 8 Sep. 2022 (in Korean). For an English translation see Korean Central News Agency, 'Law on DPRK's policy on nuclear forces promulgated', DPRK Today, 9 Sep. 2022.

[13] [Law on the Nuclear Weapons Policy] (note 12), Article 7.

[14] [Law on the Nuclear Weapons Policy] (note 12), Article 6.

[15] [Law on the Nuclear Weapons Policy] (note 12), Article 6.

[16] *Rodong Sinmun*, [State administration speech by dear comrade Kim Jong Un at the 7th session of the 14th Supreme People's Assembly of the Democratic People's Republic of Korea 8 September Juche 111 (2022)], KCNA Watch, 9 Sep. 2022 (in Korean, author translation).

[17] 'Report on 6th enlarged plenary meeting of 8th WPK Central Committee', *Minju Choson*, 1 Jan. 2023.

[18] 'Report on 6th enlarged plenary meeting' (note 17).

Fissile material and warhead production

Plutonium-production and -separation capabilities

North Korea's plutonium-production and -separation capabilities for manufacturing nuclear weapons are located at the Yongbyon Nuclear Scientific Research Centre in North Pyongan province.[19] Since its inspectors were required to leave the country in 2009, the International Atomic Energy Agency (IAEA) has monitored North Korea's nuclear programme using open-source information and commercial satellite imagery.[20]

The Yongbyon complex houses an ageing 5-megawatt-electric (MW(e)) graphite-moderated research reactor, from which plutonium can be extracted. Between December 2018 and July 2021 the IAEA found no signs that the reactor had been operational; however, in August 2021 the IAEA reported that there were indications that this had changed.[21] These indications of the reactor's likely operational status were confirmed in September 2022 by the IAEA director general, Rafael Grossi.[22] It remains unclear whether North Korea has resumed construction of the 50-MW(e) reactor at Yongbyon that began in the 1980s. However, various activities observable at the site suggest that construction may have restarted in early 2022.[23]

In July 2022 commercial satellite imagery revealed smoke emitting from the thermal plant at the Yongbyon complex, which supplies steam to the radiochemistry laboratory used for plutonium reprocessing. This suggests that, although the plant may not be operating at full power, it could have been in early stages of preparation for a reprocessing campaign or treatment of radioactive waste.[24] New activity was also observed for the first time since 2016 at Building 500, a facility used to store radioactive and toxic waste produced at the radiochemistry laboratory.[25]

Throughout 2021 and 2022, commercial satellite imagery indicated that North Korea continued construction of a new experimental light

[19] For an assessment of North Korea's nuclear weapon production facilities and infrastructure see Hecker, S. S., Carlin, R. L. and Serbin, E. A., 'A comprehensive history of North Korea's nuclear program: 2018 update', Stanford University, Center for International Security and Cooperation, 11 Feb. 2019.

[20] Dixit, A., 'IAEA ready to undertake verification and monitoring in North Korea', International Atomic Energy Agency (IAEA), 4 Mar. 2019.

[21] International Atomic Energy Agency (IAEA), Board of Governors and General Conference, 'Application of safeguards in the Democratic People's Republic of Korea', Report by the Director General, GOV/2021/40-GC(65)/22, 27 Aug. 2021, para. 12; and Pabian, F., Town, J. and Liu, J., 'North Korea's Yongbyon nuclear complex: More evidence the 5 MWe reactor appears to have restarted', 38 North, 30 Aug. 2021.

[22] Grossi, R. M., Introductory statement to the Board of Governors, International Atomic Energy Agency (IAEA), 12 Sep. 2022.

[23] Lewis, J., Pollack, J. and Schmerler, D., 'North Korea resuming construction at the Yongbyon 50 MW(e) reactor', Arms Control Wonk, 10 May 2022.

[24] Makowsky, P. et al., 'North Korea's Yongbyon Nuclear Research Center: Plutonium production continues', 38 North, 28 July 2022.

[25] Makowsky et al. (note 24).

water reactor at Yongbyon, which will eventually be capable of producing plutonium for nuclear weapons.[26] Grossi stated in September 2022 that construction of these new buildings may have been completed.[27]

In 2022 the South Korean Ministry of National Defense estimated that North Korea's plutonium stockpile had increased to approximately 70 kilograms, an increase of 20 kg in two years.[28] This is approximately 30 kg more than the estimate used for SIPRI's assessment of North Korea's nuclear weapon holdings (see section X). The latter estimate takes into account reductions to the plutonium stockpile as a result of North Korea's six nuclear tests. In April 2021 Siegfried Hecker—a former senior official in the US nuclear programme who was given unprecedented access to North Korean nuclear facilities over several years—estimated that North Korea's plutonium stocks could increase by up to 6 kg per year at full operation.[29]

Uranium-enrichment capabilities

It is widely believed that North Korea has focused on the production of HEU for use in nuclear warheads to overcome its limited capacity to produce weapon-grade plutonium. However, there is considerable uncertainty about North Korea's uranium-enrichment capabilities and its stock of HEU.

North Korea produces yellowcake—the raw material for reactor fuel rods—at its Pyongsan Uranium Concentrate Plant (Nam-chon Chemical Complex) in North Hwanghae province.[30] The IAEA director general reported in September 2022 that North Korea continued to operate its gas centrifuge enrichment facility after its floor space was expanded by approximately one third of its original size.[31] These activities were visible on satellite imagery throughout 2021 and 2022.[32]

A classified intelligence assessment by the USA in 2018 reportedly concluded that North Korea probably had more than one covert uranium-

[26] IAEA, GOV/2021/40-GC(65)/22 (note 21), para. 12; and Bermudez, J. S., Cha, V. and Jun, J., 'Yongbyon update: New activity at Building 500 and rising waters', Beyond Parallel, Center for Strategic and International Studies, 11 July 2022.

[27] Grossi (note 22).

[28] South Korean Ministry of National Defense (MND), [2022 defence white paper] (MND: Seoul, 24 Feb. 2023) (in Korean).

[29] 'Estimating North Korea's nuclear stockpiles: An interview with Siegfried Hecker', 38 North, 30 Apr. 2021.

[30] Bermudez, J. S., Cha, V. and Jun, J., 'Current status of the Pyongsan Uranium Concentrate Plant (Nam-chon Chemical Complex) and January Industrial Mine', Beyond Parallel, Center for Strategic and International Studies, 8 Nov. 2021; and Bermudez, J. S., Cha, V. and Kim, D., 'Recent activity at the Pyongsan Uranium Concentrate Plant (Nam-chon Chemical Complex) and January Industrial Mine', Beyond Parallel, Center for Strategic and International Studies, 26 Mar. 2021.

[31] Grossi (note 22).

[32] United Nations, Security Council, Midterm report of the Panel of Experts submitted pursuant to Resolution 2627 (2022), S/2022/668, 7 Sep. 2022, para. 11; Lewis, J., Pollack, J. and Schmerler, D., 'North Korea expanding uranium enrichment plant at Yongbyon', Arms Control Wonk, 14 Sep. 2021; and Cohen, Z., 'Satellite images reveal North Korea expanding facility used to produce weapons-grade uranium', CNN, 16 Sep. 2021.

enrichment plant and that the country was seeking to conceal the types and numbers of production facilities in its nuclear weapon programme.[33] A more recent open-source assessment concludes that the increased production capacity at Pyongsan indicates that North Korea does not require another uranium milling facility of comparable size.[34]

Several non-governmental researchers identified an additional suspected covert uranium-enrichment plant located at Kangson (or Kangsong), to the south-west of Pyongyang, in 2018.[35] A 2021 IAEA report noted that the plant shared 'infrastructure characteristics with the reported centrifuge enrichment facility at Yongbyon'.[36] A report by a UN panel of experts cautioned that access to the plant was required to confirm the nature and purpose of the activities being conducted on-site.[37] Other experts have suggested that the site could be used for manufacturing centrifuge components rather than for enriching uranium.[38]

Analysts agree that North Korea has HEU production capabilities, but there are many unknowns about how much HEU has been produced, especially given the uncertainties around activities at the Kangson site. Hecker estimated in early 2021 that North Korea had produced 600–950 kg of HEU by the end of 2020. The HEU stockpile estimate used for SIPRI's assessment of North Korea's nuclear weapon holdings suggests a wider range of 250–1350 kg as of the beginning of 2022 (see section X).[39]

Nuclear warhead production

It is unclear how many nuclear weapons North Korea has produced with its fissile material, how many have been deployed on missiles and what the military characteristics of the weapons are. As noted above, North Korea has demonstrated a thermonuclear capability (or a nuclear explosive test with suspected thermonuclear yield) once, in 2017.[40] There is no open-source evidence or state intelligence confirming North Korea's capability to deliver an operational nuclear warhead on an ICBM. Moreover, most of North

[33] Kube, C., Dilanian, K. and Lee, C. E, 'North Korea has increased nuclear production at secret sites, say US officials', NBC News, 1 July 2018; and Nakashima, E. and Warrick, J., 'North Korea working to conceal key aspects of its nuclear program, US officials say', *Washington Post*, 1 July 2018.

[34] Park, S. et al., 'Assessing uranium ore processing activities using satellite imagery at Pyongsan in the Democratic People's Republic of Korea', *Science and Global Security*, vol. 29, no. 3 (2021).

[35] Panda, A., 'Exclusive: Revealing Kangson, North Korea's first covert uranium enrichment site', The Diplomat, 13 July 2018; and Albright, D. and Burkhard, S., 'Revisiting Kangsong: A suspect uranium enrichment plant', Imagery brief, Institute for Science and International Security, 2 Oct. 2018.

[36] IAEA, GOV/2021/40-GC(65)/22 (note 21), para. 14.

[37] United Nations, Security Council, Midterm report of the Panel of Experts submitted pursuant to Resolution 2569 (2021), S/2021/777, 8 Sep. 2021, p. 7.

[38] 'Estimating North Korea's nuclear stockpiles' (note 29).

[39] See also Kristensen, H. and Korda, M., 'Nuclear notebook: How many nuclear weapons does North Korea have in 2022?', *Bulletin of the Atomic Scientists*, 8 Sep. 2022.

[40] Fedchencko (note 2), p. 299.

Korea's nuclear tests demonstrated yields in the range of 5–15 kilotons.[41] As a result, SIPRI estimates that North Korea has used only a small portion of its HEU for thermonuclear weapons and has probably used the majority for a larger number of fission-only single-stage weapons deliverable by an MRBM or possibly by an IRBM.[42]

It is unclear whether North Korea is prioritizing the development and production of higher-yield thermonuclear weapons or lower-yield fission-only or boosted single-stage weapons.[43] More powerful warheads with the high yield demonstrated in the 2017 test would consume more fissile material if based on a composite warhead design, or would require special hydrogen fuel if based on a two-stage thermonuclear warhead design. Lower-yield single-stage fission weapon designs would require less fissile material. The choice of assumptions can thus result in very different estimates of the number of nuclear weapons.

For this reason, SIPRI estimates that North Korea could potentially produce 50–70 nuclear weapons with its inventory of fissile material as of January 2023; however, it is likely that the number of operational warheads is smaller, potentially 30.[44] Most of those warheads are likely to be single-stage fission weapons with possible yields of 10–20 kt, similar to those demonstrated in the 2013 and 2016 tests. The SIPRI estimate falls within the range of a July 2020 assessment by the US Army that North Korea had 20–60 bombs.[45] It also falls within the range of a 2018 South Korean intelligence assessment, which estimated that North Korea's nuclear arsenal contained 20–60 weapons.[46]

Assumptions about fissile material production and warhead designs also affect projections of the future size of North Korea's nuclear arsenal. For example, a 2021 study assumed that North Korea might already have 67–116 nuclear weapons and projected that the inventory might reach 151–242 nuclear weapons by 2027.[47] It seems more plausible, however, that North Korea might be capable of adding sufficient fissile material for up to six nuclear warheads per year.[48] This would potentially be sufficient to produce a total of approximately 80–90 weapons by the end of the decade.[49]

[41] Fedchencko, V., 'Nuclear explosions, 1945–2016', *SIPRI Yearbook 2017*.

[42] Ballistic missiles are typically divided into 4 range categories: short range (less than 1000 km), medium range (1000–3000 km), intermediate range (3000–5500 km) and intercontinental (>5500 km).

[43] Kristensen and Korda (note 39).

[44] For additional assessments see 'Estimating North Korea's nuclear stockpiles' (note 29).

[45] US Army, *North Korean Tactics*, Army Techniques Publication no. 7-100.2 (Headquarters, US Department of the Army: Washington, DC, July 2020), p. 1-11.

[46] Kim, H., 'Seoul: North Korea estimated to have 20–60 nuclear weapons', AP News, 2 Oct. 2018.

[47] Bennett, B. W. et al., *Countering the Risk of North Korean Nuclear Weapons* (RAND Corp.: Santa Monica, CA, Apr. 2021).

[48] This is in line with the production estimate suggested in US Army (note 45), p. 1-11.

[49] Kristensen and Korda (note 39).

Although North Korea demolished tunnels and facilities at the Punggye-ri nuclear test site in 2018, satellite images since 2021 show that the test tunnel and support buildings have been re-opened.[50] This construction indicates that the site had not been abandoned but kept in caretaker status, potentially allowing nuclear testing to resume in the future.[51]

Land-based missiles

North Korea is increasing both the size and capability of its ballistic missile force, which consists of indigenously produced missile systems with ranges from a few hundred kilometres to more than 12 000 km (see table 7.9).[52] Since 2016, it has pursued development and production of several missile systems with progressively longer ranges and increasingly sophisticated delivery capabilities.[53] There is considerable uncertainty about the operational status of North Korea's IRBMs and ICBMs. According to independent analyses, North Korea may have deployed long-range missiles at several missile bases.[54]

It is unclear which of North Korea's missiles can carry nuclear weapons. The available evidence suggests that some MRBMs and IRBMs are the most likely to have an operational nuclear capability. South Korea's 2022 Defence White Paper notes that, given that North Korea uses uniquely lofted launch angles for its ICBM tests, 'additional confirmation is needed to determine whether North Korea has acquired core ICBM technologies, including the ability to re-enter the atmosphere'.[55]

It must be emphasized that inclusion of a specific North Korean missile in the following overview (and in table 7.9) does not necessarily indicate that it is confirmed as nuclear-capable or as having a nuclear role.

Short-range ballistic missiles

As of January 2023 North Korea had several types of SRBM, including older liquid-fuelled systems, possibly based on Soviet R-17 (Scud) missiles, and newer solid-fuelled missiles of indigenous design. These newer missiles, known by the designations given by the USA as the KN23, the KN24 and the

[50] United Nations, S/2022/668 (note 32), paras 4–5.

[51] Lee, C., 'North Korea's saber-rattling rekindles nuclear test site questions', Voice of America, 26 Jan. 2022.

[52] US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat 2020* (NASIC: Wright-Patterson Air Force Base, OH, July 2020).

[53] James Martin Center for Nonproliferation Studies (CNS), CNS North Korea Missile Test Database, Nuclear Threat Initiative, as of 24 Mar. 2022.

[54] Bermudez, J. S. and Cha, V., 'Undeclared North Korea: The Yusang-ni missile operating base', Beyond Parallel, Center for Strategic and International Studies, 9 May 2019; Frank, M., 'Continued construction at Yusang-ni missile base', Open Nuclear Network, 26 July 2021; and United Nations, Security Council, Final report of the Panel of Experts submitted pursuant to Resolution 2515 (2020), S/2021/211, 4 Mar. 2021, annexes 16–18.

[55] South Korean Ministry of National Defense (note 28), p. 30 (author translation).

KN25—and possibly all known by the common North Korean designation of Hwasong-11 (with different suffixes for each missile)—were tested or launched nearly 50 times, and possibly many more, between the beginning of 2019 and early 2023.[56] Notably, in September 2021 North Korea launched two KN23 SRBMs using a rail-mobile launcher for the first time and carried out two further test launches of the rail-mobile KN23 in January 2022.[57] Rail-mobile launchers would enable North Korea to move missiles around the country rapidly and significantly increase the survivability of its second-strike force. North Korea has also been modernizing its older SRBMs by equipping them with manoeuvrable re-entry vehicles (MaRVs) designed to evade the missile-defence systems of nearby states (particularly South Korea and Japan).[58]

In April 2022 Kim Jong Un announced the launch of two SRBMs, which he called a 'new-type tactical guided weapon' developed to enhance 'the efficiency in the operation of tactical nukes', potentially implying that such warheads have already been deployed with earlier delivery systems.[59] Accompanying images pictured a new type of solid-fuelled SRBM mounted on a road-mobile launcher.[60] As an illustration of this new capability, North Korea test-launched eight SRBMs in June and seven in November 2022.[61] The launches on 2 November were among at least 23 missiles fired that day, the highest number ever launched by North Korea in a single day. North Korean state media said that the missiles were a response to Vigilant Storm 23, a South Korean–US combined military exercise that took place between 31 October and 5 November.[62]

Medium- and intermediate-range ballistic missiles

North Korea has four types of MRBM: the Hwasong-7 (Nodong/Rodong), -8 and -9 (KN04) and the Pukguksong-2 (KN15).[63] All except the Hwasong-8 were probably operational as of January 2023. Assuming that North Korea is able to produce a sufficiently compact warhead, these MRBMs are considered to be its most likely nuclear-delivery systems. All three operational missiles

[56] James Martin Center for Nonproliferation Studies (note 53); and Zwirko, C., 'North Korea reveals internal names for several missile systems: Analysis', NK News, 3 Apr. 2023.

[57] 'Firing drill of railway-borne missile regiment held', *Rodong Sinmun*, 15 Jan. 2022.

[58] Panda, A., 'Introducing the KN21, North Korea's new take on its oldest ballistic missile', The Diplomat, 14 Sep. 2017.

[59] 'Respected comrade Kim Jong Un observes test-fire of new-type tactical guided weapon', *Rodong Sinmun*, 17 Apr. 2022.

[60] Van Diepen, V. H., 'North Korea's new short-range ballistic missile', 38 North, 25 Apr. 2022.

[61] Kristensen and Korda (note 39).

[62] 'Report of General Staff of KPA on its military operations corresponding to US–South Korea combined air drill', Uriminzokkiri, 7 Nov. 2022; and US Air Force, '8th Operations Group surges for Vigilant Storm 23', Kunsan Air Base, 7 Nov. 2022.

[63] On the Pukguksong-2 see Kristensen and Korda (note 10), p. 420.

have ranges of 1000–1200 km, meaning that they could reach targets anywhere in South Korea or Japan.[64]

The Hwasong-10 (BM-25/Musudan) IRBM, with an estimated range exceeding 3000 km, has a poor test rate, with no flight tests since 2016–17. It is likely to have been superseded by more sophisticated missile programmes—in particular the Hwasong-12 (KN17).[65] The latter is a single-stage, liquid-fuelled IRBM carried on a road-mobile transporter-erector-launcher (TEL). In January 2022 North Korea launched a Hwasong-12 for the first time in nearly five years, demonstrating a similar trajectory to its previous launches.[66] It remains unknown if the Hwasong-12 has been deployed. North Korea launched a missile that resembled the Hwasong-12 in performance in October 2022, although the images and reports subsequently released by North Korean state media implied that it was a 'new type' of IRBM.[67]

The Hwasong-8, which is another new missile, was first revealed in 2021. It appears to be composed of a modified Hwasong-12 booster and can carry multiple different payloads, including an HGV and a MaRV. The Hwasong-8 variant carrying a MaRV was tested twice in January 2022. During the second test, North Korea claimed that the missile conducted a 'corkscrew' manoeuvre.[68] This reportedly prompted the US civil aviation authority to temporarily pause commercial airline departures along the west coast of the USA for approximately 15 minutes.[69]

Intercontinental ballistic missiles

North Korea has displayed four types of ICBM: the Hwasong-13 (KN08), -14 (KN20), -15 (KN22) and -17 (KN28). It has prioritized building and deploying an ICBM that could potentially deliver a nuclear warhead to targets in the USA. However, there remains considerable uncertainty in assessments of North Korea's long-range missile capabilities. For example, neither the 2019 missile report issued by the US Department of Defense (DOD) nor the 2020 report from the US Air Force listed the Hwasong-13, -14 or -15 as being deployed.[70] The Hwasong-13 and, possibly, the Hwasong-14 are likely to have

[64] US Air Force (note 52), p. 25.

[65] James Martin Center for Nonproliferation Studies (note 53).

[66] Japanese Ministry of Defense, [North Korean missiles and other related formation], 30 Jan. 2022 (in Japanese).

[67] Xu, T., *Analysis of the DPRK's Ballistic Missile Launch Campaign in September/October 2022* (Open Nuclear Network: Vienna, 14 Oct. 2022).

[68] *Chongnyon Chonwi,* 'Distinguished feat of WPK in history of leading Juche-based defence industry success in another hypersonic missile test-fire respected comrade Kim Jong Un watches test-fire in field', KCNA Watch, 12 Jan. 2022.

[69] Liebermann, O., Muntean, P. and Starr, B., 'US grounded planes as a "precaution" after a North Korean missile launch', CNN, 11 Jan. 2022.

[70] These publications present the USA's most detailed current public assessments of North Korean long-range nuclear capabilities. The Hwasong-17 was first displayed in Oct. 2020. US Department of Defense (DOD), *2019 Missile Defense Review* (DOD: Washington, DC, 2019), p. 7; and US Air Force (note 52), p. 29.

been superseded by more sophisticated ICBM programmes and, as a result, the Hwasong-13 is excluded from SIPRI's estimate for January 2023.[71]

The Hwasong-15 has a significantly larger second stage and more powerful booster engines than the Hwasong-14.[72] The Hwasong-17 would hypothetically be large enough to accommodate multiple warheads, but such capabilities have not yet been demonstrated.[73] On 24 March 2022 North Korea claimed to have test-launched the Hwasong-17 and said the missile reached an apogee of more than 6200 km and travelled nearly 1100 km over the course of 68 minutes.[74] This suggests a possible range of approximately 15 000 km if flown on a minimum-energy trajectory. However, some analysts believe that the ICBM may have been unsuccessfully tested on 16 March, and that the missile tested on 24 March may instead have been a Hwasong-15.[75] On 18 November North Korea again claimed to have successfully tested the Hwasong-17.[76]

In December North Korea conducted a ground test of a solid-fuelled rocket motor, indicating progress towards capacity for building a solid-fuelled ICBM or SLBM.[77]

Cruise missiles

North Korea has developed at least two land-attack cruise missiles (LACMs) that are explicitly designed to deliver nuclear weapons: the Hwasal-1 and the Hwasal-2. Combined, these two cruise missiles had been tested at least eight times as of the end of 2022. Although North Korea has described these LACMs as 'strategic weapons', it also clarified in October 2022 that the missiles were 'deployed at the units of the Korean People's Army for the operation of tactical nukes'.[78]

[71] NK News, 'North Korea military parade 2020: Livestream & analysis', YouTube, 10 Oct. 2020.

[72] Kristensen, H. M. and Korda, M., 'North Korean nuclear forces', *SIPRI Yearbook 2021*, p. 402.

[73] Panda, A. (@nktpnd), Twitter, 13 Oct. 2021, <https://twitter.com/nktpnd/status/1448073861363290124>.

[74] *Pyongyang Times*, 'Striking demonstration of great military muscle of Juche Korea: Successful test-launch of new-type ICBM respected comrade Kim Jong Un guides test launch of ICBM Hwasongpho-17', KCNA Watch, 25 Mar. 2023.

[75] Zwirko, C., 'Imagery casts doubt over North Korea's Hwasong-17 ICBM claims', NK News, 25 Mar. 2022.

[76] 'Military miracles which demonstrated to whole world national prestige and honor of Juche Korea', *Rodong Sinmun*, 18 Nov. 2022.

[77] Van Diepen, V., 'The next big thing? North Korea ground tests ICBM-sized rocket motor', 38 North, 21 Dec. 2022.

[78] Shin, H. and Smith, J., 'N. Korea tests first "strategic" cruise missile with possible nuclear capability', Reuters, 13 Sep. 2021. See also Kristensen and Korda (note 10), pp. 421–22; and 'Respected comrade Kim Jong Un guides test-fire of long-range strategic cruise missiles', Korea Central News Agency, 13 Oct. 2022.

Sea-based missiles

North Korea has continued to develop its family of Pukguksong ('Polaris') solid-fuelled SLBMs as part of an effort to improve the survivability of its nuclear-capable ballistic missile systems.[79]

In October 2021 North Korea unveiled a 'new type' of smaller SLBM with an unknown designation but with characteristics seemingly similar to its newer SRBM designs.[80] This SLBM was reportedly test launched one week later from the port of Sinpo to an approximate range of 590 km, landing in the Sea of Japan.[81] The test's low apogee of 60 km indicated that this new SLBM is likely to have a shorter range than many of the Pukguksong SLBMs.[82] The missile was launched using North Korea's only Gorae-class (Sinpo) experimental submarine, *8.24 Yongung*.[83] The vessel appears to have been damaged during the launch.[84] This submarine can hold and launch only a single SLBM. The same type of missile may have also been tested on 7 May 2022.[85] It is unclear whether the test was successful. It is also possible that the same type of missile was tested on 25 September 2022 from an 'underwater launching ground' inside a reservoir; the North Korean media statement accompanying the launch explicitly stated that the missile was designed to carry a tactical nuclear warhead and implied that it was already operational.[86]

At its April 2022 military parade, North Korea revealed a sixth probable member of the Pukguksong family that is longer and wider than all of North Korea's previously displayed SLBMs.[87] The missile's name has not yet been formally announced.

[79] On North Korea's earlier Pukguksong family of missiles see Kristensen and Korda (note 72), p. 403.

[80] Xu, T., *Brief on the Defence Development Exhibition of the Democratic People's Republic of Korea* (Open Nuclear Network: Vienna, 18 Oct. 2021); and Xu, T., 'Brief on the 19 October 2021 submarine-launched ballistic missile test of the Democratic People's Republic of Korea', Open Nuclear Network, 21 Oct. 2021.

[81] Korean Central News Agency, 'Academy of Defence Science succeeds in test-launch of new-type SLBM', KCNA Watch, 20 Oct. 2021.

[82] 'N. Korea fires what seems to be SLBM toward East Sea: S. Korea', Yonhap News Agency, 19 Oct. 2021.

[83] Korean Central News Agency (note 81); Makowsky, P. and Liu, J., 'Sinpho South shipyard: Evidence of the SINPO-class SSBA participation in recent SLBM test', 38 North, 21 Oct. 2021; and Bermudez, J. S. and Cha, V., 'Sinpo South shipyard update: SLBM test launch', Beyond Parallel, Center for Strategic and International Studies, 21 Oct. 2021.

[84] Bermudez, J. S., Cha, V. and Jun, J., 'Sinpo-class submarine damaged during October 19 test launch', Beyond Parallel, Center for Strategic and International Studies, 7 Jan. 2022.

[85] Japanese Ministry of Defense, [North Korean missiles and other related formation], 7 May 2022 (in Japanese).

[86] 'Chairman of Central Military Commission of WPK Kim Jong Un guides military exercises of tactical nuclear operation units of KPA', Voice of Korea, 9 Oct. 2022.

[87] Xu, T., *Emerging Capabilities? The Unflown SLBMs of the DPRK* (Open Nuclear Network: Vienna, 25 July 2022).

In November 2020 the South Korean National Intelligence Service announced that North Korea was building a new ballistic missile submarine.[88] The vessel, designated Sinpo-C by the US DOD, appears to be based on a modified Project-633 (Romeo) diesel–electric submarine and is expected to be fitted with three missile-launch canisters.[89] This Soviet-era submarine has a noisy design and limited underwater range, and thus could encounter operational challenges. According to a 2019 report by North Korean state media, the submarine's operational deployment was 'near at hand', although by the end of 2022 it did not yet appear to be operational.[90]

[88] Bermudez, J. S. and Cha, V., 'Sinpo South shipyard: Construction of a new ballistic missile submarine?', Beyond Parallel, Center for Strategic and International Studies, 28 Aug. 2019; Cha, S., 'North Korea building two submarines, one capable of firing ballistic missiles: Lawmaker', Reuters, 3 Nov. 2020; and Dempsey, J. and Schmerler, D., 'Two halls enter: One sub leaves', Arms Control Wonk, 17 June 2021.

[89] Hotham, O., 'New North Korean submarine capable of carrying three SLBMs: South Korean MND', NK News, 31 July 2019; and Cha (note 88).

[90] 'NK leader inspects new submarine to be deployed in East Sea: State media', Yonhap News Agency, 23 July 2019.

Table 7.9. North Korean forces with potential nuclear capability, January 2023

All figures are approximate and some are based on assessments by the authors. The inclusion of a missile in this table does not necessarily indicate it is known to have a nuclear role. Systems that are unlikely to have a nuclear or operational role are excluded.

Type/ North Korean designation (US designation)	Year first displayed	Range (km)	Description and status
Land-based missiles			
Hwasong-5/-6 (Scud-B/-C)	1984/1990	300/500	Single-stage, liquid-fuelled SRBMs launched from 4-axle wheeled TEL. NASIC estimates fewer than 100 Hwasong-5 and -6 launchers. Operational.
. . (KN18/KN21)	2017	250/450	Hwasong-5 and -6 variants with separating manoeuvrable warhead. Flight-tested in May and Aug. 2017 from wheeled and tracked TELs. Deployment status unknown; may have been superseded by newer solid-fuelled SRBMs.
Hwasong-11 variants (KN23/KN24[a]/KN25)	2018/2019	380–800	New generation of solid-fuelled SRBMs. Resemble Russia's Iskander-M, South Korea's Hyunmoo-2B and the USA's ATACMS SRBMs. Successfully flight-tested at least 50 times, and possibly many more, from wheeled, tracked and rail-based launchers since 2019, including nearly 20 known launches in 2022. Deployment status unknown; probably operational.
Hwasong-7 (Nodong/ Rodong)	1993	>1 200	Single-stage, liquid-fuelled MRBM launched from 5-axle wheeled TEL. NASIC estimates fewer than 100 Hwasong-7 launchers. Two launched on 18 Dec. 2022. Operational.
Hwasong-9 (KN04/ Scud-ER)	2016	1 000	Single-stage, liquid-fuelled Scud extended-range MRBM variant launched from 4-axle wheeled TEL. Flight-tested in 2016. Probably operational.
Pukguksong-2 (KN15)	2017	>1 000	Two-stage, solid-fuelled MRBM launched from tracked TEL. Land-based version of Pukguksong-1 SLBM. Flight-tested in 2017. Probably operational.

Type/ North Korean designation (US designation)	Year first displayed	Range (km)	Description and status
Hwasal-1	2021	1 500	Land-attack cruise missile flight-tested multiple times in 2021 and 2022 from wheeled TEL. Deployment status unknown; probably operational.
Hwasal-2	2021	2 000	Land-attack cruise missile flight-tested multiple times in 2022 from wheeled TEL. Deployment status unknown; probably operational.
Hwasong-8/Unnamed 'hypersonic missile'	2021	>1 000	Two versions of HGV carried by a shortened Hwasong-12 booster. Hwasong-8 flight-tested in Sep. 2021 with unknown result; unnamed missile successfully flight-tested twice in Jan. 2022. Both systems displayed at exhibition in Oct. 2021. Suspected flight test with MaRV on 5 and 11 Jan. 2022. Under development.
Hwasong-10 (BM-25/ Musudan)	2010	>3 000	Single-stage, liquid-fuelled IRBM launched from 6-axle wheeled TEL. NASIC estimates fewer than 50 Hwasong-10 launchers. Several failed flight tests in 2016. Deployment status unknown; may have been superseded.
Hwasong-12 (KN17)	2017	>4 500	Single-stage, liquid-fuelled IRBM launched from 8-axle wheeled TEL. Flight-tested several times in 2017 with mixed success. Tested again on 30 Jan. 2022. Deployment status unknown.
'New type' IRBM	2022	>4 500	Single-stage, liquid-fuelled IRBM launched on 4 Oct. 2022. Strongly resembles existing Hwasong-12 design, but with potential modifications to the nose cone and propulsion system. Deployment status unknown.
Hwasong-14 (KN20)	2017	>10 000	Two-stage, liquid-fuelled ICBM launched from 8-axle wheeled TEL. First ICBM. Successfully flight-tested twice in 2017. Deployment status unknown; may have been superseded.

Type/ North Korean designation (US designation)	Year first displayed	Range (km)	Description and status
Hwasong-15 (KN22)	2017	>13 000	Two-stage, liquid-fuelled ICBM launched from 9-axle wheeled TEL. Successfully flight-tested in Nov. 2017. Displayed at parade in Oct. 2020 and at exhibition in Oct. 2021. Possibly launched on 24 Mar. 2022. Deployment status unknown.
Hwasong-17 (KN28)[b]	2020	15 000	Two-stage, liquid-fuelled ICBM launched from 11-axle wheeled TEL. Largest ICBM to date, possibly capable of carrying MIRVs and penetration aids. Displayed at parade in Oct. 2020 and at exhibition in Oct. 2021. May have been unsuccessfully flight-tested on 16 Mar. 2022, and missile tested on 24 Mar. 2022 may have been a Hwasong-15 instead of a Hwasong-17 as claimed by North Korea. Successful test of Hwasong-17 on 18 Nov. 2022. Under development.
Sea-based missiles			
Pukguksong-1 (KN11)	2014	>1 000	Two-stage, solid-fuelled SLBM. Flight-tested several times in 2015 and 2016 with mixed success. Displayed at exhibition in Oct. 2021. Deployment status unknown; may have been superseded.
Pukguksong-3 (KN26)	2017	1 900–2 500	Two-stage, solid-fuelled SLBM. Successfully flight-tested in Oct. 2019. Deployment status unknown.
Pukguksong-4	2020	3 500–5 400	Two-stage, solid-fuelled SLBM. Appears wider than Pukguksong-1 and shorter than Pukguksong-3. No known flight tests. Displayed at parade in Oct. 2020. Deployment status unknown.
Pukguksong-5	2021	..	Two-stage, solid-fuelled SLBM. Roughly same length as Pukguksong-3 with elongated shroud; possibly capable of carrying MIRVs and penetration aids. No known flight tests. Displayed at parade in Jan. 2021 and at exhibition in Oct. 2021. Deployment status unknown.

Type/ North Korean designation (US designation)	Year first displayed	Range (km)	Description and status
Small 'new type' SLBM	2021	400–600	Appears to deviate from traditional Pukguksong SLBM design, instead bearing similarities to KN23 SRBM. Displayed at exhibition in Oct. 2021 and successfully flight-tested a week later. Deployment status unknown; possibly operational.
Unknown SLBM	2022	. .	Revealed at military parade in Apr. 2022. Name not yet formally announced, but appears to be a member of the Pukguksong family of SLBMs.
Total warheads			**30**[c]

. . = not available or not applicable; HGV = hypersonic glide vehicle; ICBM = intercontinental ballistic missile; IRBM = intermediate-range ballistic missile; MaRV = manoeuvrable re-entry vehicle; MIRV = multiple independently targetable re-entry vehicle; MRBM = medium-range ballistic missile; NASIC = US Air Force National Air and Space Intelligence Center; SLBM = submarine-launched ballistic missile; SRBM = short-range ballistic missile; TEL = transporter-erector-launcher.

Notes: Information about the status and capability of North Korea's missiles comes with significant uncertainty. This table includes missiles that could potentially have a nuclear capability, whether or not confirmed as being equipped with nuclear warheads or assigned nuclear missions. Several missiles may have been intended for development of technologies that will eventually become operational on newer missiles. There is no publicly available evidence that North Korea has produced an operational nuclear warhead for delivery by an ICBM.

[a] North Korea refers to the KN24 as the Hwasong-11Na, which could be considered akin to 'Hwasong-11B', as Na (나) is the second letter in the Korean alphabet (Hangul). This indicates that the KN24 is an improvement on or replacement for the original Hwasong-11 (KN02 Toksa) SRBM. Many of North Korea's other new SRBMs also appear to use the official Hwasong-11 designation with different suffixes.

[b] This missile was previously assumed to be designated the Hwasong-16; however, it was revealed at North Korea's Oct. 2021 Defence Development Exhibition that it is called the Hwasong-17.

[c] SIPRI estimates that North Korea might have produced enough fissile material to build 50–70 nuclear warheads; however, it is likely that it has assembled fewer warheads, perhaps *c*. 30, of which only a few would be thermonuclear warheads and nearly all would be lower-yield single-stage fission warheads.

Sources: US Department of Defense (DOD), *2019 Missile Defense Review* (DOD: Washington, DC, 2019); US Air Force, National Air and Space Intelligence Center, *Ballistic and Cruise Missile Threat*, various years; *IHS Jane's Strategic Weapon Systems*, various editions; Hecker, S., Stanford University, Personal communication, 2020; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; published expert analyses; and authors' estimates. For the estimated number of warheads see also Hecker, S., 'What do we know about North Korea's nuclear program?', Presentation, Dialogue on DPRK Denuclearization Roadmaps and Verification, Kyung Hee University, Global America Business Institute (GABI) and Natural Resources Defense Council (NRDC), 20 Oct. 2020; 'Estimating North Korea's nuclear stockpiles: An interview with Siegfried Hecker', 38 North, 30 Apr. 2021; and Fedchenko, V. and Kelley, R., 'New methodology offers estimates for North Korean thermonuclear stockpile', *Janes Intelligence Review*, Sep. 2020, pp. 44–49.

IX. Israeli nuclear forces

HANS M. KRISTENSEN AND MATT KORDA*

As of January 2023 Israel was estimated to have a stockpile of around 90 nuclear warheads (see table 7.10), the same number as in January 2022. This estimate is at the lower end of a possible range that other analysts have suggested could reach as high as 300 nuclear weapons.[1]

Israel continues to maintain its long-standing policy of nuclear ambiguity: it neither officially confirms nor denies that it possesses nuclear weapons.[2] This lack of transparency means that there is significant uncertainty about the size of Israel's nuclear arsenal and the yields and characteristics of its weapons.[3] The estimate here is largely based on calculations of Israel's inventory of weapon-grade plutonium (see section X) and the number of operational nuclear-capable delivery systems. The locations of the storage sites for the warheads, which are thought to be stored partially unassembled, are unknown.

This section continues by briefly outlining the role played by nuclear weapons in Israel's military doctrine. It then outlines the country's capabilities for production of fissile material before describing its air-delivered, land-based and sea-based weapons.

The role of nuclear weapons in Israeli military doctrine

Since the late 1960s the Israeli government has repeated that Israel 'won't be the first to introduce nuclear weapons into the Middle East'. However, to accommodate the apparent fact that Israel possesses a significant nuclear arsenal, Israeli policymakers have previously interpreted 'introduce nuclear weapons' as publicly declaring, testing or actually using the nuclear capability, which, according to open-access sources, Israel has not yet done.[4]

Military fissile material production

Declassified United States government documents indicate that Israel may have assembled its first nuclear weapons in the late 1960s, using plutonium

[1] See e.g. Luscombe, B., '10 questions: Jimmy Carter', *Time*, 30 Jan. 2012; and Clifton, E., 'Powell acknowledges Israeli nukes', Lobe Log, 14 Sep. 2016.

[2] On Israel's 'strategic ambiguity' policy see also Cohen, A., 'Israel', eds H. Born, B. Gill and H. Hänggi, SIPRI, *Governing the Bomb: Civilian Control and Democratic Accountability of Nuclear Weapons* (Oxford University Press: Oxford, 2010).

[3] Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Commentary, 14 June 2021.

[4] For further detail see Kristensen, H. M. and Korda, M., 'Israeli nuclear forces', *SIPRI Yearbook 2022*, pp. 404–405.

* The authors wish to thank Eliana Johns for contributing invaluable research to this publication.

Table 7.10. Israeli nuclear forces, January 2023

All figures are approximate and some are based on assessments by the authors.

Type/designation	No. of launchers	Year first deployed	Range (km)[a]	No. of warheads
Aircraft	*125/50*[b]			*30*
F-16I	100/25	1980	1 600	30
F-15	25/25	1998	4 450	. .[c]
Land-based missiles	*50*			*50*[d]
Jericho II	25	1990	>1 500	25
Jericho III	25	[2011]	[>4 000]	25[e]
Sea-based missiles	*5/20*[f]			*10*
'Popeye' variant SLCM	20	[2002]	[<1 500]	10
Total stockpile	**120**			**90**[g]

. . = not available or not applicable; [ ] = uncertain SIPRI estimate; SLCM = sea-launched cruise missile.

[a] Aircraft range is for illustrative purposes only; actual range will vary according to flight profile, weapon payload and in-flight refuelling.

[b] The first figure is the total number of aircraft in the inventory; the second is the number of aircraft that might be adapted for a nuclear strike mission. It is estimated that aircraft from 2 squadrons might serve a nuclear strike role.

[c] It is not known whether the Israeli Air Force has added nuclear capability to the F-15 aircraft as the United States has done, but one US official has privately described Israel's F-15s as its 'nuclear squadron'.

[d] Commercial satellite images show what appear to be 23 caves or bunkers for mobile Jericho launchers at Sdot Micha Airbase. High-resolution satellite imagery that became available in 2021 indicates that each cave appears to have 2 entrances, which suggests that each cave could hold up to 2 launchers. If all 23 caves are full, this would amount to 46 launchers.

[e] The Jericho III is gradually replacing the older Jericho II, if this has not happened already. A longer-range version with a new solid rocket motor may be under development.

[f] The first figure is the total number of Dolphin-class submarines in the Israeli fleet; the second is the estimated maximum number of missiles that they can carry. In addition to 6 standard 533-millimetre torpedo tubes, the submarines are reportedly equipped with 4 other specially designed 650-mm tubes that could potentially be used to launch larger nuclear-armed SLCMs.

[g] Given the unique lack of publicly available information about Israel's nuclear arsenal, this estimate comes with a considerable degree of uncertainty.

Sources: Cohen, A., *The Worst-kept Secret: Israel's Bargain with the Bomb* (Columbia University Press: New York, 2010); Cohen, A., *Israel and the Bomb* (Columbia University Press: New York, 1998); US National Security Archive, various declassified US government document collections related to Israel's nuclear weapon programme; International Institute for Strategic Studies, *The Military Balance*, various years; *IHS Jane's Strategic Weapon Systems*, various issues; Fetter, S., 'Israeli ballistic missile capabilities', *Physics and Society*, vol. 19, no. 3 (July 1990); *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

produced by the Israel Research Reactor 2 (IRR-2) at the Negev Nuclear Research Center (NNRC) near Dimona, in southern Israel.[5] This heavy water reactor is not under International Atomic Energy Agency (IAEA) safeguards. There is little publicly available information about its operating history and power capacity (see section X).[6] Commercial satellite imagery has revealed progress on significant construction inside and near to the NNRC site since 2021, although the purpose of this work is unknown.

As of the beginning of 2022 Israel is estimated to have had a stockpile of 740–1090 kilograms of plutonium, depending upon the rate at which the reactor was also used for tritium production (see section X). Based on this estimate and assuming that Israel's warhead arsenal is likely to consist of single-stage, boosted fission weapons, Israel could potentially have built anywhere between 185 and 273 nuclear weapons, assuming approximately 4 kg of plutonium per weapon. However, as with other nuclear-armed states, Israel is unlikely to have converted all of its plutonium into warheads and has probably assigned nuclear weapons to only a limited number of launchers. Moreover, the available tritium required to boost the warheads would represent an additional constraint on the number of weapons Israel could build. As a result, SIPRI estimates that Israel has approximately 90 warheads, rather than several hundred.

Aircraft and air-delivered weapons

Approximately 30 of Israel's nuclear weapons are estimated to be gravity bombs for delivery by F-16I or F-15 aircraft. The status of the F-15 is unclear, but when Israel sent six F-15s from Tel Nof Airbase to the United Kingdom for an exercise in September 2019, a US official privately commented that Israel had sent its 'nuclear squadron'.[7] Nuclear gravity bombs without nuclear cores would probably be stored at protected facilities near one or two air force bases, such as Tel Nof Airbase in central Israel and Hatzerim Airbase in the Negev desert.

Israel is also acquiring 50 F-35 combat aircraft from the USA. These are particularly suitable for deep strike operations, although it is unclear whether Israel would use them for a nuclear mission.[8]

[5] For a history of Israel's nuclear weapon programme see Cohen, A., *The Worst-kept Secret: Israel's Bargain with the Bomb* (Columbia University Press: New York, 2010); Burr, W. and Cohen, A., 'Duplicity and self-deception: Israel, the United States, and the Dimona inspections, 1964–65', Briefing Book no. 733, National Security Archive, 10 Nov. 2020; and Cohen, A. and Burr, W., 'How Israel built a nuclear program right under the Americans' nose', *Haaretz*, 17 Jan. 2021. See also Kristensen and Korda (note 4), pp. 405–407.

[6] Glaser, A. and Miller, M., 'Estimating plutonium production at Israel's Dimona reactor', 52nd annual meeting of the Institute of Nuclear Materials Management (INMM), 17–21 July 2011.

[7] US military official, Interview with the author (H. M. Kristensen), Oct. 2019.

[8] Lockheed Martin, 'Israel's 5th generation fighter'.

Land-based missiles

Up to 50 warheads are thought to be assigned for delivery by land-based Jericho ballistic missiles, although the Israeli government has never publicly confirmed that it possesses the missiles. The missiles are believed to be located, along with their mobile transporter-erector-launchers (TELs), in caves or bunkers at Sdot Micha Airbase near Zekharia, about 25 kilometres west of Jerusalem. High-resolution satellite imagery suggests that an upgrade of the bunkers was ongoing during 2022. SIPRI assesses that each of the 23 bunkers might be capable of storing two launchers. Each cluster of bunkers also appears to be coupled with facilities potentially for missile handling and warhead loading. A nearby complex with its own internal perimeter has four tunnels to underground facilities that could be used for warhead storage, although SIPRI assesses that the nuclear cores are probably stored elsewhere.

Israel is upgrading its arsenal of missiles from the solid-fuelled, two-stage Jericho II medium-range ballistic missile to the three-stage Jericho III missile with a longer range, exceeding 4000 km. The latter first became operational in 2011 and might now have replaced the Jericho II.[9] In recent years, Israel has conducted several test launches of what it calls 'rocket propulsion systems'. These could be related to upgrades to its ballistic missile force; it is possible, however, that some of these tests could be related to the development of Israeli space-launch vehicles, which use solid rocket motors.[10]

Sea-based missiles

Israel operates five German-built Dolphin-class (Dolphin-I and Dolphin-II) diesel–electric submarines.[11] It plans to modernize and add to its fleet in the coming years. The home port of Israel's submarines is Haifa on the Mediterranean coast.

There are unconfirmed reports that all or some of the submarines have been equipped to launch an indigenously produced nuclear-armed sea-launched variant of the Popeye cruise missile, giving Israel a sea-based nuclear strike capability.[12] Several former officials of the German Ministry of Defence stated in 2012 that they had always assumed that Israel would use the submarines

[9] O'Halloran, J. C. (ed.), 'Jericho missiles', *IHS Jane's Weapons: Strategic, 2015–16* (IHS Jane's: Coulsdon, 2015), p. 53.

[10] Israeli Ministry of Defense (@Israel_MOD), Twitter, 31 Jan. 2020, <https://twitter.com/Israel_MOD/status/1223172528992149504>; and Lewis, J., 'Israeli rocket motor test', Arms Control Wonk, 23 Apr. 2021.

[11] SIPRI Arms Transfers Database, Mar. 2022.

[12] Bergman, R. et al., 'Israel's deployment of nuclear missiles on subs from Germany', *Der Spiegel*, 4 June 2012.

for nuclear weapons.[13] The German government subsequently denied that the submarines have the capability to carry nuclear warheads.[14] If the submarines have been equipped with nuclear missiles, SIPRI assesses that around 10 cruise missile warheads might be available for the submarine fleet.

In early 2022 Israel signed a deal with Germany to procure three new submarines, which will be known as the Dakar class, to replace the three oldest Dolphin-I-class boats.[15] Concept art for the Dakar-class submarines includes an enlarged sail (or fin) that could be fitted with a vertical-launch system that would be capable of launching existing or future missile types.[16]

[13] Bergman et al. (note 12). See also Frantz, D., 'Israel's arsenal is point of contention', *Los Angeles Times*, 12 Oct. 2003; and Sutton, H. I., 'History of Israeli subs', Covert Shores, 20 May 2017.

[14] Fisher, G., 'Israel's German-built submarines are equipped with nuclear weapons, Der Spiegel reports', *Times of Israel*, 3 June 2012.

[15] 'Israel signs $3.4 bln submarines deal with Germany's Thyssenkrupp', Reuters, 20 Jan. 2022.

[16] Newdick, T., 'Our first look at Israel's new Dakar class submarine reveals a very peculiar feature', The Drive, 20 Jan. 2022.

X. Global stocks and production of fissile materials, 2022

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INTERNATIONAL PANEL ON FISSILE MATERIALS

Materials that can sustain an explosive fission chain reaction are essential for all types of nuclear explosive, from first-generation fission weapons to advanced thermonuclear weapons. The most common of these fissile materials are highly enriched uranium (HEU) and plutonium. This section gives details of military and civilian stocks, as of the beginning of 2022, of HEU (table 7.11) and separated plutonium (table 7.12)—including in weapons—and details of the capacity to produce these materials (tables 7.13 and 7.14). The information in the tables is based on estimates prepared for the International Panel on Fissile Materials (IPFM). The most recent annual declarations on civilian plutonium and HEU stocks to the International Atomic Energy Agency (IAEA) give data for 31 December 2021 (INFCIRC/549).

The production of both HEU and plutonium starts with natural uranium. Natural uranium consists almost entirely of the non-chain-reacting isotope uranium-238 (U-238) and is only about 0.7 per cent uranium-235 (U-235). The concentration of U-235 can be increased through enrichment—typically using gas centrifuges. Uranium that has been enriched to less than 20 per cent U-235 (typically, 3–5 per cent)—known as low-enriched uranium—is suitable for use in power reactors. Uranium that has been enriched to contain at least 20 per cent U-235—known as HEU—is generally taken to be the lowest concentration practicable for use in weapons. However, to minimize the mass of the nuclear explosive, weapon-grade uranium is usually enriched to over 90 per cent U-235.

Plutonium is produced in nuclear reactors when U-238 in the fuel is exposed to neutrons. The plutonium is subsequently chemically separated from spent fuel in a reprocessing operation. Plutonium comes in a variety of isotopic mixtures, most of which are weapon-usable. Weapon designers prefer to work with a mixture that predominantly consists of plutonium-239 (Pu-239) because of its relatively low rate of spontaneous emission of neutrons and gamma rays and the low level of heat generation from alpha decay. Weapon-grade plutonium usually contains more than 90 per cent Pu-239. The plutonium in typical spent fuel from power reactors (reactor-grade plutonium) contains 50–60 per cent Pu-239 but is weapon-usable, even in a first-generation weapon design.

All states that have a civil nuclear industry (i.e. that operate a nuclear reactor or a uranium-enrichment plant) have some capability to produce fissile materials that could be used for weapons. The categories for fissile materials in tables 7.11 and 7.12 reflect the availability of these materials for weapon purposes. Material described as ‘Not directly available for weapons' and 'Unsafeguarded' is either material produced outside weapon programmes or weapon-related material that states have pledged not to use in weapons. This material is not placed under international safeguards (e.g. IAEA or Euratom) or under bilateral monitoring. The category 'Safeguarded/monitored' includes material that is subject to such controls. The data presented in tables 7.11 and 7.12 accounts only for unirradiated fissile material, a category that corresponds to the IAEA definition of 'unirradiated direct use material'.

Table 7.11. Global stocks of highly enriched uranium, 2022

All figures are tonnes and are for unirradiated highly enriched uranium (HEU) as of the beginning of 2022. Most of this material is 90–93% enriched uranium-235 (U-235), which is typically considered weapon-grade. Important exceptions are noted. Final totals are rounded to the nearest 5 tonnes.

			Not directly available for weapons		
State	Total stock	In or available for weapons	Unsafeguarded	Safeguarded/ monitored	Production status
China	14	14 ± 3	–	–	Stopped 1987–89
France[a]	29	25 ± 6	–	3.8	Stopped 1996
India[b]	5	–	4.9 ± 2	–	Continuing
Iran[c]	0.03	–	0.03	–	Continuing
Israel[d]	0.3	0.3	–	–	Unknown
Korea, North[e]	Uncertain	Uncertain	–	–	Uncertain
Pakistan[f]	5	4.9 ± 1.5	–	–	Continuing
Russia[g]	680	672 ± 120	8[h]	–	Continuing[i]
UK[j]	23	22	0.6[k]	–	Stopped 1962
USA[l]	487	361	126.2	–	Stopped 1992
Other states[m]	>3.9	–	–	>3.9	
Total	**1 245**	**1 100**	**140**	**10**	

[a] A 2014 analysis offers grounds for a significantly lower estimate of France's stockpile of weapon-grade HEU (between 6 ± 2 tonnes and 10 ± 2 tonnes) based on evidence that the Pierrelatte enrichment plant may have had both a much shorter effective period of operation and a smaller capacity to produce weapon-grade HEU than previously assumed.

[b] It is believed that India is producing HEU (enriched to 30–45%) for use as naval reactor fuel. The estimate is for HEU enriched to 30%.

[c] The data for Iran is the estimate by the International Atomic Energy Agency (IAEA) as of 19 Feb. 2022. Iran started enriching uranium up to 20% on 4 Jan. 2021 and started enriching HEU up to 60% enrichment level on 17 Apr. 2021.

[d] Israel may have acquired *c.* 300 kg of weapon-grade HEU illicitly from the USA in or before 1965. Some of this material may have been consumed in the process of producing tritium.

[e] North Korea is known to have a uranium-enrichment plant at Yongbyon and possibly others elsewhere. Independent estimates of uranium-enrichment capability and possible HEU production extrapolated to the beginning of 2022 suggest a potential accumulated HEU stockpile in the range 250–1350 kg.

[f] This estimate for Pakistan assumes total HEU production of 5 tonnes, of which *c.* 100 kg was used in nuclear weapon tests.

[g] This estimate assumes that the Soviet Union stopped all HEU production in 1988. It may therefore understate the amount of HEU in Russia (see also note i).

[h] This material is believed to be in use in various research facilities, civilian as well as military-related. In addition, this number includes the HEU that was produced for fuel for China's CFR-600 reactor. That fuel was delivered to China in Sep.–Dec. 2022. The fuel contains *c.* 7.6 tonnes of HEU with enrichments of 21% and 26%, for a total of 2 tonnes of 90% HEU equivalent.

[i] The Soviet Union stopped production of HEU for weapons in 1988 but kept producing HEU for civilian and non-weapon military uses. Russia continues this practice.

[j] The estimate for the UK reflects a declaration of 21.9 tonnes of military HEU as of 31 Mar. 2002, the average enrichment of which was not given.

[k] This figure is from the UK's INFCIRC/549 declaration to the IAEA for the end of 2021. As the UK has left the European Union, the material is no longer under Euratom safeguards.

[l] The amount of US HEU is given in actual tonnes, not 93%-enriched equivalent. In 2016 the USA declared that, as of 30 Sep. 2013, its HEU inventory was 585.6 tonnes, of which 499.4 tonnes

was declared to be for 'national security or non-national security programs including nuclear weapons, naval propulsion, nuclear energy, and science'. This material was estimated to include *c*. 360.9 tonnes of HEU in weapons and available for weapons, 121.1 tonnes of HEU reserved for naval fuel and 17.3 tonnes of HEU reserved for research reactors. The remaining 86.2 tonnes of the 2013 declaration was composed of 41.6 tonnes 'available for potential down-blend to low enriched uranium or, if not possible, disposal as low-level waste', and 44.6 tonnes in spent reactor fuel. As of the end of 2021 the amount available for use had been reduced to *c*. 468.2 tonnes, which is estimated to include 92.3 tonnes of HEU in naval reserve and 14.9 tonnes reserved for research reactors. It is estimated that at the end of 2021 the amount of material to be down-blended had been reduced to 19 tonnes.

[m] The IAEA's 2021 annual report lists 156 significant quantities of HEU under comprehensive safeguards in non-nuclear weapon states as of the end of 2021. Without knowing the exact enrichment levels, that means these states hold at least 3.9 tonnes of HEU since, for HEU, a significant quantity is defined as 25 kg of U-235.

In INFCIRC/912 (from 2017) more than 20 states committed to reducing civilian HEU stocks and providing regular reports. So far, only 2 countries have reported under this scheme. At the end of 2018 (time of last declaration), Norway held less than 4 kg of HEU for civilian purposes. As of 30 June 2019, Australia held 2.7 kg of HEU for civilian purposes.

Sources: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2022: Fifty Years of the Nuclear Non-Proliferation Treaty: Nuclear Weapons, Fissile Materials, and Nuclear Energy* (IPFM: Princeton, NJ, 2022). *China*: Zhang, H., *China's Fissile Material Production and Stockpile* (IPFM: Princeton, NJ, 2017). *France*: International Atomic Energy Agency (IAEA), 'Communication received from France concerning its policies regarding the management of plutonium', INFCIRC/549/Add.5/26, 11 Oct. 2022; and Philippe, S. and Glaser, A., 'Nuclear archaeology for gaseous diffusion enrichment plants', *Science & Global Security*, vol. 22, no. 1 (2014). *Iran*: IAEA, Board of Governors, 'Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)', Report of the Director General, GOV/2022/4, 3 Mar. 2022. *Israel*: Myers, H., 'The real source of Israel's first fissile material', *Arms Control Today*, vol. 37, no. 8 (Oct. 2007), p. 56; and Gilinsky, V. and Mattson, R. J., 'Revisiting the NUMEC affair', *Bulletin of the Atomic Scientists*, vol. 66, no. 2 (Mar./Apr. 2010). *North Korea*: Hecker, S. S., Braun, C. and Lawrence, C., 'North Korea's stockpiles of fissile material', *Korea Observer*, vol 47, no. 4 (winter 2016). *Russia*: Podvig, P. (ed.), *The Use of Highly-Enriched Uranium as Fuel in Russia* (IPFM: Washington, DC, 2017); and IPFM, 'Russia delivers fuel for China's CFR-600 reactor', IPFM Blog, 28 Dec. 2022. *UK*: British Ministry of Defence, 'Historical accounting for UK defence highly enriched uranium', Mar. 2006; and IAEA, 'Communications received from the United Kingdom of Great Britain and Northern Ireland concerning its policies regarding the management of plutonium', INFCIRC/549/Add.8/25, 7 Dec. 2022. *USA*: US Department of Energy (DOE), National Nuclear Security Administration, *Highly Enriched Uranium, Striking a Balance: A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 through September 30, 1996* (DOE: Washington, DC, Jan. 2001); White House, 'Transparency in the US highly enriched uranium inventory', Fact sheet, 31 Mar. 2016; US DOE, *FY 2021 Congressional Budget Request*, vol. 1, *National Nuclear Security Administration* (DOE: Washington, DC, Feb. 2020), p. 593; and US DOE, *Tritium and Enriched Uranium Management Plan through 2060*, Report to Congress (DOE: Washington, DC, Oct. 2015). *Other states*: IAEA, *IAEA Annual Report 2021* (IAEA: Vienna, 2021), annex, table A4, p. 149; IAEA, 'Communication dated 19 July 2019 received from the Permanent Mission of Norway concerning a joint statement on minimising and eliminating the use of highly enriched uranium in civilian applications', INFCIRC/912/Add.3, 15 Aug. 2019; and IAEA, 'Communication dated 23 January 2020 received from the Permanent Mission of Australia concerning the joint statement on minimising and eliminating the use of highly enriched uranium in civilian applications', INFCIRC/912/Add.4, 5 Mar. 2020.

Table 7.12. Global stocks of separated plutonium, 2022

All figures are tonnes and are for unirradiated plutonium as of the beginning of 2022. Important exceptions are noted. Final totals are rounded to the nearest 5 tonnes.

State	Total stock	In or available for weapons	Not directly available for weapons[a]		Military production status
			Unsafeguarded	Safeguarded/ monitored	
China	3	2.9 ± 0.6	0.04[b]	–	Stopped in 1991
France	91	6 ± 1.0	–	84.9	Stopped in 1992
India	10	0.65 ± 0.15	8.5 ± 4.9[c]	0.4	Continuing
Israel[d]	0.8	0.84 ± 0.1	–	–	Continuing
Japan	45.8	–	–	45.8	–
Korea, North[e]	0.04	0.04	–	–	Continuing
Pakistan[f]	0.5	0.5 ± 0.17	–	–	Continuing
Russia	192	88 ± 8	88.5[g]	15[h]	Stopped in 2010
UK	119.7	3.2	116.5	–	Stopped in 1995
USA[i]	87.8	38.4	46.4	3[j]	Stopped in 1988
Total	**550**	**140**	**260**	**150**	

[a] With the exception of India, figures for civilian stocks are based on INFCIRC/549 declarations to the International Atomic Energy Agency (IAEA). The data for France, Japan, Russia, the UK and the USA is for the end of 2021, reflecting their most recent INFCIRC/549 declaration to the IAEA. Some countries with civilian plutonium stocks do not submit an INFCIRC/549 declaration. Of these countries, the Netherlands, Spain and Sweden store their plutonium abroad, but the total amounts are too small to be noted in the table.

[b] These numbers are based on China's INFCIRC/549 declaration to the IAEA for the end of 2016. As of Mar. 2023, this is the most recent declaration.

[c] India's unsafeguarded civilian material is the plutonium separated from spent power-reactor fuel. While such reactor-grade plutonium can in principle be used in weapons, it is labelled as 'Not directly available for weapons' here since it is intended for breeder reactor fuel. It was not placed under safeguards in the 'India-specific' safeguards agreement signed by the Indian Government and the IAEA on 2 Feb. 2009. India does not submit an INFCIRC/549 declaration to the IAEA.

[d] Israel is believed to be operating the Dimona plutonium-production reactor. The estimate assumes partial use of the reactor for tritium production from 1997 onwards. The estimate is for the beginning of 2022. Without tritium production, stockpiles could be as high as 1090 kg.

[e] North Korea reportedly declared a plutonium stock of 37 kg in June 2008. It is believed that it subsequently unloaded plutonium from its 5-MW(e) reactor 3 additional times, in 2009, 2016 and 2018. The stockpile estimate has been reduced to account for the 6 nuclear tests conducted by the country. North Korea's reprocessing facility operated again in 2021 for 5 months.

[f] At the beginning of 2022 Pakistan was operating 4 plutonium-production reactors at its Khushab site. This estimate assumes that Pakistan is separating plutonium from all 4 reactors.

[g] This material includes 63.5 tonnes of separated plutonium declared in Russia's 2022 INFCIRC/549 declaration as civilian. Russia does not make the plutonium it reports as civilian available to IAEA safeguards. This amount also includes 25 tonnes of weapon-origin plutonium stored at the Mayak Fissile Material Storage Facility, which Russia pledged not to use for military purposes.

[h] This material is weapon-grade plutonium produced between 1 Jan. 1995 and 15 Apr. 2010, when the last Russian plutonium-production reactor was shut down. It cannot be used for weapon purposes under the terms of a 1997 Russian–US agreement on plutonium-production reactors. The material is currently stored at Zheleznogorsk and is subject to monitoring by US inspectors.

[i] In 2012 the USA declared a government-owned plutonium inventory of 95.4 tonnes as of 30 Sep. 2009. In its INFCIRC/549 declaration of stocks as of 31 Dec. 2021, the USA declared 49.4 tonnes of unirradiated plutonium (both separated and in mixed oxide, MOX) as part of the stock identified as excess to military purposes.

[j] The USA has placed *c.* 3 tonnes of its excess plutonium, stored at the K-Area Material Storage Facility at the Savannah River Site, under IAEA safeguards.

Sources: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2022: Fifty Years of the Nuclear Non-Proliferation Treaty: Nuclear Weapons, Fissile Materials, and Nuclear Energy* (IPFM: Princeton, NJ, 2022). *Civilian stocks (except for India)*: International Atomic Energy Agency (IAEA), 'Communication received from certain member states concerning their policies regarding the management of plutonium', INFCIRC/549, various dates. *China*: Zhang, H., *China's Fissile Material Production and Stockpile* (IPFM: Princeton, NJ, 2017). *Israel*: Glaser, A. and de Troullioud de Lanversin, J., 'Plutonium and tritium production in Israel's Dimona reactor, 1964–2020', *Science & Global Security*, vol. 29, no. 2 (2021). *North Korea*: Kessler, G., 'Message to US preceded nuclear declaration by North Korea', *Washington Post*, 2 July 2008; Hecker, S. S., Braun, C. and Lawrence, C., 'North Korea's stockpiles of fissile material', *Korea Observer*, vol 47, no. 4 (winter 2016); and IAEA, Board of Governors and General Conference, 'Application of safeguards in the Democratic People's Republic of Korea', Report by the Acting Director General, GOV/2019/33-GC(63)/20, 19 Aug. 2019. *Russia*: Russian–US Agreement Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation (Plutonium Management and Disposition Agreement), signed 29 Aug. and 1 Sep. 2000, amendment signed 5 Sep. 2006, entered into force 13 July 2011. *USA*: National Nuclear Security Administration (NNSA), *The United States Plutonium Balance, 1944–2009* (NNSA: Washington, DC, June 2012); and Gunter, A., 'K-Area overview/update', US Department of Energy, Savanah River Site, 28 July 2015.

Table 7.13. Significant uranium-enrichment facilities and capacity worldwide, 2022

With the exception of two facilities (marked *) that continue to use gaseous diffusion to enrich uranium in uranium-235 (U-235), all facilities use gas centrifuge isotope-separation technology.

State	Facility name or location	Type	Status	Capacity (thousands SWU/yr)[a]
Argentina[b]	Pilcaniyeu*	Civilian	Uncertain	20
Brazil	Resende	Civilian	Expanding capacity	45–50
China[c]	Lanzhou	Civilian	Operational	2 600
	Hanzhong (Shaanxi)	Civilian	Operational	2 000
	Emeishan	Civilian	Operational	1 050
	Heping*	Dual-use	Operational	230
France	Georges Besse II	Civilian	Operational	7 500
Germany	Urenco Gronau	Civilian	Operational	3 700
India	Rattehalli	Military	Operational	15–30
Iran[d]	Natanz	Civilian	Expanding capacity	22
	Qom (Fordow)	Civilian	Expanding capacity	2.5
Japan	Rokkasho[e]	Civilian	Resuming operation	75
Korea, North	Yongbyon[f]	Uncertain	Operational	8
Netherlands	Urenco Almelo	Civilian	Operational	5 200
Pakistan	Gadwal	Military	Operational	. .
	Kahuta	Military	Operational	15–45
Russia	Angarsk	Civilian	Operational	4 000
	Novouralsk	Civilian	Operational	13 300
	Seversk	Civilian	Operational	3 800
	Zelenogorsk[g]	Civilian	Operational	7 900
UK	Capenhurst	Civilian	Operational	4 500
USA	Urenco Eunice	Civilian	Operational	4 900

[a] Separative work units per year (SWU/yr) is a measure of the effort required in an enrichment facility to separate uranium of a given content of U-235 into two components, one with a higher and one with a lower percentage of U-235. Where a range of capacities is shown, the capacity is uncertain or the facility is expanding its capacity.

[b] In Dec. 2015 Argentina announced the reopening of its Pilcaniyeu gaseous diffusion uranium-enrichment plant, which was shut down in the 1990s. There is no evidence of actual production.

[c] Assessments of China's enrichment capacity in 2015 and 2017 identified new enrichment sites and suggested a much larger total capacity than had previously been estimated.

[d] The figures for Iran are for Dec. 2022 and show a significant increase compared with the beginning of 2022, when the Natanz facility had a capacity of 12 000 SWU/yr. Since the USA's withdrawal in 2018 from the Joint Comprehensive Plan of Action (JCPOA), which agreed limits on and made more transparent Iran's nuclear programme, Iran continues to increase enrichment capacities and levels at its Natanz and Fordow facilities.

[e] The Rokkasho centrifuge plant has been in the process of being refitted with new centrifuge technology since 2011. Production since the start of retrofitting has been negligible.

[f] North Korea revealed its Yongbyon enrichment facility in 2010. It appears to be operational as of 2020. It is believed that North Korea is operating at least one other enrichment facility.

[g] Zelenogorsk operates a centrifuge cascade for HEU production of fuel for fast reactors and research reactors.

Sources: Indo-Asian News Service (IANS), 'Argentina president inaugurates enriched uranium plant', *Business Standard* (New Delhi), 1 Dec. 2015; Nuclear Engineering International, 'Brazil's INB launches new centrifuge cascade', 25 Nov. 2021; Zhang, H., 'China's uranium enrichment complex', *Science & Global Security*, vol. 23, no. 3 (2015); Zhang, H., *China's Fissile Material Production and Stockpile* (International Panel on Fissile Materials: Princeton, NJ, 2017); International Atomic Energy Agency (IAEA), Board of Governors, 'Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)', Report by the Director General, GOV/2022/62, 10 Nov. 2022; Albright, D., Burkhard, S. and Faragasso, S., 'Updated highlights of comprehensive survey of Iran's advanced centrifuges', Institute for Science and International Security, 1 Dec. 2022; and Hecker, S. S., Carlin, R. L. and Serbin, E. A., 'A comprehensive history of North Korea's nuclear program: 2018 update', Stanford University, Center for International Security and Cooperation, 11 Feb. 2019. Enrichment capacity data is based on IAEA, Integrated Nuclear Fuel Cycle Information Systems (iNFCIS); Urenco, 'Global operations'; and International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2022: Fifty Years of the Nuclear Non-Proliferation Treaty: Nuclear Weapons, Fissile Materials, and Nuclear Energy* (IPFM: Princeton, NJ, 2022).

Table 7.14. Significant reprocessing facilities worldwide, 2022

State	Facility name or location	Fuel	Type	Status	Design capacity (tHM/yr)[a]
China[b]	Jiuquan pilot plant	LWR	Civilian	Operational	50
France	La Hague UP2	LWR	Civilian	Operational	1 000
	La Hague UP3	LWR	Civilian	Operational	1 000
India[c]	Kalpakkam	HWR	Dual-use	Operational	100
	Tarapur	HWR	Dual-use	Operational	100
	Tarapur-II	HWR	Dual-use	Operational	100
	Trombay	HWR	Military	Operational	50
Israel	Dimona	HWR	Military	Operational	40–100
Japan	JNC Tokai	LWR	Civilian	Shut down in 2014[d]	(was 200)
	Rokkasho	LWR	Civilian	Start planned for 2025	800
Korea, North	Yongbyon	GCR	Military	Operational	100–150
Pakistan	Chashma	HWR	Military	Starting up	50–100
	Nilore	HWR	Military	Operational	20–40
Russia	Mayak RT-1, Ozersk	LWR	Civilian	Operational	400
	EDC, Zheleznogorsk[e]	LWR	Civilian	Starting up	250
UK	Sellafield B205	Magnox	Civilian	Shut down in July 2022	1 500
	Sellafield Thorp	LWR	Civilian	Shut down in 2018	(was 1 200)
USA	H-canyon, Savannah River Site	LWR	Civilian	Operational	15

GCR = gas-cooled reactor; HWR = heavy water reactor; LWR = light water reactor.

[a] Design capacity refers to the highest amount of spent fuel the plant is designed to process and is measured in tonnes of heavy metal per year (tHM/yr), tHM being a measure of the amount of heavy metal—uranium in these cases—that is in the spent fuel. Actual throughput is often a small fraction of the design capacity. LWR spent fuel contains *c.* 1% plutonium; HWR, GCR and Magnox fuel contain *c.* 0.4% plutonium.

[b] China is building a pilot reprocessing facility near Jinta, Gansu province, with a capacity of 200 tHM/yr, to be commissioned in 2025. A second reprocessing plant of the same capacity is planned for the same site.

[c] As part of the 2005 Indian–US Civil Nuclear Cooperation Initiative, India has decided that none of its reprocessing plants will be opened for International Atomic Energy Agency safeguards inspections.

[d] In 2014 the Japan Atomic Energy Agency announced the planned closure of the head-end of its Tokai reprocessing plant, effectively ending further plutonium-separation activity. In 2018 the Japanese Nuclear Regulation Authority approved a plan to decommission the plant.

[e] Russia continues to construct the 250 tHM/yr pilot Experimental and Demonstration Centre (EDC) at Zheleznogorsk. A pilot reprocessing line with a capacity of 5 tHM/yr was launched in June 2018.

Sources: Kyodo News, 'Japan approves 70-year plan to scrap nuclear reprocessing plant', 13 June 2018; Japan Nuclear Fuel Ltd, 'Provisional operation plans for Rokkasho reprocessing plant and MOX fuel fabrication plant', 10 Feb. 2023; [Rosatom ready to start 'green' processing of spent nuclear fuel], RIA Novosti, 29 May 2018 (in Russian); and Sellafield Ltd and Nuclear Decommissioning Authority, 'Job done: Sellafield plant safely completes its mission', 19 July 2022. Data on design capacity is based on International Atomic Energy Agency, Integrated Nuclear Fuel Cycle Information Systems (iNFCIS); and International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2022: Fifty Years of the Nuclear Non-Proliferation Treaty: Nuclear Weapons, Fissile Materials, and Nuclear Energy* (IPFM: Princeton, NJ, 2022).